## Appendix 3: Handbook on Telecommunication Outside Plant in Areas Frequently Exposed to Natural Disasters

International Telecommunication Union

# ITU HANDBOOK ON TELECOMMUNICATION OUTSIDE PLANTS IN AREAS FREQUENTLY EXPOSED TO NATURAL DISASTERS

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# Chapter 1

# Natural disasters and their management

## 1 Introduction

This chapter gives the definitions of the terms hazards, emergency, disaster and catastrophe which are widely used in this Handbook. Moreover there is a description of the characteristics of the most frequent natural disasters and of the methods for measuring their intensity. The four phases of disaster management for facing the effects of a hazard are also described as the basic role played by telecommunications in emergency management.

### 1.1 Hazards/emergencies/disasters/catastrophes

Hazards, emergency, disasters and catastrophes seem like different words that mean similar things, however, differences do exist. In disaster management it is important to distinguish the meaning of these terms.

A *hazard* is a source of danger or an extreme event that has the potential to affect people, property and the natural environment in a given location. There are a variety of risks in our natural environment. These risks include both healthy and safety danger which vary by location. For example tsunami dangers do not exist in places which are very far from the run-up zone at the ocean shore, while tsunami hazards are significant on the ocean coast.

To reduce the potential for casualties and damage from hazards, it is necessary to change the physical processes that generate hazardous events or change people behavior by living in less dangerous locations, building hazard-resistant structures, or improving the ability to respond and recover from extreme events.

The term *emergency* is used in two slightly different ways. First, the term is used to describe minor events that cause a few casualties and a limited amount of property damage. Common emergency include car crashes, house fires and heart attacks. Fire departments, police departments and emergency medics are the first responders to these events. These events affect few people, so only a few community agencies need to respond. In addition, these events are well understood, so communities have standard operating procedures for responding to them.

Second, the term emergency can refer to an imminent event. For example, a hurricane that is 48 hours from landfall creates an emergency situation because there is little time to respond. The urgency of the situation requires prompt and effective action. Unlike with the previous use of the term emergency, the event is not occurred, but the consequences are likely to be major, so many community agencies need to mount a coordinated response.

In this Handbook the term emergency is used in the second meaning as defined in ITU-T Recommendation L.81: “An emergency is a sudden, urgent, usually unexpected occurrence or event requiring immediate action.”

*Disasters* are sudden occasions that seriously disrupt social routines, cause adoption of unplanned actions to adjust to the disruption, and endanger valued social objects. They are defined by human casualties, property damage, and severe social disruptions. A volcanic eruption can produce massive environmental disruption. This can occur through lava flows, ash falls and mud flows. However, it is not a disaster unless it directly impacts people or the human use system in some fashion. Disasters interrupt the ability of major community systems to afford reasonable conditions of life. This means that significant subsystems in a community no longer work to allow people to pursue their work, recreation and other activities. A town's public health protections (sewage treatment or fresh water systems) may fail. The utility system may no longer provide electricity. The hospital system may no longer be able to accommodate as many patients. The telecommunication services can be interrupted.

ITU-T Recommendation L.81 gives the following definition: "Disasters are characterized by the scope of an emergency. An emergency becomes a disaster when it exceeds the capability of the local resources to manage it. Disasters often result in great damage, loss, or destruction."

*Catastrophe* is a large scope of impact event that crosses multiple communities, produces very high levels of damage and social disruption and sharply interrupts community and lifeline services. A broad scope of impact greatly limits extra community support. In 2005, for example, Hurricane Katrina severely impacted large coastal areas of Louisiana, Mississippi and Alabama. In this setting, small towns that might otherwise count on help from larger urban centers simply found that all communities were unable to extend support. The levels of damage and social disruption are even greater than most disasters. Most of the buildings are damaged and destroyed. This includes common systems to maintain public health and safety. This disruption interrupts much preparedness and response planning. Plan for victim shelter and medical care in the community are rendered useless. Specific damage assessment is complex. It is difficult to get to the affected areas because of the debris on the roads and the destruction of roads. Following the 2004 tsunami in Indonesia, more than 90% of the medical personnel in several towns were killed. In Florida Hurricane Andrew seriously damaged or destroyed buildings housing police, fire, welfare and medical workers. Most community functions are sharply and concurrently interrupted. Lifeline infrastructures simultaneously fail. This interrupts electric power, fuel. water, sewer, transportation and telecommunication services.

Catastrophes are really exceptional events, which are not considered in planning outside plant protection.

## 1.2 Natural hazards: types, intensity, caused damages and critical areas/countries

Natural hazards are those that exist in the natural environment as result of meteorological, hydrological and geologic hazards that pose a threat to human population and communities. Natural hazards are often intensified in scope and scale by human activities including development and modification of the landscape and atmosphere. For example, the construction of communities in the floodplain or on barrier islands almost always increases risk associated with hurricane-force width, flooding and storm surge. When structures are constructed on or around seismic faults, the likelihood that they will be destroyed in a future earthquake event is greatly increased. Through better understanding of natural hazards and processes by which they affect the human and built environment, societies can better plan for these stressors and reduce vulnerability.

## *1.2.1 Meteorological hazards*

### 1.2.1.1 Tornadoes

A tornado is a rapidly rotating vortex or funnel of air extending ground ward from a cumulonimbus cloud, exhibiting wind speeds of up to 482 km for hour. Approximately 1.200 tornadoes are spawned by thunderstorms each year in the United States. Most tornadoes remain aloft, but the few that do touch the ground are devastating to everything in their path. The forces of a tornado's wind are capable of lifting and moving huge volumes objects, destroying or moving whole buildings and siphoning large volumes from bodies of water and ultimately deposing them elsewhere. Because tornadoes typically follow the path of least resistance, people living in valleys have the greatest exposure to damages. Tornados have been measured using the Fujita-Pearson Tornado Scale since its creation in 1971 (Table 1-1).

**Table 1-1: Enhanced Fujita-Pearson Tornado Scale**

| Category | Conditions | Effects |
|---|---|---|
| F-0 | 64-115 km/h | Chimney damage, tree branches broken |
| F-1 | 116-180 km/h | Mobile homes pushed off foundation or overturned |
| F-2 | 181-252 km/h | Considerable damage, mobile homes demolished, trees uprooted |
| F-3 | 253-330 km/h | Roofs and walls torn down, trains overturned, cars thrown |
| F-4 | 331-418 km/h | Well-constructed walls leveled |
| F-5 | 419-511 km/h | Home lifted out foundation and carried considerable distances, autos thrown as far as 100 meters |

Building collapse and flying debris are the principals factors behind the deaths and injuries tornadoes cause. Early warning is key to surviving tornadoes, as warned citizens can protect themselves by moving to structures designed to withstand tornado-force winds. Doppler radar and other meteorological tools have drastically improved the ability to detect tornadoes and the amount of advance warning time available before a tornado strike. Improved communications and new technologies have also been critical to giving people advance warning.

**Figure 1-1: A tornado**

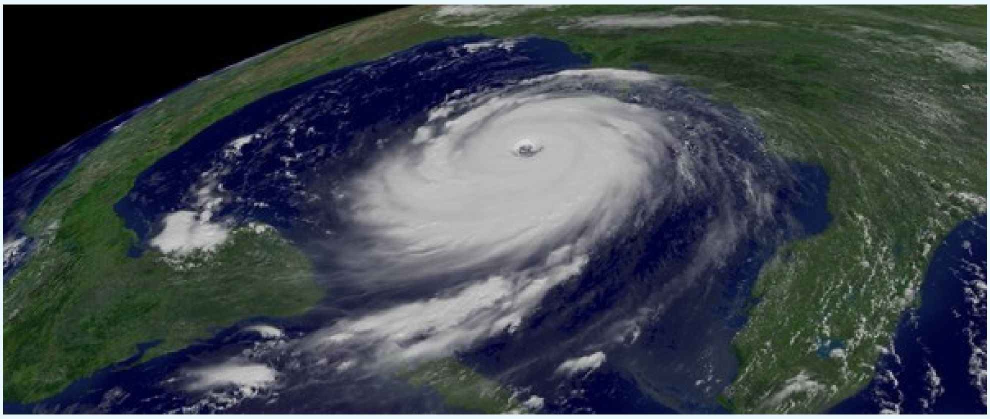
Buildings that are directly in the path of a tornado have little chance of surviving unless they are not specifically designed to withstand not only the force of the winds, but also that of the debris "missiles" that are thrown about. "Safe room" technology realized with engineered resistant design and special resistant materials offer in the path of a tornado great survival likelihoods.

### 1.2.1.2 Hurricanes

Hurricanes are cyclonic storms that begin as tropical waves and grow in intensity and size. Tropical waves continue to progress in size and intensity to tropical depressions and tropical storms as determined by their maximum sustained wind speed. The warm-core tropical depression becomes a tropical storm when the maximum sustained surface wind speed range from 62 km per hour to 117 km per hour. Tropical cyclonic storms are defined by their low barometric pressure, closed-circulation winds originating over tropical waters, and an absence of wind shear. Cyclonic storm winds rotate counter-clock-wise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

Hurricane winds extend outward in a spiral pattern as much as 650 km around a relatively calm center of up 50 km in diameter known as the "eye". Hurricanes are fed by warm ocean waters. As these storms make landfall, they often push a wall of ocean water known as "storm surge" over coastal zones (see Section 1.2.2.1). Once over land, hurricanes cause further destruction by means of torrential rains and high winds.

**Figure 1-2: A hurricane**



Hurricane season runs annually from June 1 through November 30, August and September are peak months during the hurricane season. Hurricanes are commonly described using the Saffir-Simpson scale (Table 1-2).

**Table 1-2: The Saffir-Simpson scale**

| Category | Conditions | Effects |
|---|---|---|
| 1 | Wind Speed: 119-152 km/h<br>Storm surge: 1.2-1.5 m above normal | Primary damage to unanchored mobile homes, shrubbery and trees. Some coastal flooding and minor pier damage. Little damage to building structures. |
| 2 | Wind Speed: 153-177 km/h<br>Storm surge: 1.6-2.4 m above normal | Considerable damage to mobile homes, piers and vegetation. Coastal and low-lying area escape routes flood 2-4 hours before arrival of hurricane center. Buildings sustain roofing material, door and window damage. small craft in unprotected mooring break moorings. |

| Category | Conditions | Effects |
|---|---|---|
| 3 | Wind Speed: 154-209 km/h<br>Storm surge: 2.5-3.6 m above normal | Mobile homes destroyed. Some structural damage to small homes and utility buildings. Flooding near coast destroys smaller structures, larger structures damaged by floating debris. Terrain continuously lower than 1.5 m above sea level (ASL) may be flooded up to six miles inland. |
| 4 | Wind Speed: 210-249 km/h<br>Storm surge: 3.7-5.4 m above normal | Extensive curtain wall failures, with some complete roof structure failure on small residences. Major erosion of beaches. Major damage to lower floors of structures near the shore. Terrain continuously lower than 3 m ASL may flood (and require mass evacuations) up to 9 km inland. |
| 5 | Wind Speed: over 250 km/h<br>Storm surge: over 5.5 m above normal | Complete roof failure on many homes and industrial buildings. Some complete building failures. Major damage to lower floors of all structures of all structures located less than 4.5 m ASL and within 500 yards of the shoreline. Massive evacuation of low-ground, residential areas may be required. |

Hurricanes are capable of causing great damage and destruction over vast areas. Hurricane Floyd in 1999 first threatened the states of Florida and Georgia, made landfall in North Carolina and damaged sections of South Carolina, North Carolina, Virginia, Maryland, Delaware, New Jersey, New York, Connecticut, Massachusetts and Maine. Single hurricanes can affect several countries, as was the case with Hurricane Mitch, which brought death and destruction to Nicaragua, Guatemala, el Salvador and Honduras.

### 1.2.1.3 Thunderstorms

Thunderstorms are meteorological events that bring heavy rains, strong winds, hail, lightning, and tornadoes. Thunderstorms are generated by atmospheric imbalance and turbulence caused by a combination of several conditions, including: unstable, warm air rising rapidly into the atmosphere; sufficient moisture to form clouds and rain; and upward lift of air currents caused by colliding weather fronts (cold and warm), sea breezes, or mountains.

A thunderstorm is classified as severe if its wind reach or exceed 93 km/h, it produces a tornado, or it drops surface hail at least 1.9 cm in diameter. Thunderstorms may occur singly, in clusters or in lines. Thus, it is possible for several thunderstorms to affect one location in the course of a few hours. These events are particularly devastating when a single thunderstorm affects one location for an extended period. Such conditions leads to oversaturation of the ground and subsequent flash flooding and slope erosion.

*Lightning* is a major secondary threat associated with thunderstorms. In the United States, between 75 and 100 Americans are hit and killed by lightning each year. Many air disasters have been linked to thunderstorms due to the unpredictable and turbulent wind conditions they cause and the threat of electronic or mechanical failure caused by lightning strikes. When humans or structures are hit lightning, the effect is devastating to both.

**Figure 1-3: Thunderstorms and lightening**

*Hail* is frozen atmospheric water that fall to the earth. Moisture in clouds becomes frozen into crystals at low temperatures and begins to fall under its own weight. Typically these crystals melt at lower temperatures, but in the right conditions they pick up more moisture as they fall and are then lifted to cold elevations, which causes refreezing. The cycle can continue until the individual hailstones reach several inches in diameter under the right conditions. Because of the strength of severe thunderstorms and tornadoes, both can cause this cyclic lifting, and therefore they are often accompanied by hail. When they fall, they can damage crops, break windows, destroy cars and other exposed properties, collapse roofs, and cause other destruction totaling nearly $1 billion each year in United States.

#### 1.2.1.4 Severe winter weather

W*inter storms* occur when extremely cold atmospheric conditions coincide with high airborne moisture content, resulting in rapid and heavy precipitation of *snow* and/or *ice* (snowstorms). When combined with high winds, the event is known as a *blizzard*.

**Figure 1-4: Severe winter weather**

While there is no widely accepted standard for *extreme cold* temperatures, periods of colder than normal conditions exhibit a range of negative consequences, depending on where they occur and exactly how cold temperatures fall. Any time temperatures fall below freezing, there is the risk of death from hypothermia to humans and livestock, with the degree to which populations are accustomed to those temperatures a primary factor in resilience. Extreme cold can also lead to serious economic damages from frozen water pipes; the freezing of navigable rivers, which halts commerce and can cause ice dams; and the destruction of crops.

#### 1.2.1.5 Severe summer weather

*Wildfires* (often called also wildland fires) are an annual and an increasing hazard due to air pollution (primarily smoke and ash which travel for miles causing further hazards to health and mechanical or electrical equipment), risk to firefighters, environmental effects and property destruction they cause.

**Figure 1-5: Wildfires**

### *1.2.2 Hydrological hazards*

#### 1.2.2.1 Floods and flash floods

A flood is an overabundance of water that engulfs dry land and property that is normally dry. Floods may be caused by a number of factors, including heavy rainfall, melting snow, an obstruction of a natural waterway, etc.. Floods are capable of undermining buildings and bridges, eroding shorelines and riverbanks, tearing out trees, washing out access routes, and causing loss of life and injuries.

Flash floods usually results from intense storms dropping large amounts of rain within a brief period, occur with little or no warning, and can reach full peak in only a few minutes.

**Figure 1-6: Floods**

Floods are the most frequent and widespread disaster in many countries around the world, due to the prevalence of human development in the floodplain. The close relationship between societies and water is the result of commerce (the transportation of goods has most commonly been conducted by water), agriculture, and access for drinking water. The adverse implication of this relationship has been a global increase in exposure to flood events. It is estimated that in the United States alone sustain an average of $2 billion to $3 billion in losses each year.

Floods are typically measured according to their elevation above standard water levels (of rivers or coastal water levels). This elevation is translated into the annualized likelihood of reaching such heights. For example, a flood depth that has a 1 percent probability of being reached or could be expected to occur once across a 100-year period would be considered a “100-year flood event”. Typically, structures that are contained within areas likely to experience flooding in a 100-year flood event are considered to be within the floodplain.

### 1.2.2.2 Storm surges

Storm surges, defined as masses of water that are pushed toward the shore by meteorological forces, are the primary cause of the injuries, deaths and structural damages associated with hurricanes, cyclones, and other coastal storms. When the advancing surge of water coincides with high tides, the resulting rise in sea level is further exacerbated. Storm surges may reach several meters under the right conditions, as was the case of the Hurricane Katrina. Wind-driven turbulence becomes superimposed on the storm tide, thereby causing further damage to structures that are inundated through wave action. The surge height at landfall is ultimately dictated by the expanse and intensity of the storm, the height of the tide at the time of the landfall and the slope of the sea floor approaching land. The longer and shallower the sea floor, the greater the storm surge will be.

The storm surges are usually described using the Saffir-Simpson scale (Table 1-2).

### 1.2.2.3 Tsunamis

A tsunami is wave or series of waves that is generated by a mass displacement of sea or lake water. The most common generative factor behind tsunamis is undersea earthquakes that cause ocean floor displacement, but large tsunamis have been caused by volcanic eruptions and landslides as well. Tsunami waves travel outward as movements of kinetic energy (rather than travelling water) at very high speeds in all directions from the area of the disturbance, much like the ripples caused by a rock thrown into a pond. As the waves approach shallow coastal waters, wave speed quickly decreases and the water is drawn upward and onto land. Tsunamis can strike at heights of up to and over 30 m and extend onto land for 1 km or more (depending upon topography). The force of the water causes near total destruction of everything in the path.

**Figure 1-7: A tsunami**


The areas at the greatest risk from tsunamis are those lying less than 15 m above sea level and within 1.5 km of the shoreline. Successive crests (high water) and troughs (low water) can occur anywhere from 5 to 90 minutes apart. Tsunamis travel through deep water at approximately 725 km/h, so the areas closest to the point of origin experience the greatest destruction and have the least amount of forewarning. Most tsunami-related deaths are the result of drowning, while the loss of services and related health problems associated with the incredible destruction of the infrastructure (including the loss of hospitals and clinics, water pollution, contaminated food and water socks, and damaged transmission lines) adds to this statistics.

## *1.2.3 Geological hazards*

### 1.2.3.1 Earthquakes

An earthquake is a sudden, rapid shaking of the earth's crust that is caused by the breaking and shifting of rock beneath the earth's surface. This shaking can cause the collapse of buildings and bridges, cause disruption of gas, electric and telecommunication services, and trigger landslides, avalanches, flash floods, fires, and huge, destructive ocean waves (tsunamis). Structures constructed on consolidated landfill, old waterways, or other unstable soil are generally at greatest risk unless seismic mitigation has been utilized. Seismicity is not seasonal or climate dependent and can therefore occur at any time of the year.

**Figure 1-8: Effect of an earthquake**

Over one billion people worldwide live in seismic zones. Earthquake damage can be extensive, especially when buildings have been constructed without incorporation of seismic-resistant materials and designs.

Earthquakes are sudden, no-notice events despite scientists' and soothsayers' best efforts to predict when they will occur. Seismic sensing technology is effective as measuring and tracking seismic activity, but it is yet to accurately predict a major seismic event with any degree of accuracy.

Each year hundreds of earthquakes occur worldwide, though the vast majority are barely perceptible. As earthquake strength increases, its likelihood of occurrence decreases. Major events, which are greater than 6.5 to 7 on the Richter scale, are not frequent, but such events have been among the most devastating.

The strength and effects of earthquakes are commonly described by the Richter and Modified Mercally Intensity (MMI) scales. The Richter scale assigns a single number to quantify the strength and effect of an earthquake across the entire area affected according to the strength of ground waves at its point of origin (as measured by a seismograph). Richter magnitudes are logarithmic and have no upper limit. The MMI also measures the effects of earthquakes, but rather than applying a single value to event, it allows for site-specific evaluation according to the effects observed at each location. The MMI rates event intensity using Roman numerals I to XII. Determinations are generally made using reports by people who felt the event and observations of damages sustained by structures.

The relationship between the two scales is shown in Table 1-3.

**Table 1-3: Modified Mercalli Intensity Scale and equivalent Richter scale**

| MMI Intensity | Damages sustained and sensations experienced | Richter scale equivalent |
|---|---|---|
| I-IV (Instrumental to Moderate) | No damage sustained. Sensation ranges from imperceptible to that of a heavy truck striking the building. Standing motor cars may rock. | ≤ 4.3 |
| V (Rather Strong) | Felt by near everyone, many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop. | 4.4-4.8 |
| VI (Strong) | Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. | 4.9-5.4 |
| VII (Very Strong) | Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. | 5.5-6.1 |

| MMI Intensity | Damages sustained and sensations experienced | Richter scale equivalent |
|---|---|---|
| VIII (Destructive) | Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. | 6.2-6.5 |
| IX (Ruinous) | Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. | 6.6-6.9 |
| X (Disastrous) | Most masonry and frame structures/foundations destroyed. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Sand and mud shifting on beaches and flat land. | 7.0-7.3 |
| XI (Very disastrous) | Few or no of masonry structures remains standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Widespread earth slumps and landslides. Rails bent greatly. | 7.4-8.1 |
| XII (Catastrophic) | Damage nearly total. Large rock masses displaced. Lines of sight and level are distorted. Objects are thrown into the air. | ≥ 8.1 |

### 1.2.3.2 Volcanic eruptions

A volcano is a break in the earth's crust through which molten rock from beneath the earth's surface (magma) erupts. Over time, volcanoes will grow upward and outward, forming mountains, islands, or large, flat plateau called "shields". Volcanic mountains differ from mountain chains formed through plate tectonics (movement of the earth's crustal plates) because they are built through the accumulation of material (lava, ash flows and airborne ash and dust) rather than being pushed up from below.

**Figure 1-9: Volcano**

When pressure from gases and molten rock becomes strong enough to cause an explosion, violent eruption may occur. Gases and rock shout up through the opening and spill over or fill the area with lava fragments. Volcanoes cause injuries, death and destruction through a number of processes, including direct burns, suffocation from ash and other materials, trauma from ejected rocks. Airborne ash can affect people hundreds of miles away from the eruption and influence global climates for years afterward.

Volcanic ash contaminates water supplies, causes electrical storms, and can cause roofs to collapse under the weight of accumulated material. Eruptions may also trigger tsunamis, flash floods, earthquakes and rockfalls.

### 1.2.3.3 Mass Movements

The general category of mass movements includes several different hazards caused by the horizontal or lateral movements of large quantities of physical matter. Mass movements cause damage and loss of life through several different processes, including the pushing, crushing, or burying of objects in their path, the damming of rivers and waterways, the subsequent movement of displaced bodies of water (typically in the form of a tsunami), destruction or obstruction of major transportation routes and alteration of the natural environment in ways in which humans are negative impacted. Mass-movements hazards are most prevalent in areas of rugged or varied topography, but they can occur even on level land. The main categories of mass-movement hazards are quoted in the following.

*Landslides*. Landslides occur when masses of relatively dry rock, soil, or debris move in an uncontrolled manner down a slope. Landslides may be very highly localized or massive in size and they can move at a creeping pace or at very high speeds. Landslides are activated when the mechanism by which the material was anchored become compromised (through a loss of vegetation or seismic activity, for example).

**Figure 1-10: Landslides and debris flow**

*Mudflows.* Mudflows are water-saturated rivers of rock, earth, and other debris that are drawn downward by the force of gravity. These phenomena develop when water rapidly accumulates in the material that is moved, like during heavy rainfall or rapid snowmelt. Under these conditions, solid or loose earth can quickly change into a flowing river of mud. These flow move rapidly down slopes or through channels, following the path of least resistance, and often strike with little or no warning.

*Rockfalls.* Rockfalls occur when masses of rock or other materials detach from a steep slope or cliff and descend by freefall, rolling or bouncing. Rockfalls can occur spontaneously when fissures in rock or other materials cause structural failure or due to seismic or other mechanical activity (including explosions or the movement of heavy machinery).

*Avalanches*. An avalanche is a mass of ice or snow that moves downhill at a high velocity. Avalanches can shear trees, cover entire communities and highway routes, and level buildings in their path. Avalanches are triggered by a number of processes, including exceeding critical mass on a steep slope or disturbances caused by seismicity or human activity. As temperature increase and snowpack becomes unstable, the risk of avalanches increases.

## 1.3 Disaster management activities

Disaster management activities can be grouped into four phases as follows:

– Mitigation (Prevention): Activities that actually eliminate or reduce the probability and the effects of a disaster.

– Preparedness: Activities prior to disasters that are used to support the prevention of, mitigation of, response to, and recovery from disasters. In this phase, plans are developed to save lives and minimize disaster damage (for example, installing early warning systems).

– Response: Activities following a disaster. These activities are designed to provide emergency assistance for victims, to stabilize the situation and to reduce the probability of secondary damage.

– Recovery: Activities necessary to return all systems to normal or better (for example, rebuilding destroyed property, or the repair of other essential infrastructure).

The four above quoted activities phases are both indistinct and interdependent. They are indistinct because there is not an absolute "beginning" and "end" to each period. They are interdependent because actions undertaken in one phase affect the type and range of actions that can be undertaken in another phase. The four-activity framework is simple and widely accepted. By examining more in detail each of these phases, it is possible to have a picture of the emergency planner's role.

*Mitigation activities* try to eliminate or reduce the causes and the effects of a disaster. This is done either by reducing the likelihood of its occurrence or limiting the magnitude of its negative effects. The aim is to prevent a disaster before it happens. The potential human impact of an extreme natural event, such as floods, hurricanes, or earthquakes can be altered by modifying either the natural event system or the human use system or both. In floods, the loss of life or property can be reduced by dams or levees that confined the floodwaters. Land use restrictions (zoning) limit people's intrusion into the flood plain. More stringent design requirements for the infrastructures (e.g. telecommunication outside plants) can reduce the effects of a natural disaster. Only limited control can be exercised over natural event systems. The choice of whether to mitigate hazards by controlling the hazard agent or by controlling the human use system depends on political and economic decisions about the costs and benefits of each.

*Preparedness activities* protect lives and properties when threats cannot be controlled or when only partial protection can be achieved. These activities assume that a disaster will occur. Plans, procedures and resources must be in place in advance to support an effective response to the threat. Preparedness measures fall into two general categories. The first category is alerting members of response organizations and the public about the timing and extent of a potential disaster. The second category includes actions designed to enhance the effectiveness of the response.

To alert people, it is necessary to be able to detect the threat. Detection and monitoring systems include rainfall and river gauges, radar detection and tracking of severe storms. Warning dissemination systems convey information about threats from authorities to the people.

Preparedness measures include:

– developing plans for the activation and coordination of response organizations;

– devising Standard Operating Procedures (SOPs) to guide organizations in the performance of their functions;

– training personnel in the use of those procedures;

– conducting exercises to test the effectiveness of these plans, procedures and training efforts;

– stockpiling resources;

– assembling inventories of community resources and determine their location.

*Response activities* are the actions of officials just before and during the disaster impact that protect public safety and minimize physical damage. This response begins with the detection of a threat. Response ends with the stabilization of the situation following disaster impact. Stabilization means that the risk of loss of life and property is back to the "normal" levels. Responses focuses on protecting people first. Response attempts to limit damages from the initial impact. Response also seeks to limit damage from secondary or repeated impacts.

Response activities to limit the primary impact include:

– securing the impact area;

– evacuating dangerous areas;

– conducting search and rescue for the injured;

– providing emergency medical care;

– sheltering evacuees and other victims;

– mounting operations to counter secondary threats;

– fighting urban fires and hazardous materials releases after earthquakes;

– identifying contaminated water supplies or other public health threats following floods;

– restoring telecommunication outside plants.

Response actions also assess damages and coordinate the arrival of converging equipment and supplies so they may be deployed to those areas most in needs.

*Recovery activities* begin after disaster impact has been stabilized and seek to restore lost functions. Recovery extends until the community is restored to a reasonable level of functioning. This may require long periods of time. In recovery it is to establish an acceptable quality of life. This may be improved upon as time passes. Recovery has been defined in terms of short-range measures versus long-range measures. Short-range measures include relief, rehabilitation and longer range measures as reconstruction. Relief and rehabilitation activities usually include:

– clearance of debris and restoration of access to the impact area;

– reestablishment of economic activities;

– restoration of essential government or community (including telecommunication) services;

– provision of an interim system for caring for victims, including housing, clothing and food.

Reconstruction activities tend to be dominated by rebuilding major structures and by efforts to revitalize the area's economic system. In some communities, leaders may view the reconstruction phase as an opportunity to institute the plans for change the existed before the disaster.

## 1.4 The role of communications in emergency management

Disasters often happen as sudden events that cause immense damage, loss and destruction. Disaster events occur due to the forces of nature or because of actions that stem from human sources or interventions. Disasters can have extreme magnitude, be long lasting, and cover wide geographic areas within national or international boundaries. In other words, disasters are variable in magnitude (energy), duration (time), and geographic area.

Hundreds of disasters occur each year all over the world; no country is immune. A confined disaster may be quite severe and yet by definition is local in nature. Disasters may affect an entire region, such as with nationwide or international emergency situations. Each disaster brings suffering, financial and social consequences. Regardless of the kind of disaster, telecommunications are needed to respond effectively and save lives.

The common thread to facilitate operations for all disaster recovery phases is the utility of fast, reliable, user-friendly emergency telecommunications that may be realized by technical solutions and/or administrative policy.

The goal is assured telecommunication capabilities during emergency situations. Disasters can impact telecommunications infrastructures themselves. Typical impacts may include: congestion overload and the need to re-deploy or extend telecommunications capabilities to new geographic areas not covered by existing infrastructures. Even when telecommunications infrastructures are not damaged by the disaster, demand for telecommunications soar during such events.

This Handbook is dedicated to the study of the improvement of the design of the telecommunication outside plants in areas frequently exposed to natural disasters. The scope is that of mitigating the effects of natural disasters by ensuring the continuity of telecommunication services.

## Bibliography

[1] Christopher G. Reddick "Homeleand security preparedness and information systems", IGI Global 2010

[2] George D. Haddow, Jane A. Bullock, Damon P. Coppola "Emergency management", Elsevier 2011

[3] Michael K. Lindell, Carla Prater, Ronald W. Perry "Emergency management", Wiley 2007

[4] Ronald W. Perry, Michael K. Lindell "Emergency planning", Wiley 2007

# Chapter 2

# The telecommunication outside plants technologies

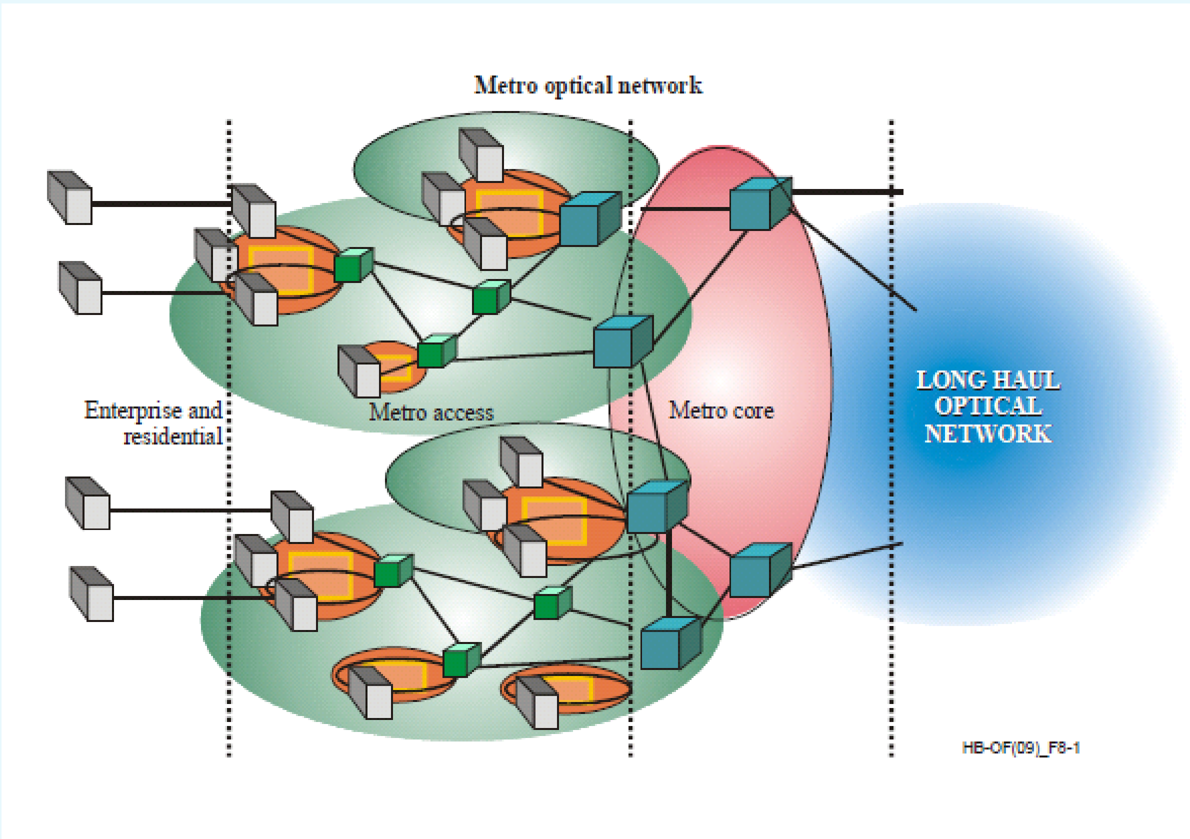
## 2 Introduction

Public telecommunication networks [PSTN (Public Switched Telephone Network/Public Switched Telecommunication Network), ISDN (Integrated Services Telecommunication Network), OTN (Optical Transport Network)] are the most capillary widespread telecommunication networks.

Public telecommunication networks provide not only telephone service, but they carry nearly all telecommunications services (e.g. data, Internet). This means that failure of the public telecommunication networks results in more losses than that of the only telephone service.

Modern telecommunication networks are generally subdivided in access networks, metropolitan access networks (or metropolitan networks), metropolitan core networks (or regional networks) and long-haul networks (or backbone networks) depending on the area they cover (Figure 2-1).

**Figure 2-1: Structure of modern optical networks**



For the purpose of this Handbook, a public network refers to the telecom network accessible to ordinary people. This is important to recognize because in the event of a disaster the number of simultaneous phone calls tends to a huge increase due to the fact that persons will tend to initiate calls to the region hit by a disaster and from that region to other regions or countries resulting in the overload of the public telecommunications network. It is well known that a public network is designed to allow about 5-10% of the subscribers to call and receive calls at the same time. However, in emergencies more people make calls and tend to talk longer resulting in jamming, blocking or congestion of the network.

Moreover, disasters will affect in general the telecommunication network as well, both directly (disruption of outside plant or exchanges) and indirectly, for example, by disruption of power supply lines. Due to the concurrency of these two facts, the network capacity will be heavily impaired just after the disaster when it will be needed to work at full capacity to allow fast recovery. Some segments of the networks are sometime protected by path diversity and equipment duplication so that in case of disaster, part of the network retains its full capacity unless a major switching node is completely destroyed.

The main purpose of this Chapter 2 is to indicate which are the outside plants generally deployed in the public telecommunication networks. Chapters 4, 5, 6 and 7 will be dedicated to the design, deployment and installation criteria for the outside plants of wireline systems, wireless terrestrial systems and satellite systems, which should be used in areas exposed to natural disasters.

## 2.1 Outside plants of wireline systems

### *2.1.1 Copper wires access*

[For further information see ITU-T Handbook “Wireline Broadband Access Networks”]

#### 2.1.1.1 Copper wires used at voice frequencies

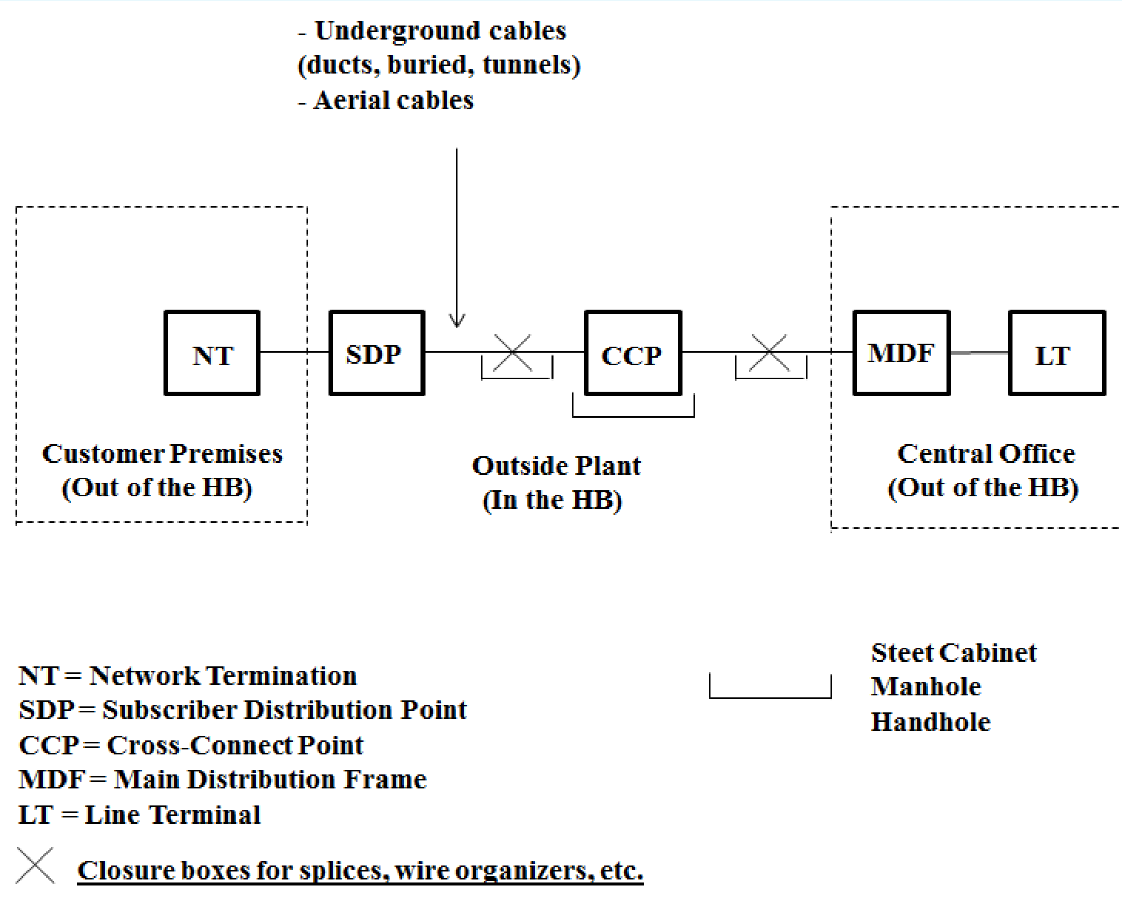
Until some decades ago the PSTN was made of copper wires only (copper pairs in the distribution segment, coaxial cables in the trunk network). Nowadays, copper has no application beyond local access and in rare cases for urban applications.

A general view of the physical model of the copper wire local loop plant is shown in Figure 2-2. Larger Central Offices (CO) may serve over 100,000 telephone lines; they all terminate at the Main Distribution Frame (MDF) in the CO. The loop plant consists of twisted wire pairs that are contained within a protective cable sheath. Within the Central Office, cables from switching and transmission equipment are lead to the MDF, which is a large wire cross-connect frame were jumper wires connect the CO equipment cables (at the horizontal side of the MDF) to the outside cables (at the vertical side of the MDF). The MDF permits any subscriber line to be connected to any port of any CO equipment. Cables leaving the Central Office are normally contained in underground conduit with up to 10,000 wire pairs per cable and are called feeder cables. The feeder cables extend from the CO to a wiring junction and interconnection point: the Cross-Connect Point (CCP). The CCP usually contains a small wire jumper panel that permits the feeder cable pairs to be connected to any of several distribution cables. The CCP is generally at 0.5 - 1.0 km from the customer premises and typically serves 1,500-3,000 living units. The CCP contains only a wiring cross-connect field; it has no active electronics. The loops emanating from the CCP to the customer are usually called “distribution plant”.

Distribution cables contain 25 to 1000 pairs. For residential and small business areas, the distribution cable connects to the drop wires via a distribution terminal (SDP, Subscriber Distribution Point), which typically serves four to six leaving units. Inside wire is often two twisted pairs of 0.4 mm, even if a wide range of wiring practices may be found inside the customer premises.

In other words the feeder and distribution cables are configured as a cascade of cable sections of different diameters and lengths. The copper wire local loop is therefore a multi-level star network with cable branching at each intermediate distribution point.

**Figure 2-2: The copper wire local loop plant**




The copper wire "local loop" used in the PSTN has the advantage that the telephone at the user's premises is powered from a battery at the telephone exchange. If power at the user's premises is lost, the phone will still work as long as the lines are not damaged.

The outside plants of the copper wire local loop are shown in Figure 2-2.

### 2.1.1.2 Copper wire access with xDSL

[For further information see ITU-T Handbook "Wireline Broadband Access Networks"]

Digital Subscriber Line (DSL) technology provides transport of high bit rate digital information over copper wire telephone subscriber lines. By the time the standardization of the xDSL systems started (about 20 years ago) copper-pair cable networks were already extremely widespread around the world. As a consequence, the objective of xDSL systems standardization was to exploit existing networks, re-using their physical and electrical characteristics.

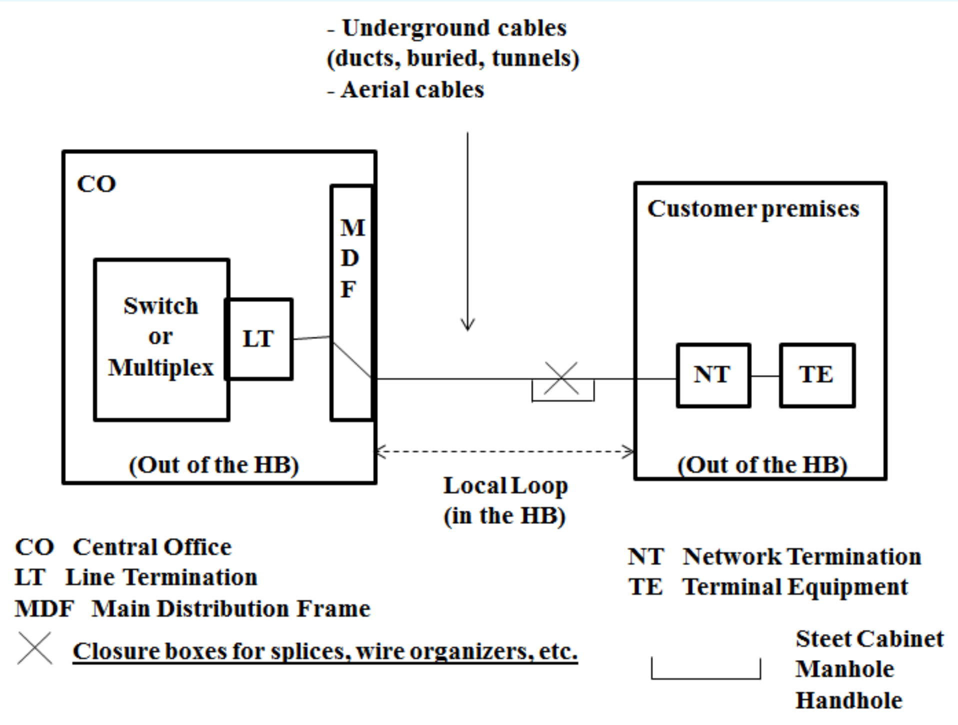
So DSL technology has added a new twist to the utility of telephone lines, which were originally constructed to carry a single voice signal with a 3.4 kHz bandwidth channel. They can now convey several tens of Mbit/s. High speed digital transmission via telephone lines requires advanced signal processing to overcome transmission impairments due to signal attenuation, crosstalk noise from the signals present on other wires in the same cable, signal reflections, radiofrequency noise and impulse noise. So the twisted wire pair infrastructure connect to virtually any home and workplace in the world, but DSL have their limitations and some of the copper pairs will require upgrade activity to permit high speed DSL operation.

A DSL consists of a local loop (telephone line) with a transceiver at each end of the wires. The transceiver is also known as a modem (modulator/demodulator). The transceiver at the network end of the line is called Line Termination (LT), the transceiver at the customer end of the line is known as the Network Termination (NT).

The majority of the DSLs are served via copper lines extending all the way from the central office to the customer's premises, as shown in Figure 2-3.

The outside plants of the copper access with xDSL are shown in Figure 2-3.

**Figure 2-3: DSL Reference Model**




Several species of DSL have resulted from the evolution of technology and the market it serves. The term xDSL applies to all the types of DSL family.

The upstream and downstream rates supported by the various xDSL technologies, both symmetric and asymmetric, are shown in Table 2-1.

**Table 2-1: Transport capacity of the xDSL systems**

| | Bit rate | Maximum frequency |
|---|---|---|
| HDSL | 1.544 and 2.048 Mbit/s (on one/two/three pairs) | 485 kHz |
| SHDSL | 192-5696 kbit/s (on one pair)<br>384-11392 kbit/s (on two pairs) | 350 kHz |
| ADSL | 6.144 Mbit/s downstream<br>640 kbit/s upstream | 1.1 MHz |

| | Bit rate | Maximum frequency |
|---|---|---|
| Splitterless ADSL | 1.536 Mbit/s downstream<br>512 kbit/s upstream | 552 kHz |
| ADSL2 | 8 Mbit/s downstream<br>800 kbit/s upstream | 1.1 MHz |
| Splitterless ADSL2 | 1.536 Mbit/s downstream<br>512 kbit/s upstream | 552 kHz |
| ADSL2plus | 16 Mbit/s downstream<br>800 kbit/s upstream | 2.2 MHz |
| VDSL | 52 Mbit/s downstream<br>2.3 Mbit/s upstream | 12 MHz |
| VDSL2 | 50-200 Mbit/s bidirectional (e.g. 120 Mbit/s downstream and 80 Mbit/s upstream or 100/100 Mbit/s) | 30 MHz |

#### 2.1.1.3 Outside plants of copper wires access

The main outside plants of copper wire access are shown in Figures 2-2 and 2-3. In Chapter 4 there is no specific section dealing with these outside plants for two reasons:

– most of these outside plants are the same used for the optical plants which are widely discussed in Chapter 4;

– as said above, nowadays copper has no application beyond local access and in rare cases for urban applications.

### *2.1.2 Optical fibre*

[For further information see ITU-T Handbook "Wireline Broadband Access Networks"]

#### 2.1.2.1 Optical fibre access

Optical fibre is used for access networks to major business customers in city or town centres and, increasingly, for residential access.

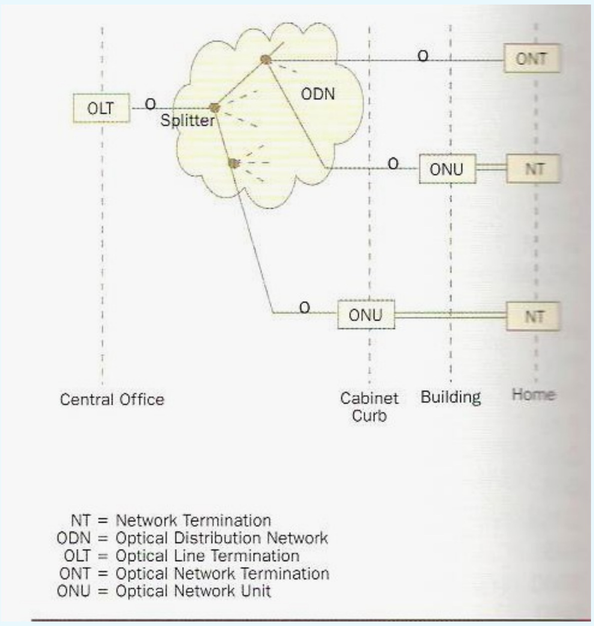
Optical fibre is capable of delivering bandwidth intensive integrated voice, data and video services at distances beyond 20 km in the access network. Various configurations can be imagined for the deployment of the optical fibre in the local access network. The most well known are Fibre to the Home (FTTH), Fibre to the Building (FTTB) and Fibre to the Curb (FTTC).

In the FTTH approach the optical fibre in the local access network can be used in a point-to-point (P2P) topology, with a dedicated fibre running from the local exchange to each end-user subscriber. While this is a simple architecture, in most cases it is cost prohibitive due to the fact that it requires significant outside plant fibre deployment as well as connector termination space in the local exchange. Considering N subscribers at an average distance L km from the central office, a P2P design requires 2N transceivers and N*L total fibre length (assuming single fibre is used for bidirectional transmission).

To reduce fibre deployment, it is possible to deploy a remote switch (concentrator) close to the customer (FTTC, FTTB). This reduces fibre consumption to only L km (assuming negligible distance between the switch and customers), but actually increases the number of transceivers to 2N+2 since there is one more link added to the network. In addition, a curb-switched architecture requires electrical power as well as back up power at the curb unit. Currently, one of the highest costs for local exchange carriers is providing and maintaining electrical power in the local loop. Moreover, as the service is given over the existing copper subscriber lines, the maximum speed achievable with xDSL systems is limited with respect to that of fibre-based systems.

An alternative solution to the two above quoted is to replace the hardened active curb-side switch with an inexpensive passive optical component. Passive Optical Network (PON) is a technology viewed by many network operators as an attractive solution to minimize the amount of optical transceivers, central office terminations and fibre deployment. A PON is a point-to-multipoint optical network with no active element in the signal path from source to destination (Figure 2-4). The only interior elements used in a PON are passive optical components such as fibre, splices and splitters. Access networks based on single-fibre PON require only N+1 transceivers and L km of fibre.

**Figure 2-4: General structure of a PON [Figure 9-1 Manual Fibres]**




At the network side there is an OLT (Optical Line Termination), which is usually installed at the local central office (CO). The OLT is the interface between all the users connected to the given PON and the metropolitan network. Such users have access to the services offered by the network, through the network terminal (NT), and to the optical network through the ONU (Optical Network Unit)/ONTs (Optical Network Termination).

The OLT and the ONUs are connected via an optical distribution network (ODN), which in many cases has a point-to-multipoint configuration with one or more splitters. Typical splitting factors include 1:16/1:32/1:64 or more.

PON splitters can be placed near the OLT or at the user sites, depending on the availability of fibres in the ODN, and/or on the ODN deployment strategy adopted by network operators.

The PON shown in Figure 2-4 is completely passive and the maximum distance between the OLT and the ONU is typically limited to 20 km at nominal split ratios. However, there are also solutions that include deployment of active elements in the network structure (e.g., optical amplifiers) when it is necessary to achieve a longer reach (e.g., up to 60 km) or to reduce the number of CO sites (CO concentration), or to connect a larger number of users to a single OLT port (e.g., where higher power budget is required due to a higher split ratio). Such solutions are typically referred to as “long-reach PON”.

As shown in Figure 2-4, a PON can be deployed in a FTTH (fibre to the home) architecture, where an ONU/ONT is provided at the subscriber's premises, or in FTTB (fibre to the building), FTTC (fibre to the curb) or FTTCab (fibre to the cabinet) architectures, depending on local demands. In the latter cases, the optical link is terminated at the ONU, and the last stretch to the subscriber's premises is typically deployed as part of the copper network using e.g., existing xDSL lines. Various types of xDSL family technologies are typically used, e.g., VDSL2 (Very high speed Digital Subscriber Line 2).

In order to reduce the need for dual fibre (one for each direction of transmission) ODNs, the PON systems can take advantage of the Wavelength Division Multiplexing (WDM) technique, where downstream (from the CO to the user) and upstream (from the user to the CO) channels are transmitted at different wavelengths: 1260-1360 nm for the upstream and 1480-1500 nm for the downstream.

Based on the supported upstream and downstream data rate, there two main categories of PON: the BPON (Broadband PON) and the G-PON (Gigabit capable PON).

BPON and G-PON systems are very similar at the physical layer with the main difference being the supported data rates. At present G-PON systems represent with the most widely used because of:

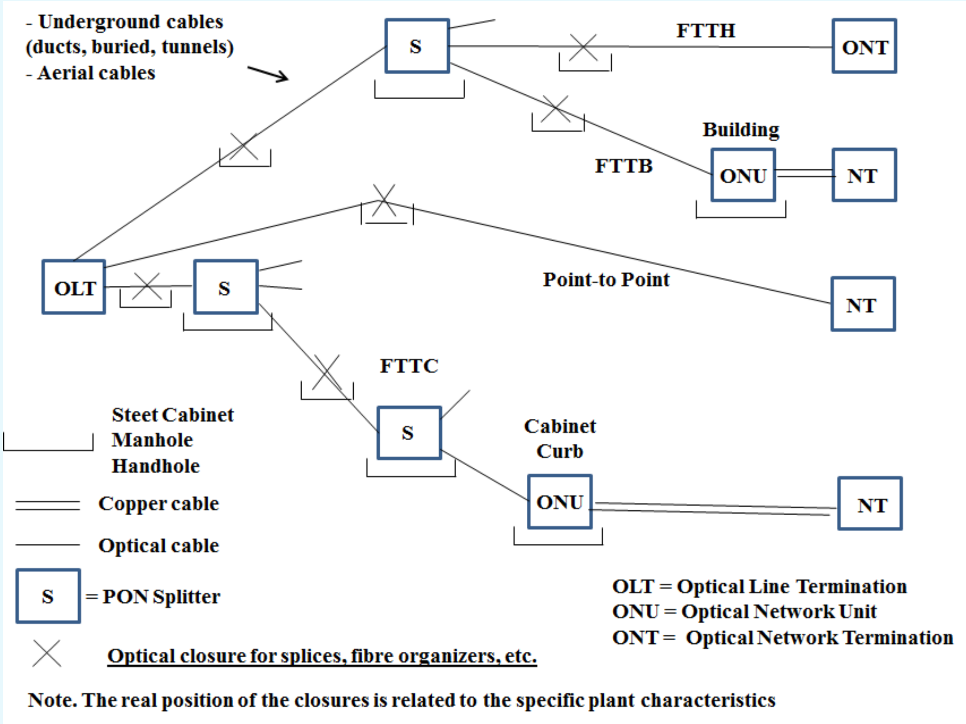
i) higher capacity (BPON: 622 Mbit/s downstream/155 Mbit/s upstream, G-PON: 2,488 Mbit/s downstream/1,244 Mbit/s upstream);

ii) higher split ratio (BPON 1:32, G-PON 1:64 with potential support for 1:128);

iii) maximum reach (BPON 20 km, G-PON supports optical amplifiers in the ODN, called reach extenders, which extend the system reach up to 60 km).

The main outside plants of an optical access networks are shown in Figure 2-5.

**Figure 2-5: General structure of a PON**




### 2.1.2.2 Optical fibre links in metropolitan and backbone networks

[For further information see ITU-T Handbook "Optical Fibres, Cables and Systems"]

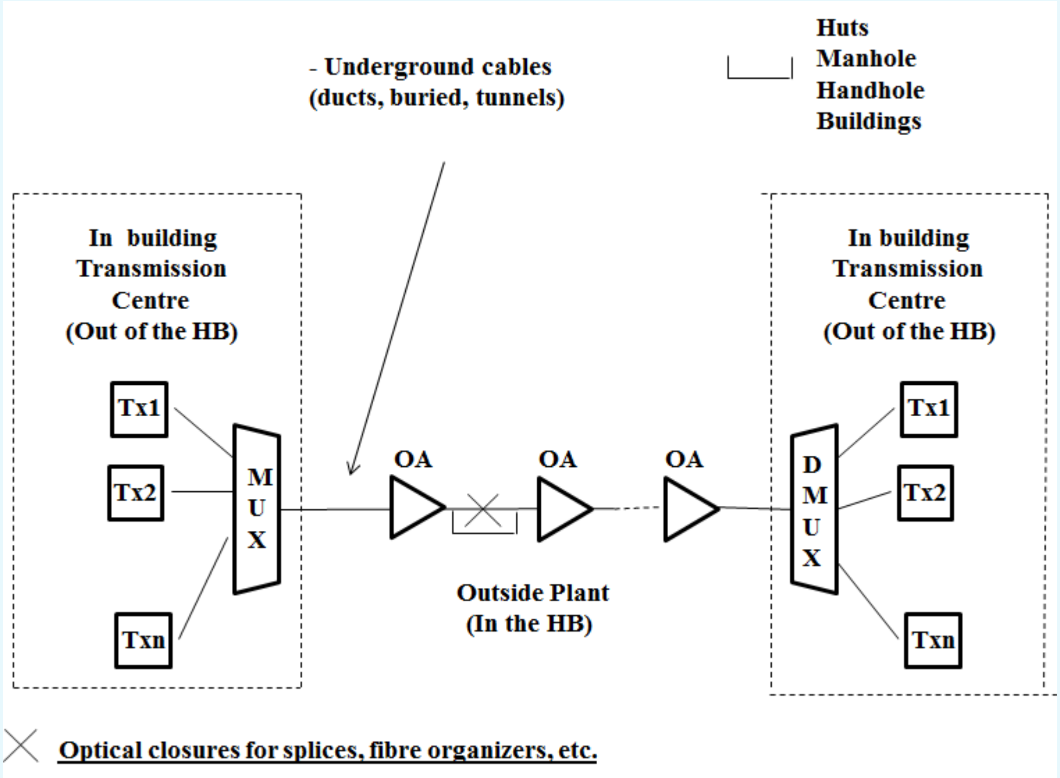
Optical fibre, with its unsurpassed capacity, is particularly suitable for metropolitan, regional and backbone (long distance) networks and plays a key role in migration to broadband services. It is favoured over terrestrial radio (microwave) transmission systems when the usage level is high enough to justify fibre's higher capital and operating costs.

The link length may vary from a few kilometres to thousands of kilometres, depending on the specific application. For example optical links are used to connect different equipment between two buildings placed a short distance apart. The low attenuation and wide bandwidth of optical fibres are not of primary importance for such links. Fibres are used mainly because of their other advantages, such as immunity to electromagnetic interference. The situation is different for systems which are used for high speed transmission across continents or between continents with a link length of hundreds/thousands of kilometres. Low attenuation and large bandwidths of optical fibres are important factors in these links in order to reduce the overall cost per unit transmission capacity.

When the link length exceeds a certain value, depending on the operating wavelength, it becomes necessary to compensate for fibre attenuation, as the signal would otherwise become too weak to be detected correctly. Fibre attenuation can be compensated by using optical amplifiers. Amplifiers are especially valuable for WDM systems as they can amplify many channels simultaneously. Point-to-point systems can be connected in a mesh structure.

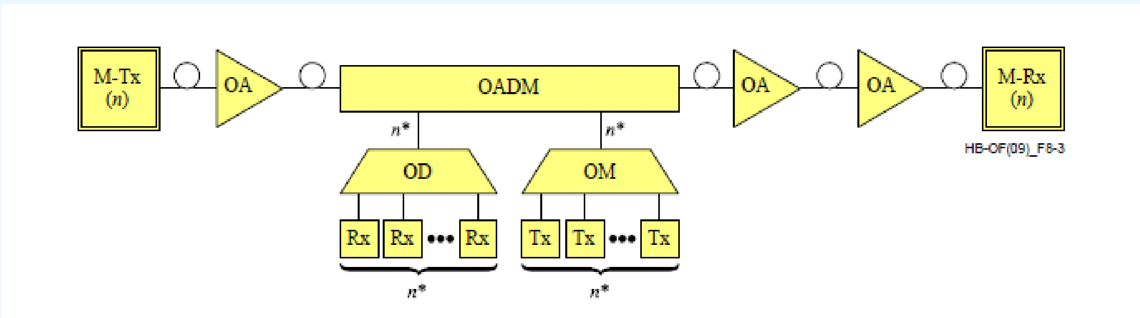
Figure 2-6 shows a typical trunk line in a point-to-point topology. Wavelength Division Multiplexing (WDM) is commonly used to increase the link capacity by sending many channels, with different wavelength (colours), over the same fibre. Figure 2-6 also shows the outside plants involved in this part of the optical network.

**Figure 2-6: Point-to-point link with WDM optical transmission systems**




Point-to-point links constitute the simplest kind of optical systems. Their role is to transport information available in the form of a digital bit stream, from one place to another. In order to introduce more flexibility in the long-haul network, other topologies have been implemented taking advantage from the introduction of all-optical routing devices such as Optical Add Drop Multiplexers (OADM) or Optical Cross Connects (OXC). OADM's allow the use of bus structures whose representation is shown in Figure 2-7.

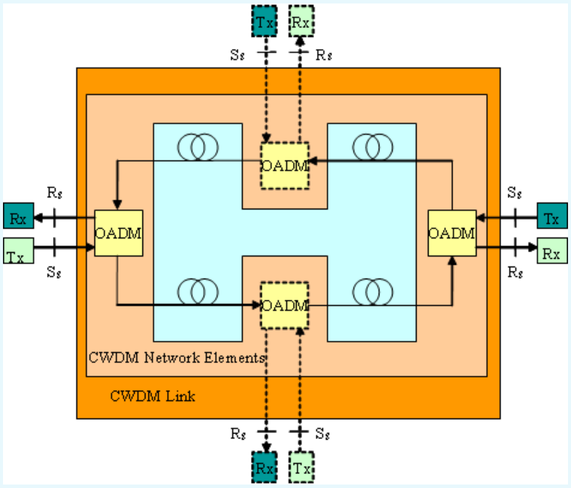
**Figure 2-7: Example of bus structure for long-haul systems**



In this example, a number (n) of WDM channels is travelling along the fibre and enters the OADM. A subset (n*) of WDM channels is dropped and added by the OADM. The number n* of dropped and added channels may range between 0 and n. This scheme can be generalized incorporating a sequence of optical amplifiers and optical add/drop multiplexers (OADMs). The outside plants are not indicated in the figure because they are the same indicated in Figure 2-6. As a matter of fact the OADMs are located inside buildings.

Many modern trunk systems feature automatic recovery systems, such as rings and other automatic re-configuration methods so that a redundant link or route can take the load from a failed link (Figure 2-8). This of course depends on quite a lot of redundant capacity being designed into the system in the first place. There are also cost considerations and in the present de-regulated environment many small operators in developing countries, who have limited resources, consider this a luxury. Even in well developed countries there have been spectacular flops, caused by the gradual erosion of redundant capacity as it is sold to paying customers in today's highly competitive business. When the network rings are broken, there may not be enough spare capacity in the ring to carry the entire load in case of a fault.

**Figure 2-8: Ring configuration**




### 2.1.2.3 Outside plants of optical fibre access and links

The outside plants of optical fibre access and of optical fibre links in metropolitan and backbone networks, shown in the previous figures can be roughly grouped as follows:

i) Optical fibres and cables (fibres, cables, cable protection, installation methods, etc.);

ii) Passive optical devices and nodes (splices, connectors, fibre organizers, passive optical splitters, optical closures, fibre distribution units, etc.);

iii) Active optical devices and nodes (ONU, DSLAM, xDSL Terminals, Reach Extender, etc.).

iv) Infrastructures (underground ducts/conduits, street cabinets, manholes, handholes, etc.);

The above plants are considered as outside plants because they are generally located in the plant between the buildings with switching and terminal equipment. They are shown in Figures 2-5 and 2-6 and are in the scope of this Handbook. Chapter 4 is dedicated to these plants.

## 2.2 Outside plants of wireless terrestrial systems

### *2.2.1 Microwave radio systems*

[For further information see "Telecommunications and Data Communications Handbook", Ray Horak, John Wiley & Sons]

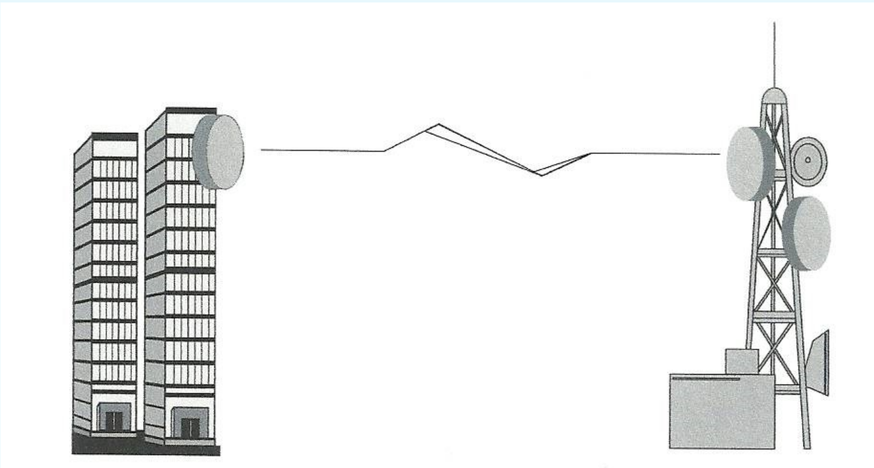
#### 2.2.1.1 General characteristics

Microwave systems are point - to - point radio systems operating in the GigaHertz (GHz) frequency range. The *wavelength* is in the millimeter range, which is to say that each electromagnetic cycle or waveform is in the range of a millimeter, which gives rise to the term *microwave*. As such high frequency signals are especially susceptible to attenuation; they must be amplified (analog) or repeated (digital) frequently. In order to maximize the strength of such high frequency signals over long distances, the radio beams are tightly focused. Much as a light bulb in a flashlight is centered in a mirror that serves to focus the light beam, the microwave transmit antenna is centered in a concave, reflective metal dish that serves to focus the radio beam with maximum effect on the receiving antenna (Figure 2-9).

Similarly, the receiving antenna is centered in a concave metal dish that serves to collect a greater amount of incoming signal and reflect it into the receiver.

NOTE – Antennas serve both transmit and receive functions, with transmit and receive frequencies separated to avoid self-interference.

**Figure 2-9: Point-to-Point microwave link**

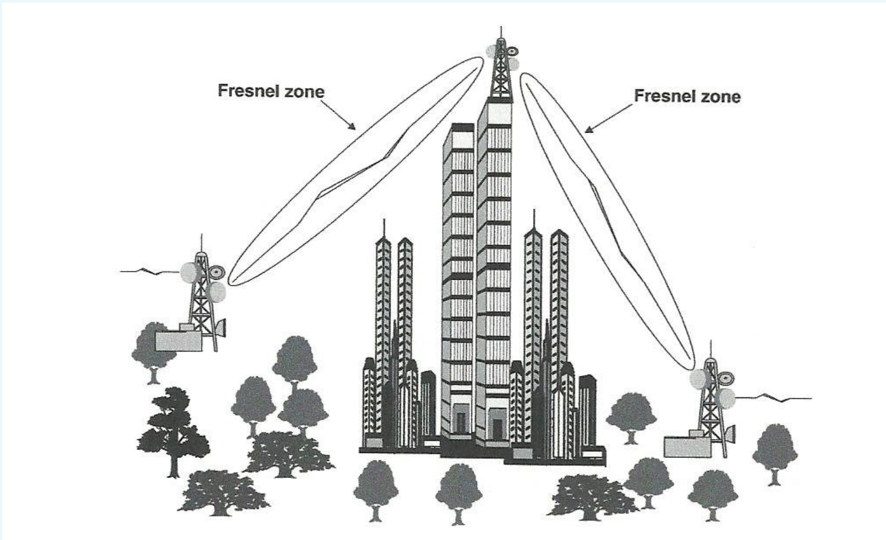


The requirement to so tightly focus the signal, clearly limits microwave to application as a *point - to - point*, rather than a *broadcast*, transmission system. Additionally, microwave is a *Line - Of - Sight* (LOS) technology as such high - frequency radio waves will not pass through solid objects of any significance (e.g., buildings, mountains, or airplanes). Actually, line of sight is not quite enough, as the signal naturally disperses (i.e., spreads out) in a conical pattern. As a result, portions of the signal reflect off of bodies of water, buildings, and other solid objects and can interfere with the primary signal through a phenomenon known as multipath fading. The impact of multipath fading is that multiple copies of the signal reach the receiving antenna at different levels of strength at slightly different times and slightly out of phase, thereby confusing the receiver and distorting the signal much like the *ghosting* effect that can be so aggravating at times to broadcast television viewers. So, additional clearance is required in the form of a Fresnel ellipse, an elliptical zone that surrounds the direct microwave path. In consideration of LOS and

Fresnel zone clearance, antenna positioning and tower height are important considerations in microwave path selection and network design.

Clearly, so to speak, antennas atop tall towers positioned on the roofs of tall buildings and the peaks of high mountains tend to provide optimum signal paths. Figure 2-10 illustrates a multi-hop microwave configuration with consideration given to Fresnel zone clearance.

**Figure 2-10: Multi-hop microwave configuration with Fresnel zone clearance**




If a microwave route traverses a smooth earth path involving no hills, mountains, bulges of earth, tall buildings, or other signal obstructions, the link length is sensitive to factors including frequency band, air quality, and curvature of the earth. Higher frequencies suffer more from attenuation than do lower frequencies. In the context of an airwave system such as microwave, air quality and environmental interference issues include dust, smog, agricultural haze, precipitation, fog, and humidity. Table 2-2 lists example international frequency bands allocated by the International Telecommunications Union – Radiocommunications Sector (ITU-R) for commercial microwave and makes clear the relationship between frequency band and antenna separation, assuming typical allowable power levels. These frequency bands are representative of those used throughout the world for microwave applications, although the specifics can vary from region to region and nation to nation.

At the lowest microwave frequencies, attenuation is low enough that the horizon becomes a major consideration, as the curvature of the earth limits LOS. In this scenario, it is necessary to consider the difference between optical LOS and radio LOS. True *optical LOS* is a straight line between the two antennas. *Radio LOS* can be somewhat longer as the density gradient in the atmosphere acts like a lens and tends to bend radio beams back toward the earth, as illustrated in Figure 2-11.

**Figure 2-11: Microwave path illustrating differences between optical and radio LOS**

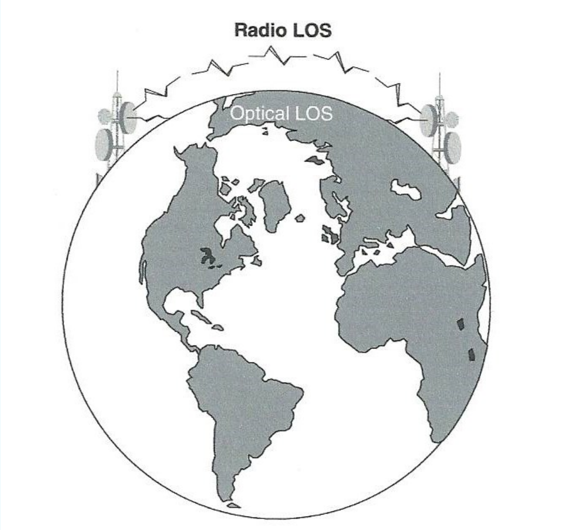



**Table 2-2: Example of Microwave Frequency Bands (ITU) and Antenna Separation**

| Frequency Bands (GHz) | Typical Maximum Antenna Separation (km) |
|---|---|
| 2-6 | 32-48 |
| 10-12 | 16-24 |
| 18-23 | 8-11 |
| 28-30 | 0.6-1.2 |

Microwave technology has been extensively used for long-haul point-to-point telecommunications. Competing long – distance carriers, first in the United States, found microwave a most attractive alternative to cabled systems, due to the relatively high speed and low cost of deployment. Where technically and economically feasible, however, fibre - optic technology currently is used in most long – haul applications.

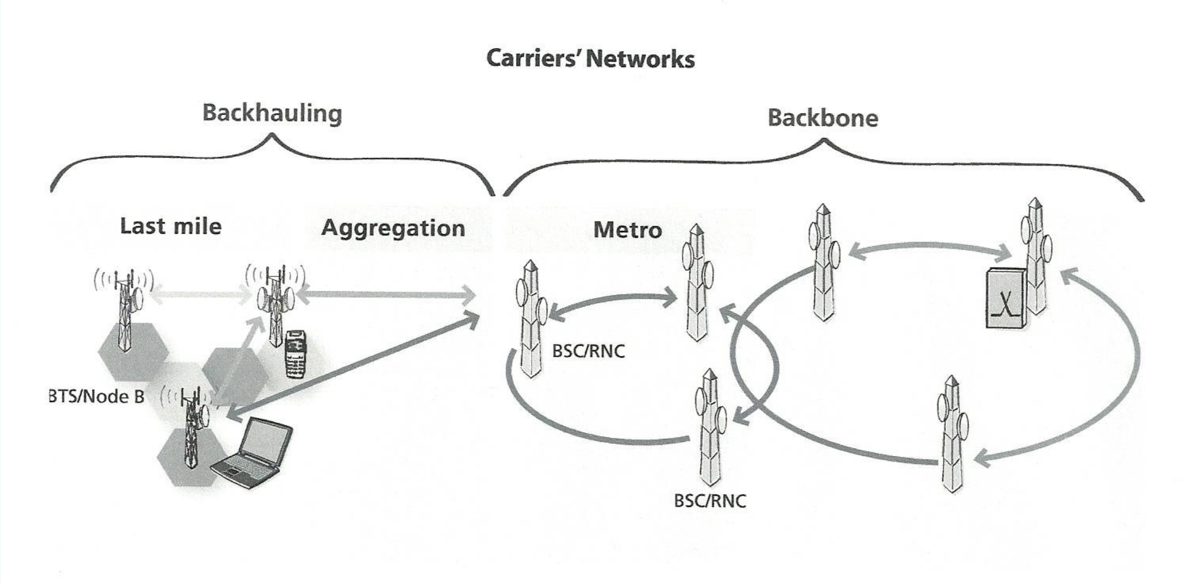
Contemporary there are numerous microwave applications such as private networks, carrier bypass, disaster recovery, interconnection of cellular radio switches, and WLL (Wireless Local Loop). Microwave certainly is an excellent alternative to cabled systems where terrain is challenging. In nations where regulatory authorities have liberalized telecommunications, emerging competitors find microwave to be an excellent means for deploying competing networks quickly and at low cost, particularly in WLL applications.

As cellular and PCS (Personal Communication Service) networks continue to grow, microwave radio links are deployed for connecting cell sites or backhauling traffic to the switch. The broad range of capacities and frequency bands provide ultimate flexibility for both long- and short-haul applications.

The unlicensed versions of the radio also permit rapid deployment of point-to-point links, allowing new cell sites to be turned up quickly to meet service demands.

Some of the above said applications are shown in Figure 2-12.

**Figure 2-12: Some applications of microwave links**




*Source: Alcatel-Lucent, http://lightspeedt.com/wp-content/uploads/2011/06/MDR-8000_brochure.pdf*

#### 2.2.1.2 Outside plants of point-to-point microwave links

The outside plants of microwave links are essentially antennas and towers. Chapter 6 deals with these outside plants.

### *2.2.2 High Frequency radio systems*

[For further information see "HF Communications: a system approach" Nicholas Maslin, Pitman]

#### 2.2.2.1 General characteristics

High frequency (HF) is the ITU-designated range of radio frequency electromagnetic waves (radio waves) between 3 and 30 MHz. HF band is also known as the decameter band or decameter wave as the wavelengths range from one to ten decameters (ten to one hundred metres). The HF band is a major part of the shortwave band of frequencies, so communication at these frequencies is often called shortwave radio. HF communications are possible through ground wave paths. Moreover, because radio waves in this band can be reflected back to Earth by the ionosphere layer in the atmosphere (skywave propagation), these frequencies can be used for long distance communication, at intercontinental distances.

High operational flexibility, easy maintenance of equipment make High Frequency system techniques very useful in world communications; this is particularly emphasized in the case of large geographical areas with low density of telecommunications traffic. When the need for a new communications capability between two or more points is first envisioned, and HF radio link is suggested as a possible solution, a feasibility study is required to analyse and define the whole system.

#### 2.2.2.2 Outside plants of HF radio systems

The outside plants of the HF radio systems are substantially the antennas, the basements and the power plants. Chapter 5 deals with this subject.

### 2.2.3 Cellular mobile networks

[For further information see "Telecommunications and Data Communications Handbook", Ray Horak, Wiley]

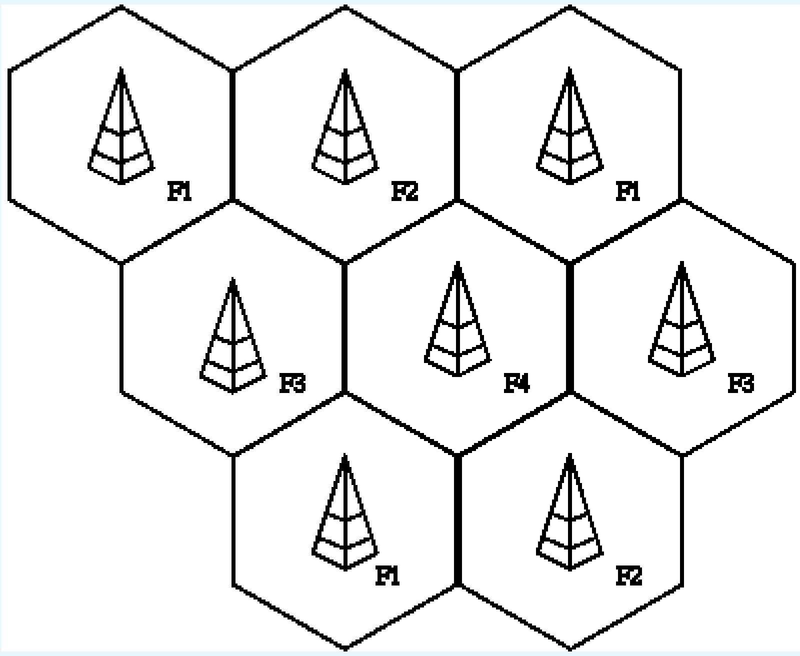
Note. Wireless, quite simply, refers to communications without wires. There are several types of wireless communications. Microwave and satellite communications are types of wireless communications deployed in high speed network backbone and access networks that are point to point, point to multipoint or broadcast in nature. Cellular mobile networks are another type of wireless communications which are local in nature and with an emphasis on mobility.

#### 2.2.3.1 General characteristics

A cellular mobile network is a radio network distributed over land areas called cells, each served by at least one fixed-location transceiver, known as Base Transceiver Station. In a cellular network, each cell uses a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed bandwidth within each cell.

When joined together these cells provide radio coverage over a wide geographic area (Figure 2-13). This enables a large number of portable transceivers (e.g., mobile phones, pagers, etc.) to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base stations, even if some of the transceivers are moving through more than one cell during transmission.

**Figure 2-13: Example of frequency reuse factor or pattern 1/4**




In a cellular radio system, a land area to be supplied with radio service is divided into regular shaped cells, which can be hexagonal, square, circular or some other regular shapes, although hexagonal cells are conventional. Each of these cells is assigned multiple frequencies which have corresponding radio base stations.

The increased capacity in a cellular network, compared with a network with a single transmitter, comes from the fact that the same radio frequency can be reused in a different area for a completely different transmission. Unfortunately, there is inevitably some level of interference to the signal from the other cells which use the same frequency. This means that, in a standard FDMA system, there must be at least a one cell gap between cells which reuse the same frequency.

In cities, each cell site may have a range of up to approximately 0.8 km, while in rural areas, the range could be as much as 7 km. It is possible that in clear open areas, a user may receive signals from a cell site 40 km away.

Radio waves are used to transfer signals to and from the cell phone. All of the cell sites are connected to telephone exchanges (or switches), which in turn connect to the public telephone network.

#### 2.2.3.2 Outside plants of Base Transceiver Stations

The outside plants of the mobile (cellular) networks are substantially the Base Transceiver Stations. Chapter 5 deals with this subject.

## 2.3 Outside plants of satellite systems

[For further information see "Handbook on satellite communications" Wiley-ITU]

### *2.3.1 General characteristics*

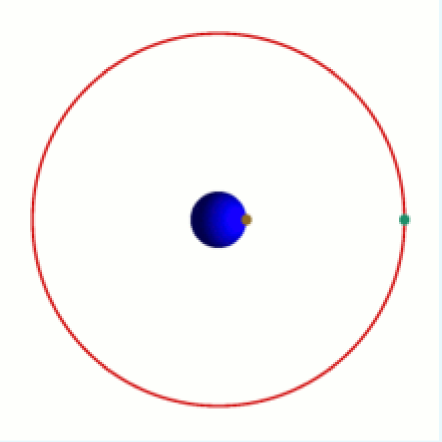
A communications satellite is an artificial satellite stationed in space for the purpose of telecommunications. Modern communications satellites use a variety of orbits including geostationary orbits and low (polar and non-polar) earth orbits.

For fixed (point-to-point) services, communications satellites provide a microwave radio relay technology complementary to that of communication cables. They are also used for mobile applications such as communications to ships, vehicles, planes and hand-held terminals for which application of other technologies, such as cable television, is impractical or impossible.

#### 2.3.1.1 Geostationary orbits

A satellite in a geostationary orbit appears, from earth, to be in a fixed position. This is because it revolves around the earth at the earth's own angular velocity (360 degrees every 24 hours, in an equatorial orbit) (Figure 2-14).

**Figure 2-14:** Geostationary orbit



A geostationary orbit is useful for communications because ground antennas can be aimed at the satellite without their having to track the satellite's motion. This is relatively inexpensive. In applications that require a large number of ground antennas, such as DirectTV distribution, the savings in ground equipment can more than outweigh the cost and complexity of placing a satellite into a geostationary orbit.

The main drawback of a geostationary orbit is that, with no direct line of sight, a satellite cannot service extreme northern and southern areas of the world. Another drawback is the height of the orbit, usually 36.000 kilometres, which requires more powerful transmitters, larger-than-normal (usually dish) antennas, and higher-sensitivity receivers on the earth. This distance also introduces a significant delay, of ~0.25 seconds, into communications.

#### 2.3.1.2 Low-Earth-orbiting satellites

A Low Earth Orbit (LEO) typically is a circular orbit about 400 kilometres above the earth's surface and, correspondingly, a period (time to revolve around the earth) of about 90 minutes. Because of their low altitude, these satellites are only visible from within a radius of roughly 1000 kilometers from the sub-satellite point. In addition, satellites in low earth orbit change their position relative to the ground position quickly. So even for local applications, a large number of satellites are needed if the mission requires uninterrupted connectivity.

Low earth orbiting satellites are less expensive to launch into orbit than geostationary satellites and, due to proximity to the ground, do not require as high signal strength (signal strength falls off as the square of the distance from the source, so the effect is dramatic). Thus there is a tradeoff between the number of satellites and their cost. The earth stations must "follow" the satellite in their movement in respect of the earth.

#### 2.3.1.3 Satellite constellation

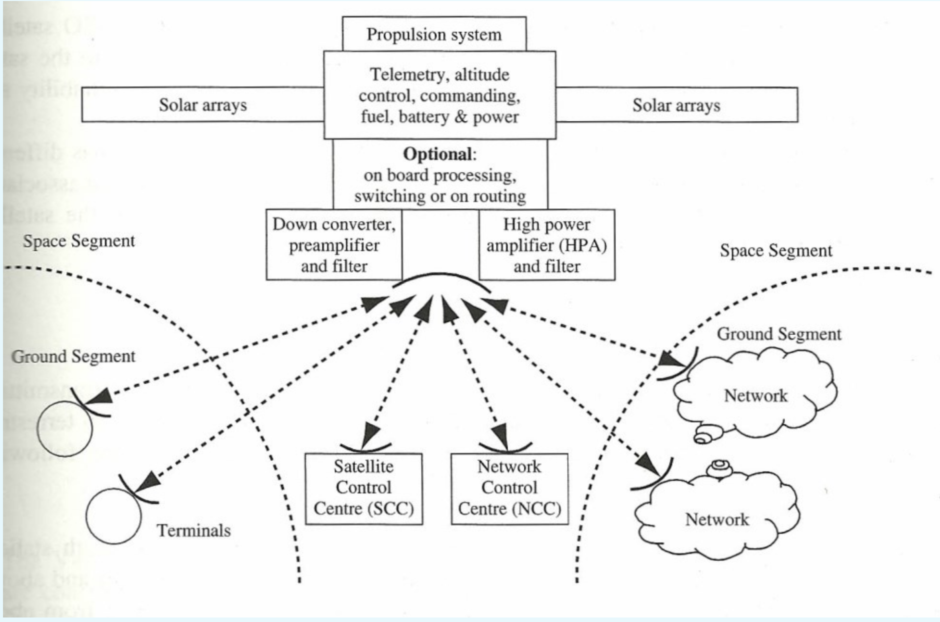
A group of satellites working in concert is known as a satellite constellation. Example of such constellations, intended to provide satellite phone services, primarily to remote areas, are the Iridium and Globalstar systems. The Iridium system has 66 satellites.

It is also possible to offer discontinuous coverage using a low Earth orbit satellite capable of storing data received while passing over one part of Earth and transmitting it later while passing over another part. This will be the case with the CASCADE system of Canada's CASSIOPE communications satellite. Another system using this store and forward method is Orbcomm.

### 2.3.1.4 Structure of a communications satellite

A typical satellite communication includes the following elements (Figure 2-15):

**Figure 2-15: Satellite Networking**




– space segment: one or several spacecraft with in-orbit spare capability. The spare capability could be transponders on the same spacecraft or it could be a whole spare spacecraft. Usually there is at least one spare spacecraft on the ground ready to be launched;

– earth station for communications: a system may include a great variety of earth stations. These stations may vary in size of dish, transmitting power, receiving sensitivity, capacity, access mode (FDMA, TDMA, CDMA), etc. Usually a certain number of these stations may constitute a subnetwork dedicated to a specific service;

– terrestrial distribution: from the earth station the signal is carried to the customers' premises through a terrestrial transmission medium. Coaxial cable, optical fibre cable, microwave link etc. can be used for carrying the signal to the user. The nature of the signal and the distance to be carried will influence the economics and the selection of the appropriate terrestrial transmission system. Quite often, when the signal is carrying messages to be widely distributed within a metropolitan area, a central office is located in the center of the city where the satellite system is carried for demultiplexing and distributing through the public distribution system.

  Even in cases in which the earth station is located at the premises of the end user, a short interconnecting facility may be required to reach the computer room, the private automatic branch exchange (PABX) room or the service equipment which requires the satellite transmission service. Networks of earth stations with the corresponding terrestrial distribution facilities may be dedicated to a particular user and they may also be simultaneously interconnected to a general purpose network including public telephone facilities;

– power supply: most of the terrestrial facilities, including the earth stations, require a backup power system in case of commercial power failure. The term "uninterruptable power supply" is used for special designs that switch automatically to the backup power generating system in case of commercial power failure: storage batteries absorb the load during the switching period. Such backup power systems can be very expensive, depending on the size and duration of the load that they have to carry and the sophistication of the design.

#### 2.3.1.5 Satellite service categories

The ITU has three broad radiocommunications satellite service categories: Fixed Satellite Service (FSS), Mobile Satellite Service (MSS) and Broadcasting Satellite Service (BSS). While some of the basic characteristics of these services are similar, there are crucial differences in their network architecture, capabilities and service offerings.

FSS and BSS operators are capable of providing capacity for fixed-to-fixed and point-to-multipoint services. Both FSS and BSS typically operate from the geostationary (GSO) orbit 36,000 kilometers above the equator. Depending on how the system is configured, a single GSO satellite can be capable of offering service coverage of up to one-third of the Earth's surface.

MSS systems offer voice and lower-rate data services to portable satellite phones and vehicle-mounted terminals for ships, aircraft, trucks or automobiles. MSS systems operate from both the GSO and Low Earth Orbits (LEO), but the user is usually unaware of the orbit used and can simply connect, similar to how someone would use a cellular phone or modem without reference to the specific terrestrial network they are on.

Global Mobile Personal Communications Systems (GMPCS) fall under the MSS category, and indicate highly-portable variants of MSS systems. These applications are particularly suitable for situations where a high degree of mobility is required. While a line of sight connection to the satellite is required, their mostly-omni directional antennas need not be aligned accurately.

#### 2.3.2.6 Outside plants of satellite systems

The outside plants of the satellite systems are essentially antennas, their basements and the power plants. An example is shown in Figure 2-16. Chapter 6 is dedicated to this subject.

**Figure 2-16: Basement and antenna of a satellite system**

## Bibliography

The bibliography is indicated at the beginning of the various sections.

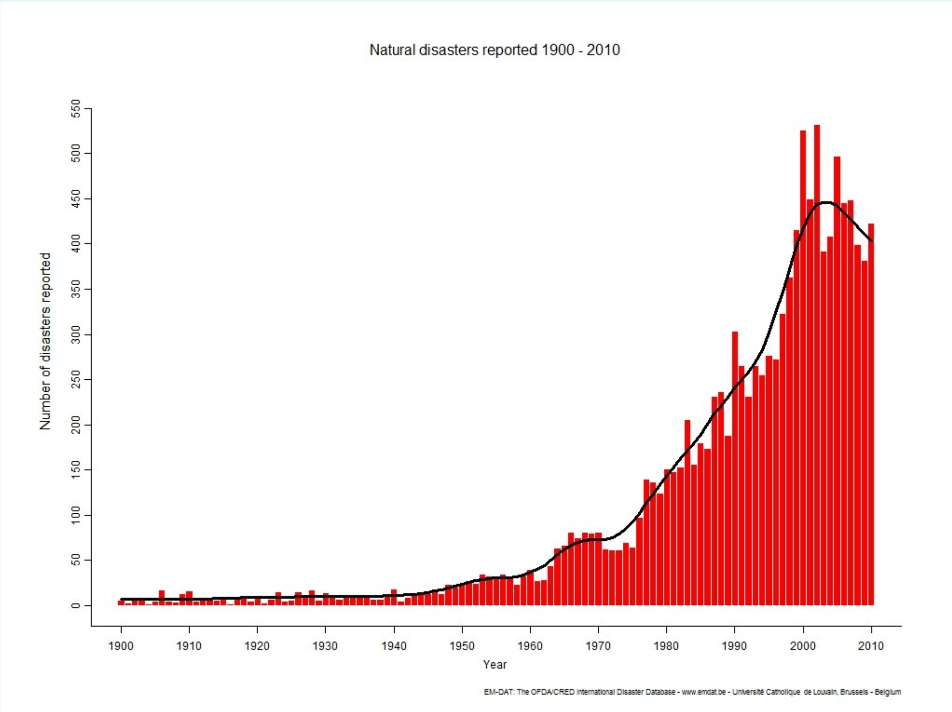
# Chapter 3

# Survey and evaluation of the natural disasters' impact on telecommunication outside plants

## 3 Introduction

The number of natural disasters has been rapidly increasing during the past years as shown in Figure 3-1. In the same way their impact on the outside telecommunication plants is becoming more and more devastating. This chapter outlines the effects of some major natural disasters on the telecommunication outside plants.

**Figure 3-1: Natural disasters reported in the years 1900-2010**




*Source: EM-DAT The International Disaster Database.*

## 3.1 Answers to the questionnaire on "Technical considerations on protecting outside plant facilities from natural disasters"

[For further information see ITU-T Recommendation L.92]

A questionnaire on "Technical considerations on protecting outside plant facilities from natural disasters" was sent to ITU-T Q17/15 members to collect materials such as observations, knowledge, experiences and practices of each country. Sixteen countries (Argentina, Costa Rica, Cyprus, Estonia, Indonesia, Iran, Japan, Korea, Mongolia, Mozambique, Poland, Spain, Switzerland, Tanzania, Turkey and Ukraine) replied to the questionnaire.

As illustrated in Figures 3-2 and 3-3, 81 percent of responded countries have experienced disasters and 87 percent of countries have experienced communication service interruption due to the failure of outside plant facilities.

**Figure 3-2: Percentage of disaster experienced**

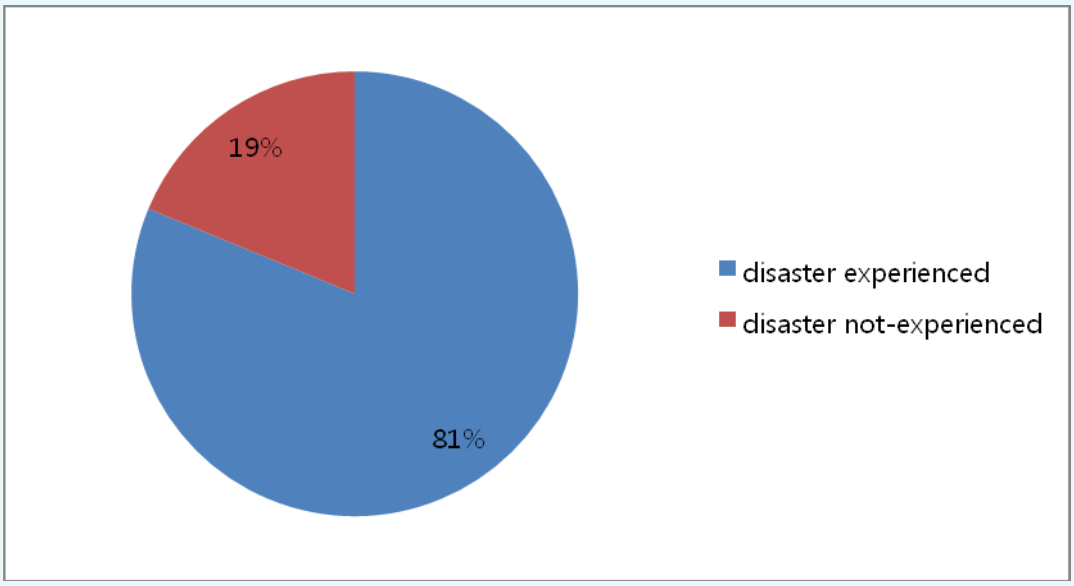
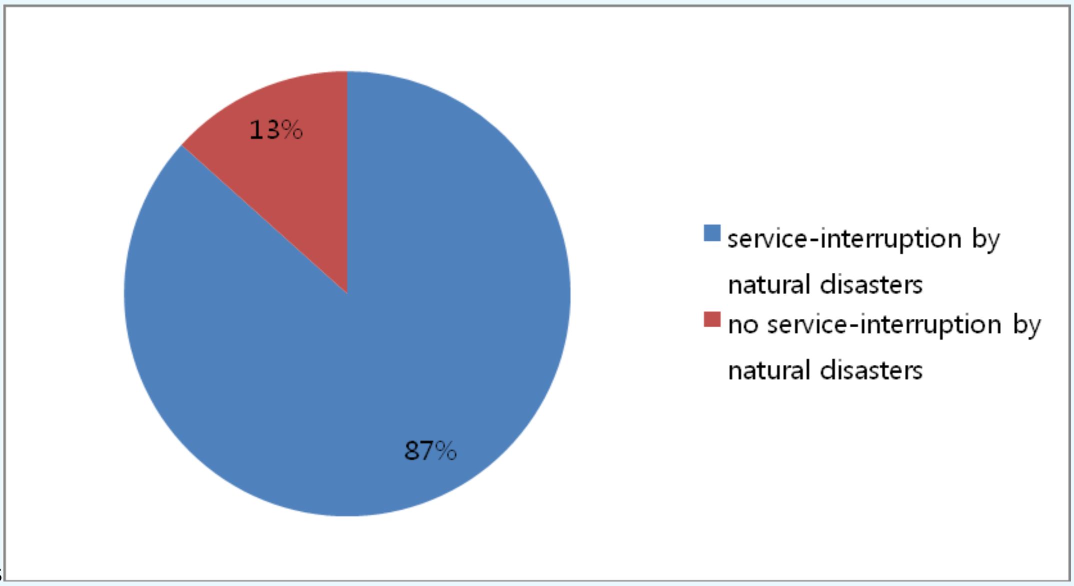



**Figure 3-3: Percentage of service-interruption by natural disaster**




It is found that the most frequently occurring natural disasters are flash floods and strong winds as illustrated in Figure 3-4. Among these natural disasters, flashfloods, earthquake, and strong winds are ranked as the most destructive (see Figure 3-5).

**Figure 3-4: Most frequently occurring natural disasters**

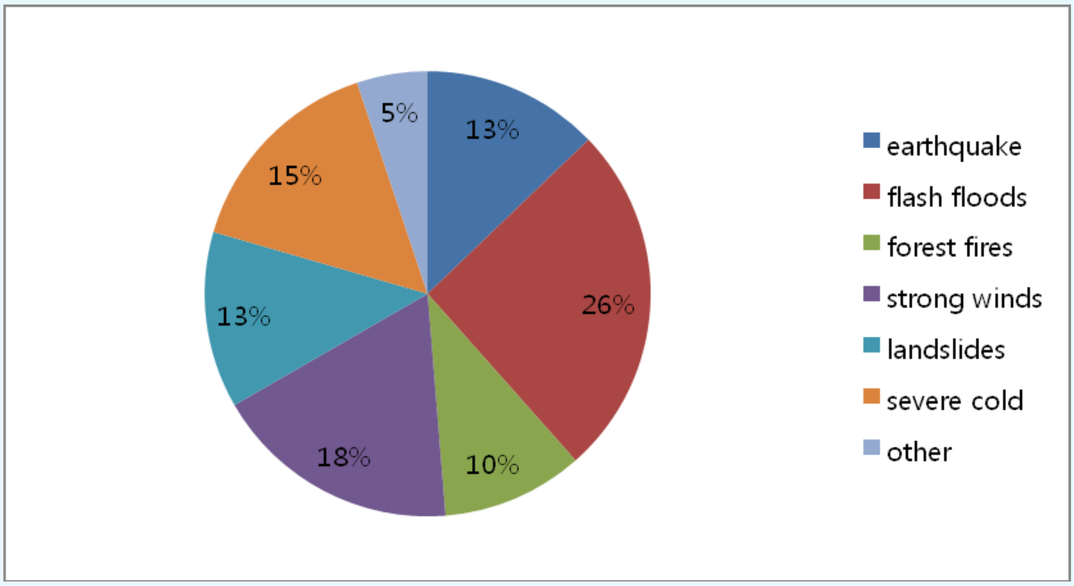
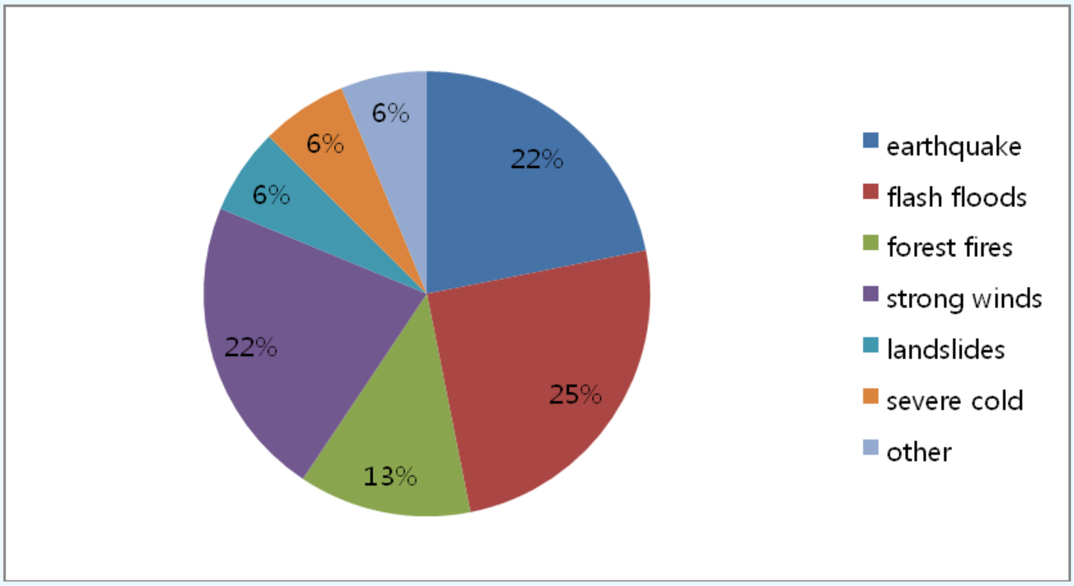



**Figure 3-5: Most destructive natural disasters**




Countermeasures for natural disasters are summarized in Table 3-1.

**Table 3-1: Countermeasures for natural disasters**

| Natural disasters | Countermeasures |
|---|---|
| Earthquake | Rubber joints for cable tunnels, liquefaction countermeasures on manhole, extendable joints for ducts and seismic simulations;<br>Increasing strength of materials which are used in outside plant facilities. |
| Flash floods | Water pumps, sealed pipe ends;<br>Draining water out (from pits) whenever necessary using water pumps;<br>Sealing the ends of the plastic tubes (at the manholes/pits of our underground infrastructure) with foam filler;<br>Submersion detection modules and cable tunnel management systems;<br>Installing drainage pumps in cable tunnels and installing flood walls in cable tunnels;<br>Installing concrete structures at the site in which ground settlement may be expected due to heavy rains;<br>Installing retaining structures or guardrails between outside plant facilities and steep slopes;<br>Cables and cable joints within manholes and cable tunnels are normally constructed to be waterproof;<br>Placing waterproof materials in cable tunnel ends inside manholes;<br>Water-proof cable channels, tight joints of pipes for cable channels, water-tight manholes, and installing water pump in the cable tunnels. |
| Forest fires | Using fire breaks (isolating clean land strips-mostly in the rural area) allover the island;<br>Protecting outside plant facilities with non-flammable or fire-retarding materials;<br>Using non-flammable materials in cable structures. |
| Hurricanes/tornados/typhoons/wind storms (strong wind) | Using stay wires, protect our poles by using stay wires;<br>Bracing poles alternatively with steel wires when the expected wind speed exceeds 40 m/s;<br>Using bracing between poles in windy locations. |
| Landslides | Increasing the slope's stability; keeping away from landslide-prone areas. |
| Severe cold, snow, ice or heat | A manhole cover for snow covered areas and installing tubes for antifreeze in ducts;<br>Outside plant facilities that are installed at sites where there is extreme heat or cold should be provisioned with adequate countermeasures in order to operate with stability;<br>Outside plant facilities that are installed at the site or environment where its temperature difference is excessive should be provisioned with adequate countermeasures in order to operate with stability. |

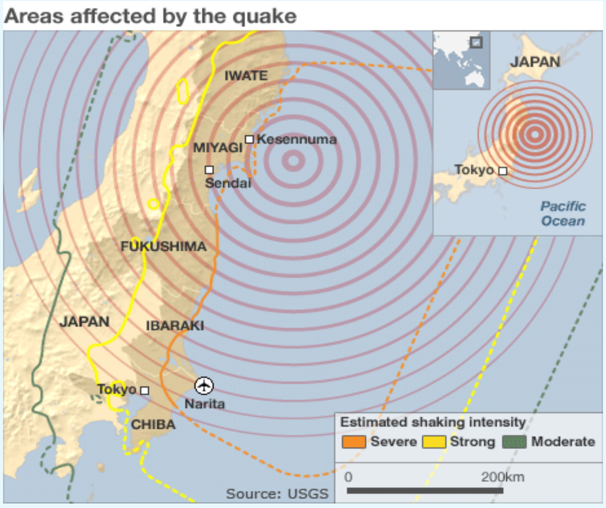
## 3.2 The Great East Japan earthquake and tsunami (11 March 2011)

[For further information see Bibliography.]

### *3.2.1 The main characteristics of the earthquake/tsunami*

In Japan, infrastructure, and telecommunications infrastructure in particular, has been put to the test by the biggest earthquake ever recorded in the country's history, that struck at 14:46 hours on 11 March 2011 off the eastern coast of Japan (Figure 3-6).

**Figure 3-6: Areas affected by the Great East Japan Earthquake**




*Source: ITU-T D.305 New Breeze, p. 3.*

This earthquake can be characterized as follows:

– Earthquake generation date: 14:46, March 11th , 2011;

– Hypocenter: Coast of Sanriku (38.1°N/142.9°E, Depth of 24 km, Magnitude 9.0);

– Japan Meteorological Agency Seismic intensity scale (Over 6):

  - 7 (North of Miyagi),
  - 6 upper (South and middle of Miyagi, Fukushima, and so on),
  - 6 lower (South of Iwate, South of Gunma, and so on)

– The direction of the pressure axis of this reverse fault earthquake was from west-northwest towards east-southeast;

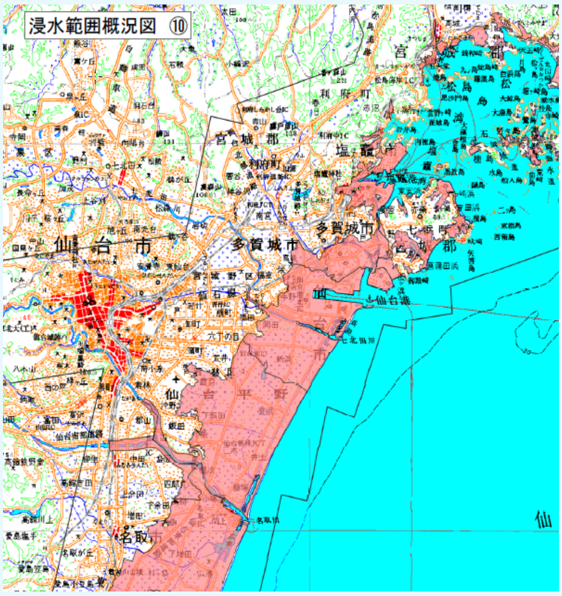
– The maximum amount of land shift was about 25 m, and the scale of the fault was about 200 km in a north-south direction and about 500 km in an east-west direction, as a result, large geographical displacement, 5.3 m enhancement in horizontal direction and 1.2 m in vertical direction, was introduced;

– The fault rupture expanded in the vicinity of the point where the destruction began, then progressed north and south, continuing for about three minutes.

A huge tsunami was generated by this quake, with maximum run-up height was about 38 m. The tsunami caused a flood of large coastal areas. The two natural disasters caused a catastrophe with about 390,000 buildings and houses, about 4,200 roads, about 120 bridges damages, and about 19,000 fatalities.

Figures 3-7 and 3-8 show the flood area generated by the tsunami. Figure 3-7 shows the area in Miyagi.

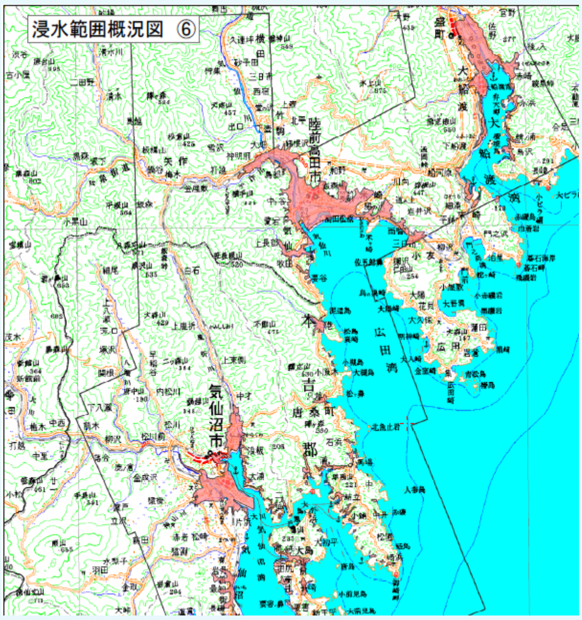
**Figure 3-7: Chart of flood rate (I)**




*Source: ITU-T C896 slide 5.*

Figure 3-8 shows the area in Iwate.

**Figure 3-8: Chart of flood rate (II)**




*Source: ITU-T C896 slide 5.*

In these area maps, flood area is indicated by red color. As shown in these figures, the tsunami had intruded deeply into land.

### 3.2.2 Damages to the telecommunication plants

The telecommunications plants as well suffered unprecedented earthquake and tsunami damage across a wide area, including the collapse, submersion and washing away of equipment inside telecommunications office buildings, the severing and destruction of underground cables and ducts, the collapse of utility poles, the destruction of aerial cables, and the collapse and washing away of mobile phone base stations. The disaster also caused long-term electrical blackouts, meaning even facilities undamaged by the earthquake and tsunami which ought to have been capable of providing service became non-functional due to shortages of batteries or fuel for private electric generators, etc.

As to the specifics of quake damage, the NTT East fixed telecommunications network suffered from cessation of functioning in 385 buildings, 6,300 km of coastal aerial cables being washed away or damaged, and 90 severed transmission routes, as well as 65,000 utility poles washed away or broken in coastal areas. As a result, approximately 1.9 million subscriber lines were affected. Meanwhile, transmission routes (entrance lines) between cellular and PHS base stations operated by NTT East Japan were damaged, and the damage to these routes and using up of batteries, etc., as electrical blackouts continued, resulted in a total of approximately 29,000 base stations shutting down. The damage inflicted on the telecommunications infrastructure by the March 11 earthquake was greater in scale than that caused by previous earthquakes, but swift restoration work by each telecommunications carrier meant that recovery was complete by the end of April with the exception of certain areas.

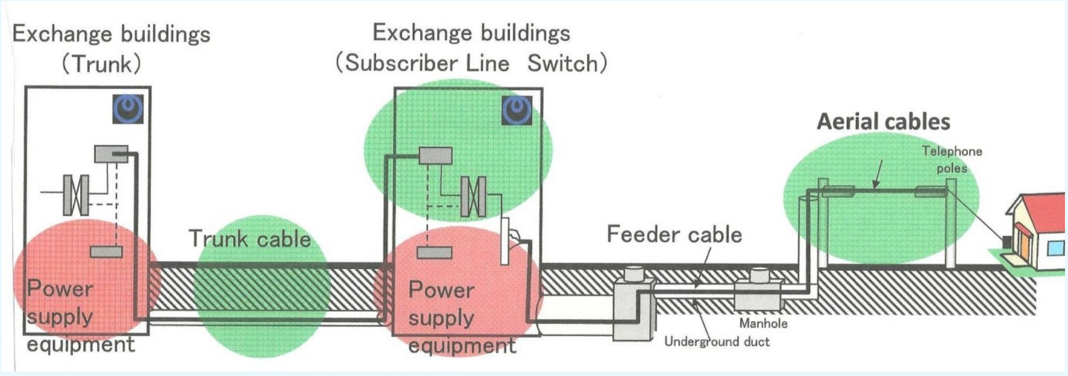
In conclusion the impact of the disasters can be summarized as follows:

– About 19,000 fatalities;
– Material damages estimated at US $ 210 billion;
– About 390,000 buildings and houses destroyed;
– About 4,200 roads destroyed;
– About 120 brides destroyed;
– Nuclear power plants severely damaged;
– Power, water and gas supplies cut.

The damage to the telecommunication infrastructure can be summarized as follows:

– NTT East’s fixed network (the damages on a typical site are shown in Figure 3-9)
  - 385 buildings being out-of-service. The tsunami destroyed outside plant and flooded buildings and accounted for about 20% of the damage, while the remaining 80% of buildings were put out of action as a result of the widespread and prolonged power cuts and the inability to refuel temporary generators.
  - 90 transmission routes were broken.
  - 6,300 km of coastal aerial cables washed away or otherwise damaged.
  - 65,000 utility poles washed away or otherwise damaged.

**Figure 3-9: Situation of communications equipment damage**



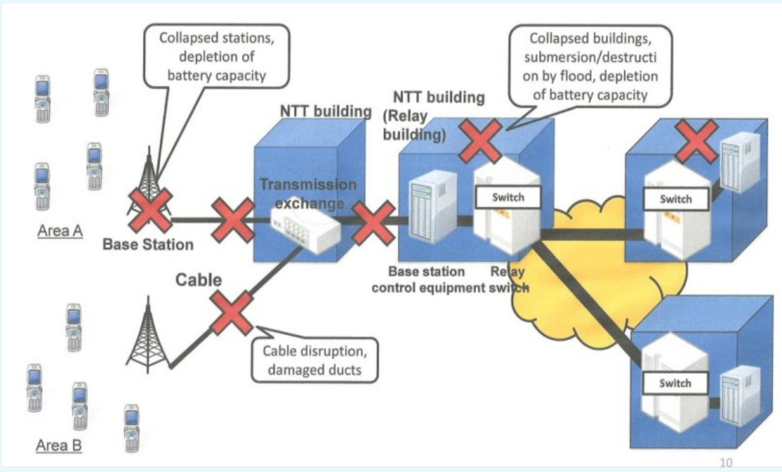

*Totally destroyed or flooded buildings and cable severed by tsunami ⇒About 20% of damaged buildings (green)*
*Widespread, long term power cuts, "cuts to power fuel" ⇒About 80% of damaged buildings (red)*

*Source: Natsuo Minamikawa, Sendai Seminar, March 2012, page 4.*

– Total number of damaged fixed lines (of all the operators): about 1,9 million

– Total number of damaged base stations (cellular service): damages to the transmission routes between cellular base stations and the wired network, using up of batteries as electrical blackouts continued (Figure 3-10) resulted in a total of approximately 29,000 base stations shutting down.

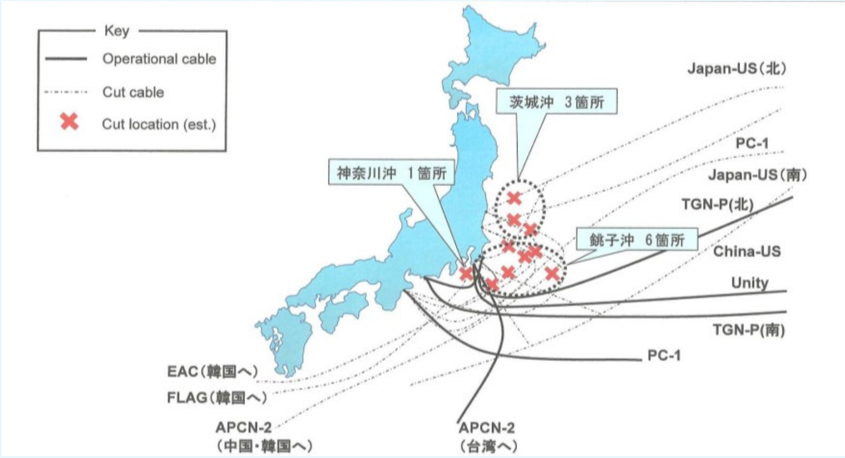
**Figure 3-10: Damaged Points of Mobile Network**




*Source: ITU-D 2-INF-77, Sept. 2011, slide 10.*

– Damage to submarine cables affected international dedicated lines, international IP-VPN (Virtual Private Networks), international subscriber services. (Figure 3-11)

**Figure 3-11: Damages to submarine cables (KDD, Sendai Seminar Slide 7)**




– Power blackout: practically all of Tohoku region suffered a power blackout, with many places experiencing a complete breakdown in communications. Portable radios were at times the only means left for obtaining information.

– Aerial facilities fared much worse than those underground with a damage rate of 0.3% for underground facilities and 7.9% for aerial facilities.

– The earthquake itself caused little damage in respect of the tsunami.

### *3.2.3 Recovery actions (emergency repair)*

Telecom operators/carriers, have been working to restore damaged communications infrastructure and to support victims in the disaster area from the viewpoint of communication lifeline. As of the end of April, services had been restored at all disrupted fixed-line telephone exchanges operated by NTT East, with the exception of a few regions, 3 buildings in difficult area corresponding to the Fukushima nuclear power plant and 2 buildings in refuge island outside area. The above quoted results have been obtained mainly through the following actions/efforts.

#### 3.2.3.1 Telecommunication infrastructures

– Efforts to restore communications infrastructure can be summarized as follows:

  - Deployment of base station vehicles and temporary base stations using satellite;
  - Deployment of battery vehicles;
  - Provision of satellite communications circuits (rental of ultra-small earth stations);
  - Deployment of temporary relay stations outside the area covered by MCA;
  - Release of restoration area map and provision of restoration information.

#### 3.2.3.2 Transmission routes

Transmission routes are also used as entrance lines (transmission routes between mobile phone carriers' base stations and switching equipment), so when they are damaged in disasters, it will also lead to damage of mobile phone transmission routes and disruption of service. Telecom operators engaged in emergency repairs including clearing away of rubble, replacement of utility poles, and laying of cable. Meanwhile mobile phone carriers have been ensuring the viability of entrance lines through use of satellite circuits and fixed micro-lines, etc.

### 3.2.3.3 Submarine cables

Cut optical land cables along highways were found and repaired nonstop for two straight days (about 20 km worth) to hasten the recovery. The interrupted submarine cables, Japan-US, APCN2, China-US and PC-1, are shown in Figure 3-11.

Submarine cable traffic was rerouted on March 15 in order to restore international service.

### 3.2.3.4 Base stations and local stations

During the March 11 earthquake, a total of about 29,000 base stations for cell phones and PHS ceased functioning, and 385 NTT East telecommunications buildings stopped operating.

Emergency repairs to base stations and local stations entails (Figure 3-12):

– in place of damaged communications buildings, portable boxes containing communications equipment were delivered and set up, and communications services resumed;

– expanding the zones of existing base stations;

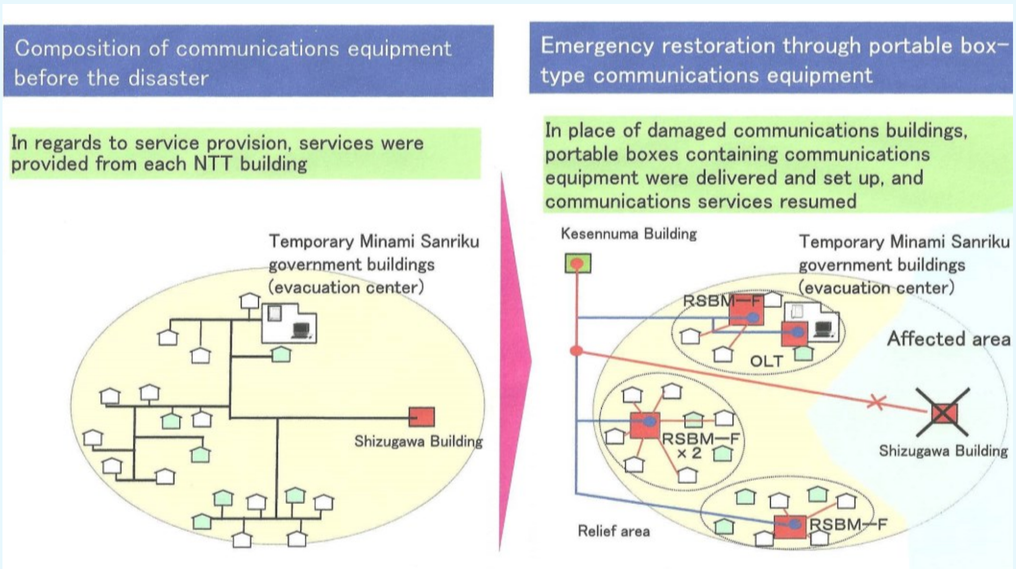
– deploying mobile and compact base stations (femtocells);

– setting up mobile base stations with satellite radio entrance line equipment;

– installation of small, transportable base stations equipped with land radio entrance;

– deploying outdoor line trunk accommodation units and shifted resources from other stations (laying in cable from other areas and out-rigging of network facilities).

**Figure 3-11: Emergency restoration of equipment**




*Source: ITU-D Sendai Seminar March 2012, Natsuo Minamikawa slide 9.*

The mobile service coverage had almost fully recovered by the end of June, with the exception of the restricted area around the Fukushima I Nuclear Power Plant, adopting the above quoted activities.

#### 3.2.3.5 Ensuring stability of power supplies

Electrical blackout countermeasures for telecommunications facilities include requirements for the installation of backup generators or batteries (both backup generators and batteries in the case of switching equipment). In the wake of the March 11 earthquake blackouts were widespread and lasted for long periods of time, and even telecommunications facilities undamaged in the quake were subject to power shortages and service disruptions as batteries and fuel for generators were used up.

As a consequence, the March 11 earthquake highlighted the need for batteries, etc. that can last through long-term electrical blackouts. However it is not practical from a cost perspective to provide for batteries that can serve through very long-term blackouts as regards all telecommunications facilities.

### *3.2.4 Lessons learnt by the earthquake/tsunami*

The earthquake and tsunami that struck Japan in March 2011 affected the access infrastructure such as conduits, cable tunnels, manholes and so on, essential to supporting communication systems. Technologies now exist that are earthquake-resistant but much current equipment is superannuated, in which about 50 % of conduits and about 40 % of cable tunnels are 30 years or more passed after the construction. Moreover, 80% or more manholes have been working for more than 30 years. A lot will undoubtedly be learned from analyzing the damage caused by the March disaster. **Some lessons learnt from damages caused to communications infrastructure are listed in the following Table 3-2.**

At this purpose it is of interest to look, as an example, to look at some cases of gaps between planning and reality.

**Table 3-2: Lessons learnt**

| | Assumptions | Actual damage |
|---|---|---|
| Network Station facilities | – Earthquake preparedness: based on a 7 on the Seismic Intensity Scale<br>– Tsunami preparedness: flood walls installed, floor height raised, etc. | – The vibrations from the earthquake had no effect on stations<br>– The tsunami was larger than the assumptions and had wide spread impact |
| Switches and transmission equipment | Redundancy: redundant switches and transmission equipment, n+1 redundancy architecture should be used | – There were no problems switching to the redundant switches and transmission equipment<br>– The earthquake affected a much wider area than expected and line equipment was damaged in many places |
| Backup power | The necessary backup power equipment was based on the different needs of each station.<br>Examples:<br>– Central office: backup power supply for more than 24 hours<br>– Base stations: battery for at least 3 hours | – Batteries and backup power generation specifications were sufficient in terms of duration of power generation, etc.<br>– The effects on equipment operation were as follows:<br>• Central office no effect on equipment operations<br>• Base stations black out conditions lasted longer than expected and a great number of stations were affected |

Another consideration is related to water leaks caused by the disaster in the communications cable tunnel. Pumping stopped because of loss of power, but the communications cable was not affected and remained usable: optical fiber cable has proof stress to water. Concrete flaked off in the cable tunnel, but there was little damage. The reason for this is because the cable tunnel was built using technology that is in accordance with standards for earthquake resistance.

It might be asked why there was not more earthquake-resistant infrastructure in Japan. The answer is depressingly simple – because of the high cost of applying these technologies in construction.

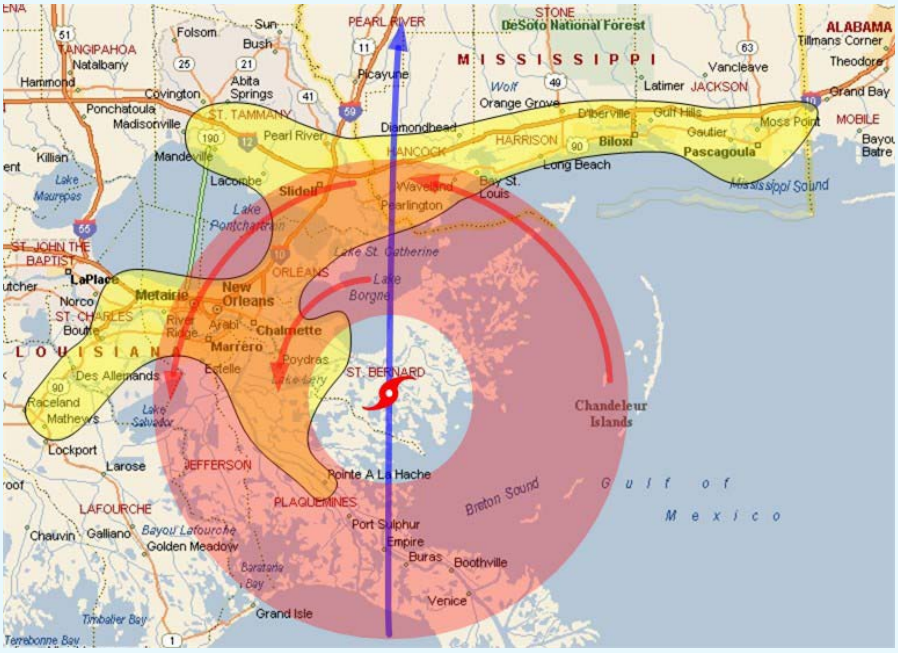
## 3.3 Hurricane Katrina (29 August 2005)

[For further information see Bibliography and, in particular, 16 and 17]

### *3.3.1 The main characteristics of the hurricane/flooding*

Katrina developed as a tropical depression on August 23, 2005, in the southeastern Bahamas. It made its first landfall as a Category 1 storm near Hollywood in South Florida and continued westward across the state into the Gulf of Mexico, where conducive weather conditions, warm sea-surface temperatures, and an upper-level anticyclone allowed it to develop into a major Category 5 hurricane. By the time it made landfall at the Mississippi-Louisiana border on August 29, the huge storm system had 40-50 km radius. Although it had diminished to a strong Category 3 storm, it crashed into the shore with sustained winds of about 180 km per hour. Just six hours later, hurricane Katrina weakened to a tropical storm northwest of Meridian, Mississippi (Figure 3-13).

**Figure 3-13: Hurricane Katrina at 6:45 local time on Aug. 29 2005**




*Source: Kwasinski, Bibl.17.*

The area of hurricane force winds is indicated with a red donut. The path is marked with a blue vertical arrow and the wind direction with counterclockwise red arrows. The site survey region is the lightly-shadowed area

By the time it died out, Katrina had caused one of the worst damage the United States had ever seen. With losses estimated at more than $ 125 billion, it became the costliest hurricane in U.S history. Roughly 230 square kilometer in parts of Mississippi, Louisiana and Alabama – an area slightly larger than the Great Britain – were damaged. The number of death was about 2,000 persons. More than 1.7 million houses lost electricity and up to 1 million people were displaced.

Hurricane Katrina was a strong natural system. The catastrophic combination of high winds, extreme storm surge and flooding from levees breaches set the stage for disaster's impact. In terms of storm surge, the areas hardest hit were Hancock and Harrison Counties in Mississippi, which experienced surge heights of 7-8 m; the surge flattened block after block in the cities of Waveland, Bay St. Louis and Long Beach. The rest of the Mississippi's coast experienced a surge height of 5-6 m. The surge, which extended 9-10 km inland and up to 18 km along bays and rivers, left behind nothing but a few concrete slabs and pilings.

### *3.3.2 Damages to the Telecommunication infrastructures and recovery actions*

The sheer force of the hurricane Katrina and the extensive flooding resulting from the breached levees severely tested the reliability and the resilience of communication networks in the Gulf Coast region. Katrina also affected areas of the Gulf Coast in varied fashions. In the high impact zones near Gulfport, MS and New Orleans, LA, the hurricane created much heavier damage to the infrastructure due to the strong winds and, in New Orleans, extensive flooding in the days after the storm. In less impacted areas, damage was less severe and recovery efforts were more easily accomplished.

As said above, to understand the precise impact that Hurricane Katrina had on telecommunication networks, it is useful to distinguish between the impact of the storm itself (i.e. hurricane force winds and rain) and the effects of what came later (extensive flooding from breached levees and widespread, long term power outages). As detailed below, it appears that most communication infrastructure in areas impacted by Katrina faired fairly well through the storm's wind and rain, in most cases sustaining only minor damage or damage that should have been promptly repairable. Indeed, the tower industry reported that all the towers in the path of the 2005 hurricane in the Southeastern and Gulf Coat areas of the United Sates, less that 1 % suffered any structural damage. The coastal areas that bore the brunt of the storm suffered the worst infrastructure damage from the hurricane. Not to diminish the significant impact of the hurricane itself, what made Katrina unique and particularly catastrophic were the unique conditions after the winds subsided – substantial flooding and widespread, extended power outages. These developments impacted telecommunication networks greatly, causing irreparable damage to submerged electronics and prolonged outages in many cases. The observations on how each type of communications infrastructure withstood Katrina and its challenging aftermath is presented below.

#### 3.3.2.1 Public Safety Communications Networks

Public safety communications networks are generally built to be reliable in extreme conditions. To ensure this, the systems are planned to accommodate everyday peak service times as well as large incidents. They are also designed to account for radio systems disruptions, such as power outages, transmission failures, system interconnect failures and personal radio equipment failures. However, these systems are generally not designed for widespread catastrophes of long duration – the situation resulting from Katrina. As a result of the storm and its aftermath, public safety networks in the Gulf states experienced a large number of transmission outages that impacted the functionality of both primary and back-up systems. The loss of power and the failure of switches in the wireline telephone network also had a huge impact on the ability of public safety systems to function. Public safety personnel's apparent lack of familiarity with the operation of back-up or alternate systems (such as satellite systems) also limited functionality.

Wireline and Network Infrastructure Failures. Katrina and the subsequent levee breaches caused significant failures to the Public Switched Telephone Network (PSTN), particularly in the New Orleans area. Public safety radio networks rely on interconnection with the PSTN or by fixed microwave links to get communications through to public safety responders. Given PSTN failures. as well as damage to fixed microwave links, public safety communications were significantly affected.

In general, public safety's antenna towers remained standing after the storm. The winds did not blow antennas out of alignment, requiring readjustment. However the main cause of transmission failures was loss of power (as discussed below). Most public safety radio systems by design are able to handle and manage a single or isolated subsystem failure or loss. However Katrina affected parts of four states, causing transmission losses at much greater number and over a larger area than public safety planning had envisioned.

Power for radio base stations and battery/chargers for portable radio devices are carefully planned for public safety systems. However, generators are typically designed to keep base stations operating for 24 to 48 hours. The long duration of power outages in the wake of Katrina substantially exceeded the capabilities of most of public safety's back-up generators and fuel reserves. Similarly, portable radios and back-up batteries generally have an 8 to 10 hours duty cycle. Without access to power to recharge the devices and backup batteries, portable devices quickly ran out of power.

#### 3.3.2.2 Wireline network

More than 3 million customer phone lines were knocked in the Louisiana, Mississippi and Alabama area following Hurricane Katrina. The wireline telephone network sustained significant damage both to the switching centres that route calls and to the lines used to connect buildings and customers to the network. Katrina highlighted the dependence on tandems and tandem access to SS7 switches. The high volume routes from tandem switches, especially in and around New Orleans were especially critical and vulnerable. Katrina highlighted the need for diversity of call routing and avoiding strict reliance upon a single routing solution. One tandem switch, which was critical for 911 call routing, was lost from September 4 to September 21. This switch went down due to the flooding that did not allowed for fuel to be replenished. Due to the high winds and severe flooding, there were multiple breaks and fibre network supporting the PSTN. Katrina demonstrated that in many areas there may be a lack of multiple fibre routes throughout the wireline network and that aerial fibre was more at risk than underground fibre. As with other private sector communications providers, lack of access to facilities due to flooding, lack of commercial power, and lack of security greatly hampered recovery efforts. Nevertheless, ten days after Katrina, nearly 90 percent of wireline customers in the Gulf region who had lost service had their service restored. However the vast majority of those customers were in the less impacted regions of the Gulf; regions that were harder hit sustained more infrastructure damage and continued to have difficulty in restoring service.

One of the solutions implemented to replace most destroyed switches was to provide limited services to priority lines with a digital loop carrier (DLC) system linked to an undamaged CO through an optical fibre cable (Figure 3-14).

**Figure 3-14:Pass Christian CO showing the DLC system used to replace the destroyed switch**


*Source: Kwasinski, Bibl.17.*

This implementation indicates that the outside plant was in adequate condition to support the lines connected to the DLC, and that the damage was more severe in the central network elements than in the distribution. Using DLC systems to replace destroyed switches is advantageous from a planning perspective because they can be quickly deployed and they provide more flexibility to adapt to uncertain demands. DLC cabinets fed by optical fibre cables were used to replace damaged copper feeder cables in six COs. Some DLC systems were operating in the area before the storm, mainly in areas of the Mississippi Gulf Coast, to provide service to subscribers far away from the corresponding central office. Only a few of these were destroyed. The undamaged sites were equipped with portable generators.

The most important disadvantage of using DLC cabinets so extensively is the logistical effort of deploying portable generators to each site to maintain service during long electric outages. Moreover reliability will be negatively affected when DLC systems replace a switch; subscriber circuit elements, such as DLC, are usually designed with a lower target reliability than main network components, such as a switch fabric.

Switch on wheel (SOW) had previously been used in some countries during the initial set-up of new networks. Although SOW are more expensive than DLC enclosures, they are more reliable, provide better functionality for trunks, and reduce congestion nodes by allowing better traffic distribution. SOW disadvantages include need for periodic maintenance and floating the batteries during the year.

As said before, the cause of the majority of central office outages was power-related. In New Orleans, flooding caused six CO failures, indicated in Figure 3-15.

**Figure 3-15: New Orleans satellite picture showing the flooded areas**


*Source: Kwasinski, Bibl.17.*

In a darker color with the location of 6 central offices that failed indicated with yellow dots. Levees breaches are marked with red dots.

In some of these sites, direct flood water contact damaged the genset, the fuel tanks or the power plants, but not the main communications equipment. In the other cases, high water levels or civil unrest prevented the possibility of reaching the site with fuel, as in Chalmette. With the exception of Lake CO, whose oldest switch suffered damage, extensive damage at these sites was prevented because the majority of the equipment was located on high floors. Lake CO suffered the highest floodwaters of all the central offices with power related outages. In this location, floodwaters reached more than 3 meters. Besides being in one of the lowest points in the city, the building is located 300 m from the London St. canal levee, which breached 800 m southwest of the central office.

Mid City was the other CO with equipment damage, in this case affecting the power plant located in the basement. Some of these central offices also had damage to copper feeders, probably when pumps that inject air into the cables failed to operate, either because of power failure or direct water contact at the cable entrance. Two other central offices that had direct flood-induced power failure were Michoud and Venice. The latter is Louisiana's southernmost central office located near the mouth of the Mississippi river 15 km west of the landfall point.

All the remaining failed central offices had outages due to genset engine fuel starvation. Two primary reasons for this failure were disrupted local diesel supply and obstructed roads. In these locations flooding did not persist and played no significant role in the outage.

Fuel consumption can be dramatically reduced by installing solar energy panels. In addition, solar power in COs used throughout the year can reduce expenses owed to the electric utility company. A long-term solution may also involve more complex distributed generation systems to reduce the dependency on the electric grid.

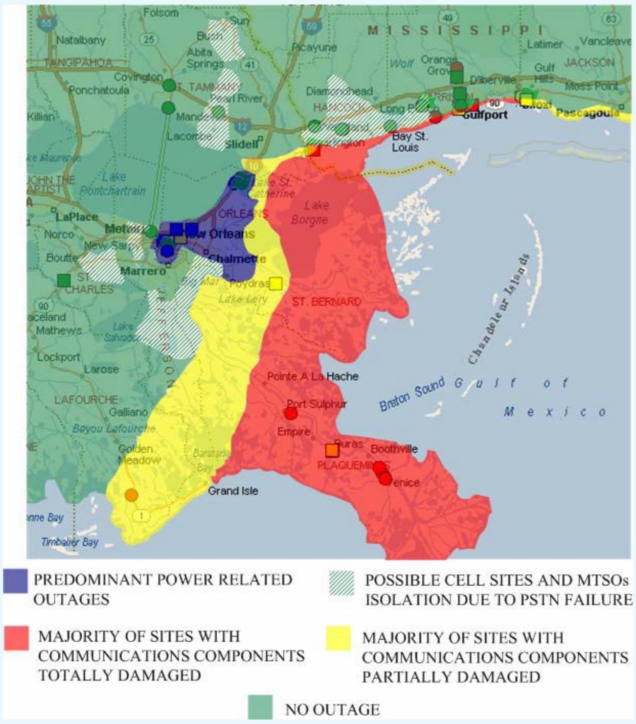
Equipment damage, not power outages, was the most important cause of transmission network failures. Sprint was the long distance carrier that suffered the most severe damage in its network, including the total loss of two key facilities: a POP (Point of Presence) in Biloxi and a switch in New Orleans. When these two facilities flooded, all the sites between them along the coast were cut off, affecting not only the transmission network, but also the links between mobile communications cells sites. Neither did loss of electric power play a role in the single outage reported by AT&T transmission network capacity by 5%. It was restored by redirecting traffic using software that automatically reconfigured transmission equipment and by installing a new optical fibre cable. An important factor in avoiding major disruptions in the AT&T network was keeping operational their main switch in New Orleans, located in Bellsouth's Main CO.

#### 3.3.2.3 Wireless terrestrial Networks/Local Cellular

Local cellular and personal communication service (PCS) networks received considerable damage with more than 1000 base stations sites impacted. In general, cellular & PCS base stations were not destroyed by Katrina, although some antennas required adjustment after the storm. Rather, the majority of the adverse effects and outages encountered by wireless providers were due to the lack of commercial power or a lack of transport connectivity to the wireless switch (wireline T1 line lost or fixed microwave backhaul offline). As a matter of fact PSTN outages affected not only local calls using fixed lines, but also extended into wireless service. In particular many cell sites was isolation from their host mobile telephony switching office (MTSO) when their link through the PSTN was interrupted due to a CO outage. Wireless providers cited security for their personnel, access and fuel as the most pressing needs and problems affecting restoration of wireless service. However, within one week after Katrina, approximately 80 percent of wireless cell sites were up and running. Consistent with other systems, the 20 percent of base stations still affected were in the areas most impacted by Katrina.

As Figure 3-16 indicates, destruction of cell sites due to storm surge, flood and strong winds is found in the Plakuemines, the eastern half of St. Bernard Parish and a 1 km wide strip of the Mississippi Gulf Coast between the border of Louisiana and Mississippi, and Biloxy Bay. Even though this is a large area, it includes less than 1% of all cell sites in the affected region. Some of these sites had inadequate construction for a hurricane-prone zone, such as having the equipment on the ground of areas below sea level.

**Figure 3-16: Map prepared by the authors showing sampled cell site locations and predominant failure type zones**




*Source: Kwasinski, Bibl.17.*

The yellow areas in Figure 3-16 mark zones where the majority of the cell sites may have been only partially damaged rather than destroyed. At least one of the base stations in each of these locations survived. As in the previous area, less than 1% of the total cell sites affected by the Hurricane Katrina are located in this region. The fact that only a portion of a cell site may have been damaged at a particular cell site is explained by a lack of uniformity in cell site construction practices, such as having base stations installed at different heights with respect to flood plane. Figure 3-17 shows one of many such sites. In this case, the cell site was located approximately 1.5 m below sea level with all the base stations but one inside the south shelter installed on the ground. When the site flooded, the water reached the top of the fence indicated on Figure 3-17, avoiding damage to only the base station inside the south shelter.

**Figure 3-17: Cell site in New Orleans with 2 indoor and 2 outdoor base stations. The south shelter is on the front of the picture**


*Source: Kwasinski, Bibl.17.*

Wireless communications companies restored service in damaged cells either by direct repair or by using a cell on wheels (COW). Cellular base stations On Wheels were successfully used as needed to restore survive throughout the affected region. Over 100 COWs were delivered to the Gulf Coast region. A COW is a standard base station mounted inside a container that is placed on a trailer or directly inside the back of a truck. Figure 3-18 shows a COW setup next to a portable transmission site, which was likely used to restore Sprint's coastal links. Damaged cell site links were often replaced by microwave connections. One alternative is to use satellite links. However, there were few COWs and regular base stations using satellite links, likely because establishing them is not a standard feature of most base stations software.

**Figure 3-18: Sprint-Nextel's COW (middle of the image) and portable transmission site**

*Source: Kwasinski, Bibl.17.*

The widespread solution for powering cells during long lasting power outages was to use generator sets.

Cell sites without permanent gensets were equipped with portable generators, such as those depicted in Figure 3-19. In preparation for the storm, portable gensets were stored in safe places away from the storm but close enough to their assigned sites so that they could be deployed quickly. After the storm, taking the genset to the site was usually complicated because roads were damaged or filled with debris, and bridges were washed away. Security checkpoints and areas closed during rescue activities added more complication to the portable power distribution. The same logistic issues persisted during the refueling period that lasted several weeks in some areas. Several portable gensets were refueled daily by a single person who drove hundreds of miles every day. As with COs, an alternative solution to ease the logistic burden of deploying and refueling gensets would have been to have photovoltaic (PV) systems in cell sites.

**Figure 3-19: Cell site in Biloxi, MS With 4 portable gensets**

*Source: Kwasinski, Bibl.17.*

Another stationary generator not shown in the picture was also installed at the site.

Figure 3-19 shows a common occurrence in many cell sites; each company deployed and refueled its own portable genset to each location. Thus a significant number of cell sites received multiple gensets. Logistical burdens may have been eased if cellular companies and tower owners had coordinated their efforts so that only one genset was used at each site to power all the base stations. Cellular telephony companies made extensive use of COWs and portable diesel fueled gensets in Hurricane Katrina's aftermath. Cingular deployed approximately 500 portable gensets and 30 COWs. Verizon, Sprint-Nextel, Cingular South and T-Mobile also used hundreds of gensets and dozens of COWs. Because of all the mobile company efforts during the restoration process, a week after Katrina hit the coast, the cellular telephony networks were almost fully operational in the Gulf Coast and partially operational in New Orleans and Plaquemines. The mobile telecommunications networks proved to be more flexible and resilient to natural catastrophes than the PSTN, thanks to their modular architecture and the lack of fixed connection to the subscribers. Wire-line networks were more complicated to restore than wireless networks due to the PSTN fixed outside plants and especially non flexible CO main distribution frame.

Another advantage of cellular telephony networks over fixed telephony networks is their switch location; MTSO's do not need to be close to the demand centres and, thus, can be located further inland in less vulnerable locations. For instance, Verizon's switches maintained full operation during the storm because they were located further inland.,

### 3.3.2.4 Satellites systems/networks

Satellite networks appeared to be the communications service least disrupted by Hurricane Katrina. As these networks do not heavily depend upon terrestrial-based infrastructure, they are typically not affected by wind, rain, flooding or power outages. As a result, both fixed and mobile satellite systems provided a functional, alternative communications path for those in the storm-ravaged region. Mobile satellite operators reported a large increases in satellite traffic without any particular network/infrastructure issues. More than 20,000 satellite phones were deployed to the Gulf Coast region in the days following Katrina. Broadband capacity was provided by fixed satellite operators for voice, video and data network applications.

Nevertheless, there were functionality issues with satellite communications largely due to lack of user training and equipment preparation. Some satellite phones require specialized dialing in order to place a call. They also require line of sight with the satellite and thus do not generally work indoors. Users who had not been trained or used a satellite phone prior to Katrina reported frustration and difficulty in rapid and effective use of these devices. Satellite phones also require charged batteries. Handsets that were not charged and ready to go were of no use as there was often no power to recharge handsets. Additionally, most of Louisiana parishes (all but three) did not have satellite phones on hand because they had previously chosen to discontinue their service as a cost-saving measure.

### 3.3.3 Lessons learnt by Katrina

From the above description of the damages, it can be seen that there were three main problems that caused the majority of communications network interruptions: i) flooding; ii) lack of power and/or fuel; iii) failure of redundant pathways for communication traffic. Each of these three areas of concern is described below.

Hurricanes typically have flooding associated with them due to the torrential rainfall and storm surge associated with the storms. However, in addition to these sources of flooding, the levee breaks in New Orleans caused catastrophic flooding that was extremely detrimental to the communication networks. While communication infrastructure had been hardened to prepare against strong winds from a hurricane, the widespread flooding of long duration associated with Katrina destroyed or disabled substantial portions of the communications networks and impeded trained personnel from reaching and operating the facilities. In addition, as detailed below, the massive flooding cause widespread power outages that were not readily remedied (electric substations could not be reached nor were there personnel available to remedy the outages). The flooding also wiped out transportation options, preventing fuel for generators from getting where it needed to be.

Power and Fuel. Katrina caused extensive damage to the power grid. Significant portions of electrical facilities in Mississippi, Alabama and Louisiana – including both power lines and electric plants – were severely impaired due to wind and flooding. As a result, power to support the communications networks was generally unavailable throughout the region. This meant that, for communications systems to continue to operate, backup batteries and generators were required. While the communications industry has generally been diligent in deploying backup batteries and generators and ensuring that these systems have one to two days of fuel or charge, not all locations had them installed. Furthermore, not all locations were able to exercise and test the backup equipment in any systematic fashion. Thus, some generators and batteries did not function during the crisis. When generators were installed and operational, the fuel was generally exhausted prior to restoration of power. Finally, flooding, shortages of fuel and restrictions on access to the affected area made refueling extraordinary difficult. In some instances, fuel was confiscated by federal or local authorities when it was brought into the Katrina region.

Redundant pathways. The switches that failed, especially tandems, had widespread effects on a broad variety of communications in and out of the Katrina region. In addition, T1 and other leased lines were heavily used by the communications networks throughout the region, with those failures leading to loss of service. As an example, a major tandem switch in New Orleans was isolated, which meant that no communications from parts of New Orleans to outside the region could occur. This switch, an access tandem that carried long distance traffic through New Orleans and out to other offices, had two major routes out of the city (one to the east and one to west). The eastern route was severed by a barge that came ashore during the hurricane and cut the aerial fibre associated with the route. If only this route had been lost, the access tandem traffic could have continued. However, the western route was also severed – initially by large trees falling across aerial cables, then subsequently by construction crews removing debris from highway right-of-way. While there were provisions for rerouting traffic out of the city, the simultaneous loss of both of these two major paths significantly limited communications service in parts of New Orleans.

In conclusion, Katrina taxed each type of communications infrastructure in a variety of ways: i) strong winds and rain made it difficult for technical stuff to support and maintain the networks and blew antennas out of alignment; ii) heavy flooding following Katrina overwhelmed al large portion of the communication infrastructure, damaging equipment and impeding recovery; iii) single points of failure in vital communications links led to widespread communications outages across a variety of networks; iv) the duration of power outages far outlasted most generators fuel reserves, leading to the failure of otherwise functional infrastructure.

However, there were resiliency successes in the aftermath: i) a large portion of the communication infrastructure withstood the storm's wind and rain with only minor damage (as distinguished from levee breaches and power outages, which had a more devastating impact); ii) satellite networks, although taxed by extensive number of additional users, remained available and usable throughout the affected region. By examining the failures in network resilience and reliability, along with the successes, it is possible better to prepare infrastructure to withstand or quickly recover from future catastrophic events.

## 3.4 Disasters in China

[For further information see Bibliography 14]

In 2008, China suffered a series of disasters such as large snow and earthquake; communications played a prominent role in disaster relief, known as the rescue "lifeline". On 12 May, the Wenchuan earthquake, killing nearly 90,000 persons, caused communications to be fully blocked in 8 counties of Sichuan province and 5 counties of Gansu province, which caused great difficulties for disaster relief efforts. After emergence transfer of satellite phones, the external communication was gradually resumed. After the earthquake, it was concluded that it would has been very important to improve communications network survivability, and that especially building a number of network elements against major natural disasters could avoid communication islands and provide key communication support. To this background, China Mobile proposed the innovative concept of SBS (Super Base Stations), and carried out large-scale deployment, and achieved good results.

Based on research about communication facilities' damage caused by natural disasters such as earthquakes, floods, typhoons and snow, the SBS, which could keep working telecommunication services whatever happens, through improving base station's construction standards, power supply, transmission, building, installation techniques. Compared to normal base stations, the SBS has more reasonable location, stronger backstop, its own oil machine for power supply and satellite transmission equipment.

# Bibliography

1 **–** Site with papers on Katrina

http://www.google.it/search?sourceid=navclient&aq=&oq=&hl=it&ie=UTF-8&rlz=1T4AURU_itIT502IT502&q=hurricane+kkatrina+and+telecommunication+operators&gs_l=hp..0.41l129.0.0.0.3745...........0.#q=hurricane+katrina+and+telecommunication+operators&hl=it&rlz=1T4AURU_itIT502IT502&prmd=imvns&ei=FjaRUN7XE8PStAakwIHQCQ&start=10&sa=N&bav=on.2,or.r_gc.r_pw.r_qf.&fp=f082ff46dee2e554&bpcl=36601534&biw=1140&bih=440

2 – "Technologies for quake- and tsunami-resistant access network infrastructure" (Hideaki Kimura, April 2011) ITU-T NGN-GSI – C 896 Rev.1

http://www.itu.int/md/choice_md.asp?id=T09-NGN.GSI-C-0896!R1!ZIP-E&Errormsg=Please%20authenticate,%20to%20download%20the%20requested%20document.&lang=en&type=sitems

3 – "Telecommunications for Disaster Relief, Network Resilience and Recovery" (Keith Mainwaring, FG Workshop 25 June 2012)

4 – "The Role of Communication Systems in the Great East Japan Earthquake" (New Breeze) ITU-T TD 305 GEN (Dec. 2011),

http://www.itu.int/md/T09-SG15-111205-TD-GEN-0305/en

5 – "Handbook on Public Telecommunications Systems in Disaster Situations " ITU-T FG 14 (Sept 2012)

http://www.itu.int/md/T09-SG15-111205-TD-GEN-0305/en

6 – "Japan after the earthquake and tsunami" (ITU News, July/August 2011)

https://itunews.itu.int/En/1538-Japan-after-the-earthquake-and-tsunami.note.aspx

7 – "Japan: what forces did the infrastructure have to face and how did it stand up to the disaster? Lessons learnt" (ITU News, July/August 2011) https://itunews.itu.int/En/1539-Japan-what-forces-did-the-infrastructure-have-to-face-and-how-did-it-stand-up-to-the-disaster.note.aspx

8 – "Disaster Response in the Field of ICT after the Great East Japan Earthquake " Document ITU-D 2/INF/77, September 2011

9 – **"**Emergency communication system"

http://en.wikipedia.org/wiki/Emergency_communication_system

10 – "Communications network damage by the Great East Japan Earthquake and securing communications" Natsuo Minamikawa, Sendai Symposium,

http://www.itu.int/ITU-D/emergencytelecoms/presentations_Japan2012.htm

11 – "KDD initiatives after the Great East Japan earthquakes" Yoshihisa Oouchi Sendai Symposium,

http://www.itu.int/ITU-D/emergencytelecoms/presentations_Japan2012.htm

12 – List and text of many papers on Great East Japan

http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/presentation.html#mar16

13 – "Maintaining Communications Capabilities during Major Natural Disasters and other Emergency Situations Final Report" MIC, December 27, 2011

http://www.soumu.go.jp/main_content/000146938.pdf

14 – "China Deployed Super Base Station on a Large Scale" Document 2/104-E , 19 August 2011

15 – "List of catastrophic collapses of radio masts and towers"

http://en.wikipedia.org/wiki/List_of_catastrophic_collapses_of_radio_masts_and_towers

16 – Report to the FCC on telecommunication in Katrina

http://transition.fcc.gov/pshs/docs/advisory/hkip/karrp.pdf

17 – "Telecommunications Power Plant Damage Assessment Caused by Hurricane Katrina – Site Survey and Follow-Up Results" Kwasinski

https://netfiles.uiuc.edu/akwasins/www/Intelec06_Katrina.pdf

18 – "EM-DAT The International Disaster Database"

http://www.emdat.be/natural-disasters-trends

19 – Cell on wheels

http://en.wikipedia.org/wiki/Cell_on_wheels

# Chapter 4

# Outside plant of wireline systems to be deployed in disaster areas: design, implementation, operation and maintenance

## 4 Introduction

Recently, natural disasters such as earthquakes and floods have occurred more frequently. Outside plant facilities such as manholes and poles are occasionally damaged by these disasters, and as a result, telecommunication services stop. In order to minimize damage and/or to protect outside plant facilities safely, appropriate disaster management is needed.

The plants of optical fibre access and of optical fibre links in metropolitan and backbone networks can be roughly grouped as follows (see Chapter 1):

i) Optical fibres and cables;

ii) Passive optical devices and nodes;

iii) Active optical devices and nodes;

iv) Infrastructures for the outside optical plants.

The plants of type iii) are generally located inside the switching buildings. However with the introduction of the broadband access both on copper wires (e.g. xADSL terminals) and on optical fibres (e.g. ONU) some active devices are deployed between the switching buildings, so that they can also be considered in the scope of this Handbook.

The typical natural disasters, which may potentially affect outside plant facilities, can be classified in the following seven categories: earthquakes, tsunami, floods/flash floods, strong wind (hurricanes/tornados/typhoons/wind storms), landslides, forest fires, severe temperature conditions (cold, snow, ice or heat). (For further information see the Preface).

To make outside plant facilities more reliable and stable against disasters, it is recommended that disaster management should be provided. Disaster management activities can be grouped into the following four phases: Mitigation (Prevention), Preparedness, Response and Recovery (For further information see the Preface).

This Chapter 4 deals with the design requirements for the various elements of the wireline outside plants and with the possible management activities aimed at reduce the impacts of the natural disasters.

## 4.1 Requirements and design aspects of wireline outside plants

### *4.1.1 Optical fibres and cables*

#### 4.1.1.2 Optical fibres

[For further information see ITU-T Handbook "Optical Fibres, Cables and Systems", Chapters 1 and 2]

Optical fibres differ mechanically from copper and steel wires, mainly as regards elastic properties and failure mechanisms. Glass used for optical fibre behaves elastically up to a few percent, then it fails in brittle tension. The strength of fibres is mainly governed by the size of flaws, which are always present, under the influence of stress which causes the glass fibre to weaken. This weakening is accelerated if the stress is combined with moisture. When designing optical fibre cable, it is important to know the minimum strength of the fibres. For this reason, optical fibres are proof-tested to a certain stress level during manufacture. Studies of flaw growth mechanisms and accelerated aging experiments have shown that in order to achieve fibre lifetime of 20-40 years, the residual fibre stresses should not exceed 20-30% of the proof-test stress.

In special circumstances where the cable is to be used in a high moisture environment or for aerial cable applications taking into account large thermal changes and strong winds, it should be noted that a larger proof-test strain may be necessary or the installation must compensate for the conditions. For example, a heavier support strand may be used for aerial applications to limit strains.

A good cable design will limit the long-term strain to the safe levels above to prevent the growth of surface flaws, which could eventually lead to fracture of the fibres. The proof test strain may therefore be specified by the permissible strain and the required life time. Usually the fibre is proof tested with a load applied to the fibre. The value of the load is specified for each type of fibre in Recommendations ITU-T G.65x.

#### 4.1.1.2 Optical cables

*Terrestrial cables*

[For further information see ITU-T Handbook "Optical Fibres, Cables and Systems", Chapter 2]

Optical cables are installed in various environments (aerial, buried, duct, tunnel, etc.) and are therefore exposed to different environmental conditions. The range of environmental conditions must be considered with great care in order to determine the cable construction that will continuously maintain the desired characteristics. The external factors relating to the various environmental conditions can be divided into two categories:

i) natural external factors (temperature, wind, water, earthquakes, etc.);

ii) man made factors (smoke, air pollution, fire, etc.).

The main objective in the design of an optical cable is to ensure that the protection technique used will maintain the good properties of the optical fibres, under all the kinds of conditions to which the cables may be exposed to during manufacture, installation, and operation. The external factors (natural and man-made) quoted above, as well as the type of installation of the cable in the telecommunication network are the basic requirements for determining the structure, the dimensions and the materials of an optical fibre cable.

The cable core should be covered with a sheath suitable for the relevant environmental and mechanical conditions associated with installation and operation. The sheath maybe of a composite construction and may include strength members or a protective armour to meet particular environmental conditions.

From a general point of view the main components of an optical cable may be divided into the following five groups:

i) optical fibre coatings;

ii) cable core;

iii) strength members;

iv) water-blocking materials (if necessary);

v) sheath materials (with armour, if necessary).

*Aerial cables*

[For further information see ITU-T Handbook "Optical Fibres, Cables and Systems", Chapter 2 and Recommendations ITU-T L.26 and L.89]

In the event of damage to the cable sheath or to a splice closure, longitudinal penetration of water in a cable core or between sheaths can occur. The penetration of water causes an effect similar to that of moisture. The longitudinal penetration of water should be minimized or, if possible, prevented. In order to prevent longitudinal water penetration within the cable, techniques such as filling the cable core completely with a compound or with discrete water blocks or swellable components (e.g., tapes ) are used. In the case of unfilled cables, dry-gas pressurization can be used.

Overhead cable vibrations are produced either by laminar wind stream causing curls at the lee side of the cable (aeolian vibration) or by variations in wind direction relative to the cable axis (galloping effect). A well-established surveillance routine will identify the activity in order to make a careful choice of the route and to decide installation techniques and/or the use of vibration control devices to minimize this type of problem.

During storage, installation and operation, cables may be subjected to several temperature variations. Generally, aerial cables are more exposed to significant temperature variation than underground cables. Therefore, this issue is very important. Expansion of the cable due to a variation in temperature to a high level may cause a significant reduction of the safe clearance to ground. Shrinkage of the cable due to a variation in temperature to a low level may cause the maximum working tension to be reached. Under these conditions, the variation of attenuation of the fibres shall be reversible and shall not exceed the specified limits.

The fibre strain may be caused by tension, torsion and vibration occurring in connection with wind pressure. Induced dynamic and residual strain in the fibre may cause fibre breakage if the specified long-term strain limit of the fibre is exceeded. To reduce any fibre strain induced by wind pressure, the strength member should be selected to limit this strain to safe levels, and the cable construction may mechanically decouple the fibre from the sheath to minimize the strain. Alternatively, to reduce fibre strain, the cable may be lashed to a high-strength support strand. In aerial installations, winds will cause vibrations and, in figure-of-eight and suspension wire installations, galloping of the entire span of the cable may occur. In these situations, cables should be designed and/or installed to provide stability of the transmission characteristics and mechanical performance. Cable installations should be designed to minimize the influence of wind.

The fibre strain may also be caused by tension occurring in connection with snow loading and/or ice formation around the cable. Induced fibre strain may cause excess optical loss and may cause fibre breakage if the specified long-term strain limit of the fibre is exceeded. Dynamic strain in the fibre may be induced by vibration caused by the action of snow and/or ice falling from the cable. This may cause fibre breakage. Under the load of snow and/or ice, excessive fibre strain may easily be induced by wind pressure. To suppress the fibre strain by snow loading and/or ice formation, the strength member should be selected to limit this strain to safe levels, and the cable profile may be selected to minimize snow loading. Alternatively, to suppress fibre strain, the cable may be lashed to a high-strength support strand. Cable should be designed and installed to provide stability of the transmission characteristics, cable sag/tension, fatigue of the strength member and tower/pole loading.

A knowledge of span, sag, wind and ice-loading is necessary to design a cable for use in aerial applications. The general criteria for the design of an aerial cable infrastructure are indicated in Annex 4A1.

As quoted above, for aerial application, some special cable structures may be adopted:

– All Dielectric Self-Supporting (ADSS): the tensile element is provided by a non-metallic reinforcement (e.g., aramid yarns, glass-fibre-reinforced materials or equivalent dielectric strength members) placed under or within the plastic sheath; the outer shape is circular (Figure 4-1 a);

– Self-Supporting (SS) cable: the sheath includes a metallic or non-metallic bearing element, to form a figure ''8'' (Figure 4-1 b);

– Lashed cable: non-metallic cables installed on a separate suspension catenary and held in position with a binder cord or special preformed spiral clips.

**Figure 4-1: Examples of aerial cable structures**

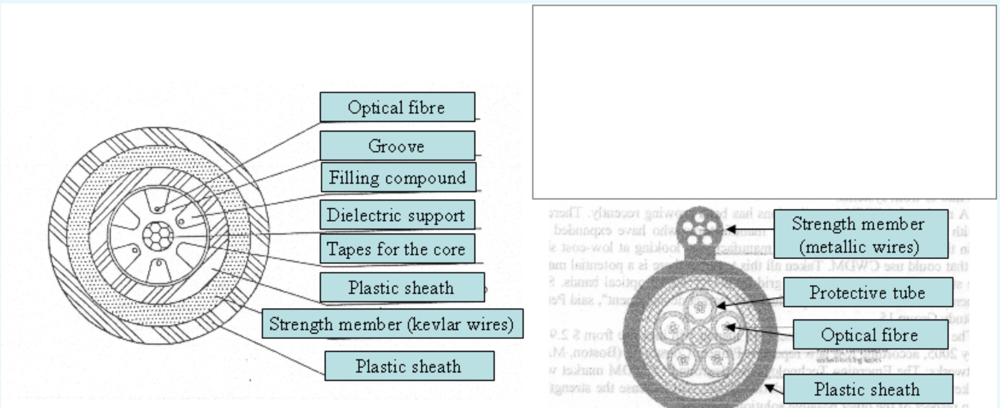



**Figure 2-10a**
**All Dielectric Self-Supporting cable**

**Figure 2-10b**
**Self-Supporting cable (figure 8 cable)**

*Submarine cables*

[For further information see ITU-T Handbook “Optical Fibres, Cables and Systems”, Chapter 2 and ITU Recommendation G.978]

Underwater optical fibre cables are classified according to the ITU-T Recommendations, in the three following categories:

i) marinized terrestrial cable;

ii) repeaterless submarine cable;

iii) repeatered submarine cable.

Marinized terrestrial cables are generally used for crossing lakes and rivers. Repeaterless submarine cable is suitable for use in both shallow and deep waters for lengths up about 300 km. Repeatered submarine cables can be used in all underwater applications, mainly for deep waters on lengths that require the deployment of submerged repeaters.

The optical submarine cable is an underwater optical fibre cable designed to be suitable for shallow and deep water use, which is required to ensure protection of optical fibres against water pressure, longitudinal water propagation, chemical aggression and the effect of hydrogen contamination throughout the cable design life. The submarine cable is extensively tested to show it can be installed and repaired *in situ*, even in worst weather conditions, without any impairment of optical, electrical or mechanical performance or reliability.

The cable, with the cable jointing boxes, the cable couplers, and the cable transitions, should be handled with safety by cable ships during laying and repair operation (depth up to about 8,000 m); it should withstand multiple passages over the bow of a cable ship.

### 4.1.2 Passive optical devices and nodes

[For further information see ITU-T Handbook “Optical Fibres, Cables and Systems”, Chapter 4 and 5, Recommendation ITU-T L.51].

The quality of an optical network is also determined by the performance of each of its individual devices/nodes.

Passive applies to devices that do not contain active electronics or other devices that are exothermic. On the contrary active devices contain active electronics. A “node” is defined as a point of intervention in the network, e.g. it occurs at each opening or end of a cable jacket. Each node shall be capable of performing its expected function in the network, while exposed to the environment in which it is intended to reside. In order to achieve and to maintain a suitable network performance level the optical nodes should be able to properly store and protect all compatible devices without altering their performance characteristics.

#### 4.1.2.1 Passive optical devices

The main passive optical devices deployed in the outside optical network are shortly indicated in the following.

*Optical fibre splices*

[For further information see Recommendations ITU-T L.12 and ITU-T G.671]

Splices are critical points in the optical fibre network, as they strongly affect not only the quality of the links, but also their lifetime. In fact, the splice shall ensure high quality and stability of performance with time. High quality in splicing is usually defined as low splice loss and tensile strength near that of the fibre proof test level. Splices shall be stable over the design life of the system under its expected environmental conditions.

A suitable procedure for splicing should be carefully followed in order to obtain reliable splices between optical fibres. This procedure applies both to single fibres or ribbons (mass splicing). All optical fibre splices should be suitable for indoor applications as well as for outdoor environments, when suitably protected in appropriate accessories.

*Optical connectors*

[For further information see ITU-T Recommendations L.36 and G.671]

Fibre optic connectors provide a method for jointing the ends of two optical fibres. Such a joint is not a permanent one, but it can be opened and closed several times. The optical connectors are required in the points of the network in which it is necessary to have flexibility in terms of network configuration and test access.

Fibre optic connectors have application in all types of network, at the input and output ports of the transmission systems and are also used to connect test equipment and instrumentation.

*Optical fibre organizers*

[For further information see ITU-T Recommendation L.50]

In a node, the optical fibres are to be properly managed and guided from where a cable or pigtail enters the node, to where it leaves again. A fibre organizer, put inside the node, comprises the whole of the means and features that are intended to guide and store fibres, pigtails, splices, connectors and passive devices inside a node, at any location where they are not protected by the cable sheath.

Moreover the fibre organizer system of a node shall provide features and methods to store fibre excess lengths (over-length) in a reliable and consistent way.

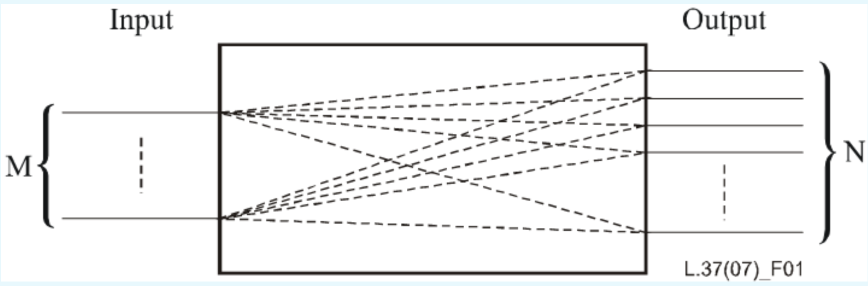
*Optical branching devices (including PON splitters)*

[For further information see ITU-T Recommendations L.37, L.52 and G.671]

An optical branching component (wavelength non-selective) is a passive component possessing three or more ports, which shares optical power among its ports in a predetermined fashion, without any amplification, switching, or other active modulation.

Optical branching components provide a method for splitting optical signals between M input and N output ports (Figure 4-2). Optical branching components are required when an optical signal has to be split into two or more fibre lines or when several signals coming from different fibre lines have to be mixed in a single fibre line; in general, optical branching components are dividers/combiners of transit signals.

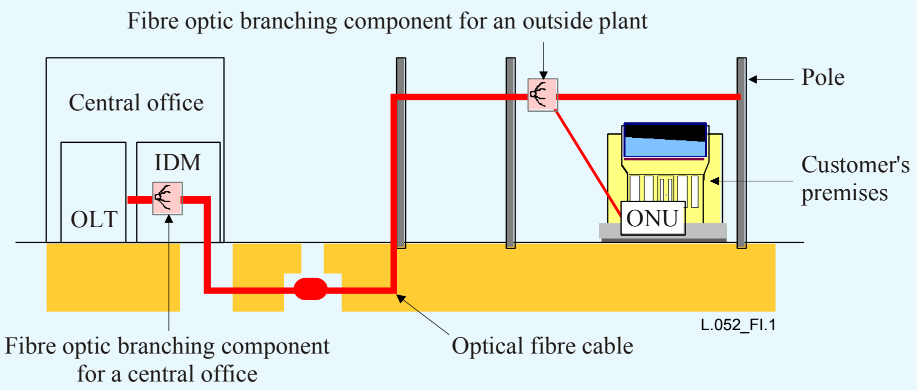
**Figure 4-2: Schematic of an MxN branching component**




In passive optical networks (PON) with a point-to-multipoint distribution architecture, optical branching components are used to connect an OLT located at a central office to several ONUs located in outside plant or on subscriber premises. The specified values for PONs are 1 input port and X output ports, where X = 4, 8, 16, 32. [For further in formation see Chapter 1]

An example of deployment of branching components both in the central office and in the outside plant of an optical access network is shown in Figure 4-3.

**Figure 4-3: Configuration of optical fibre network using a (fibre optic) branching component for a central office and an outside plant**




### 4.1.2.2 Passive optical nodes

*Optical nodes for terrestrial applications*

[For further information see ITU-T Recommendations L.13 and L.51]

Optical nodes for terrestrial applications properly store and protect all compatible passive devices, such as splices, branching devices and connectors, without altering their performances. Moreover they contain, protect and manage the fibre extra length. A node occurs at each opening or end of a cable sheath. When an optical node resides in an outdoor environment, it is generally contained in a sealed enclosure. This is commonly also referred to as an optical closure, optical cable joint or optical sheath joint. Here the term "optical closure" will be used.

An optical closure comprises a mechanical structure (closure housing) that is attached to the ends of the sheaths joined and a means (organizer) for containing and protecting the fibres and passive optical devices. The term closure housing only refers to the sealed container or box, not including the organizer system. Its main functions are: sealing to the cables, mechanical attachment of the cable and protection of its content.

The optical closure will:

i) restore the integrity of the sheath, including mechanical continuity of strength members when required;

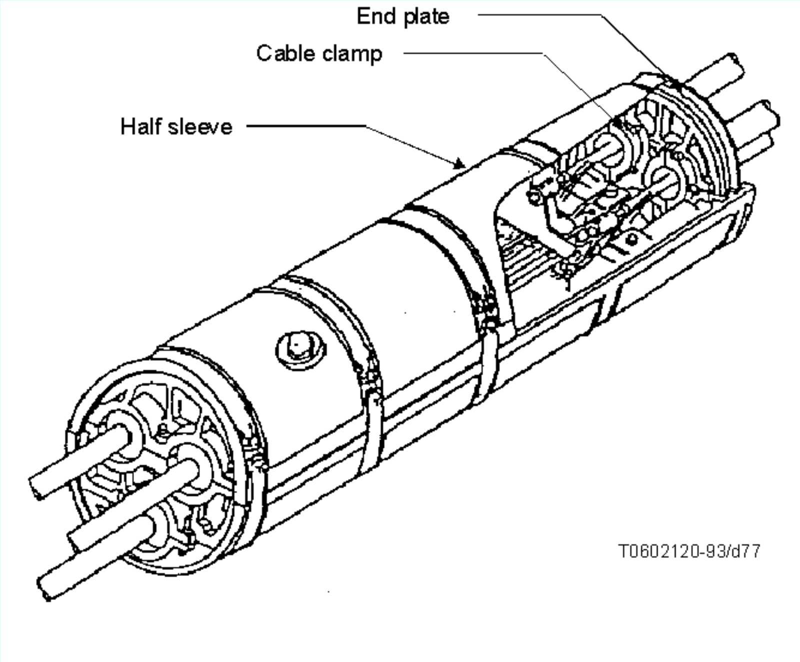
ii) protect the fibres, fibre joints and optical devices from the environment in all types of outdoor plant (aerial, direct buried, in ducts, etc.);

iii) provide for the organization of the fibre joints, passive devices and the storage of fibre overlength

iv) provide electrical bonding and grounding of the metal parts of the sheath and strength members where required.

An example of fibre closure is in Figure 4-4.

**Figure 4-4: Example of optical closure**




In addition to the node's optical functionality in the network, performance requirements and test severity shall also reflect the environmental conditions to which a passive node is exposed during its lifecycle.

Once installed, optical nodes typically may reside in one of the basic environments indicated in Table 4-1:

**Table 4-1 – Application environments**

| | | |
|---|---|---|
| **Indoor** | temperature controlled | IC |
| | non-temperature controlled | IN |
| **Outdoor** | above ground | OA |
| | at ground level | OG |
| | under ground (sub-terrain) | OS |

Typical values, applicable to passive optical nodes, can be found in Table 4-2.

**Table 4-2 – Summary of typical parameters for the basic environmental classes**

| Exposure ↓ | Indoor | | Outdoor | | |
|---|---|---|---|---|---|
| | IC | IN | OA | OG | OS |
| | Temp controlled | Temp non-controlled | Above ground | Ground level | Underground |
| **Temp Min (°C)** | +5 | –10 | –40 | –40 | –30 |
| **Temp Max (°C)** | +40 | +60 | +65 | +65 | +60 |
| **Solar Radiation** | No | | Yes | Yes | No |
| **Relative Humidity (max) (%)** | 93%<br>(decreasing once above 30° C) | | 100%<br>(occasional/permanent exposure to water possible) | | |
| **Precipitation** | No | | Rain, Snow, etc. | Rain, Snow, etc. | N.A. |
| **Submersion** | No (Note 2) | | No | No (Note 2) | Yes |
| **Vibration (m/s$^2$)** | 10-55 Hz<br>1 m/s$^2$ (~0.1 g) (whole system)<br>5 m/s$^2$ (~0.5 g) (components) | | 5-500 Hz<br>10 m/s$^2$ (~1 g)<br>(due to e.g., traffic, wind, etc.) | | |
| **Chemical** | Negligible (Note 1) | | Atmospheric | Atmospheric + Soil (base only) | Soil/waterborne |
| **Biological** | Negligible | | Atmospheric | Atmospheric + Soil (base only) | Soil/ waterborne |
| NOTE 1 – In areas where corrosive atmospheres can be expected (marine and coastal areas, industrial areas, urban pollution), increased corrosion protection may be requested as an additional requirement.<br>NOTE 2 – If accidental flooding may occur, e.g., in vaults or basements, this is to be added as a conditional requirement. This will also correspond to a higher IP rating according to IEC 60529. | | | | | |

NOTE – For further information on the environmental conditions see Section 4.1.3.2 of this Chapter 4 “Protection of the active devices and nodes”.

*Optical nodes for submarine applications*

[For further information see Recommendation ITU-T G.977].

There are two passive nodes that are specific to submarine cables: the submarine repeater housing and the branching unit.

– The submarine repeater housing is the mechanical piece-part of a repeater.

  A submarine repeater is equipment that essentially includes one or more regenerators or amplifiers and associated devices.

  Submarine repeater housing must be designed to allow operation, laying, recovery, and re-laying in large depths with no degradation in mechanical, electrical and optical performance.

  Technical requirements for submarine repeater housings are as follows:

  - The internal unit. Inside the repeater housing, the internal unit can contain several power feed modules and OFA (optical fibre amplifiers) pairs to amplify in both directions optical signals from one or several fibre pairs;
  - Corrosion protection. The external housing of an OSR (optical submarine repeater) should be designed to not suffer from corrosion due to sea water;
  - Water pressure resistance. The submarine repeater housing must be designed to support large pressure strengths in deep sea water;

- High-voltage insulation. High-voltage insulation is required between the repeater housing and the internal unit to ensure repeater operations;
- Thermal management. Heat generated by the electronic components inside the OSR may be dissipated sufficiently via thermal conduction with the repeater housing;
- Repeater housing sealing. The repeater must be provided with a protection against water and gas ingress, both directly from the surrounding sea and from axial cable leakage resulting from a cable break close to the repeater;
- Ambient atmosphere control. Reliability and proper operation of components may require a controlled internal atmosphere regarding relative humidity or any expected gas that may be generated inside the repeater.

– The branching unit (BU) is an optical node in which it is possible to interconnect three cable (and not only two, as in terrestrial closures), allowing a complete connectibility among the cables (Figure 4-5).

**Figure 4-5: Example of branching unit**

With the use of the branching units it is possible to interconnect three landing points (three terminal stations) with only one submarine cable. The deployment of two BU on the same cable widens the number of landing points that can be reached with the same submarine cable.

Technical requirements for a branching unit housing are very similar to those of a submarine repeater housing.

### 4.1.3 Active optical devices and nodes

#### 4.1.3.1 Active optical devices

The main active devices deployed in the outside optical network are shortly indicated in the following.

*ONU*: Optical Network Unit is a device that transforms incoming optical signals into electronics at a suitable place of the access network in order to connect the optical access network to a part of the metallic network. (see also Chapter 1).

*DSLAM*: Digital Subscriber Line Access Multiplexer (DSLAM) equipment collects the data from many modem ports and aggregates their voice and data traffic into one complex composite "signal" via multiplexing.

*xDSL Terminal*: a Digital Subscriber Line terminal provide for the transmission of asymmetric and symmetric aggregate data rates up to tens of Mbit/s on twisted metallic pairs. xDSL is an access technology that exploits the existing infrastructure of copper wires that were originally deployed for the telephone service.

*Reach Extender*: XG-PON (XGbit – Passive Optical Networks) often needs to increase both overall fibre length and overall splitting ratio. This can be obtained through an active extension node placed in the middle of the optical network, generally indicated as reach extender.

#### 4.1.3.2 Protection of the active optical devices and nodes

[For further information see ITU-T Recommendation L.70]

In order to obtain maximum reliability at a minimal cost, network electronics are generally centralized in locations with controlled environments. This is also typical in the initial layout of copper networks for plain old telephone service (POTS). However, with the increasing demand for connections and bandwidth, operators often face the need to apply active electronics at remote locations. These active nodes cannot always be located inside building but also in the outside plants.

Active network nodes in outside plant have a number of characteristics that make their design and maintenance more complex than that of passive nodes:

- active nodes perform a transformation between input and output signal;
- active nodes require electrical powering;
- active nodes dissipate heat.

The following elements should be considered when applying network electronics in outside plant locations (both in above ground and in underground applications):

- environmental protection and related sealing requirements;
- mechanical protection;
- thermal management;
- electrical powering;
- safety and environmental aspects;
- maintenance aspects.

*Environmental conditions*

Once installed, optical nodes typically may reside in one of the basic environments quoted in Table 4-1.

**Table 4-1: Application environments**

| | | |
|---|---|---|
| **Indoor** [(1)] | temperature controlled | IC |
| | non-temperature controlled | IN |
| **Outdoor** | above ground | OA |
| | at ground level | OG |
| | underground (sub-terrain) | OS |
| [(1)] "Indoor" is intended as in sheltered locations, hunters, street cabinets, etc. | | |

The five basic environmental classes indicated in Table 4-1 cover the majority of the applications around the globe and can be described as follows:

i) IC: Indoor temperature controlled

- inside buildings protected by a roof and walls all around, heating or air-conditioning available;
- contact with chemical and biological contaminants is negligible, e.g., inside central offices, some remote network buildings/houses, residential buildings.

ii) IN: Indoor non-temperature controlled

- inside buildings protected by a roof and walls all around, no heating or air-conditioning available;
- contact with chemical and biological contaminants is negligible, e.g., cable vaults, basements, remote network buildings/houses, inside garages, warehouses, homes.

iii) OA: Outdoor above ground

- all outdoor non-sheltered locations, above ground level;
- no other sources of heat or extreme temperatures than the surrounding air or solar radiation;
- exposed to contaminants and dust that may occur in the atmosphere in rural, city or industrial areas, e.g., wall mounted, pole mounted, strand mounted nodes.

iv) OG: Outdoor ground level

- outdoor, standing on the ground, perhaps with a base that resides partially below the ground; this class may also apply to outdoor, wall mounted products that are close to ground level;
- exposed to contaminants and dust that may occur in the atmosphere in rural, city or industrial areas. The base of the product may be permanently in contact with soil, biological and chemical contaminants that occur at or just below ground or street-level, e.g., along roads, pavements and railroads.

v) OS: Outdoor underground (Sub-terrain)

- outdoor below ground level;
- exposed to soil or water-borne contaminants, including organic and inorganic agents related to the presence of roads and traffic, e.g., in manholes, handholes or direct buried.

Table 4-2 summarizes the typical parameters for the five basic environmental classes. related to the active nodes.

**Table 4-2: Summary of typical parameters for the outdoor environmental classes**

| Exposure ↓ | Outdoor | | |
|---|---|---|---|
| | OA | OG | OS |
| | Above ground | Ground level | Underground |
| $T_{air}$ Min (°C) (Note 3) | –40 | –40 | –30 |
| $T_{air}$ Max (°C) (Note 3) | +45 | +45 | +45 |
| Solar radiation | Yes<br>(up to 1120 watt/m²) | | No |
| Relative humidity (max) (%) | 100%<br>(occasional/permanent exposure to water possible) | | |
| Precipitation | Rain, snow, etc. | Rain, snow, etc. | NA |
| Submersion | No | No (Note 2) | Yes |
| Vibration | 5-500 Hz<br>10 m/s² (~1g)<br>(due to, e.g., traffic, wind, etc.) | | |
| Chemical | Atmospheric<br>(Note 1) | Atmospheric soil<br>(base only) (Note 1) | Soil/waterborne |

| Exposure ↓ | Outdoor | | |
|---|---|---|---|
| | OA | OG | OS |
| | Above ground | Ground level | Underground |
| Biological | Atmospheric | Atmospheric soil (base only) | Soil/waterborne |
| NOTE 1 – In areas where corrosive atmospheres can be expected (marine and coastal areas, industrial areas, urban pollution), increased corrosion protection may be requested as an additional requirement.<br>NOTE 2 – If accidental flooding may occur, this is to be added as a conditional requirement. This will also correspond to a higher IP rating according to [IEC 60529].<br>NOTE 3 – For active nodes, air temperature (as measured in a thermometer hut) is to be considered separate from solar radiation effects. For passive nodes, these effects are generally combined, resulting in a higher maximum temperature for the node. | | | |

*Special environmental conditions*

– Extreme: any environment for which at least one of the environmental parameters exceeds the boundaries of the five basic environmental classes as specified above: e.g., more extreme temperature excursions;

– Additional requirements: in specific cases, extra constraints may be required on top of the conditions of one of the basic environmental classes (e.g., bullet resistance, accidental flooding, etc.). This is not included under the term "extreme" conditions. For these occasions, additional requirements or tests can be added on top of the test program of the basic environmental class.

  This a non-exclusive list of potential additional requirements. limited to those related to natural disasters:

  - Accidental flooding above ground;
  - Earthquake resistance;
  - Freeze-thaw resistance.

*Sealing against ingress of solids and fluids*

For nodes above or at ground level (OA and OG), the minimum recommended protection level against ingress of objects and water is International Protection 55 according to Specification IEC 60529 (protected against dust and resistant to jets of water).

For nodes at ground level (OG), it is recommended to provide a separation plate with cable entrance seals to avoid intrusion of dirt, water, rodents or insects via the bottom.

For nodes below ground level (OS), the recommended sealing level is IP 68 according to Specification IEC 60529 (suitable for permanent submersion). Required submersion depth should be at least 1 m above the top of the enclosure, but may be more if applied in deep manholes (in this case, the maximum required submersion depth is to be agreed explicitly between user and supplier in order to obtain proper sealing performance and structural strength).

*Mechanical protection*

The enclosure should be resistant to the mechanical loads and influences that it may encounter in the outdoor environment.

For nodes above or at ground level (OA and OG):

– a minimum recommended protection level against impact of IK 10 according to [IEC 62262];

– the enclosures, including fixation system, should resist loads induced by wind.

For underground nodes (OS):

– Enclosure should be resistant to accidental impact from above.

– Enclosure should be resistant to a static load on top equivalent to the weight of at least one installer.

– Node should be resistant to vibration and shock.

– Cables must be properly attached to resist axial tension, flexure and torsion loads that may occur during typical installation and maintenance.

*Thermal management*

The temperature inside the enclosure ($T_{inside}$) must be kept within the operational temperature range of the electronics.

*Thermal model*

The temperature inside an above ground active enclosure (Figure 4-6) will be determined by a number of factors:

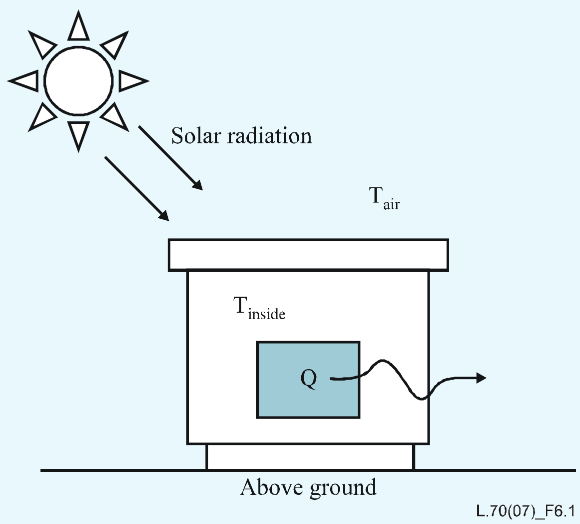
– the air temperature of the environment ($T_{air}$) (as measured in a thermometer hut);

– solar radiation;

– the heat dissipated by the electronics (Q);

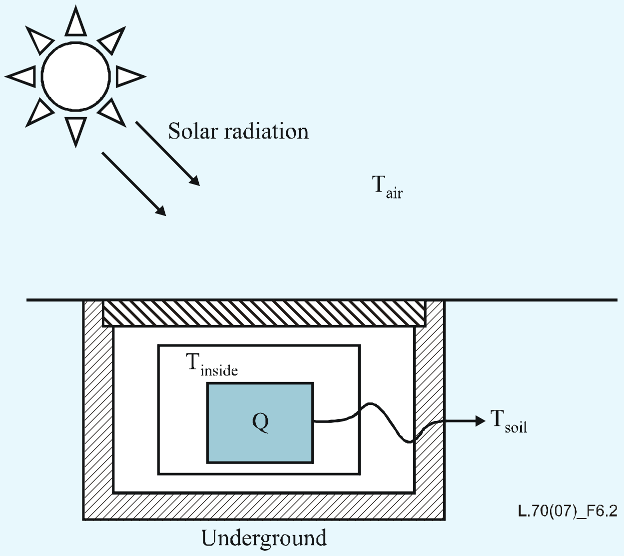
– the construction of the enclosure.

**Figure 4-6: Above ground active node**




For underground nodes (Figure 4-7), a similar model is applicable, however, there will be no direct solar exposure to the enclosure, while the dissipated heat is transferred via the hand-hole and the surrounding soil.

**Figure 4-7: Underground active node**




*Operational temperature range of the electronics*

Electronic equipment is typically qualified to an operational temperature range of 0°C to +40°C, corresponding to an indoor controlled environment. Applying this type of equipment in outdoor enclosures would require extensive climatic control provisions, increasing initial investment as well as operational cost.

For outdoor applications, it is recommended to use "temperature-hardened equipment" with an operational temperature range of at least –40°C to +65°C, unless there is a different agreement between a manufacturer and a user.

*Enclosure design*

The thermal design of the enclosure for active equipment should be selected, taking into account operational temperature, climate and amount of heat to be dissipated as well as economical aspects such as initial investment and operating cost. Therefore, it is recommended to observe the following parameters:

– minimize the effect of solar radiation on internal temperature;

– minimize the extra power required for thermal management;

– consider a modular approach that allows scope to increase cooling capacity when upgrading to more powerful equipment;

– minimize the need for maintenance due to thermal management features.

The most common thermal designs of enclosures for active electronics are described in Annexes 4A2 and 4A3.

#### 4.1.3.3 Electric power supply for active optical nodes

[For further information see ITU-T Recommendation L.44]

Some intermediate equipment (e.g. repeaters) needing a power supply had existed before optical fibres were installed. At that time, electrical power had been mainly supplied from the central office by using a superimposition technique or by having insulated communication and power conductors in the same cable.

After optical fibres were introduced, many kinds of optical/electrical equipment which require a power supply system were installed into a telecommunication network, in order to increase capacity. The problem is that optical fibre cannot be used to directly transmit electrical power.

As a consequence power is supplied by one of three ways:

– to feed power from the central office by using metallic wires. To connect the power supply between the central office and the equipment, individual metallic cables or cables with both fibres and copper conductors may be used;

– to use a local power supply. In this method, one power supply provides power to all the equipment located within its area by using metallic cables or cables with both fibres and copper conductors. The numbers of equipment that can be supported in this way may be from two to several tens;

– each equipment has its own power supply.

This section deals with the methods of the power feeding and back-up systems.

*Power supply methods*

In order to select a power supply method, telecommunication companies should consider:

1) the outage rate of commercial power suppliers;

2) the cost when using commercial power suppliers;

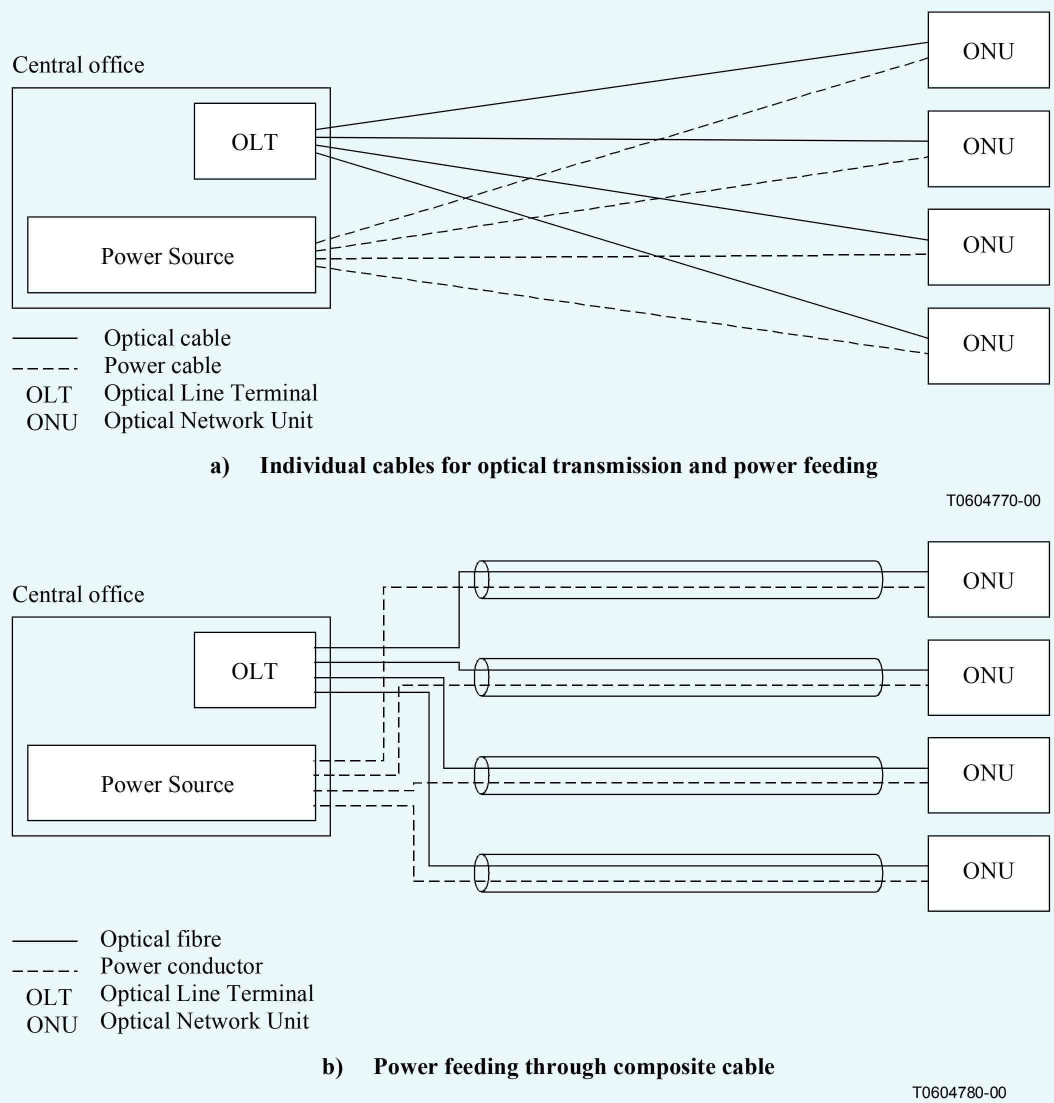
3) the time to repair power source failure.

Based on the suitability of the electric power supplies in each country, telecommunication companies should select a power supply method from the following.

– Power supply from central office

When optical transmission is used, the basic structure of power supplies from the central office is shown in Figure 4-8. The power source is located in the central office. Power is fed by power cables or composite cables (power conductors and optical fibres). This method allows telecommunication companies to control the quality of electrical power (that is, those technical issues covering the stability of the current, voltage and frequency, and the outage rate). However, the telecommunication companies then have the duty to operate and manage power networks.

**Figure 4-8: Structure of power supply from central office**

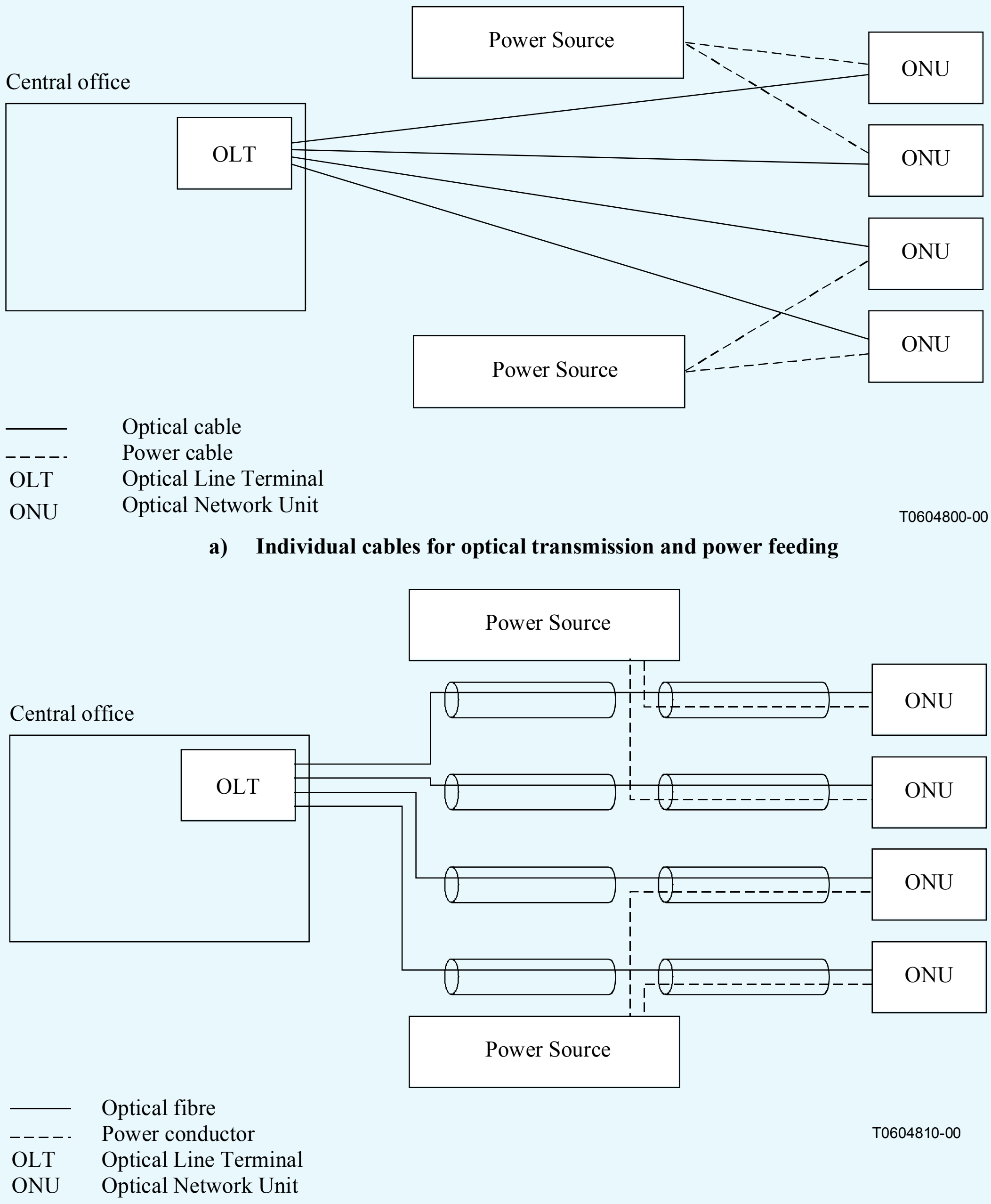



– Local power supply

Using optical transmission, the basic structure of local power supplies is shown in Figure 4-9. Power sources are set up near the ONU locations. Power can be supplied to several ONUs from each power source. The number of ONUs which are covered by one power source is dependent upon supplied power from the power source, the power consumption of ONUs and the power losses in the power cables. Power is fed by power cables or composite cables (combined power and communication cables).

To control the local power supplies, monitoring systems or alarm systems are set up in the central office in order to obtain information about the condition of the power sources. Usually, the duty to operate and manage the power sources belongs to telecommunication company. However, when the power sources are located in the customer premises, then customers may operate and manage the power sources themselves. The supply of electrical power from other customers' power sources should be avoided.

**Figure 4-9: Structure of local power supply**



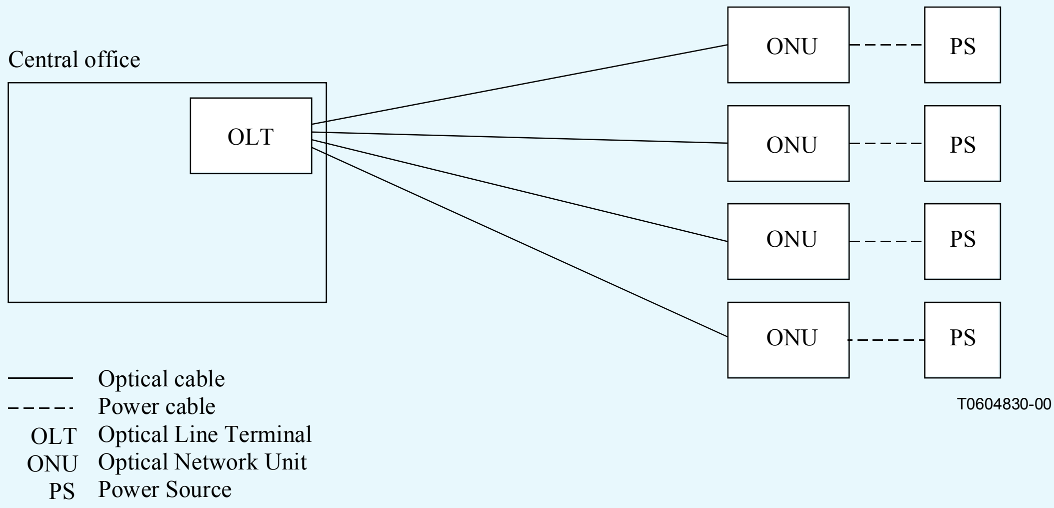

**a) Individual cables for optical transmission and power feeding**

**b) Power feeding through composite cable**

– Individual power supply

The basic configuration of this method is shown in Figure 4-10. Electrical power is fed to each Optical Network Unit (ONU) from each power source. Usually, the duty to operate and manage the power source belongs to the customers.

**Figure 4-10: Individual power supply**




*Power sources for usual operation*

In order to select a power source for usual operation, the following should be considered:

1) capacity;

2) stability of power feeding;

3) quality of electrical power;

4) operating cost.

– Power company

Where the electrical power is supplied by a power company, a telecommunication company should condition the electrical power in order for it to be suitable for the telecommunication equipment. When conditioning electrical power, a telecommunication company should consider the power quality supplied by a power company. Poor power quality may affect the quality of transmission or in the worst case damage telecommunication equipment.

In order to design a backup system, a telecommunication company should know the outage rate of the power supply.

NOTE – A separation (disconnection) point (e.g. switch) in the cabinets is provided in order to separate the competence of power and telecommunication companies as well as to allow safe maintenance of the telecommunication equipment.

– Generator

Where the electrical power is produced by a generator, a telecommunication company should condition the electrical power in order for it to be suitable for the telecommunication equipment. When conditioning electrical power, a telecommunication company should consider the power quality produced by a generator. Poor power quality may affect the quality of transmission, or may damage telecommunication equipment in the worst case.

In order to design a backup system, a telecommunication company should know the failure rate (such as MTBF) of the generator.

– Battery

When using batteries, a telecommunication company may condition the electrical power in order for it to be suitable for the telecommunication equipment. In this case, the capacity of a battery is most important. Use of a battery for equipment with high power consumption should be carefully evaluated.

*Power sources for backup*

In order to select a power source for backup operation consideration should be given to the following:

1) backup duration;

2) time to start backup system;

3) lifetime;

4) outage rate of power source for usual operation;

5) operating cost.

– Generator

When a generator is used for a backup system, the most critical issue is time to start-up. Usually, some time is required in order to stabilize the electrical power when starting a generator. Therefore, this method is not suitable for systems which require quick recovery. Backup duration is determined by the amount of stored fuel. The power quality produced by a generator should be considered. Poor power quality may affect the quality of transmission or in the worst case may damage the telecommunication equipment.

– Battery

A battery can supply high quality electrical power rapidly. Therefore, it is suitable for powering a backup system which requires a quick recovery. However, backup duration and lifetime is relatively short. Therefore, when designing backup systems with batteries, the following should be considered:

1) outage rate of usual power source;

2) time to repair the failed power source;

3) time to change batteries.

### 4.1.4 Infrastructures for the outside optical plants

[For further information see ITU-T Handbook “Optical Fibres, Cables and Systems”, Chapter 3]

Optical fibres must be protected from excessive strains, produced axially or in bending, during installation and various methods are available to do this. The aim of all installation methods and systems should be to install the cable with the conductors in, as near as possible, a strain free condition, ready for splicing.

Attention is to be given on the fact that methods and practices used in the handling of cables during installation can, without producing any immediately evident physical damage or transmission loss, affect their long term transmission characteristics.

Moreover the optical cables are to be protected during their useful life from the outside environment. At this purpose they are very frequently laid in suitable infrastructures. The most widespread types of these infrastructures are shortly described in the following.

#### 4.1.4.1 Underground ducts/conduits

[There are no ITU-T Recommendation specifically dealing with the construction of ducts. only as an example it can be said that the subject is dealt in http://plasticpipe.org/pdf/chapter14.pdf ]

*Applications*

The general purpose of a conduit, or duct, is to provide a clear, protected pathway for a cable, or for smaller conduits, sometimes called inner-ducts. Advances in cable technologies, as well as the expense of repairing sensitive cable materials like optical fibre cable, have driven preferences for protective conduit over that of direct burial. Plastic (PVC, PE) conduits provide mechanical protection to fragile cable materials like optical fibres, as well as protection from moisture or chemicals and even, in some cases, animals. Furthermore, the permanent pathway provided by conduit also facilitates replacement projects or future installations of additional cable or duct.

Plastic conduits can be installed below ground by a variety of methods, including open trench (Figure 4-11), trenchless technique (see ITU-T Recommendation L.38), mini-trench technique (see ITU-T Recommendation L.48), etc.. Also, its flexibility and availability in continuous coiled lengths facilitates installation into existing conduits or ducts as inner-duct. In addition conduit provides many above ground or aerial options. Flexible conduit can be wound onto reels, does not require manufactured bends, and can be easily navigated around unexpected obstructions (in the ground or within existing ducts), simplifying installation. The few joints that are required can be made reliably through a number of options.

*Design considerations*

Determination of a conduit dimensions begins with the largest cable, or group of cables or inner-ducts, intended for occupancy. From a functional viewpoint, selection of diameter can be broken down into the following general considerations:

– The inside diameter of the conduit is determined by the cable diameter and placement method (pulling or air-assisted pushing).

– Pulling cables into underground conduits requires sufficient free clearance and is typically further distinguished by the type of cables, in particular if there are long lengths of cable.

– Long pulling lengths require low volume fill, i.e. 36% max.

– Short pulling lengths may be filled up to 53%

– Push-blow installation methods for long length fiber cables utilize higher volume fills, i.e. up to 70% max.

– Innerducts are smaller diameter conduits, intended for placement into larger conduits or casings. Their purpose is to subdivide the larger conduit space into discrete continuous pathways for incorporation of fiber optic cables. Diameters of conduits and innerducts are often specially designed to maximize the conduit fill.

Conduit and duct products come in a wide range of sizes, e.g. spanning 5 mm to 600 mm. The standard dimension ratio, SDR, of a conduit is defined as the ratio of the average conduit diameter divided by the minimum wall thickness. Wall thickness typically ranges between SDR 9 to SDR 17. (Larger SDR numbers indicate a thinner wall thickness.) Determination of the wall thickness becomes a function of either the method by which the conduit is placed, or the nature of environmental stresses that it will be exposed to over the service life.

Loads are applied to conduits both by the environment that they are placed into and by the placement means under which they are installed; the chief difference being the duration over which the load is applied. For example, a common means to install multiple conduits is to directly plow them into the ground using either a railroad plow or tractor-drawn plow. During this installation process, a certain amount of bending and tensile stress is encountered over a rather short period of time (only seconds to minutes). Whereas, after the plow cavity collapses about the conduit, the ground continues to settle upon stones that may be pressing directly against the conduit, thus setting up a long-term compressive load. For this application there is a requirement for both long-term and short-term moduli to assess the deflection resistance.

*Types of installation*

There are several below ground installations methods:

– Open Trench/Continuous Trenching

– Direct Plow

– Conduit Network Pulling (inner-ducts)

Moreover there is the above ground aerial installation method. There are many applications for aerial conduit, which include but are not limited to road crossings, rail crossings, trolley line crossings, and water crossings.

*Joining methods*

Conduit can be joined by a variety of thermal and mechanical methods. Since conduit does not experience any long-term internal pressure and acts only as a pathway for the telecommunication cables, the owner of the system may be tempted to neglect the importance of specifying effective couplings. However, an integral part of any conduit system is the type and quality of joining method used. Proper engineering design of a system will consider the type and effectiveness of these joining techniques. The owner of the conduit system should be aware that there are joint performance considerations that affect the system's reliability well beyond initial installation. Some of those might include:

– Pull out resistance, both at installation and over time due to thermal contraction/expansion, must be considered.

– Pressure leak rates, for "blow-in" installations. Consideration must be given to how much leakage can be tolerated without reducing the distance the cable can consistently be moved through the conduit.

– Infiltration leakage, allowing water and/or silt to enter the conduit over time, can create obstacles for cable installation and repair or cause water freeze compression of fiber optic cables.

– Corrosion resistance is important as conduit systems are often buried in soils exposed to and containing alkali, fertilizers, and ice-thawing chemicals, insecticides, herbicides and acids.

– Cold temperature brittleness resistance is required to avoid problems with installation and long-term performance in colder climates.

**Figure 4-11: Ducts laid in a trench**

The condition and geometry of duct routes is of great importance for the installation of the cables. Where the infrastructure includes ducts in poor condition, contains excessive curvature, includes ducts already containing cables or access points with abrupt changes of direction, the maximum pull distance will be reduced accordingly.

### 4.1.4.2 Tunnels

[For further information see ITU-T Recommendation L.11]

Duct tunnels are constructions containing one or generally more ducts belonging to different networks. Tunnels which can be inspected (inspectable tunnels) include one or more gangways for initial assembly work and for subsequent control, maintenance and repair operations.

Tunnels may contain ducts belonging to the following types of networks:

– collective antennas;

– telecommunications;

– electricity;

– gas;

– water;

– district heating;

– ducted transport (e.g. pneumatic tubes);

– drainage water.

Tunnel routing must take into account the structure of networks and their levels of priority.

The transport ducts of different networks do not generally follow the same itinerary, since neither the production units (e.g., power plants, pumping stations or telephone exchanges) nor the transit points from transport to primary distribution coincide. On the other hand, in densely populated areas, primary and secondary distribution ducts often do follow the same itineraries, so that it is advisable to run tunnels under arteries containing primary and secondary distribution ducts.

*Tunnels and trenches*

Several factors should be taken into account when opting between trenches and tunnels. Some of them are listed in the following.

– Distribution security

A high level of distribution security will depend on the following factors:

- durability of material and joints;
- rapid location of damage when it occurs, easy access and minimum repair times;
- low exposure to outside effects (e.g. damage caused by third parties or by earthquakes).

Ducts laid in tunnels generally offer high durability and a low risk of deterioration. They may be repaired rapidly.

– Economic considerations

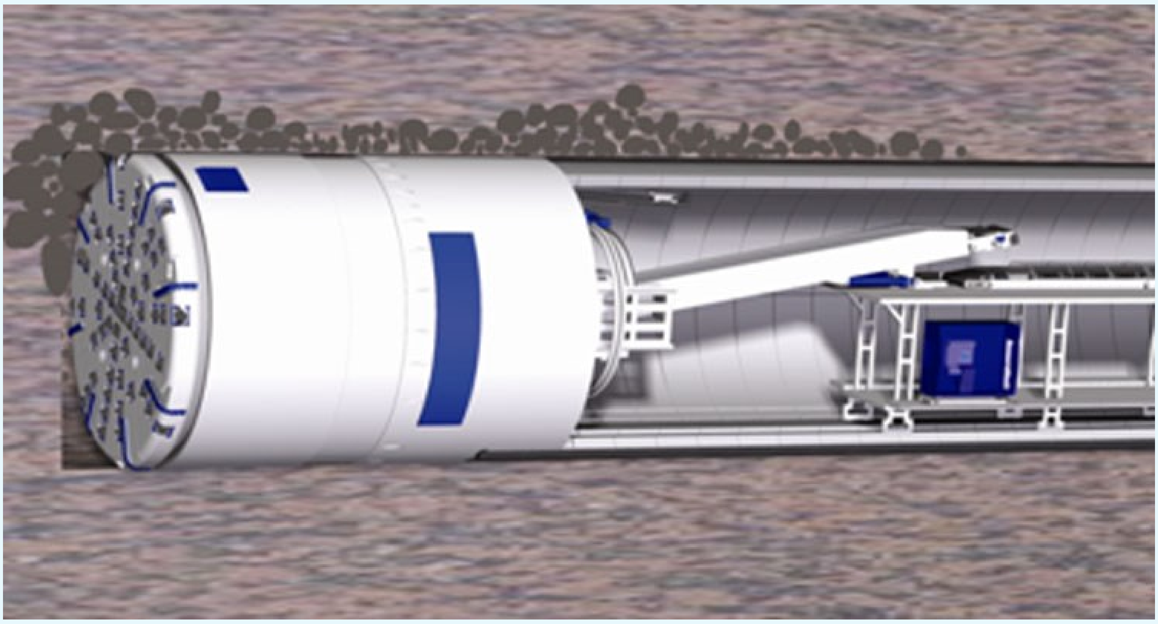
Economic considerations should include not only the cost of constructing and maintaining tunnels, but also the savings which will arise in the future from avoiding the secondary effects of buried ducts. By secondary effects are meant the effects produced on local inhabitants, local activities, vehicle traffic and the environment in general by the installation, malfunction, repair and maintenance of ducts.

– Types of tunnels

There are two basic different cross section features of tunnels: open cut (Figure 4-12) and shield cable (Figure 4-13). The cable tunnel has higher reliability due to their higher rigidity compared by buried pipes. Shield tunnel has highest reliability due to deep construction compared with open cut cable tunnel without any effects of liquefaction and ground settlement.

**Figure 4-12: Open-cut tunnel**

**Figure 4-13: Shield tunnel**



*General requirements*

Some general requirements applicable to tunnels, when used for telecommunication cables, are listed in the following.

– Distances from power lines

Minimum distances from main ducts should be applied.

– Protection against thermal load

Since telecommunications cables are vulnerable to thermal load, thermal conditions in tunnels must be taken into account. This applies especially for optical cables.

– Protection against mechanical forces

Suitable shields may be used to protect cables against mechanical effects such as vibrations or impacts.

– Protection against outside effects

Plastic-covered cables may be protected against rodents with fibre glass or aramid-fibre shielding.

Contractable cable joints may provide protection against earthquakes.

– Bends

Since cable curvature is limited, layout plans must take account of permitted curvature radii.

– Specialized work

Since work has to be done relatively frequently on telecommunication installations, particularly on sleeves, sufficient working space should be provided (e.g. alcoves or chambers).

*Safety plans*

Tables 4-4 and 4-5 show a model of a safety plan in the operational phase, with an indication of possible preventive measures. The rules applicable to the construction of a tunnel should be established in the light of the safety plan.

**Table 4-4: Safety plan against outside risks**

| Risk | Consequences | Level of risk | Security requirement | Possible preventive measures |
|---|---|---|---|---|
| Seismic tremors | Duct bursts, particularly at transit point from tunnel to ground | Variable possibility according to regions<br>Substantial effects | Continued operation of all ducts | Tremor-resistant fixtures<br>Special design of duct exit points |
| Incoming water from outside | Possibility of drowning<br>Damage to duct | Rare | Distribution security | Protection against flood water |
| Unstable ground Foundation | Duct bursts, particularly at transit point from tunnel to ground | Foreseeable effects | Same as for load-bearing structure | Consolidation of foundation ground |

**Table 4-5: Safety plan for risks inherent in tunnel ducts**

| Description of risks | | Consequence | Level of risk | Security required | Possible preventive measures | | |
|---|---|---|---|---|---|---|---|
| Network | Risk | | | | At source | During Construction | In service |
| Water | Tunnel flooding due to duct burst | Possibility of drowing<br>Damaged ducts | Rare Personal risk and little material damage | For persons, same as for load-bearing structures | Careful design and construction of installation | Strong fixtures<br>Automatic Valves<br>Effective water drainage system<br>All pipes to be secured against upward pressure | Regular checks for possible leaks<br>Corrosion Checks<br>Alarm system (with floater switch) |
| Drainage Water (I) | Partial flooding | Damage to ducts | Rare, Little material damage | Limitation of material damage | Ducts to placed above the highest water level | | |
| Drainage Water (II) | Complete flooding of tunnel | Physical injury and material damage | Rare | For persons, same as for load-bearing structures | Leakproof and lockable access points and inspection holes | Ducts to be secured against upward pressure | |

Figures 4-14 and 4-15 show an example of circular and rectangular tunnel cross-sections respectively. They show how the available space can be divided among the different networks.

*Construction*

The main requirements to be considered in the construction of tunnels are listed in the following.

– Permanent loads

Permanent loads should be indicated in the operating plan.

– Lifting

All ducts should, generally speaking, be secured against lifting forces.

– Seismic effects

All ducts brackets, supports and cable racks should be able to resist the effects of seismic forces, in accordance with national standards.

– Explosions

The ducts and other contents of a tunnel may be strongly shaken by explosions. If the safety plan shows that essential ducts may be exposed to such overloading, it should be ensured that the operation of such ducts is not affected by breakage or deformation and that no movement may occur which might wrench essential supply ducts off their supports or allow them to collide against tunnel walls or other part of the construction. Such risks may be avoided with the introduction of shockproof ties and an appropriate arrangement of ducts.

– Protection against corrosion

It is important to protect supports and ties against corrosion in view of the long life of installations.

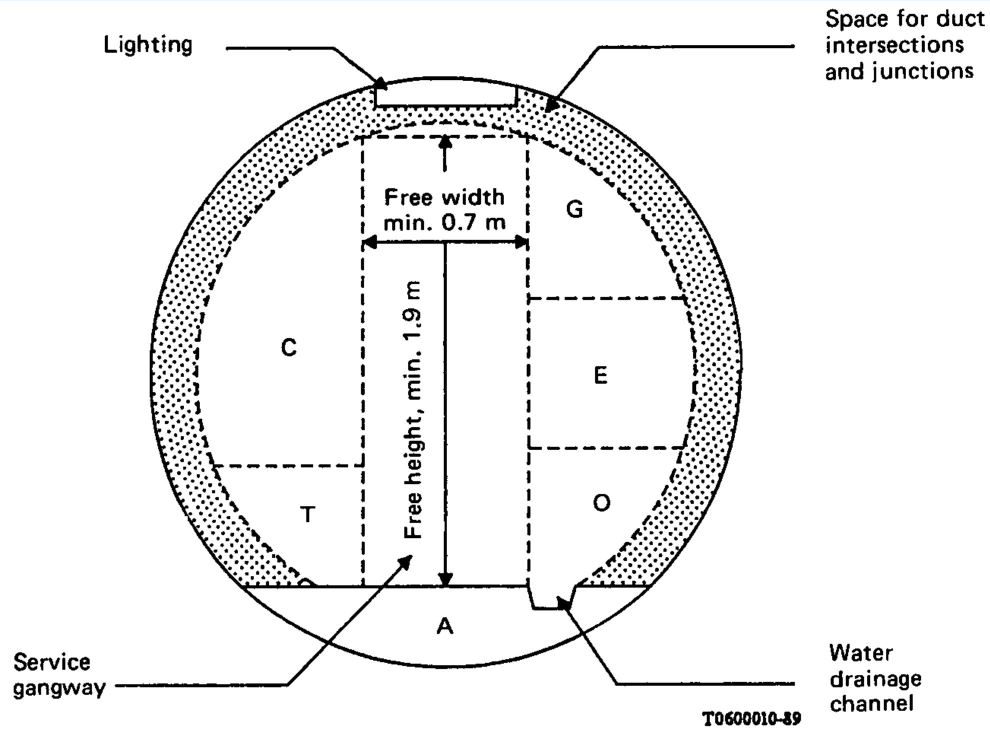
– Transit points between tunnels and open ground

At points where ducts transit between tunnels and open ground, due account should be taken to relative movements which may occur between the two types of environment. Tunnel exit points should be as leakproof as possible, so as to avoid the penetration of gas or water in the tunnel.

– Flood alarm systems

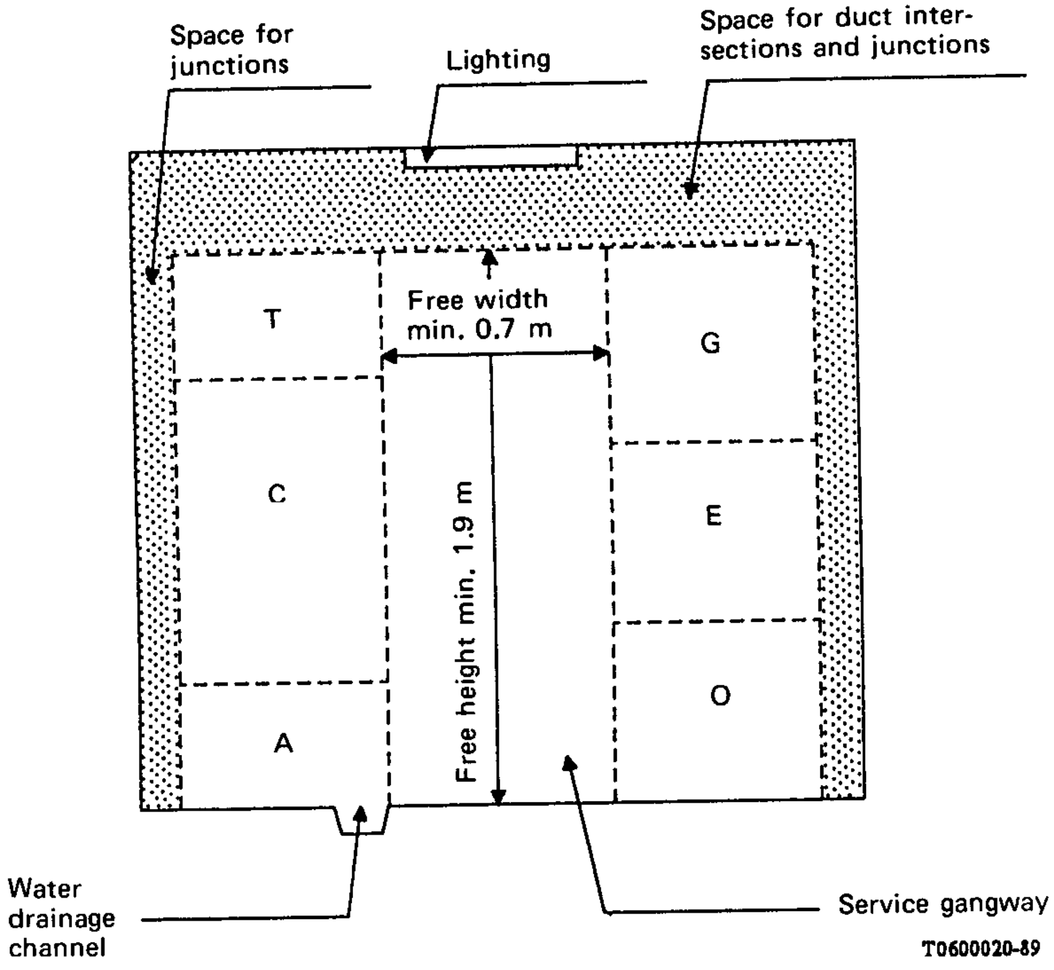
Flood alarm systems should include floater switches placed at low points and in drainage wells, with additional floaters on different levels, thus setting off successive alarms.

**Figure 4-14: Example of circular cross-section**




T Telecommunication duct area (in tubes)
E Power duct area
G Gas duct area
O Water duct area
C District heating duct area
A Waste water duct area

**Figure 4-15: Example of rectangular cross-section**




| | |
|---|---|
| T | Telecommunication duct area (exposed cables) |
| E | Power duct area |
| G | Gas duct area |
| O | Water duct area |
| C | District heating duct area |
| A | Waste water duct area |

### 4.1.4.3 Telecommunication poles, suspension wires and guy-lines for aerial cables

[For further information see ITU-T Recommendation L.89]

Pole routes are vulnerable to disasters involving water penetration, high winds, earthquakes, snow, etc. Any disaster causing just one of the poles on the route to fall down, or the cable to be cut even at one point, will disrupt the circuit. Restoring service may take days especially if the roads are inaccessible.

This section describes the general requirements for suspension wires, telecommunication poles and guy-lines that support aerial cables for optical access networks. In Annex 4A1 there are the main design guidelines for these infrastructures.

*The main characteristics of the aerial cable infrastructure*

The intent of such an infrastructure is to support outdoor cables that will be attached by lashings, clips, or similar mechanisms. Self-supporting cables, while not specifically addressed by this Section, have the same issues applicable to their installation. Loads applied to the infrastructures are also indicated.

Suspension wires, telecommunication poles and guy-lines that support aerial optical fibre cables are important facilities for providing broadband services. An appropriate design is needed to maintain the reliability of these facilities and services. Moreover, they are big facilities installed at a high position, and so they should be managed in a way that ensures sufficient safety. To realize these requirements, a design is needed that carefully considers facility strength.

*Definitions*

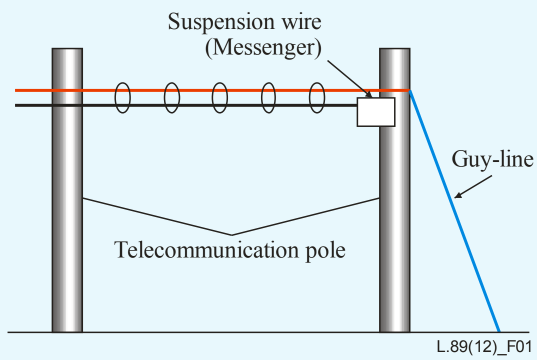
– Guy-line is a wire installed to prevent poles collapsing as a result of tension imbalances that occur during or after cable installation. One end of the guy-line is fixed to the pole and the other end is fixed to the ground by a guy anchor.

– Messenger is an alternative term for suspension wire.

– Suspension wire is a wire that is installed in advance between telecommunication poles from which aerial optical cables are suspended. It supports a tension applying to non-self-supporting aerial optical cables.

– The aerial infrastructure consists of a suspension wire (messenger), a telecommunication pole, a guy-line, as shown in Figure 4-16, and the optical fibre cables for aerial applications.

**Figure 4-16: Aerial infrastructure**




The general requirements for aerial infrastructure design are shown in the following.

*Classification of site conditions*

Ideally, aerial infrastructure is designed in accordance with the conditions of each individual site. However, designing on such an individual basis raises capital expenditure (CAPEX). Therefore, a certain level of design standardization is necessary to simplify the design and construction process, in order to reduce CAPEX. As one example of this standardization, site conditions may be classified based on wind loading, ice loading and/or soil property. Network operators should carefully investigate the site conditions so that the site can be correctly classified.

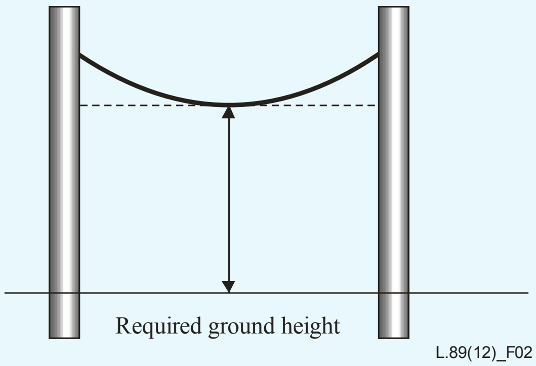
*Safety and economic considerations*

Aerial infrastructure consists of large facilities that are installed high above the ground. So, it is recommended that telecommunication companies carefully consider safety and avoid any accidental destruction to aerial infrastructure by employing a design with sufficient strength and protection against lightning. Note that telecommunication companies should also consider reducing CAPEX while maintaining safety.

*Management of ground height and offset distance*

It is recommended that aerial infrastructure (including cables shown in [ITU-T L.26], [ITU T L.58] and [ITU-T L.87]) has sufficient ground height to prevent any component from being a traffic barrier and to eliminate risks to people and other constructions (Figure 4-17). The ground height shall be evaluated in wind-free conditions. An offset distance that is as great as possible should be established between optical fibre cables and electrical cables to achieve safety and workability. In general, ground height and offset distances are defined by regulations, and so telecommunication companies shall follow these regulations when designing aerial infrastructure.

**Figure 4-17: Ground height**




*Loads applied to aerial infrastructure*

Aerial infrastructure should be designed in accordance with the loads applied to them to maintain their reliability and safety. In particular, telecommunication companies should carefully consider wind loading, suspension wire tension and vertical load. These loads must include the weight of the cable(s) which are expected to be supported by the suspension wire.

The design criteria based on the above requirements are in Annex 4A1.

#### 4.1.4.4 Street cabinets

[For further information see ITU-T Recommendations L.70, L.71 and L.oxcon (under preparation)]

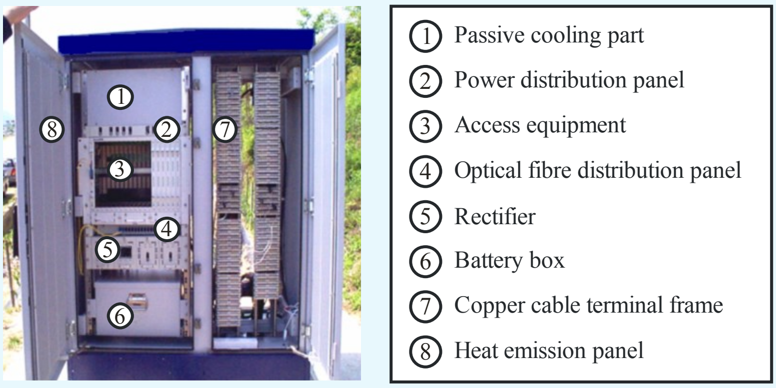
Street cabinets accommodate passive and active optical devices and can be configured only for fibres, for a combination of copper and fibre, for splices, and passive optical splitters. Example of street cabinets for the broadband access network are shown in Figures 4-18 and 4-19.

The outdoor cabinets should be installed considering the size of the cabinet, occupation area and the risk of flood damage. Also, it can be considered whether to purchase or rent the place to install outdoor cabinets. A series of these processes can minimize the OPEX for environmental damage or moving of cabinets in future. As for the power supply for active equipment (e.g., ONU or remote xDSL) deployed in street cabinets see Section 4.5.

**Figure 4-18: Example of cabinet for broadband services**

L.71(08)_FI.1

**Figure 4-19: Example of the structure of a cabinet for broadband services**




L.71(08)_FI.2

### 4.1.4.5 Manholes and Handholes

[Guide to Post-Earthquake Investigation of Lifelines, ASCI]

[http://books.google.it/books?id=Zi6vvZDbDH0C&pg=SA14-PA19&lpg=SA14-PA19&dq=Manholes+and+handholes&source=bl&ots=5PSqY3RYM9&sig=ZUF4cZqXW1y9dsMyx_jIZI1N6sk&hl=it&sa=X&ei=93qxUb-6HcGUhQfgmYFw&ved=0CG4Q6AEwCg#v=onepage&q=Manholes%20and%20handholes&f=false]

Manholes and handholes are means to branch the cables and protect the splice joints from the environment (Figure 4-20). They also allow service people to add or to repair cables in the network. Cables can be easily added between manholes by stringing the new cable through the conduits. Handholes are used for direct buried cables and cables entering a building. As the name implies, handholes are much smaller than manholes.

The majority of manholes and handholes are concrete structures buried underground. The size of the manholes is dependent of the amount of cables and repeaters for the location. Recently some operators have used some fiberglass construction; these manholes are lighter in weight and easier to handle than concrete.

All manholes and handholes are required to be water tight. Therefore, cables entering or exiting a manhole or a handhole have to be sealed. Normally, cables in a manhole are tied to shelves away from the manhole floor so that they cannot be damaged by water when water leaks into the manhole. It is common practice to inspect manholes for water after a major rain storm and pump them out where necessary.

**Figure 4-20: Protection system for extra length cable in handholes**

## 4.2 Maintenance aspects

[For further information see ITU-T Recommendations L.omtl, L.73, L.74, L.88, G.979]

An optical fibre line testing system is essential for reducing maintenance costs and improving service reliability in optical fibre networks. The system requirements described in this Section, for sake of brevity, is limited to deal with some maintenance aspects of optical cables for trunk lines and of active optical nodes.

### *4.2.1 Maintenance aspects of optical trunk systems*

NOTE – An optical trunk line is a part of the optical fibre cable network that is located between two central offices.

Data communication traffic in both access networks and optical trunk lines is rapidly increasing. Therefore, the optical fibre cable for trunk lines is becoming increasingly important because of its large transmission capacity. The fundamental requirements for optical fibre cable maintenance support, monitoring and testing systems for optical trunk lines are as follows:

– An optical fibre cable maintenance support, monitoring and testing system must perform the maintenance work described in [ITU-T L.25] efficiently.

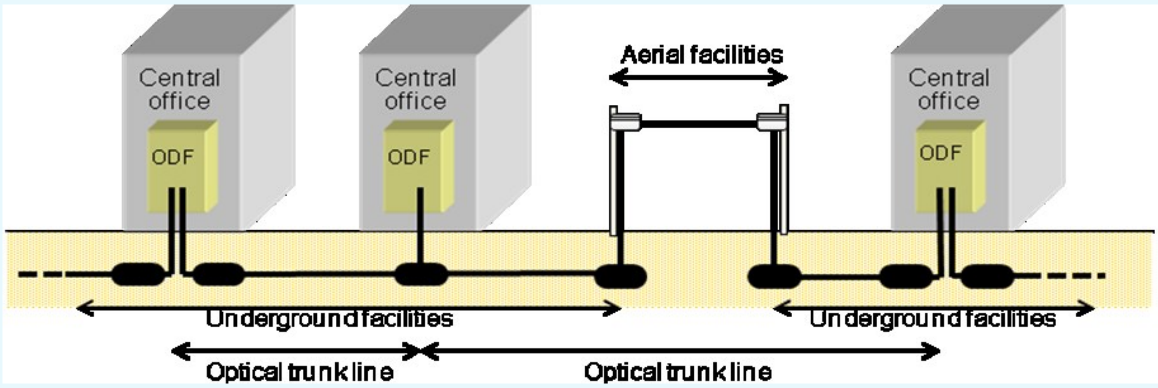
– An optical fibre cable maintenance support, monitoring and testing system should provide the surveillance, testing and control functions listed in [ITU-T L.40] to meet the system specifications for optical fibres or fibre-optic components even when applied to optical trunk lines.

– It must be safe for network operators to handle the optical fibre cables, cords and fibre-optic components of the optical fibre cable maintenance support, monitoring and testing system. Network operator safety must be in accordance with [ITU-T G.664], [IEC 60825-1] and [IEC 60825-2].

*Maintenance aspects of optical trunk line*

Figure 4-21 shows a typical configuration of an optical trunk line. In general, an optical trunk line has a long transmission distance and must have a low attenuation. Therefore, the fibre-optic devices that are inserted in the communication lines for testing must also have a low insertion loss. In addition, test equipment must provide highly accurate measurements because of the importance of the optical trunk line. Specific requirements and functions for trunk lines are described below.

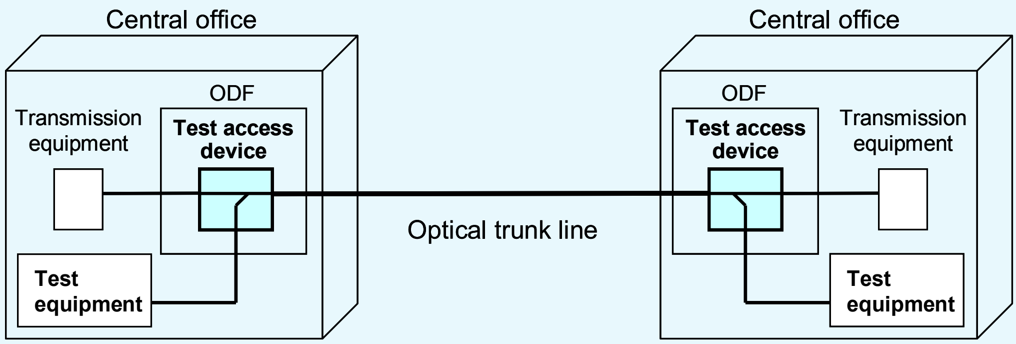
**Figure 4-21: Typical configuration of an optical trunk line**




There are several ways to implement the maintenance functions described in [ITU-T L.40] and in [ITU-T G.667]for testing an optical fibre cable, the optical loss and the optical power of optical signals. Optical fibre cable maintenance systems should have optical branching devices for test light insertion (e.g., an optical coupler). The branching device for test use should have a low insertion loss in both the communication and test ports when we assume a long distance trunk line. Therefore, wavelength selective couplers or WDM couplers would appear to be efficient devices for testing. Also, the optical branching device should have a wide wavelength range for communication signals when the optical trunk lines accommodate services using WDM transmission systems.

When the length of an optical trunk line cable exceeds the measurable range of the test equipment, branching devices must be inserted at both ends of the optical trunk line for bidirectional testing. A typical configuration of the optical trunk line with test access devices is shown in Figure 4-22.

**Figure 4-22: Typical configuration of an optical trunk line with test access devices**




## 4.2.2 Maintenance aspects of active nodes

[For further information see ITU-T Recommendation L.70]

In general, remote active nodes require more maintenance effort than passive outdoor nodes or active equipment in central offices. The main reasons for the more intensive maintenance are:

– limited lifetime of the equipment and moving parts (e.g., fans);

– potential pollution of ventilation systems;

– temperature excursions that have a negative effect on the lifetime of equipment and batteries;

– damage (accidental or intentional).

Compared to centralized electronics, the cost per maintenance intervention will be higher due to the required travel time. In order to minimize the need for maintenance interventions, the following design features and practices are recommended:

– minimum lifetime of fan and equipment should be five years;

– avoid forced ventilation when possible;

– apply multiple fans in parallel (redundancy);

– mount air intake of ventilation systems away from the ground to reduce risk of pollution (e.g., in the "roof" of the enclosure);

– apply air filter types with a minimum need for maintenance or replacement;

– avoid the application of active cooling ("chillers") unless absolutely necessary;

– minimize the need for intervention related to the powering of the node (e.g., resetting of safety switches or fuses, meter reading, battery breakdown, etc.);

– apply a maintenance plan (e.g., annual, bi-annual, etc.) to execute a number of standard activities that will prevent sudden breakdown due to deterioration of the node (e.g., battery replacement, filter replacement, fan replacement, cleaning, etc.);

– apply remote monitoring of critical parameters such as internal temperature, humidity level, fan status, open door contacts, etc.

## 4.3 Natural disasters management

[For further information see ITU-T Recommendations L.92 and L.81]

### *4.3.1 Earthquakes*

Outside plant facilities may be damaged during earthquakes. Telecommunication services may be lost because of damage to underground conduits, aerial cables, etc. Therefore it is necessary to perform an initial evaluation of the earthquake hazard and outside plant facilities vulnerability. In addition seismic design standards for outside plant facilities are needed to improve their earthquake performance.

#### 4.3.1.1 Damages to the outside plants

*Duct /conduits*

When conduit is damaged, water can penetrate into the closure and small flaws in cables will eventually allow water to enter and degrade cable performance. PVC ducts can be damaged by ground deformation caused by an earthquake.

The following countermeasures using ducts with flexibilities to relative displacements are effective.

i) Sliding joint for general ducts

The joint structure is changed from a screw type to a sliding type to improve flexibility of a range of a motion (Figure 4-23(2)).

ii) Sliding joint for manhole ducts (duct sleeve)

This is a sleeve for a duct connecting to a manhole, which also acts as a sliding joint (Figure 4-23(1)).

iii) Sliding joint with a stopper

This is used near a bridge section and in a liquescent ground. The stopper embedded in the joint limits excess movement of ducts (Figure 4-23(3)).

iv) Flexible building access duct

This is used for connecting a handhole and a customer’s building and absorbing large relative displacements (Figure 4-23(6)).

*Poles/guy lines of aerial cables*

Poles (concrete poles and steel poles) have several failure modes: falling, sinking, and breaking. Poles fall to the ground when the bearing capacity of foundation is weak. In liquefied soils, poles sink into the soil. Poles can also be broken at the weakest point. The failure of the pole is attributed to ground motions or to being pulled over when an adjacent pole fails. Appropriate countermeasures should be applied according to these failure modes.

*Terrestrial cables*

Terrestrial cables are one of the important infrastructures and have to meet a set of requirements. These requirements are intended to protect the cables from the hostile outside plant environment including earthquakes. It is recommended that cables should have good seismic performance. It is desirable that cables have enough length at manholes so as not to be cut due to ground settlement by earthquake.

*Tunnels*

Cable tunnels are designed to withstand a large scale earthquake based on a sufficient strength design, and so cables inside tunnels are not damaged. However, water leakage and flooding occur at connections. So following countermeasures are developed.

(1) Flexible joint for open-cut tunnel

This is used to prevent a damage caused by relative displacements at the attachment point of the open-cut tunnel between a building and a vertical shaft (see Figure 4-23 (5)).

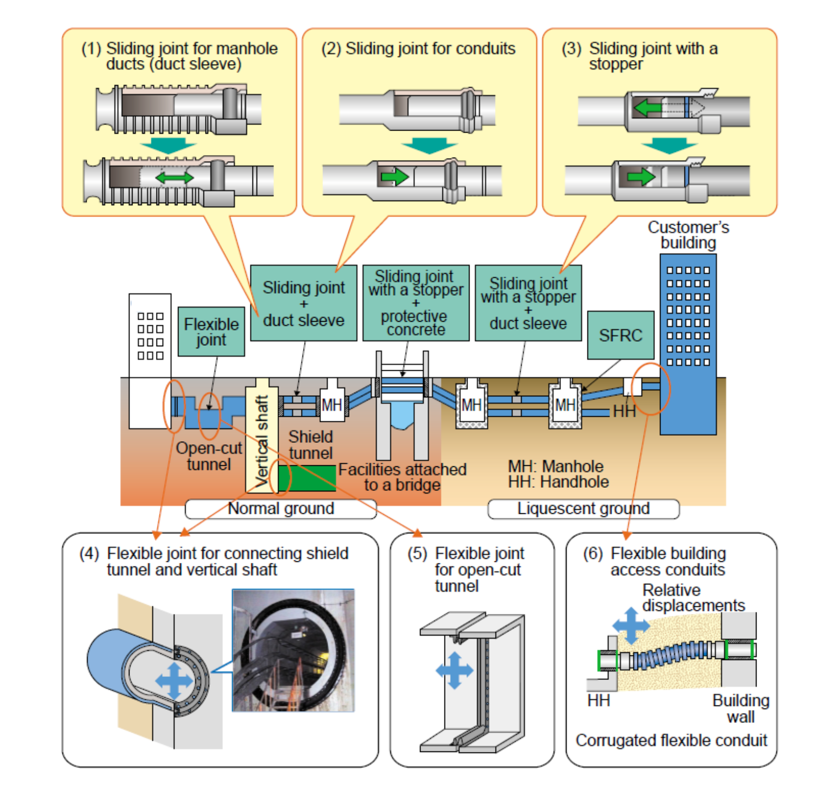
(2) Flexible joint for connection between a shield tunnel and a vertical shaft

This is used to maintain connections between the shield tunnel and the vertical shaft (see Figure 4.1(4)).

[For further information see "Research on reliability assessment of buried Telecommunication facilities during earthquakes"

[http://www.bhrc.ac.ir/Portal/LinkClick.aspx?fileticket=lOD8ZaSB9xw%3D&tabid=562]

**Figure 4-23: Japanese experience of earthquake countermeasure for underground facilities**




*Manholes/handholes*

Manholes and handholes are also critical components of outside plant facilities because they are usually damaged during earthquakes. Manholes are damaged when[1]soil liquefaction occurs. The soil around the manhole liquefies and loses its shear strength, and as a result, the manhole can sink or float, breaking conduits connected to the manhole.

[1] Soil liquefaction is a phenomenon whereby a soil loses strength and stiffness during an earthquake, causing it to behave like a liquid. Surface-supported structures have settled several feet below grade, and buried tanks have floated to the surface.

*Bridges*

As countermeasure to earthquake, bridges have a quake absorbing structure. When an earthquake occurs, a bridge will oscillate in all directions (360 °) owing to the structure. This behavior of the bridge prevents the failure of the bridge. However, on the other hands such flexible structure of the bridge requires the flexible range of motion to conventional ducts put on the bridge. Therefore, it is insufficient to take into account oscillation in only the forward direction as the countermeasure of ducts put on the bridge. Considerations should be focused on more flexible connection technologies for ducts.

#### 4.3.1.2 Possible measures to face earthquakes

Mitigation measures:

– Observe earthquake-resistance design standards and building codes;

– Restrict installation in active earthquake faults;

– Increasing strength of materials which are used in outside plant facilities.

Preparedness measures:

– Rubber joints for cable tunnels, liquefaction countermeasures on manhole, extendable joints for ducts and seismic simulations;

– Installation of vibration controlling or mitigating systems.

Response measures:

– Installation of structural health monitoring systems.

### *4.3.2 Tsunami*

A tsunami consists of a series of sea waves and is usually caused by massive submarine earthquake. Central offices and outside plant facilities in coastal areas may suffer serious damage. It takes a long time to repair damaged telecommunication services at central offices due to the wide variety of specialized equipment typically installed there. There is a need to design alternate trunk cable routes that can be used to sustain telecommunication services when a large portion of the trunk network is degraded.

#### 4.3.2.1 Damages to the outside plants

It is important to prevent water damage in cable tunnels, in submarine cables, in manholes, in handholes, to the power supplies and to have backup power supplies available for use during power supply failures.

#### 4.3.2.2 Possible measures to face tsunami

Preventive mitigation measures:

– Locating central offices and cable routes on higher ground;

– Strengthening trunk line backup systems by subdividing physical network loops;

– Laying cables with ducts under riverbed rather than installing cables along bridges near the mouths of rivers;

– Ensuring an electrical power supply, for example, by establishing duplication using a multiple electrical distribution route and an emergency electrical generation system.

### *4.3.3 Flood/Flash floods*

#### 4.3.3.1 Damages to the outside plants

Outside plant facilities are also damaged by floods.

– Water can enter manholes, handholes, which can cause telecommunication equipment to break down. Therefore, manholes and handholes are required to be water tight. Cables entering or exiting a manhole or handhole have to be sealed. Cables in a manhole should be tied to shelves away from the manhole floor to avoid damage by water when water leaks into a manhole.

– Tunnels: in the cable tunnels, waterproof doors and water pumps should be provided.

– Cables: liquid can penetrate into cables.

#### 4.3.3.2 Possible measures to face floods

Preventive mitigation measures:

– Restrict installation in potential flood zones;

– Installing concrete structures at the site in which ground settlement may be expected due to heavy rains;

– Installing retaining structures or guardrails between outside plant facilities and steep slopes.

Preparedness measures:

– Installation of waterproof doors and water pumps;

– Sealing the ends of the plastic tubes (at the manholes/pits of our underground infrastructure) with foam filler;

– Installing drainage pumps in cable tunnels and installing flood walls in cable tunnels.

Response measures:

– Submersion detection modules and cable tunnel management systems;

– Installation of early-warning systems.

### *4.3.4 Strong wind (hurricanes/tornados/typhoons/wind storms)*

Outside plant facilities may be affected by strong winds, and there is always a risk of loss of telecommunication services.

#### 4.3.4.1 Damages to the outside plants

Telecommunication poles should be braced and guyed to withstand maximum expected wind velocities and optical cables should be installed to resist damage due to wind-driven vibration.

The following damages are possible:

i) falling telecommunication poles;

ii) physical damage to aerial structures;

iii) disconnection of aerial cables.

#### 4.3.4.2 Possible measures to face strong winds

Mitigation measures:

– Observe design criteria for protection against strong winds.

Preparedness measures:

– Installation of supports (i.e. struts, guy line or stay wires);

– Bracing poles alternatively with steel wires when the expected wind speed exceeds 40 m/s;

– Using bracing between poles in windy locations;

– Using vibration dampers to protect cables.

Table 4-6 shows some examples of maximum wind pressure loads allowed to act on vertical profile area.

**Table 4-6: Wind pressure loads**

| Facilities | Wind pressure loads per vertical profile area (kg/m2) |
|---|---|
| Wooden poles, concrete poles | 80 |
| Steel poles | 80 |
| Towers | 170 |
| Cables | 100 |

### *4.3.5 Landslides*

#### 4.3.5.1 Damages to the outside plants

Typical damages of the landslides are the destruction of underground ducts and the failure of retaining structures.

#### 4.3.5.2 Possible measures to face landslides

Mitigation measures:

– Restrict installation in potential landslide zones;

– Keeping away from landslide-prone areas;

– Increasing the slope's stability.

Preparedness measures

– Periodic inspection;

– Installation of monitoring systems, and monitoring by measurement.

Response measurements:

– Installation of early-warning systems

### *4.3.6 Forest fires*

#### 4.3.6.1 Damages to the outside plants

Typical damages of forest fires are burned down telecommunication poles and disconnection of aerial cables.

#### 4.3.6.2 Possible measures to face forest fires

Mitigation measures:

– Using fire breaks (isolating clean land strips-mostly in the rural area).

Preparedness measures:

– Protecting outside plant facilities with non-flammable or fire-retarding materials;

– Using non-flammable materials in cable structures.

Response measurements:

– Installation of early-warning systems.

### *4.3.7 Severe cold, snow, ice or heat*

#### 4.3.7.1 Damages to the outside plants

Severe atmospheric conditions can impact all the types of telecommunication equipment.

#### 4.3.7.2 Possible measures to face severe cold, snow, ice or heat

Mitigation measures:

– Outside plant facilities that are installed at sites where there is extreme heat or cold should be provisioned with adequate countermeasures in order to operate with stability;

– Outside plant facilities that are installed at the site or environment where its temperature difference is excessive should be provisioned with adequate countermeasures in order to operate with stability.

Preparedness measures:

– A manhole cover for snow covered areas and installing tubes for antifreeze in ducts.

*[TBD]ry analysis method.*

## 4.4 Disaster monitoring systems for outside plant facilities

[For further information see Recommendations ITU-T L.81, L.25, L.40 and L.53]

[For the aspects related to active monitoring of the transmission equipment see also ITU-T G.697].

This Section:

– describes typical emergency management for outside plant facilities;

– describes monitoring systems for outside plant facilities using wireless or wired network;

– provides an overview of disaster monitoring systems for outside plant facilities;

– provides design considerations for disaster monitoring systems for outside plant facilities.

*Definitions*

– disaster: Disasters are characterized by the scope of an emergency. An emergency becomes a disaster when it exceeds the capability of the local resources to manage it. Disasters often result in great damage, loss, or destruction.

– early warning: The provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response.

– emergency: An emergency is a sudden, urgent, usually unexpected occurrence or event requiring immediate action.

– structural health monitoring (SHM): The process of continuously monitoring the status of a structure to detect damage.

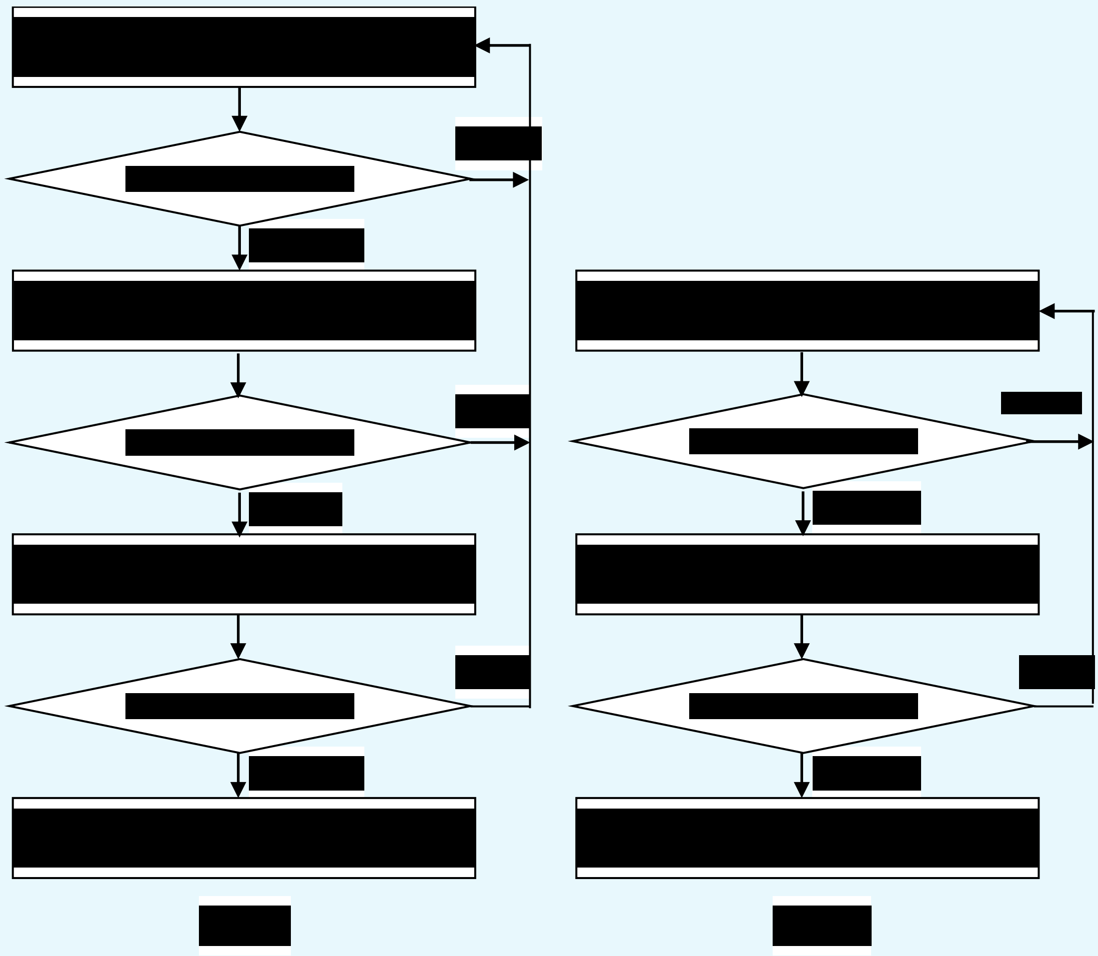
– wireless sensor network (WSN): A wireless network consists of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations.

### *4.4.1 Manually operated monitoring systems*

Manually operated monitoring procedures for outside plant facilities are described in Figure 4-24 a). Patrolling and visual inspections are carried out by facility member staffs, and a detailed investigation follows when any defects are detected. If critical factors which may cause an accident are detected at this stage, additional safety assessment is carried out.

As shown in Figure 4-24 (b), monitoring systems by sensor network omit some of these stages, and thus make it labour-saving and efficient to maintain the outside plant facilities. In addition, monitoring systems allow facility member staffs to quickly find critical data that ensure outside plant facilities operate 24 hours a day.

**Figure 4-24: Monitoring flow diagram: (a) manually operated monitoring method; (b) monitoring systems**




### 4.4.2 Monitoring system for outside plant facilities

The objective of the monitoring system is to detect defects in an early stage, and to deliver warning messages to disaster managers rapidly when the defects are not tolerant. These activities can be performed by persons, but it may cost much time and effort when the structures or facilities to be monitored are big and spatially scattered over a wide area. In addition, small defects that may cause great disasters are apt to be overlooked by only manual inspection. Therefore, it is required to establish more sophisticated countermeasures such as an early-warning monitoring system.

*General requirements*

It is recommended that the monitoring system for outside plant facilities be:

– designed to carry out proper response action rapidly in the emergency;

– implemented by reliable, stable and proven technology not to give a false alarm;

– operated in real-time or near real-time manner;

– designed to provide alerting without delay for facility staff members;

– tested and verified before application and regularly checked.

*Wired/wireless systems*

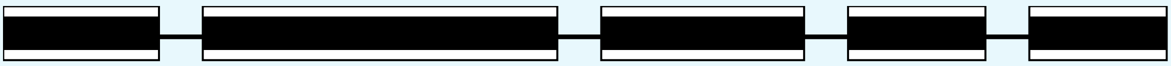
Monitoring system for outside plant facilities is to sense the physical or environmental conditions by sensors, and then to notify facility staff members through the way of wired or wireless system. Comparisons between wired and wireless systems are presented in Table 4-7. Wired system is recommended when a higher reliability is required.

**Table 4-7: Comparisons between wired and wireless system**

| Type | Advantages | Disadvantages |
|---|---|---|
| Wired system | – stable and proven technology. | – involves many long lengths of cable to cover the large spatial distances;<br>– expensive to install;<br>– cables can fail due to exposure to the environment or potential damage during extreme events;<br>– long cables result in sensor signal degradation. |
| Wireless system | – no cables are required for data transfer;<br>– system setup and maintenance cost can be remarkably reduced;<br>– in the case of partial system failure, the rest of the system is capable of performing its task independently. | – power and communication bandwidth available on the node are very limited;<br>– each node has restricted battery life. |

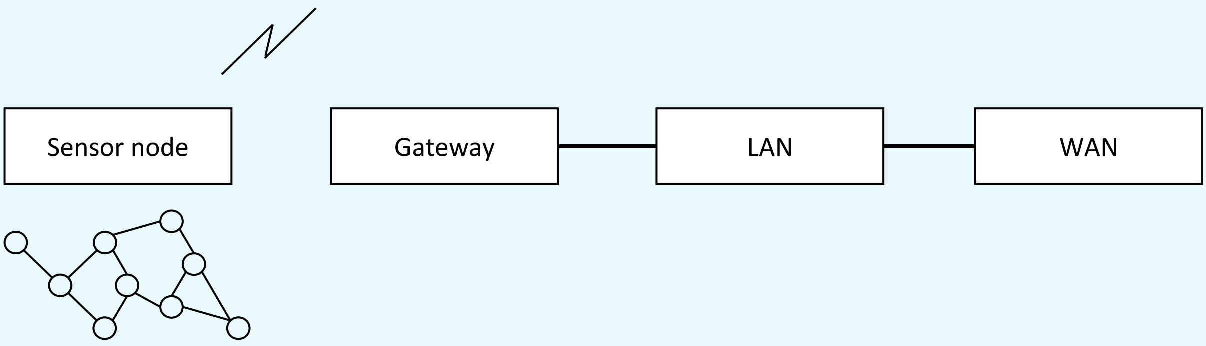
In a wired system, the sensor is generally hard-wired to a data acquisition system which is linked to the base station (Gateway) by a cable. An example of network configuration using Ethernet is shown in Figure 4-25.

**Figure 4-25: Example of network configuration (wired system)**




In a wireless system, the sensed data are sent to a gateway (Base Station) via radio. Radio frequencies, power and protocols vary greatly among different systems. Some of the wireless systems available are GSM, WiFi, Bluetooth, and ZigBee, etc. The type of wireless systems to be used depends upon factors such as frequency, data rate, range, and monitoring characteristics, etc. Typical network configuration is shown in Figure 4-26. A sensor node is a basic unit which is composed of sensing, processing, communication, and a power unit. Communication between gateway and LAN will be via wired or wireless.

**Figure 4-26: Typical network configuration (wireless system)**




*Sensors*

Parameters to be sensed in the monitoring system are deformation, angle, vibration, and temperature, etc. Typical sensors and their applications are presented in Table 4-8.

**Table 4-8: Typical sensors for outside plant facilities**

| Parameters | Sensors | Descriptions | Applications |
|---|---|---|---|
| Deformation | • Crack gage, Convergence gage, Strain gage | • To monitor changing distances between two points | • Monitoring crack width of building, cable tunnel, and manhole |
| | • Fibre-optic sensor | • To monitor changing distances between two points<br>• Optical fibre Bragg grating (FBG) | • Monitoring deformation of civil infrastructures such as buildings, slopes, tunnels, underground pipes, etc. |
| | • Probe extensometer | • To monitor the changing distance between two or more points along a common axis | • Monitoring ground movement and settlement |
| | • Inclinometer | • To monitor the changing vertical deformations along a common axis | • Landslide detection |
| Angle | • Tiltmeter | • To monitor the change in inclination (rotation) of points | • Monitoring earth retaining wall<br>• Detecting inclination of telecommunication pole or tower |
| Vibration | • Accelerometers | • To monitor dynamic response, either harmonic (e.g., vibration) or transient (e.g., earthquake) | • Monitoring office vibration by traffic or earthquake |
| Temperature | • Thermometer | • To monitor temperature | • Monitoring temperature in server rack |

| Parameters | Sensors | Descriptions | Applications |
|---|---|---|---|
| Water level | • Piezometer | • To monitor water level and/or water pressure | • Flood detection in telephone office or cable tunnel |
| Security | • Motion detector | • To detect motion | • Detecting intruder to secure restricted area |

There are two types of communication models: a pull model and a push model. A pull model requests sensed data periodically in a certain time interval. A push model proactively transmits sensed data only when an event exceeds a predetermined level. It is recommended that a push model be used for a disaster monitoring system.

### 4.4.3 Application of monitoring systems on outside plant facilities using WSN

[Korean experiences in ITU-T Recommendation L.81]

Design considerations on the deployment of WSN (Wireless Sensor Network) monitoring system are presented in Table 4-9.

**Table 4-9: Design considerations**

| Items | Descriptions |
|---|---|
| Network topology | – In WSN, there are star and tree (mesh) network topologies. Network topology affects network characteristics such as latency, robustness, and capacity. |
| Power supply | – WSN can be easily deployed to the sites even where the infrastructures such as communication and electricity are not installed. But the battery which provides sensor node with depletable energy, and thus power unit is one of the most important components to be considered. |
| Threshold | – Monitoring system performs early warning. Real-time data gathered by WSN are analysed and alarm is issued if the data exceed prescribed thresholds.<br>– If the threshold is set too low, there will be too many false warnings, so that genuine warnings will not be heeded. On the contrary, if the threshold is set too high, the event which may cause accidents will be missed.<br>– This activation threshold should be set case by case for outside plant facilities. |
| Sampling rate | – Sampling rate determines how often sampling can take place. A faster sampling rate acquires more data in a given time, and therefore often forms a better representation of the original signal.<br>– For example, earthquake monitoring needs at least 200 Hz data sampling rate, whereas, in the case of temperature or humidity sensing, several samples per day may be enough. |

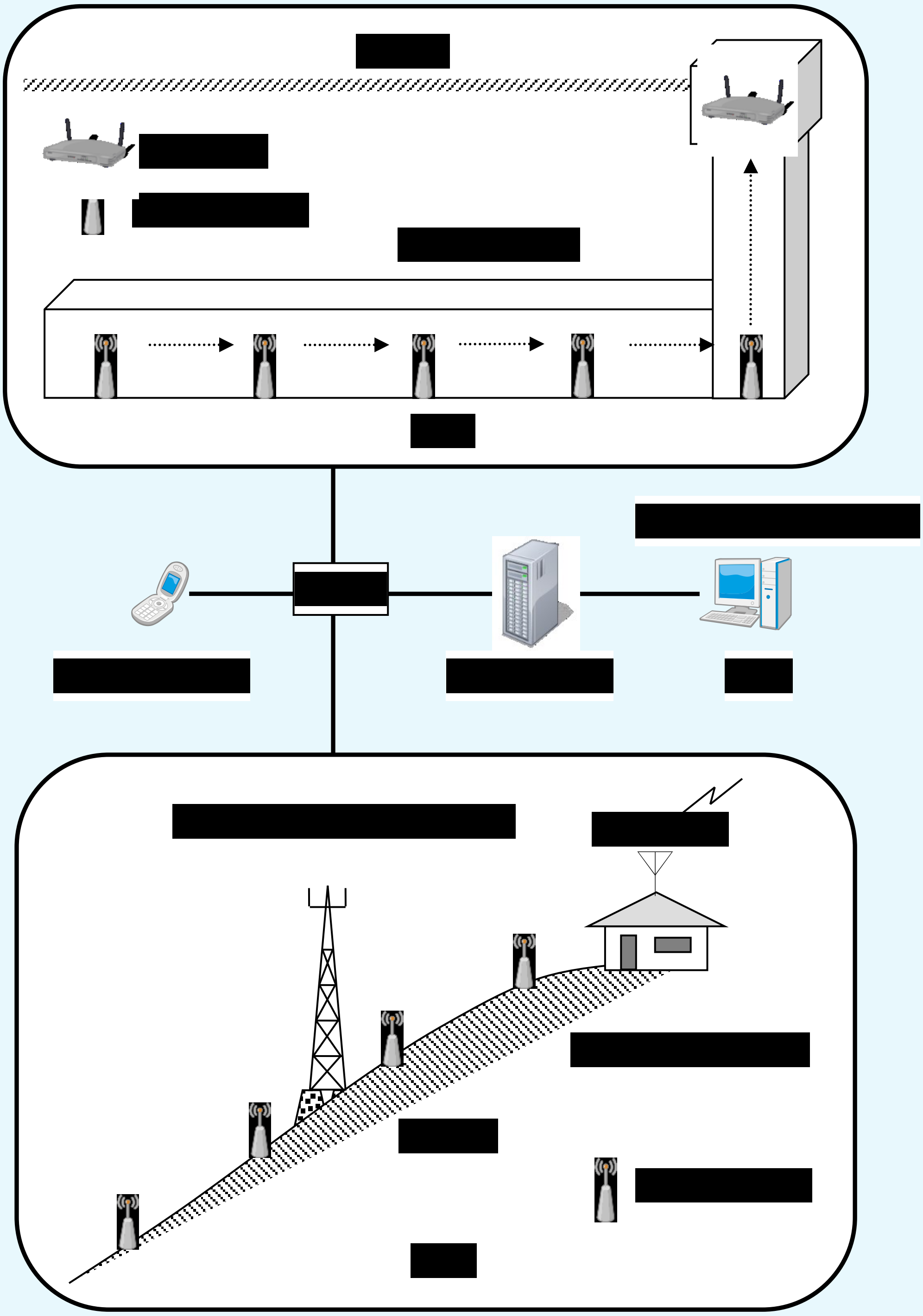
*Cable tunnel monitoring*

We deployed the cable tunnel monitoring system using WSN. Fire, flood, vibration, temperature and intruder monitoring are performed by sensor nodes, and sensed data are transmitted to the gateway by wireless communication. Data are displayed on a web browser through the Internet, and a facility staff member is notified automatically when an event exceeds the warning level. Schematic drawing of this system is shown in Figure 4-27 (a).

*Landslide monitoring*

In the case of outside plant facilities on or near steep terrain, landslides are one of the most significant natural hazards. Slope angle and ground vibration are measured every minute, and these data are transmitted to a server computer via radio. Schematic drawing of this system is shown in Figure 4-27 (b).

**Figure 4-27: Schematic drawing of monitoring systems: (a) cable tunnel monitoring system; (b) landslide monitoring system**



# Annex 4A1: General criteria for the design of an aerial cable infrastructure

[For further information see ITU-T Recommendation L.89]

## 4A1.1 Loads applied to aerial infrastructures

Aerial infrastructure should be designed in accordance with the loads applied to them to maintain their reliability and safety. In particular, telecommunication companies should carefully consider wind loading, suspension wire tension and vertical load, as shown in Figure 4A1-1. These loads must include the weight of the cable(s) which are expected to be supported by the suspension wire.

*Wind loading*

The wind load peaks when the wind blows at right angles to an aerial infrastructure (Figure 4A1-1). At that time, the wind load $T_w$ [N] can be obtained by the following equation.

$$T_w = \frac{1}{2}\rho C_D V_w^2 S$$

where ρ, $C_D$, $V_w$ and S are the air density, the drag coefficient of the infrastructure determined by wind tunnel testing, the wind velocity and the profile area of the cable and the suspension wire, respectively. Note that ice accretion to the cable and suspension wire may increase in their profile area.

*Suspension wire tension*

The suspension wire tension is the load supported by suspension wire. The suspension wire tension T [N] can be obtained with the following equation.

$$T = \frac{WL^2}{8d}$$

where L is a span length. d is a sag and has an inverse ratio to T. In terms of the ground height, a smaller sag is desirable, but this increases suspension wire tension as shown in Figure 4A1-2, and so an aerial infrastructure with greater mechanical strength is required. Therefore, telecommunication companies should design the sag and the suspension wire tension so that they are in balance. As shown in Figure 4A1-3 , W is the load imposed by the sum of the wind load and the cable weight. Note that the resultant load W [N/m] should be defined as the value per unit length. So, it is given by:

$$W = \sqrt{w^2 + \left(\frac{T_w}{D}\right)^2}$$

where w and D are an aggregate of cable and suspension wire weights per unit length and aggregate of cable and wire diameters, respectively. Note that the suspension wire tension reaches its maximum value at its minimum temperature because metal contracts as the temperature falls. Ice loading should be included in cable weight. Ice loading guidelines are generally established by local, regional, or national authorities. Different ice density values for radial and rime ice may be used depending upon local conditions.

*Vertical load*

This is load applied to a telecommunication pole vertically. Typical vertical loads are as follows:

– weight of telecommunication pole;

– weight of snow and ice adhering to telecommunication pole;

– vertical component of guy-line tension;

– weight of workers and tools.

It is recommended for telecommunication companies to consider maximum vertical load when designing telecommunication poles.

**Figure 4A1-1: Wind load, suspension wire tension and vertical load**

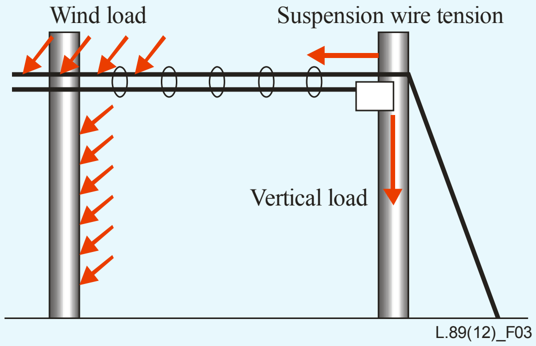



**Figure 4A1-2: Relationship between suspension wire tension and sag**

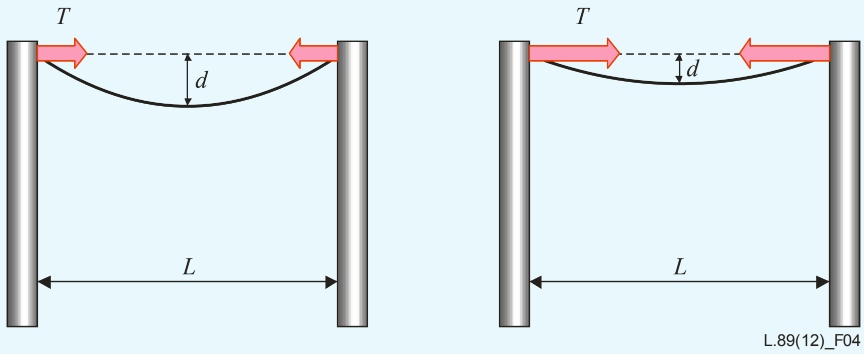
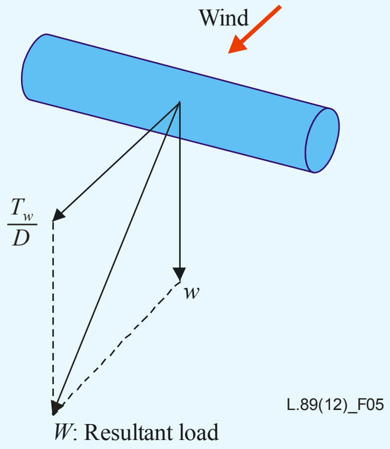


**Figure 4A1-3: Resultant load applied to a suspension wire**




### 4A1.2 Design of suspension wires

*Materials*

It is recommended that stranded steel wire be used as suspension wire. Anticorrosive material, e.g., aluminium-coated steel or zinc-coated steel, should be used for the suspension wire in areas with a corrosion risk. Typical corrosion risk areas are as follows:

– Near the coast; corrosion by salt breeze.

– Industrial and mining areas; corrosion by sulphur dioxide gas.

– Hot springs (warm water found in a volcanic location) and volcanic areas; corrosion by hydrogen sulphite.

*Selection of suspension wire type*

It is recommended for telecommunication companies to select the suspension wire in accordance with the specifications of the aerial cables that it supports. When a future expansion plan for optical cables becomes clear, telecommunication companies may employ the suspension wire that conforms to their plan in advance. The applicable type of suspension wire should be decided carefully based on its tensile strength, calculated suspension wire tension and safety margin.

*Sag*

The sag of a suspension wire reaches its maximum value at the maximum temperature or under the maximum weather loading. So, it is recommended for telecommunication companies to carefully consider the temperature conditions at the installation site.

### 4A1.3 Design of telecommunication poles

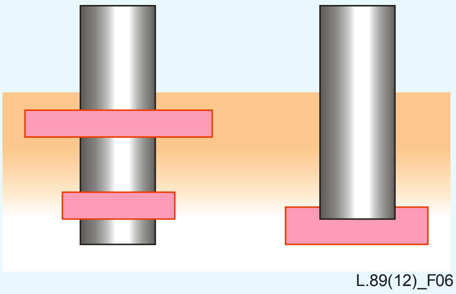
*Materials*

Telecommunication poles should be made of steel, reinforced concrete or wood.

– Embedded depth

The embedded depth of the pole shall be decided in accordance with the subsurface condition of the ground and the material of the pole to prevent poles from collapsing. A greater embedded depth shall be employed for soft ground such as a paddy field area, an embanked zone and peat soil. The use of a pole anchor is also effective for coping with such ground conditions (Figure 4A1-4). The method for evaluating a telecommunication pole's foundation is described in [ITU-T L.88].

**Figure 4A1-4: Example of pole anchor**




*Pole length*

The pole length is limited by the ground height defined by regulations. So, the pole length should be designed to satisfy the required ground height whenever the sag (temperature) reaches its maximum value. At that time, the embedded depth and the surplus length should also be considered.

*Classification*

Telecommunication poles are typically classified based on their purpose as follows (Figure 4A1-5):

– intermediate pole;

– corner pole;

– terminal pole.

The intermediate pole is located midway in the rectilinear cable region. The intermediate pole is affected by wind loads acting on it, wires and cables. So, guy-lines should be installed on both sides of the intermediate pole. The installation interval of the guy-line should be decided in accordance with the wind load at the site. It is recommended that two side guy-lines be installed every two poles as long as the site condition permits it when the wind load is classified at the highest level.

A corner pole is installed at a bent section of an aerial optical cable line. This corner pole is affected by the resultant load of angular bidirectional suspension wire tensions. So, it is recommended that a guy-line be installed on one side. Note that there is no need to use a guy-line when the suspension wire tension is sufficiently small.

The terminal pole is located at the start and end points of cable lines, and is affected by unbalanced suspension wire tension. So, it is recommended that a terminal guy-line be installed. Note that there is no need to use a guy-line when the suspension wire tension is sufficiently small.

### 4A1.4 Design of guy-lines

*Configuration*

A guy-line consists of an upper and a lower part. The upper part of the guy-line (i.e., upper guy-line) is attached to telecommunication poles. The lower part of the guy-line (i.e., guy anchor) is buried to exploit the bearing capacity of the soil.

*Installation angle of upper guy-lines*

The installation angle, which is formed by the pole and the upper guy-lines, may be more than 25 degrees.

*Classification of upper guy-lines*

Upper guy-lines are typically classified based on their purpose as follows (Figure 4A1-5):

– terminal guy-line;

– one side guy-line;

– two side guy-line.

Terminal guy-lines are attached to terminal poles, and should be installed parallel to optical cables. If the allowable strength of the single guy-line is insufficient, two guy-lines can be used. One side guy-lines are attached to the corner poles. One side guy-lines should be installed in the direction bisecting the corner angle. Two side guy-lines are mainly attached to the intermediate poles. Two side guy-lines should be installed every two poles when the wind load is classified at the highest level.

*Classification of guy anchors*

Guy anchors are typically classified according to their purpose as follows (Figure 4A1-6):

– piton anchor;

– block anchor;

– spiky bolt anchor.

The piton anchor, which is a spiky steel piton driven into the ground, is used in most cases except when the installation is on rock or when the driving action might damage existing underground installations or facilities. When it cannot be used, the next choice is the block anchor. The guy-line is held in place by an anchor block formed on site by pouring concrete into a hole, which is then refilled and compacted. However, this also cannot be installed on rock. For an installation on rock, a shallow hole is drilled and a spiky bolt is inserted and mortared in place.

**Figure 4A1-5: Classification of telecommunication pole and upper guy-line**

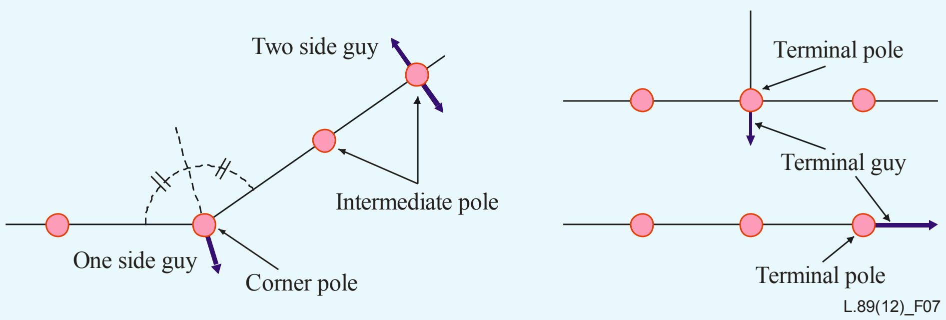
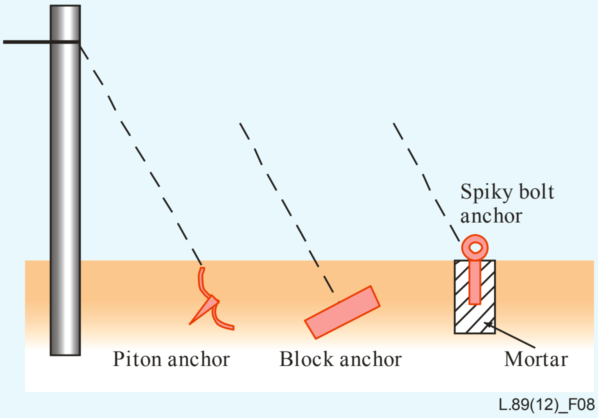


**Figure 4A1-6: Classification of guy anchors**



# Annex 4A2: Thermal design of above ground enclosures

[For further information see ITU-T Recommendation L.70]

The most typical designs for thermal management of above ground outdoor enclosures are listed in this appendix, with their typical properties. The thermal design of the enclosure is to be chosen as a function of various parameters such as:

– surrounding environment and climate;

– dissipated power level of the equipment;

– maximum operating temperature of the equipment;

– size of the enclosure;

– future expandability;

– power consumption;

– etc.

## 4A2.1 Single wall, natural convection

The most simple enclosure type for housing active electronics would be a single wall box or cabinet, without any specific features for thermal management. Heat is transferred via natural convection along the inside and outside of the enclosure walls (Figure 4A2-1).

The outer walls are exposed to solar radiation and a significant amount of solar energy is transferred to the inside of the closure, increasing temperature.

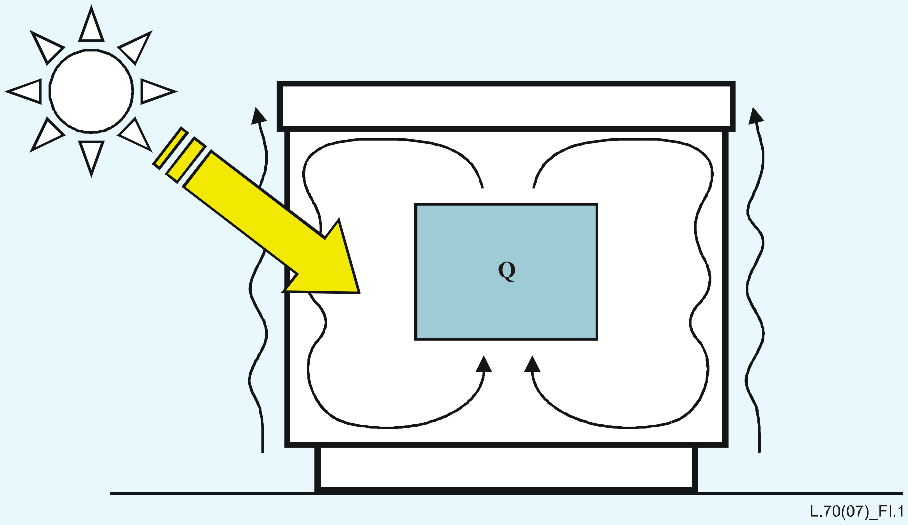
This cooling method does not require extra energy and is maintenance-free.

Internal temperature will rise at least 15-20°C above external air temperature.

NOTE – "At least" means that on a day with intense sunshine, the temperature inside the enclosure will be 15°C or more above the temperature of the surrounding air, even if thermal dissipation inside the enclosure is minimal. E.g., in a passive single wall cabinet, the temperature will rise to about 55°C while the surrounding air is at 40°C.

Due to poor thermal management properties, this design is not recommended for active nodes.

**Figure 4A2-1: Single wall, natural convection**



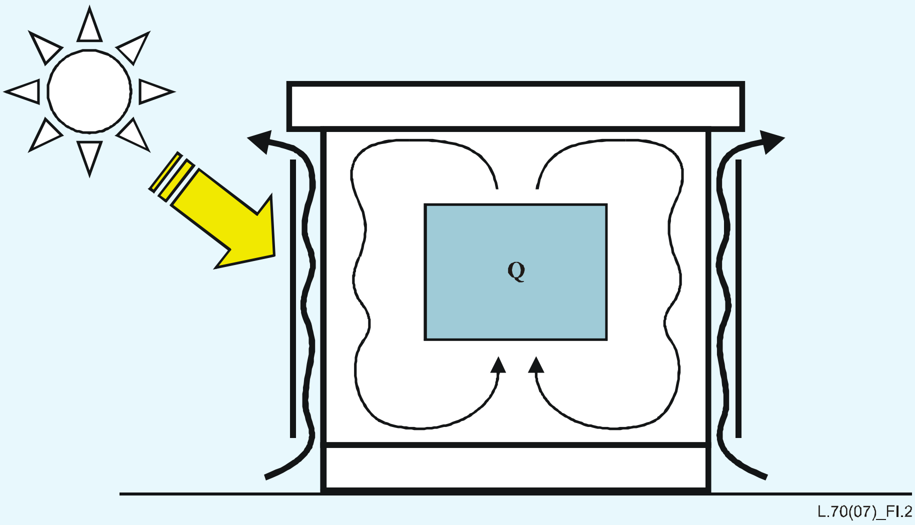

## 4A2.2 Vented dual wall, natural convection

By applying a double wall construction, the effect of solar load on internal temperature can be reduced. The space between the inner and outer wall must be vented in order to evacuate both the heat generated by solar radiation as well as by the equipment by natural convection (Figure 4A2-2). When properly dimensioned, a "chimney-effect" will be created, increasing effectiveness of the cooling.

This enclosure design combines the advantages of effective thermal management at a low operating expense (no extra energy for cooling and virtually maintenance free).

Internal temperature will be at least 7-8°C above external air temperature.

**Figure 4A2-2: Dual wall, natural convection**




### 4A2.3 Forced convection

Increasing airspeed and airflow will make heat transfer to the environment even more effective.

Inside the enclosure, this may be obtained by fans, separate from or integrated into the electronics units. Outside, air can be forced through the dual wall construction. Preferably, the air is circulated top-down, to avoid aspiration of dirt or sand particles from the ground (Figure 4A2-3).

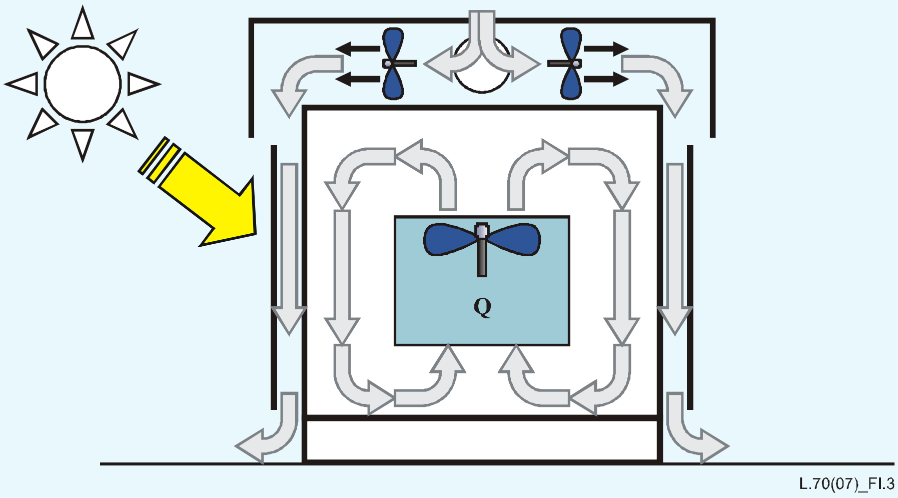
The extra fans in the enclosure will require about 10-20% extra electrical power, on top of the energy to operate the actual equipment.

Recommended fan lifetime is at least five years to minimize fan maintenance.

Fan speed may be regulated as a function of internal temperature. This would increase fan lifetime and decrease power consumption.

Internal temperature will be at least 7-8°C above external air temperature.

**Figure 4A2-3: Dual wall, forced convection**



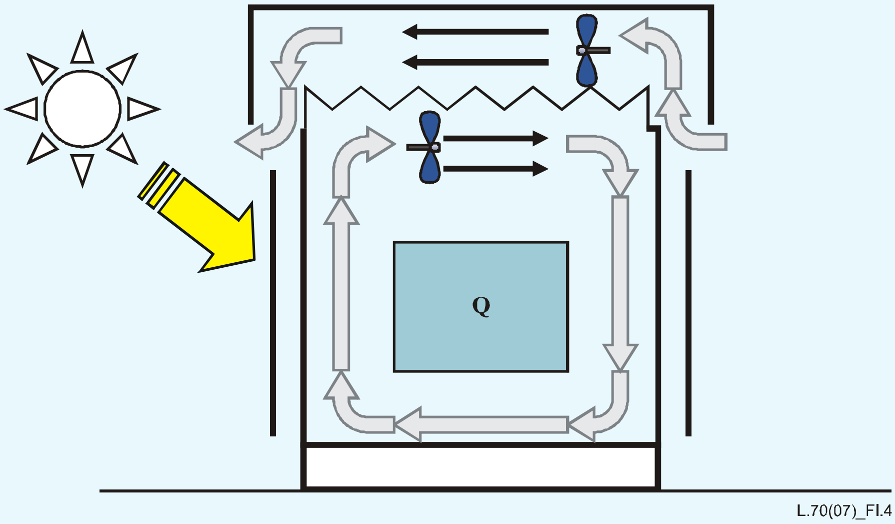

## 4A2.4 Air-to-air heat exchangers

Cooling by forced convection can still be improved by applying heat exchanger elements. Heat exchangers increase the effective contact surface for cooling (Figure 4A2-4).

The fans of the heat exchanger will typically require 15-30% extra electrical power for cooling.

Heat exchangers should respect the IP 55 sealing level to avoid exchange of external air and intrusion of dust or moisture into the enclosure. The external circuit of the heat exchanger should be designed to minimize dust or dirt build up, that would result in early deterioration of cooling capacity and the related need for maintenance.

**Figure 4A2-4: Dual wall, heat exchanger**



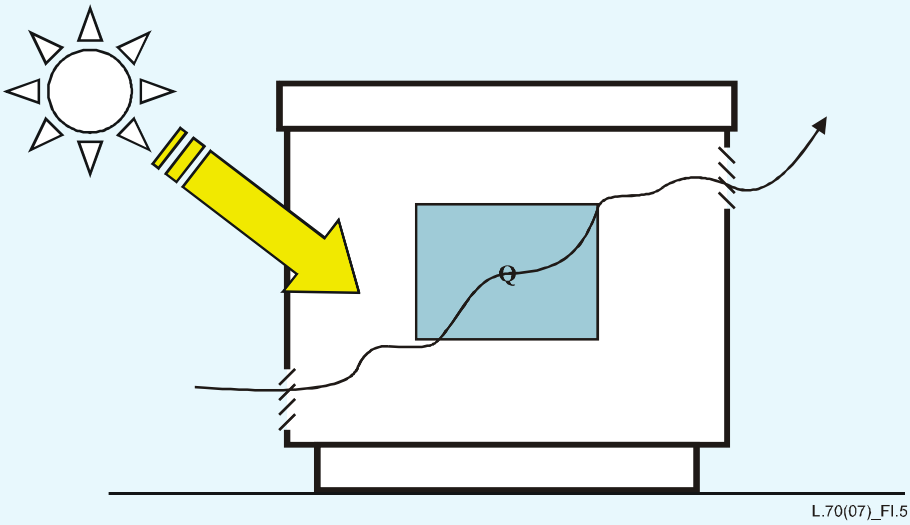

## 4A2.5 Natural and forced ventilation

For the cases described in clauses 4A2.1 to 4A2.4, the air is constantly re-circulating inside the enclosure. The heat is transferred from the air inside to the air outside through the walls of the enclosure.

By blowing external air directly into the enclosure, a more effective heat transfer can be achieved, resulting in a smaller temperature difference compared to the external air (Figure 4A2-5).

Ventilation by free convection is sometimes applied to improve heat transfer in single wall cabinets; however, it is difficult to achieve a proper sealing level for this method. Adding sealing filters would obstruct the rather weak airflow. Therefore, this layout is not recommended for active nodes.

**Figure 4A2-5: Single wall, ventilation by natural convection**



The most appropriate method for cooling by ventilation is the use of fans and filters. This is the combination of a fan, driving the external air in and out of the enclosure, with a filter system that prevents intrusion of dust, insects and liquid water. Filter design with minimal need for regular cleaning or replacement is recommended (Figure 4A2-6).

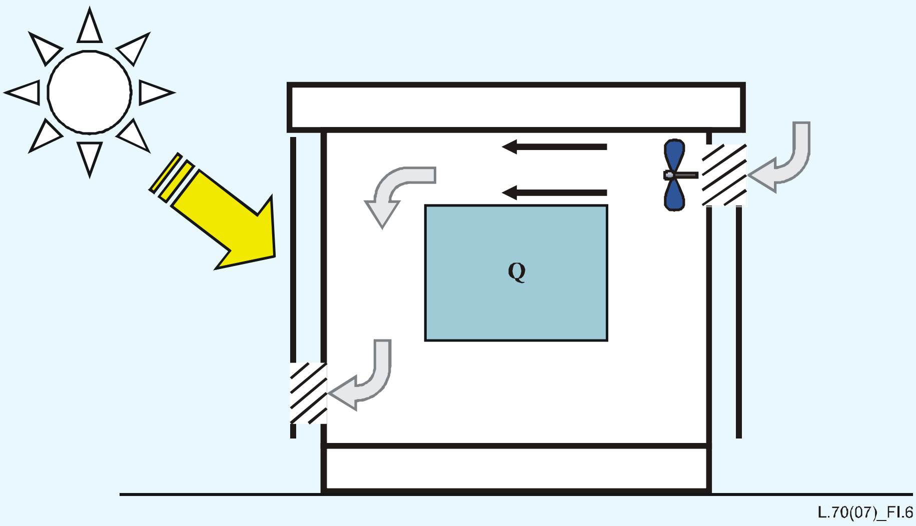
Even when applying IP 55 filters, the air flow will contain water vapour.

Sufficient resistance to corrosion of the equipment is also to be considered.

Filter fans will require about 10-30% of extra electrical power for cooling.

Internal temperature will be at least 3-5°C above external air temperature.

**Figure 4A2-6:f Dual wall, forced ventilation (filter fans)**




## 4A2.6 Active cooling ("chillers")

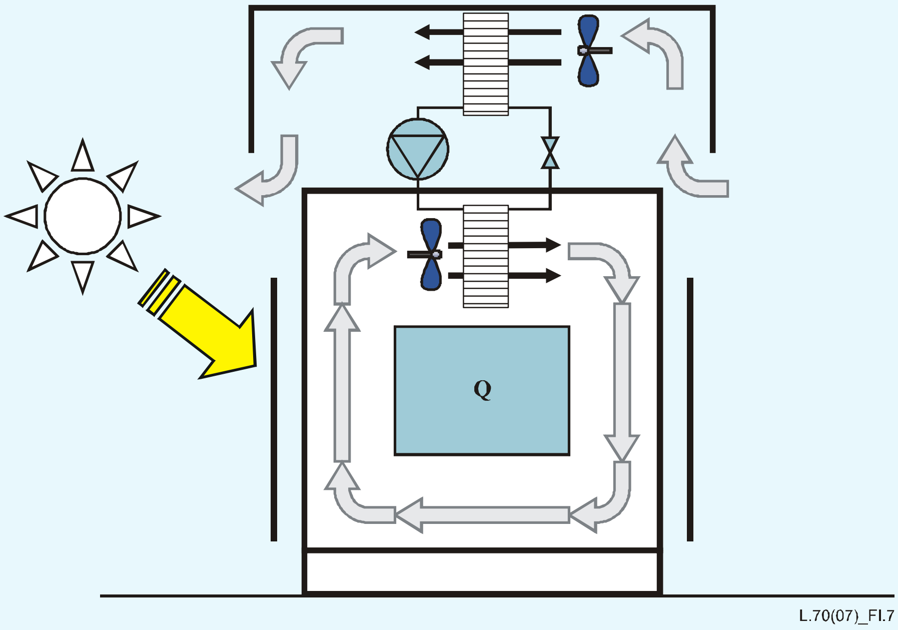
All above methods move heat from the warmer interior to the cooler environment. The temperature inside the enclosure will always be higher than the surrounding air. For certain types of equipment, e.g., when using indoor equipment, it may be required to maintain operating temperatures below the maximum ambient air temperature (Figure 4A2-7). This can only be obtained by applying active cooling devices (chillers). These devices are able to "pump" heat from a cooler to a warmer environment (as in a refrigerator or air conditioner).

About 40-70% of extra electrical power is required to power the cooling unit and its fans. These units will also require more space and more frequent maintenance than the above solutions.

Practically, active cooling is therefore only recommended for specific applications, in extreme conditions or in very large nodes, where the investment and operating expense can be shared over a large number of subscriber lines (operating cost to be compared to a small building).

Internal temperature can be maintained up to 20°C or more below external air temperature.

**Figure 4A2-7: Active cooling**




## 4A2.7 Heaters

In some cases, it is recommended not only to manage the maximum temperature but also the minimum temperature range inside an enclosure:

– maintain minimum operating temperature of the equipment (operating temperature ranges for equipment starting at 0°C are still very common);

– obtain minimum temperature before (cold) start of the equipment;

– avoid condensation inside the enclosure.

## Annex 4A3: Thermal properties of underground enclosures

This appendix lists the most typical designs for thermal management of underground outdoor enclosures, with their typical properties. Here, only designs are considered that have no above ground elements.

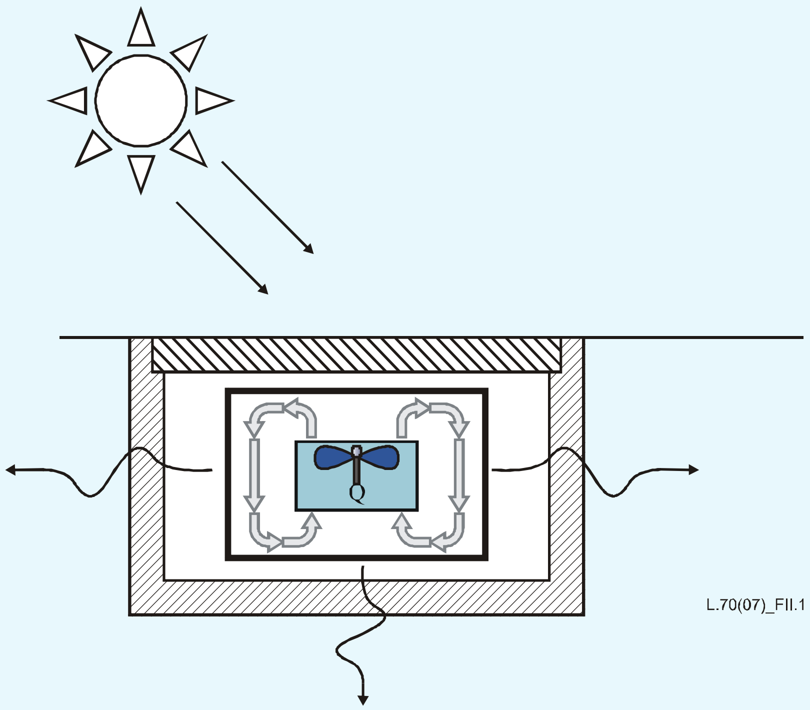
### 4A3.1 Free or forced convection inside

The most simple design for an underground active node is to store the node in a single wall, sealed enclosure inside a hand- or manhole. Air inside the enclosure will circulate due to natural or forced convection. Fans are often an integrated feature of the electronic equipment (Figure 4A3-1).

The heat is transferred through the walls of the enclosure to the air inside the manhole, and then further to the walls of the hand-hole into the surrounding soil.

In case the manhole fills up with water (partially or completely), the heat will be transferred through convection in the water. In this mode, heat transfer is more effective than in a dry manhole.

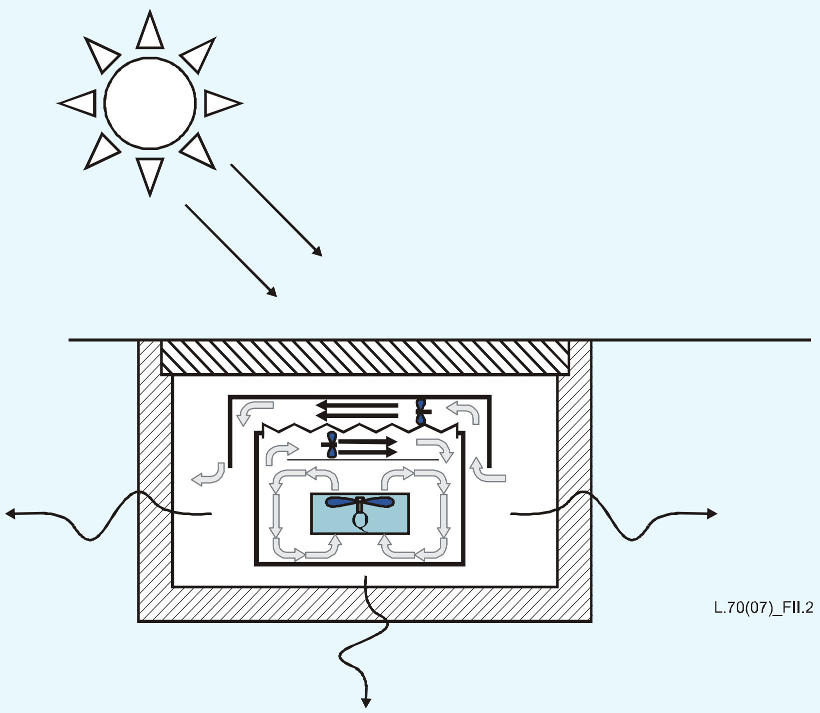
**Figure 4A3-1: Forced convection inside**



### 4A2.2 Heat exchanger

If more or better heat transfer is desired, a heat exchanger may be added. More effective heat transfer is obtained by higher airspeeds and increased contact surface area. The forced convection on the outside of the enclosure will also increase airspeeds in the hand-hole, with a positive effect on heat transfer (Figure 4A3-2). The heat exchanger design should maintain the IP 68 sealing level of the enclosure. External fans should be protected or even shut down when the hand-hole fills with water.

**Figure 4A3-2: Heat exchanger**




## Bibliography

The bibliography is indicated at the beginning of each section.

# Chapter 5

# Outside plant of land fixed/mobile wireless systems to be deployed in disaster areas: design and implementation

## 5 Introduction

This Chapter provides guidance on design and implementation of radio systems (HF and microwave links) and of Base Transceiver Stations (cellular service).

### 5.1 High Frequency radio systems

[For further information see ITU-R F.1610, http://www.itu.int/rec/R-REC-F.1610/en]

#### *5.1.1 General*

High operational flexibility, easy maintenance of equipment make High Frequency (3-30 MHz) system techniques very useful in world communications; this is particularly emphasized in the case of large geographical areas with low density of telecommunications traffic. When the need for a new communications capability between two or more points is first envisioned, and HF radio link is suggested as a possible solution, a feasibility study is required to analyse and define the whole system.

This study will verify that HF radio link is the appropriate means of communication for the set of system requirements pending, based on a comparison of technical and operational alternatives, and that the economic aspects for the new HF system are compelling.

The system designer must select a site having adequate access roads, water and electrical power supply, fuel for generators, telephone service, post office, medical facilities, and adequate housing and shopping areas for site personnel. In the vast majority of cases, the radio site will be located near a city or large town, and the support considerations mentioned above, will normally be available. But in a few cases obtaining these services may require special logistics effort.

If the site is a new one, then an equipment building/control facility must be constructed to house the equipment and to provide a place for the site's personnel to operate. If the site is an existing one, then it may be necessary to construct additional rooms for the site building(s) to house the new capability.

The HF system requires a.c. power, from the local power company grid, to run the HF equipment, and site to provide support for equipment such as heating, ventilation, and air-conditioning. If the site is an existing one, this power may be already provided, but in many cases the power distribution system may have to be upgraded with larger transformers, and additional circuit breakers. The engineering plan may also call for the installation of an auxiliary power source, such as a gasoline- or diesel-powered electrical power generator for emergency use.

### 5.1.2 System analysis and design

The steps to system engineering a typical HF radio system might include the following three levels of planning:

– the first is an analysis of the requirements for the communications system, to establish that the use of HF radio is suitable;

– the second level of planning is to develop estimated data to substantiate project funding requests and approvals;

– lastly, the third level of planning is the detailed engineering analysis.

In this Handbook only the third item is of interest. As for the two others, reference should be made to ITU-R Recommendation F.1610.

### 5.1.3 Tentative site selection

The selection of an HF radio site requires a detailed analysis of the physical surroundings in which the radio site must function. Above all, the site chosen must be technically adequate. Specifically, the engineer must consider the site's noise environment, ground conductivity, the obstacles in the foreground, and things such as buildings or mountains nearby that would obstruct the received or transmitted signals. Secondary considerations include ease of construction, access to utilities (water, electrical power, etc.) and access to the site.

### 5.1.4 Site/field surveys

The primary technical objectives for a good HF radio site are to obtain the maximum $S/N$ at the receiver site and maximum effective power radiated in the desired direction from the transmitter site. Site topography affects the signal radiated from the transmitting site and signal arrival at the receiver site. The presence of natural and man-made noise detracts from the ability to obtain a good $S/N$ at receiver sites. Desirable ground constants improve the performance of both transmit and receive antennas. These and other factors which enter into the selection of HF sites often involve compromises and trade-offs between economy, availability, and convenience.

#### 5.1.4.1 Topography

The technically ideal HF radio site requires a broad expanse of flat, treeless land away from natural and man-made obstacles. Terrain flatness is necessary for uniform ground reflection of the antenna radiation. Obstacles may mask portions of the signal-radiation path at transmit and receive sites.

*Site terrain features*

The nature of the terrain in front of an antenna has a significant influence on the vertical radiation pattern. A good antenna site will have a smooth reflection zone and will be free of obstacles that may block the radiation path.

– Reflection zone: The reflection zone is the area directly in front of the antenna that is required for the reflection of the ground-reflected component of the sky wave signal. The surface of the reflection zone should not have any abrupt changes in elevation greater than 10% of the antenna height nor a slope greater than 10% in any direction. Surface irregularities in the area should be limited to 0.1 wavelength in height at the highest operating frequency. The reflection zone at fixed sites and wherever else practicable should be cleared of all trees and brush. A low ground cover of grass, clover, or similar growth should be maintained for erosion control.

– Obstacles: In the direction of propagation, any substantial obstruction (such as a terrain mass, man-made structures, and trees) should subtend a vertical angle less than one-half of the angle between the horizontal and the lower 3 dB point of the required take-off angle. At potential HF sites where obstructions are likely to be encountered, a manually plotted site azimuth-elevation profile should be made. Elevation profile records are also useful for future planning in the event of expansion.

*Land area requirements*

The area required for an HF site depends upon the size and number of antennas, the spacing between antennas, the clearance required for ground reflection, and the clearance required avoiding mutual coupling. In addition to known initial plans, space should usually be set aside for unspecified future antenna field expansion. Sites may vary from a minimum of a few hectares for a small site to up to 30 hectares for a medium-sized site.

#### 5.1.4.2 Radio transmitting station site choice

Two essential technical factors may influence the site choice for the installation of a radio transmitting station:

– availability of an expanse of flat land, clear from natural and artificial encumbrances over the whole horizon, for the antenna installation;

– possibility of easy utilization of the existing main networks for the transmitter power supply.

#### 5.1.4.3 Radio receiving station site choice

A good quality reception and ease of operating can be attained with a site having the following:

– considerable ground space, possibly a square surface, both for allowing an optimal installation of directional antennas at a suitable distance (for diversity reception 200-300 m) and for obtaining a minimum beam as a safety guarantee against mechanical encumbrances and neighbourhood electrical interferences;

– level ground configuration, so as to install an antenna array having a regular electric behaviour;

– a clear, unobstructed view of the horizon around the antenna, for an elevation angle of less than 40°;

– man-made noise negligible with respect to atmospheric noise;

– no buildings, high voltage lines or other radio electric interference sources nearby;

– possibility of easy utilization of existing main networks for receiver power supply.

*Environmental RF noise receiving station site*

For reliable reception of weak signals from distant stations, the receiving antennas must be located in an electromagnetically quiet area relatively free from man-made noise. At HF, there are three major sources of RF noise: galactic, atmospheric, and man-made. The latter is of chief concern since it is the only source over which some control can be exercised. At many locations the noise from power lines dominates in the lower part of the HF band. Ignition noise from motor vehicles tends to predominate over power-line noise in the upper part of the HF band. Any strong, nearby source can be dominant in controlling the noise environment.

*Site separation*

Radio transmitters located within several kilometres of a receiving station may create serious interference due to harmonics or co-channel operation. In addition, intermodulation products may be generated in receivers due to intense radio energy fields from nearby transmitters even when operated on widely separated frequencies. Radio receiver and transmitter sites must be isolated from each other, from other radio facilities, and from heavily travelled highways, cities, and industrial areas. Exceptions are sometimes required for small sites where antennas may be as close as 300 m from each other. Transmitters with less than about 1 kW of transmitting power can be co-located with receivers if special attention is given to frequency selection. The use of RF filters may be necessary at collocated sites.

*Earth constants*

Resistivity and conductivity of the earth and the relative dielectric constant at the HF site should be considered during site selection. The resistivity of the earth affects the quality of the earth electrode grounding system. Good conductivity of the earth increases the range of ground wave propagation and lowers the take-off angle of sky wave signals, thereby increasing their range. Ground conductivity is difficult to measure accurately. However, it may be estimated by the nature of the terrain.

*General site requirements*

In addition to the technical factors, other important features of a general nature should be considered when selecting HF sites, are availability, suitability, accessibility and security:

– Availability

Land which meets the flatness criteria of an HF site is generally prime construction land or agricultural land. When this land is acquired, the area required even in small sites, can be very expensive. In fact, land acquisition may be the single greatest expense in the project. Therefore, the site selector should always consider the use of existing facilities. The least expensive siting of an HF installation is to use and expand an existing HF site.

– Suitability

The general suitability of a potential site is dependent upon the magnitude of construction required for site development, implementation, and maintenance of facilities. The existence and capacity of nearby utilities such as electrical power, water, gas, and sewage disposal are important factors in site selection. Information relating to geological conditions such as soil and drainage data, wind and weather data (including icing conditions), and seismic activity should be gathered and considered. Soil and drainage data should be available from the supporting facility engineer. Wind and weather data are available from area weather stations**,** while records on seismic activity are usually available from the geological survey or from a nearby university geophysics department.

– Accessibility

Access to HF sites should be supported by the existence of adjacent roads and highways leading to the site. Conditions such as slopes, constrictions, curves, overhead and side clearances, surfacing, turnouts, and weight limitations on bridges and culverts should allow transportation of equipment during installation as well as during support operation and maintenance after installation. The facility engineer should be consulted about existing road conditions or for new road construction.

– Security

HF radio site selection should consider provision for fences, area lighting, guard and alarm systems and proximity to other facilities.

*Site survey procedures*

Site surveys are conducted for the purpose of determining the technical and general suitability of land for an HF transmitting or receiving site. Each survey will have unique requirements for the number and size of transmitters, number of receivers, and the land and topography requirements for antennas. The process of selection of a site for a radio transmitting or receiving facility involves three distinct steps:

– Step 1: Entails map studies, ownership studies, logistics studies, and long range planning to select several tentative candidate areas.

– Step 2: Consists of teams who conduct preliminary site surveys to gather general site information of all the likely candidate areas. From the general site information, the list of candidate sites is then reduced to a potential few.

– Step 3: Involves survey teams who visit one or more of the final sites selected. The teams will gather detailed information which will be analysed to determine the adequacy of the site or sites. From this information, a decision is made as to the best site to use for the facility.

### *5.1.5 Typical power plants layout*

Generator power installations of 100 kW output power or less may be integrated into the operations building complex, but ideally are installed in a separate building near the operations building. Power building should be of well-bonded metal construction with fuel storage facilities. Fuel storage may be in above ground tanks near the power building, but ideally should be buried and located with a trench at least 10 m from the power building.

### *5.1.6 System test*

After the ... be foundnk or a photosAfter the Afinstallation of the HF radio system, the system test and evaluation plan must be implemented. Possible areas of interest of this Handbook might include:

*Power considerations:*

– adequate power for all operations, including emergency conditions;

– clean power with only minor noise and fluctuations.

*Review site security plan:*

– physical security adequate on all parameters;

– no hazardous conditions left from construction or implementation;

– network security is functioning.

## 5.2 Microwave radio links

[For further information on microwave radio links see Chapter 1]

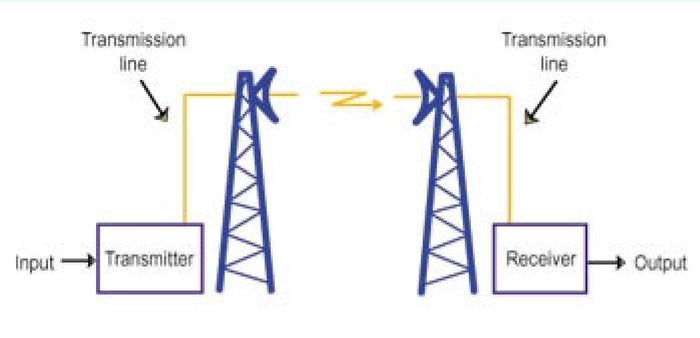
### *5.2.1 General characteristics*

The basic components required for operating a microwave link are transmitter, receiver and antennas. Transmitter functions typically include multiplexing, encoding, modulation, up-conversion from baseband or intermediate frequency (IF) to radio frequency (RF), power amplification, and filtering for spectrum control. Receiver functions include RF filtering, down-conversion from RF to IF, amplification at IF, equalization, demodulation, decoding, and demultiplexing. To achieve point-to-point radio links, antennas are placed on a tower or other tall structure at sufficient height to provide a direct, unobstructed line-of-sight (LOS) path between the transmitter and receiver sites (Figure 5-1).

The design of microwave radio systems involves engineering of the path to evaluate the effects of propagation on performance, development of a frequency allocation plan, and proper selection of radio and link components. This design process must ensure that outage requirements are met on a per link and system basis.

Various phenomena associated with propagation, such as multipath fading and interference, affect microwave radio performance. As a consequence the modes of propagation between two radio antennas may include not only a direct, line-of-sight (LOS) path, but also a ground or surface wave that parallels the earth's surface, a sky wave from signal components reflected off the troposphere or ionosphere, a ground reflected path, and a path diffracted from an obstacle in the terrain. The presence and utility of these modes depend on the link geometry, both distance and terrain between the two antennas, and the operating frequency. For frequencies in the microwave (~ 2-30 GHz) band, the LOS propagation mode is the predominant mode available for use; the other modes may cause interference with the stronger LOS path. Line-of-sight links are limited in distance by the curvature of the earth, obstacles along the path, and free-space loss. Average distances for conservatively designed LOS links are 40 to 50 km, although distances up to 150 km have been used. A link between two stations not in LOS can be realized through an intermediate radio repeater station.

**Figure 5-1: Line of sight propagation**




### 5.2.2 Antennas

Various types of antenna have been used in the network's history. At first, prime-focus parabolic reflectors were used. In about 1960, dual-band horn antennas (Figure 5-2) started to be used widely, and a few of these survive to the present day. They began to go out of fashion at the end of the 1960s, when types of parabolic antenna with an improved performance became available.

**Figure 5-2: Horn antennas**

### 5.2.3 Infrastructures

[For further information see next Section dealing with BTS]

To operate properly, a microwave antenna must be located high atop a microwave tower. Placing these antennas on towers allows microwave signals to be sent longer distances that would be possible otherwise. This is because there cannot be any structures, including mountains or large buildings, directly between the two antennas. Only when this has been achieved data can travel through the microwave system.

There are many types of towers. Some of them are quoted in the following.

*Steel lattice*

The steel lattice is the most widespread form of construction. It provides great strength, low weight, wind resistance and economy in the use of materials. Lattices of triangular cross-section are most common, and square lattices are also widely used. As shown in Figure 5-3 many antennas can be installed on the same tower..

*Tubular steel*

Guyed masts are sometimes also constructed out of steel tubes. This construction type has the advantage that cables and other components can be protected from weather inside the tube and the structure may look more clean. These masts are mainly used for FM-/TV-broadcasting.

NOTE – The terms "mast" and "tower" are often used interchangeably. However, in structural engineering terms, a tower is a self-supporting structure, while a mast is held up by stays or guys. Mast tend to be cheaper to build, but require an extended area surrounding them to accommodate the guys wires. Towers are more commonly used in cities where land is in short supply.

*Reinforced concrete*

Reinforced concrete towers are relatively expensive to build, but provide a high degree of mechanical rigidity in strong winds, where is required.

*Fibreglass and other composite materials*

Fibreglass poles are occasionally used for low-power non-directional beacons or medium-wave broadcast transmitters. Carbon fibre monopoles and towers have traditionally been too expensive but recent developments in the way the carbon fibre tow is spun have resulted in solutions that offer strengths similar or exceeding steel for a fraction of the weight - now allowing monopole and towers to be built in locations that were too expensive or difficult to access with the heavy lifting equipment that is needed for steel structure.

*Wood*

There are fewer wooden towers now than in the past.

Shorter masts may consist of a self-supporting or guyed wooden pole, similar to a telegraph pole.

**Figure 5-3: Relay towers (Frazier Mountain, Southern California)**

## 5.3 Base Transceiver Stations for cellular service

[For further information on BTSs see Chapter 1]

### *5.3.1 General*

A cell site is a term used to describe a site where antennas and electronic communications equipment are placed, usually on a radio mast, tower or other high place, to create a cell (or adjacent cells) in a cellular network. The elevated structure typically supports antennas, and one or more sets of transmitter/receivers transceivers, digital signal processors, control electronics, primary and backup electrical power sources, and sheltering (Figure 5-4).

A cell site is sometimes called a "cell tower", even if the cell site antennas are mounted on a building rather than a tower (Figure 5-5). In GSM networks, the technically used term is Base Transceiver Station (BTS), but frequently also the term "base station" is used. The term "base station site" might better reflect the increasing co-location of multiple mobile operators, and therefore multiple base stations, at a single site. Depending on an operator's technology, even a site hosting just a single mobile operator may house multiple base stations, each to serve a different air interface technology (CDMA2000 or GSM, for example).

**Figure 5-4: A steel structure decorated with colored glass, in Piazza Matteotti, Treviso, Italy**

**Figure 5-5: Cell site placed atop an existing building**

Design criteria for the infrastructures related to Base Transceiver Stations, i.e. lattices, poles, and poles on existing structures, are dealt with in this Section.

## *5.3.2 General characteristics of Base Transceiver Stations (BTS)*

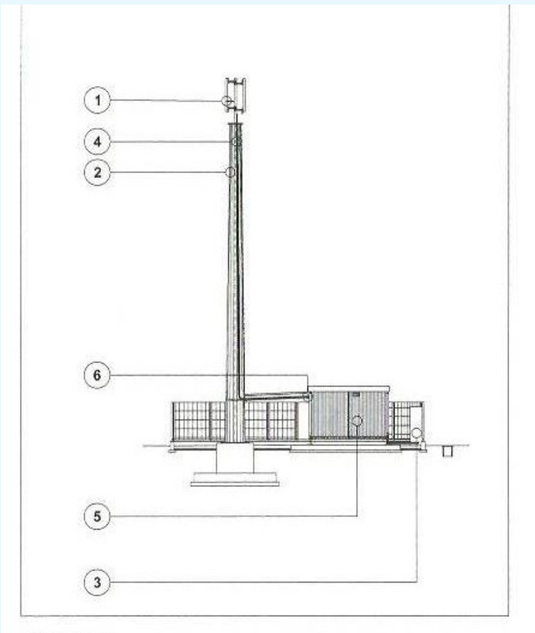
### 5.3.1.1 Types of BTS

A typical Base Transceiver Station (BTS) is generally composed of a system of antennas, which receive and transmit the radio signal and by some equipment.

The antennas are maintained in the orientation and at the height elevation necessary to ensure the radio coverage of project by suitable structures, referred to as antenna supporting structures that, depending on the type of site, can be classified as follows:

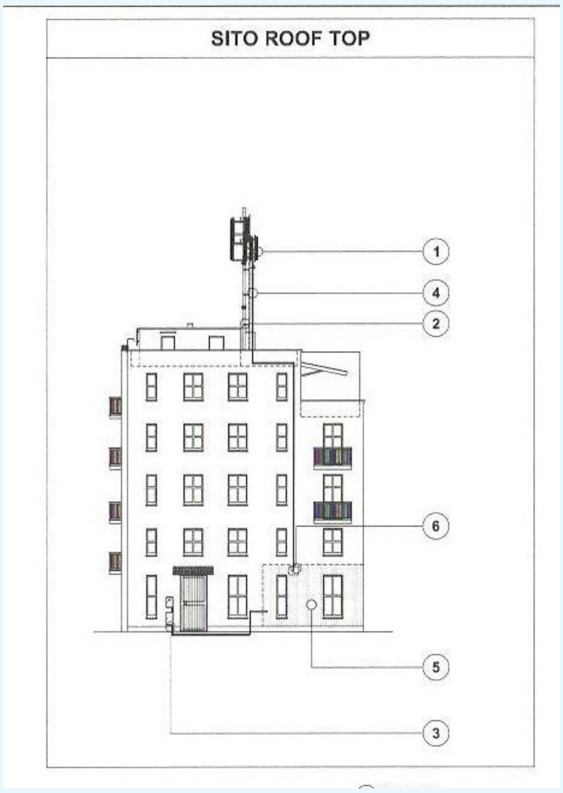
– Raw Land: is the so-called site on the ground, that is, where the station is constituted by a pole or a lattice with foundations on the ground. These structures may have heights up to 30 meters (sometimes even superior) where antennas and satellite dishes are positioned (Figure 5-6);

**Figure 5-6: Raw Land structures**



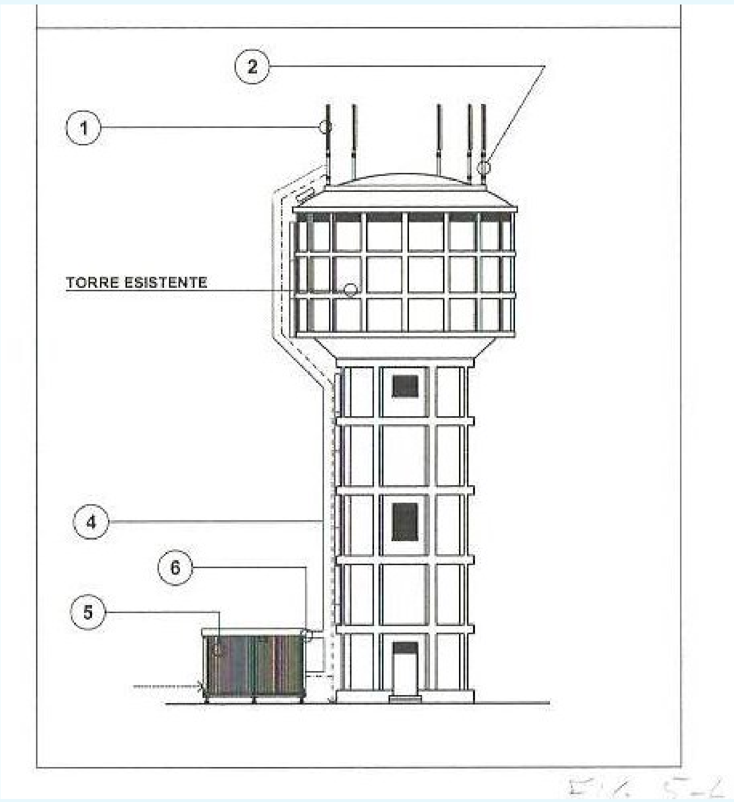

– Roof Top: consists of a pole (a steel pole small compared to that of the sites Raw Land) as support for antennas, anchored or clamped on structures on the roof of a building. This type of site is often found in urban centers (Figure 5-7);

**Figure 5-7: Roof Top structures**




– Co-located: in this case the antennas are installed on poles, lattices or towers where are already radio equipment (with its antennas) of different feature and functionality (Figure 5-8).

**Figure 5-8: Co-located structures**




The equipment are housed in premises specially prepared which may be of prefabricated type (shelter) or derived from the adaptation of existing environments (indoor). Alternatively the equipment can be inserted into appropriate outside cabinets, suitably made at this purpose.

The equipment can be of two types:

– ”conventional” equipment, directly connected to the antennas by coaxial cables.

– "splitted" equipment, consisting of a main unit connected via fiber optic cables to remote units placed at bottom of the pole. The remote units are then connected to antennas using coaxial cables.

The "splitted" equipment are compact and can be allocated in limited spaces.

The radio base station is connected to the power network and to the telecommunication network.

### 5.3.2.2 Characteristics of the sites

The spaces devoted to the BTSs must ensure the functionality of the equipment, of the antennas and of all the operations related to their maintenance. As a consequence different areas are necessary for the base stations depending of the types of equipment. Some examples are the following:

i) Conventional equipment:

  – area for urban sites: 15 $m^2$;

  – area for rural sites: 50 $m^2$.

ii) Splitted equipment:

– area for urban sites: 10 $m^2$;

– area for rural sites: 30-40 $m^2$.

The internal height of the areas are usually at least 2.40 m.

#### 5.3.2.3 Security aspects

The Base Transceiver Stations, as regards both the equipment and the antennas, should be located in a dedicated area, so as to avoid any interference and risk of vandalism. In particular the space should be protected from possible interference and mechanical damage (shocks). In order to ensure no accessibility, the stations should be equipped with fences and other protections that prevent or mitigate risks to do so. Moreover the equipment should be protected from the risk of contact with water and moisture and from the risk of fire. The room for equipment should ensure a minimum fire resistance in accordance with the requirements provided by the specific agencies (Fire Brigade, etc.) in relation to the characteristics of the site (intended use of the building, etc.). For the antennas it should always be possible to identify a dedicated area, inside of which it is not allowed access to anyone other than maintenance workers.

### *5.3.3 Design criteria for the BTS infrastructures*

The infrastructure of BTS must be compliant with the relevant local regulations. In particular it is necessary to take all the measures of prevention and protection, collective and individual, to ensure the security, to eliminate or to reduce to a minimum the risks relating to the operations to be carried out and to avoid damage to persons and property.

Some of the materials frequently used for realizing support for the antennas of the BTSs are the following:

– Steel lattice

The steel lattice is the most widespread form of construction. It provides great strength, low weight, wind resistance, and economy in the use of materials. Lattices of triangular cross-section are most common. Square lattices are also widely used.

– Tubular steel

Guyed masts are sometimes also constructed out of steel tubes. This construction type has the advantage that cables and other components can be protected from weather inside the tube and consequently the structure may look cleaner. These masts are mainly used for FM-TV broadcasting.

– Reinforced concrete

Reinforced concrete towers are relatively expensive to build, but provide a high degree of mechanical rigidity in strong winds. This can be important when antennas with narrow beamwidths are used, such as those used for microwave point-to-point links, and when to the structure is to be occupied by people.

– Wood

There are fewer wooden towers now than in the past. Many of them were built in a situation of a shortage of steel. Most of them have since been demolished.

As said above, depending on the type of site it is possible to distinguish the following antenna supporting structures:

– lattices;

– poles;

– support structures for the antennas placed on existing buildings.

### 5.3.4 Lattices

#### 5.3.4.1 General

The lattices, with square cross-section and shape of a truncated pyramid, are structures formed by loose elements to be assembled on site by means of bolted joints.

The lattices often have nominal modular heights, with a pitch of 5 meters from 15 meters above ground level. By way of example the nominal heights sometimes used are the following: 15, 20, 25, 30, 35, 40 m. The lattices can be based on reference types 15, 25 and 35 m and then be super-elevated in the following manner:

– tower of 15 m to 20 m.

– tower of 25 meters to 30 m.

– tower of 35 meters to 40 m.

The above example refers to lattices which can be super-elevated by a module 5 meters without having to carry out works of reinforcement.

#### 5.3.4.2 Actions acting on the lattice

Actions to be taken into account in a lattice design are the following:

– Permanent actions "P" (Permanent):
  - weight of structural steel;
  - weight of the antennas for the cellular service;
  - weight of the parabolic antennas for the microwave radio links;
  - weight of the accessories (ladders, rack carrying cables, etc.).

– Variable action "W" (Wind)

Actions arising from wind should be considered taking into account the size of the antennas, cables, support structures, ladder lifts, etc..

In the case of presence of ice the areas of the elements should be increased (e.g. 15%).

– Variable action "S" (Snow)

Actions related to the presence of the snow should be considered.

– Variable action "I" (Ice)

Actions related to the presence of ice should be considered. As an example it can be assumed the presence of a sleeve of ice of 12.5 mm, uniformly distributed on the structure (specific weight 700 kg/$m^3$).

– Variable action "M" (Maintenance)

Actions related to the maintenance should also be considered. As an example, in the case of normal situations a vertical overload of 200 daN/$m^2$ can be considered on working and rest balconies.

– Seismic action "E" (Earthquakes)

Seismic actions related to the site of installation of the lattice should be considered.

#### 5.3.4.3 Limit states

The infrastructures and the structural components should be designed and constructed so as to permit the intended use in an economically sustainable way and with the level of security required. The safety and performance of an infrastructure should be in relation to the limit states that may occur during its nominal life. Limit state is a condition beyond which the infrastructure no longer meets the needs for which it was designed. Generally “Ultimate Limit States” and “Service Limit States” are considered.

The main Ultimate Limit States to be verified are the following:

– Limit State of Equilibrium, in order to control the equilibrium of the structure and its parts throughout its nominal life, including the construction and repair phases;

– Limit State of Collapse, corresponding to the reaching of the yield point or the ultimate strains of the material (excessive deformation of a section, of a member or of a link) or the formation of a collapse mechanism, or the onset of phenomena of instability of equilibrium in the elements or components in the structure as a whole;

– Limit State of Fatigue, controlling stress changes induced by repeated loading.

The main Service Limit States to be verified are:

– Limit states of Deformation and Displacement, in order to avoid deformations and displacements that can compromise the efficient use of the structure and its contents;

– Limit State of Vibration, in order to ensure that the sensations perceived by users ensure acceptable levels of comfort and the getting over of which might be an indication of poor strength and/or an indicator of possible damage in secondary elements;

– Limit State of local Plasticization, in order to avoid plastic deformations that can generate irreversible deformation and unacceptable.

NOTE – The criteria for the verification of the Limit States are outside the scope of this Handbook.

### *5.3.5 Poles*

#### 5.3.5.1 General

Poles supporting cellular antennas are generally deployed in sites of rural type. The pole structures can be of two types:

– Flanged poles. The flanged poles are made from constant circular section tubes, connected by flanged joints and bolted;

– Polygonal poles. The poles are constituted by truncated cone sections welded longitudinally. The mounting of the segments forming each pole must be done on site by overlapping and dap jointed in order to ensure the minimum values of overlap.

Suitable support elements for the cellular antennas will be mounted on these poles. On the poles are also installed ladders lifts in order to allow an easy maintenance of cellular antennas.

The poles, whether flanged or polygonal, usually have nominal modular heights. As an example, with a pitch 6 meters the nominal heights could be: 12, 18, 24, 30, 36 m.

The poles, whether flanged or polygonal, can be of two types, depending on the applied loads:

– type "light" or "slim";

– type "heavy" or "with rings" which make possible to install more cellular antennas and additional parabolic dishes.

#### 5.3.5.2 Actions acting on the pole

See Section 5.3.4.2.

#### 5.3.5.3 Limit states

See Section 5.3.4.3.

### *5.3.6 Structures for the support of antennas on existing buildings*

#### 5.3.6.1 General

Antennas supporting structures for cellular systems can be also placed on existing buildings/sites, such as:

– civil buildings.

– industrial buildings.

– chimneys.

The necessary works are related to the specific conditions of the building/site. Therefore planning should be done case by case, always keeping in mind the necessity to reduce the structural weight and the visual impact of the new structures. The added structures will generally consist of poles supporting the new antennas suitably fixed to existing structures.

The conditions and the resilience of existing structures should be accurately checked before proceeding with the final design. In particular, it is necessary to check and verify the following:

– No evident defects in design and implementation;

– Previous actions, even exceptional, the effects of which are not fully manifest;

– Degradation and/or significant changes compared to initial situation.

#### 5.3.6.2 Actions affecting the structure

See Section 5.3.4.2.

#### 5.3.6.3 Limit States

See Section 5.3.4.3.

### *5.3.7 Design criteria of lattice steel structures resistant to wind and seismic loads (Korean experience)*

[For further information see ITU-T Recommendation L.92]

Towers are lattice steel structures which are used to support telecommunication cables. The design criteria for towers include both seismic and wind loads, but wind loads usually control the design. Earthquake resistance design for towers can be substituted by wind resistance design, if wind load is proved to be greater than earthquake load. On building supported towers the dynamic amplification introduced by the building should be evaluated. Though wind loads usually control tower design, earthquake performance evaluation is explicitly considered.

Outside plant facilities that are constructed on the ground should have earthquake-resistance performance by applying a ground response spectrum. A ground response spectrum use design parameters of building structure criteria. Outside plant facilities that are constructed on the building should have earthquake-resistance performance for a floor response spectrum. Towers should comply with the extra-first class of earthquake-resistance design. Outside plant facilities should comply with the first class of earthquake-resistance design. Wind loads are applied to tower design when wind loads are larger than earthquake loads. It is recommended that earthquake-resistance performance should be evaluated (Tables 5-1 and 5-2).

**Table 5-1: Earthquake resistant design facilities**

| | | Facilities | Remarks |
|---|---|---|---|
| Towers | Building roof | Towers for backbone network;<br>Wireless base transceiver station. | If wind loads are larger than earthquake loads, earthquake-resistance design is not considered. |
| | Ground | Towers for backbone network;<br>Wireless base transceiver station. | If wind loads are larger than earthquake loads, earthquake-resistance design is not considered. |

[TBD]ry analysis method.

**Table 5-2: Earthquake resistant class**

| | | Facilities | Remarks |
|---|---|---|---|
| Towers | Building roof | Towers for backbone network;<br>Wireless base transceiver station. | To be designed using roof response spectrum or floor response spectrum;<br>To be designed by extra-first class criteria; |
| | Ground | Towers for backbone network;<br>Wireless base transceiver station. | To be designed by extra-first class criteria (KBC2005) |

## 5.4 Power plants for BTSs

[For further information see "Power systems considerations for cell tower applications", Wissam Balshe, http://www.cumminspower.com/www/literature/technicalpapers/PT-9019-Cell-Tower-Applications-en.pdf ]

Experts in Asia and South America are estimating the wireless market to grow about 7–10% every year for the next five years. Over 50 million additional wireless subscribers are expected in Africa alone over the next two years. This means that more than 75,000 new off-grid telecommunications cell towers will be built in developing countries during the next two years. Most of these cell towers will need generator sets, either for emergency backup in urban areas or as the prime source of power in remote locations. This section examines some of the factors to be considered in designing and configuring these generator sets.

NOTE – A power (electrical) grid is an interconnected network for delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers. Power stations may be located near a fuel source, at a dam site, or to take advantage of renewable energy sources, and are often located away from heavily populated areas. They are usually quite large to take advantage of the economies of scale. The electric power which is generated is stepped up to a higher voltage at which it connects to the transmission network.

### 5.4.1 The reliability of the grid

Because the power grid is not always reliable in many parts of the world, just extending the grid will not answer the need of additional BTSs. Concerns about the reliability of the grid are especially common in rural regions of developing countries. But these concerns apply to the grid in many urban areas as well. Many so-called "standby" generator sets installed at urban cell towers are in fact running for several hours every day.

With the sustained rise of global energy prices, the fuel costs of running these diesel, natural gas or propane generators are a major piece of the Total Cost of Ownership (TCO) for these cell towers. For example, the fuel cost (as a percentage of TCO) could be as high as 64% for a typical 12 kW diesel generator running for about eight hours per day. This cost is driving many telecom cell tower operators to consider other power system options, which are covered in Section 5.4.4.5.

### 5.4.2 Power system configuration for cell towers

Power requirements for base transceiver stations vary widely depending on a number of factors:

– Is the site indoor or outdoor?

– Is the location urban or rural?

– In which region is the site?

In light of these variables, it is unrealistic to create one load profile for all cell tower power system configurations. A couple of alternative configurations are shown in the following:

– One generator set or two. Most cell tower operators in North America and Europe use one diesel-fueled generator for emergency backup to the main utility power. But in developing countries and prime power markets, two generators are typically used: one running continuously and alternating with the other generator set weekly, or whatever interval the automatic transfer switch (ATS) is set to use.

– Air conditioning units play a major role in determining the size of the generator set needed in indoor base stations, because most indoor BTS loads require air conditioning during the summer. Typically there will be two air conditioning units: a primary and a secondary unit. It is rare, however, for both air conditioning units to run at the same time, so in sizing the generator set, the engineer should assume it will start and operate only one unit at a time. For outdoor applications, there is no requirement for air conditioning, hence no need to supply a large alternator to meet the starting requirements of air conditioning units. A smaller generator set can be used.

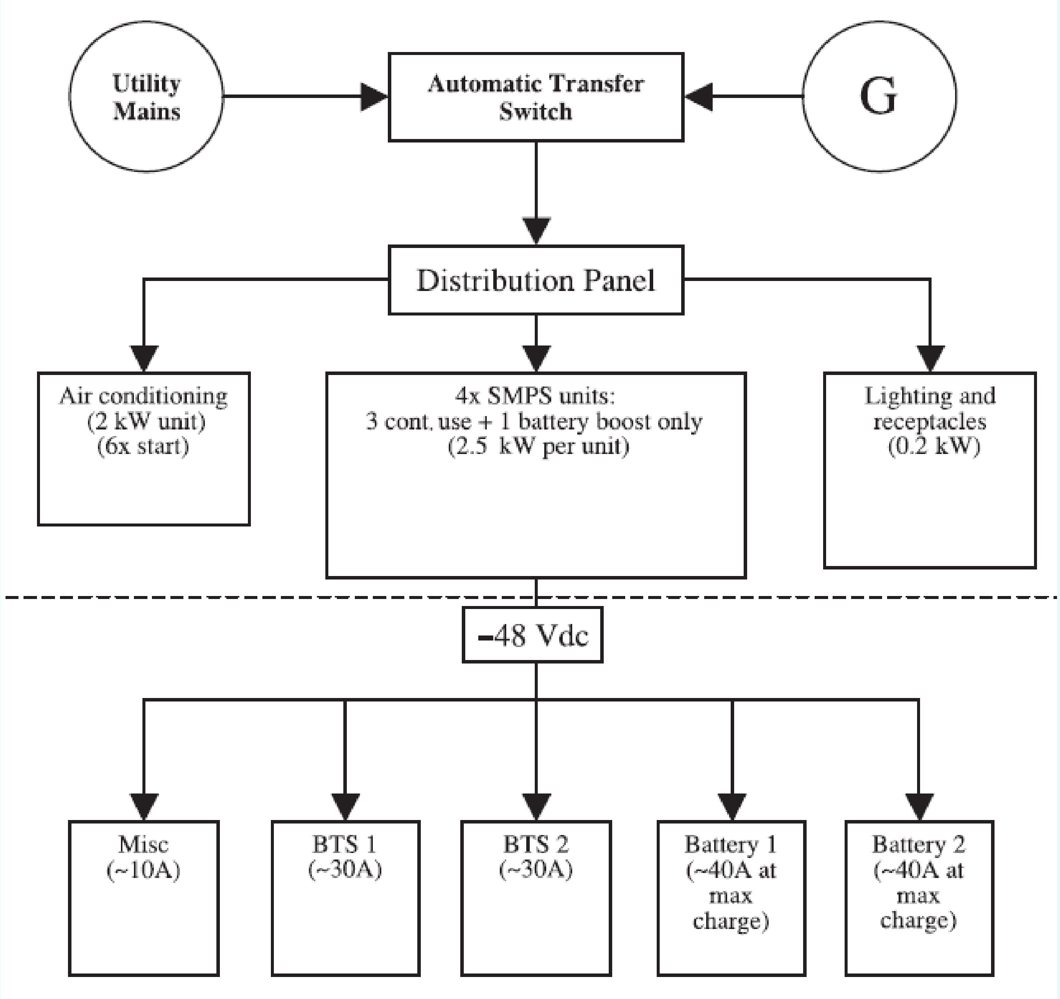
### 5.4.3 Design aspects

#### 5.4.3.1 General layout

The differences in the size of transceivers, ambient environmental conditions, type of rectifiers and inverters used in the Switch Mode Power Supply (SMPS), number and size of batteries, and other factors (such as maximum allowable fuel tank size limit or design for future load expansion) are the major variables that need to be considered when selecting the generator set and power system configuration for the cell tower.

At the same time, there are certain loads that every base transceiver station will use. These loads are pictured in Figure 5-9, which shows a typical one-line electrical layout for a base station employing a 12 kW (15 kVA) generator set that would meet the demands of a cell tower in most regions.

**Figure 5-9: General layout of a power plant for BTSs**




As it can be seen, the load consists mainly of microwave radio equipment and other housekeeping loads such as lighting and air conditioning units. The actual BTS load used on the cell tower is powered via the SMPS, which is the direct current (DC) power plant.

### 5.4.3.2 48V and -48V

Although other voltages are possible, most radio transceiver loads used in telecom base stations run on a –48V DC bus. This practice originated in the early days of telephony, when 48V DC was found to be suitably high for long telephone lines, but low enough to prevent serious injury from touching the telephone wires. Consequently, most electrical safety regulations consider DC voltage lower than 50V to be a safe low-voltage circuit. It is also practical, because this voltage is easily supplied from standard valve regulated lead acid (VRLA) batteries by connecting four 12V batteries (like those used in cars) in series, making it a simple system.

The positive grounded or -48V system is another survivor from earlier industry practice. Negative voltage on the line was found to be superior to positive voltage in preventing electrochemical reactions from destroying copper cables if they happen to get wet. Negative voltage also protects against sulphation on battery terminals. Sulphation, the buildup of crystals of lead sulphate, is the leading cause of early battery failure.

#### 5.4.3.3 Alarms

There are shutdown alarms and warning alarms on the generator set. The shutdown alarms include over-speed, overvoltage, overcurrent, under-voltage, high engine temperature, overcrank, low oil pressure, and circuit breaker trip. The warning alarms notify the operator of the following:

– Loss of fuel pressure and fuel level (important because of vandalism and theft concerns in many remote locations);

– Low battery bus voltage;

– Start switch not in auto;

– Remote/manual start;

– Engine oil temperature.

Alarms can also be linked to other parameters that can help the operator flag any potential problems that could lead to the generator set shutting down, and potentially dropping its loads.

#### 5.4.3.4 Design factors: sizing the generator and alternator

The first thing power system designers need to address is size. They need to know the total steady-state requirements of all the equipment on the cell tower that will be powered by the generator set, and then match it with the right alternator to supply the locked rotor amp (LRA) requirements for starting the air conditioning units in the BTS room (for indoor installations). It's important to note that the LRA could be as high as *6 times* the rated full load amp (FLA) output of 3-phase motors, and up to *12 times* the FLA for single-phase motors.

Similarly, the alternator also needs to meet the steady state reactive power requirements of all other loads in the BTS. This requirement explains why the alternator is typically oversized by about 150-200% of the actual kW needed to power the cell tower.

#### 5.4.3.5 Other factors to consider

There are other technical considerations to keep in mind when selecting the generator set.

– For BTS stations located in residential locations, a quiet generator set is required. This can be achieved by housing the generator set in a sound-attenuation enclosure.

– For rural and remote locations, the generator should have at least eight input/output dry contacts and relays for remote monitoring devices, as well as an oversized fuel tank and fuel pressure sensors.

– For sandy and dusty environments, heavy-duty air filters should be used.

– For wet and humid environments, specify aluminium enclosures and anti-condensation heaters to prevent insulation failures and short circuits between the windings in the alternator stator.

– For cold climates, engine block and oil heaters are required, especially for standby applications.

### *5.4.4 Industry trends*

Certain trends in the telecom industry have a direct impact on generator set power requirements for cell towers. In particular many telecommunication equipment vendors are making considerable investments in the development of more efficient equipment to reduce the capital expenses (capex) and operating expenses (opex) associated with standby power systems. The main developments in progress are listed in the following.

#### 5.4.4.1 No air conditioning

Radio transceivers are being designed to handle high ambient temperatures, in order to eliminate air conditioning in the cell tower BTS shelter. The impact of this trend is substantial, because air conditioning more than doubles the size of generators needed for steady state operation.

For example, in a typical cell tower, the BTS load itself requires only about 2 to 3 kW, but up to 12 kW generator sets are being used to meet the occasional peak power requirements for starting air conditioning units. Therefore, as the use of the high ambient radio equipment increases, the size of the generator set required to power future telecom cell towers will be reduced substantially.

#### 5.4.4.2 Energy-efficient radio equipment

In addition to the reduction in the starting power requirements from eliminating air conditioning units, the steady-state power requirements are also being reduced. To cut capital and operating costs, telecom companies are investing heavily in the development of more energy-efficient radio equipment to reduce the total power consumption and hence, the size of the generator set and ATS (Automatic Transfer Switch) required for the BTS station. This trend will lower the initial capital cost, and with smaller generator sets, will also reduce the operating (mainly fuel) costs of cell towers.

#### 5.4.4.3 Building materials

To have an energy-efficient cell tower does not always require investing in new technologies for BTS equipment. Some telecom operators are switching to simpler cell tower designs. For example, the shelter traditionally was built from brick and concrete, but now many operators are using high-thermal-efficiency plastic, which reduces the energy costs for operating cell towers. All these new design considerations and technology improvements in BTS equipment and shelters are dropping the generator size needed for telecom cell towers from 12 kW to about 5 kW.

#### 5.4.4.4 Policy changes and shared equipment

Certain trends in the telecom space are driven by public policy, which may have a direct impact on the power requirements of cell towers. For example, in many developing countries, governments are requiring the use of backup power at telecom sites due to the critical nature of their service during a national catastrophe. However, they are also requiring providers to share towers and equipment to reduce the number of towers and their environmental impact. Accordingly, multiple operators are entering into agreements to share infrastructure and support equipment such as the tower itself, shelters, generators and accessories, thereby reducing costs substantially. Third parties are also taking advantage of this trend, building cell towers and leasing space on them to multiple operators. These towers have separate radio equipment for each operator, but still share one generator.

This trend of sharing towers by different operators is reducing the number of cell towers needed to cover a region or network, but it is also increasing the size of the generators needed to run these towers. This increase in generator size is also being driven by the increased demand for 3G and 4G data services used by smartphones.

#### 5.4.4.5 Alternative energy sources and DC generators

Finally, in response to government subsidies and fuel cost savings, telecom prime power markets are utilizing more renewable energy solutions to power their cell towers. Some towers are powered by wind turbines or photovoltaic (PV) solar cells, especially for small load sites (less than 2 kW). Other solutions use natural gas or variable-speed DC generator sets for better fuel economy and efficiency.

However, due to the variability in wind speed across the globe, wind-only solutions are likely to be restricted to locations with abundant wind resources such as coastal and mountainous regions. The efficiency of PV is still an issue, and solar cells are more expensive than conventional power generators, hence less economical for large sites. Until green power sources become more economical and efficient, telecom operators will continue to use traditional generators to power their cell towers, but many will start combining the generator with wind and solar cell power sources.

### *5.4.5 Conclusions of the power plants for BTSs*

There are no universal features recommended for all generator sets used in telecommunication cell tower applications, because requirements and duty ratings vary from region to region. In general, for standby applications in urban areas connected to a reliable utility grid, standard generator set features as required by local codes and regulations should be sufficient. In other words, there is nothing unique about a standby generator set used in such telecom cell tower applications. However, when specifying generator sets for prime duty applications, such as those used in remote cell tower applications and some urban sites in developing countries, an oversized fuel tank with fuel alarm sensors, and 8–10 dry contacts and relays for remote monitoring are recommended. A fuel-efficient engine, or the use of batteries to supply the BTS load for a few minutes of power interruption or during peak demand, will save fuel costs substantially, and lower the operating costs of running the cell tower.

In the next 5 to 10 years, telecom equipment manufacturers will continue to reduce the power consumption of BTS equipment. This trend will mean smaller generator sets. Manufacturers will continue to explore hybrid power systems that use renewable energy sources or batteries running in parallel with generator sets. Some generator set manufacturers will start developing DC or variable-speed generators to meet the increased fuel-efficiency requirements of cell tower sites. Most manufacturers, however, will continue to supply synchronous-speed AC generators with oversized alternators to meet the starting power requirements of air conditioning units, but these generators will be driven by smaller and more fuel-efficient diesel engines.

## Bibliography

Bibliography is indicated under the title of the various subjects.

# Chapter 6

# Outside plant of satellite systems to be deployed in natural disaster areas: design and implementation

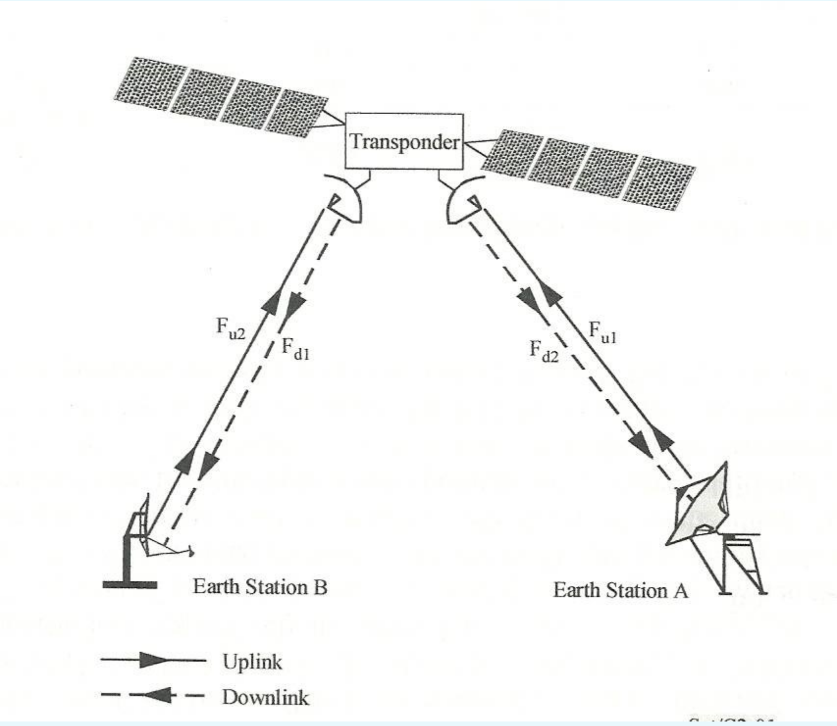
NOTE – Fixed and Transportable and portable VSAT earth stations are dealt with in Chapter 7

## 6 Introduction

[For further information see "Handbook on satellite communications", Wiley-ITU]

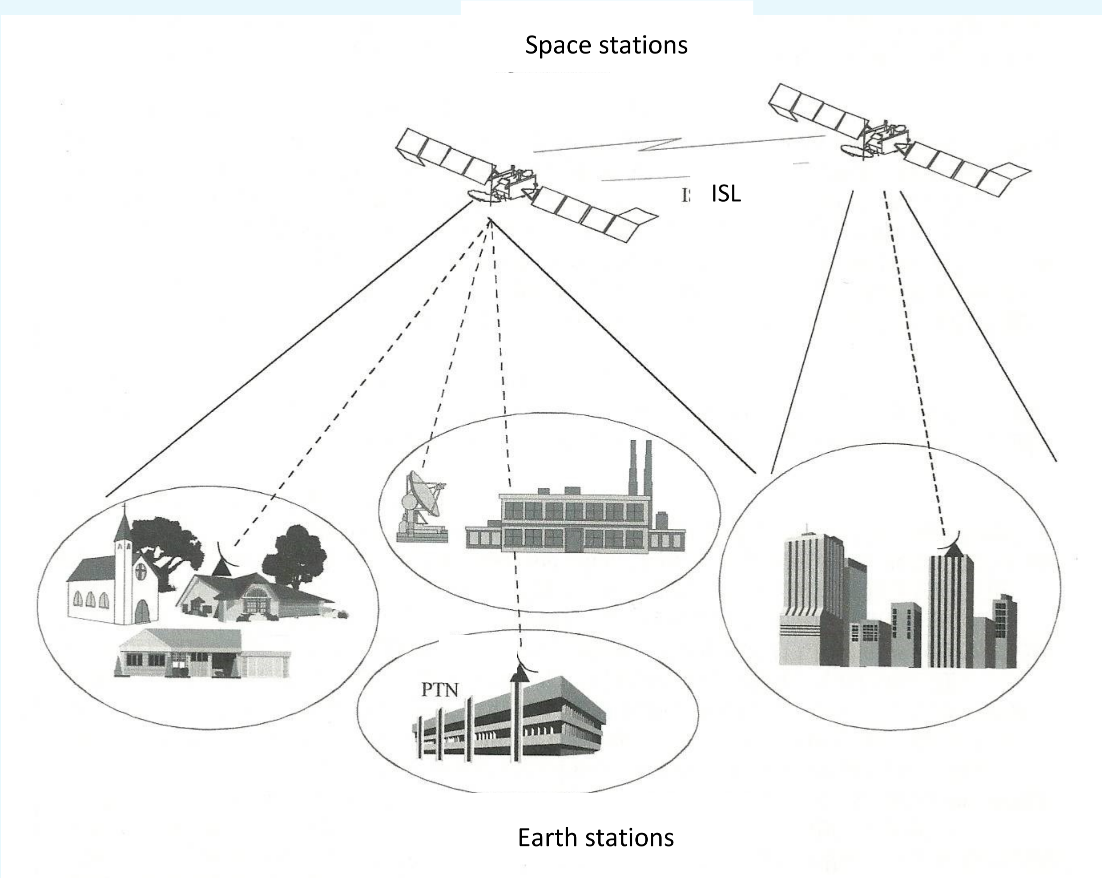
A set of space stations and earth stations working together to provide radiocommunications is called a satellite system (Figure 6-1). There are three main types of satellite services: Fixed Satellite Services (FSS), Mobile Satellite Services (MSS) and Broadcasting Satellite Services (BSS).

**Figure 6-1: The basic satellite link**



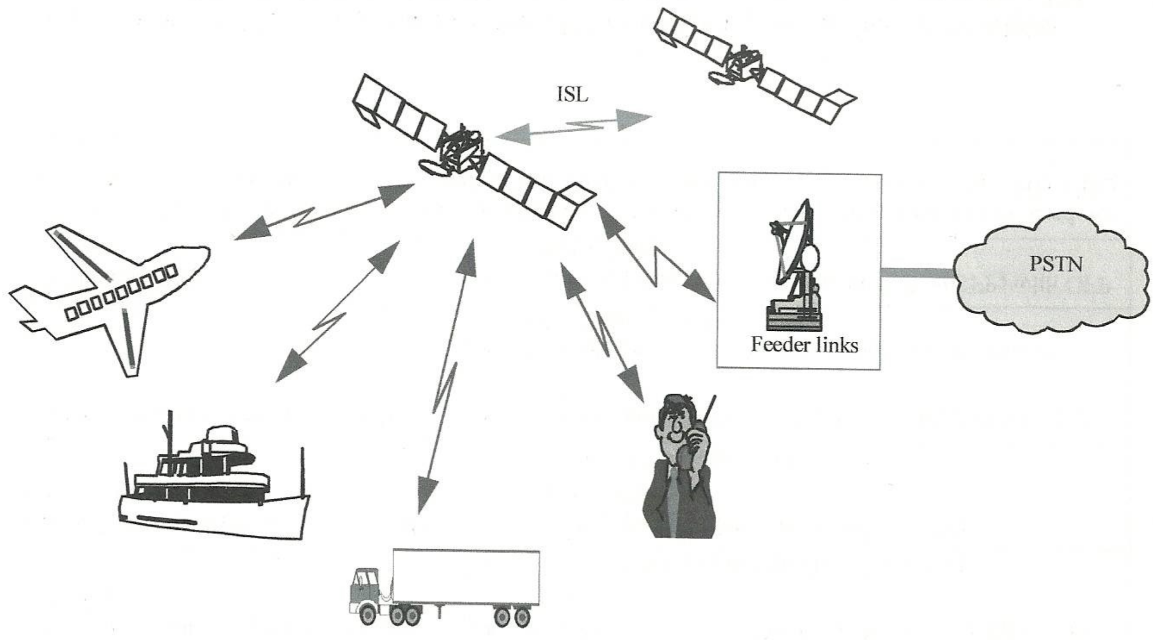

The FSS is a radiocommunications service between given positions on the Earth's surface when one or more satellites are used. The stations located at given positions on the Earth's surface are called earth stations of the FSS. The given position may be a specified fixed point or any fixed point within specified areas. Stations located on board the satellites, mainly consisting of the satellite transponders and associated antennas, are called space stations of the FSS (Figure 6-2).

**Figure 6-2: Generic illustration of FSS**




Mobile-satellite service (MSS) is a radiocommunications service between mobile earth stations and one or more space stations, or between mobile earth stations by means of one or more space stations (Figure 6-3). This includes maritime, aeronautical and land MSSs. Note that, in some modern systems the earth stations may consist of very small, even hand-held, terminals.

**Figure 6-3: Generic illustration of mobile-satellite services**




(A possible inter-satellite link (ISL) with another satellite is represented)

PSTN: public switched telephone network

Broadcasting-satellite service (BSS) is a radiocommunications service in which signals transmitted or retransmitted by space stations are intended for direct reception by the general public using very small receiving antennas (Television Receive only, TVROs). The satellites implemented for the BSS are often called direct broadcast satellites (DBSs). The TVROs needed for BSS reception should be smaller than the ones needed for operation in the FSS. The direct reception shall encompass both individual reception (DTH) and community reception (CATV and SMATV) (Figure 6-4).

During times of natural disaster, civil disturbance or serious accidents, normal terrestrial-based communication facilities are frequently overloaded, temporarily disrupted or destroyed. The availability of satellite communication facilities ensures that one element of the system remains isolated from terrestrial-based disruptions, i.e. the satellite or space segment. Through the deployment of small transportable earth terminals to the emergency location, communications can be established and the process of restoring the necessary services (communications, aid, food/water distribution, etc.) assisted. [See also Chapter 7]

A typical satellite communication includes the following elements:

i) space segment: one or several spacecraft (satellites) with in-orbit spare capability;

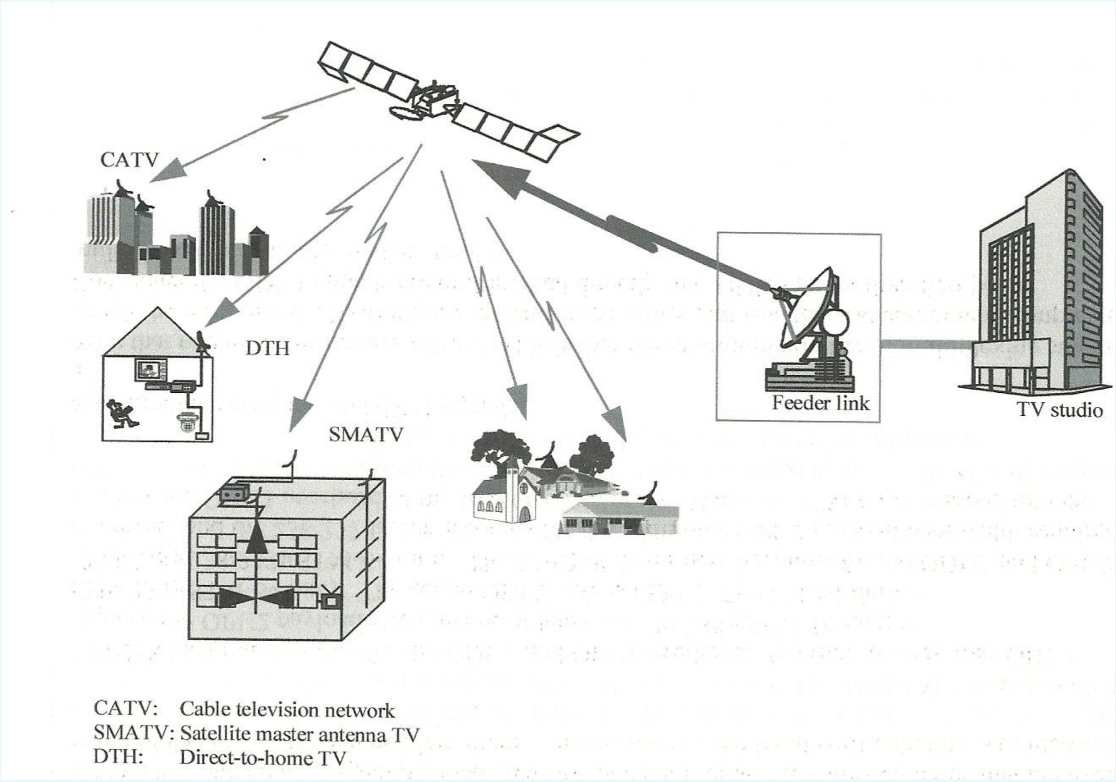
ii) earth station for communications: a system may include a great variety of earth stations;

iii) terrestrial distribution: from the earth station the signal is carried to the customers' premises through a terrestrial transmission medium;

iv) power supply plants: most of the terrestrial facilities, including the earth stations, require a backup power system in case of commercial power failure.

The satellites are outside the scope of this Handbook because they are not impacted by the natural hazards. The terrestrial distribution realized by terrestrial distribution medium is dealt with in Chapters 4 and 5. Therefore the attention of this Chapter 6 will be focused on the earth stations and on the power supply plants.

**Figure 6-4: Generic illustration of broadcasting-satellite services**




## 6.1 The earth segment

The earth segment is the term given to that part of a communication-satellite system which is constituted by the earth stations used for transmitting and receiving the traffic signals of all kinds to and from the satellites, and which form the interface with the terrestrial networks.

An earth station includes all the terminal equipment of a satellite link. Its role is equivalent to that of a terminal radio-relay station. Earth stations generally consist of the following six main items:

- the transmitting and receiving antenna, with a diameter ranging from 50 cm (or even less in some new systems) to more than 16 m. Large antennas are usually equipped with an automatic tracking device which keeps them constantly pointed to the satellite; medium-sized antennas may have simple tracking devices (e.g. step-track), while small antennas generally have no tracking device and although normally fixed, can usually be pointed manually;
- the receiver system, with a sensitive, low noise amplifier front-end having a noise temperature ranging from about 30 K, or even less, to several hundred K;
- the transmitter, with power ranging from a few watts to several kilowatts, depending on the type of signals to be transmitted and on the traffic;
- the modulation, demodulation and frequency translation units;
- the signal processing units;

- the interface units for interconnecting with terrestrial networks (with terrestrial equipment or directly with user equipment and/or terminal).

The size of this equipment varies considerably according to the station capacity.

Planning of the earth segment would involve the following main steps:

- collection of service requirements and traffic matrix, finalization of transmission plan taking into consideration the specified space segment characteristics;
- preparation of the overall definition for the ground segment;
- finalization of earth-station equipment specification, preparation of request-for-proposals for ground segment, evaluation of RFP and ordering of equipment;
- selection of earth-station sites and electromagnetic compatibility (EMC) survey;
- notification and frequency clearance for selected sites;
- preparation of plans for building and award of contract for building construction;
- ordering of water, electric supplies and power plant.

## 6.2 Configuration and general characteristics of earth stations

### *6.2.1 Configuration, block diagrams and main functions*

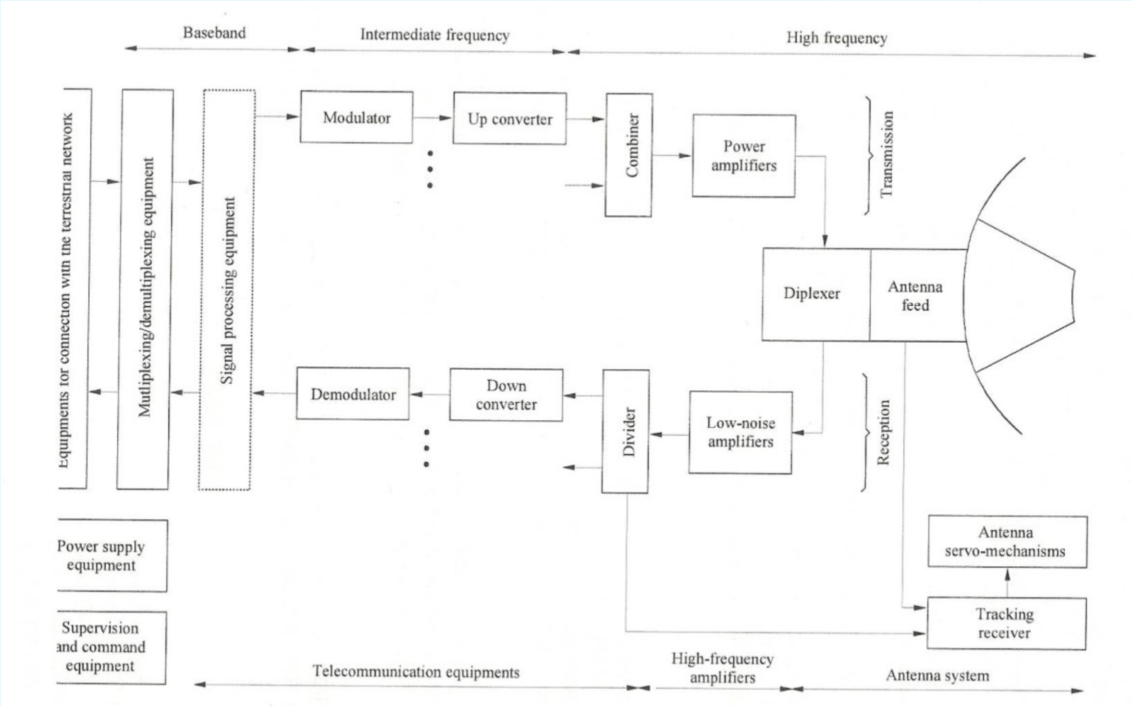
As said above, the earth station is the transmission and reception terminal of a telecommunication link via satellite. The general configuration of an earth station is not substantially different from that of a radio-relay terminal, but the very large free-space attenuation (about 200 dB) undergone by the carrier radio waves on their path between the station and satellite (up to 36 000 km) usually requires the main subsystems of an earth station to have a much higher performance level than those of a radio relay terminal.

The general operational diagram of an earth station is shown in Figure 6-5, where it is possible to see the following main subsystems:

- the antenna system; (*)
- the receiver amplifiers (low-noise);
- the transmitter amplifiers (power);
- the telecommunication equipment (frequency converters and modems);
- the multiplexing/demultiplexing equipment;
- the equipment for connection with the terrestrial network; (*)
- the auxiliary equipment;
- the power-supply equipment; (*)

(*) These subsystems are of interest of this Handbook and will be described in the following sections.

**Figure 6-5: General operational diagram of an earth station**




To achieve the required availability, the practice of providing equipment redundancy is widely used.

In fact, an earth station with multiple access links comprises two categories of subsystems, i.e. those which are common to all RF links and those which are specific to a particular link.

The first category includes primarily the antenna system, the receive low noise amplifiers and the transmitter power amplifiers. Low noise amplifiers and power amplifiers are usually backed up by hot, automatically switched, stand-by units. On the contrary, the antenna system (feed, tracking device, mechanical structure, drive and servo-controlled mechanism) cannot generally be provided with redundant units and great care must be applied to its design and construction in order to guarantee a very long MTTF (mean time to failures). Note also that power supply equipment is often designed for uninterruptible operation.

The second category may include telecommunication equipment, multiplex units, etc. when the configuration of the station, the link distribution and also the MTTF of the units allows it, those subsystems may possibly be provided with one-for-n type redundancy, i.e. with a single stand-by unit (also possibly automatically switched) common to n (identical) active units.

### 6.2.1.1 The antenna

The antenna, with a diameter which may vary between about 33 m and 3 m or even smaller, is the most conspicuous and often the most impressive subsystem of an earth station.

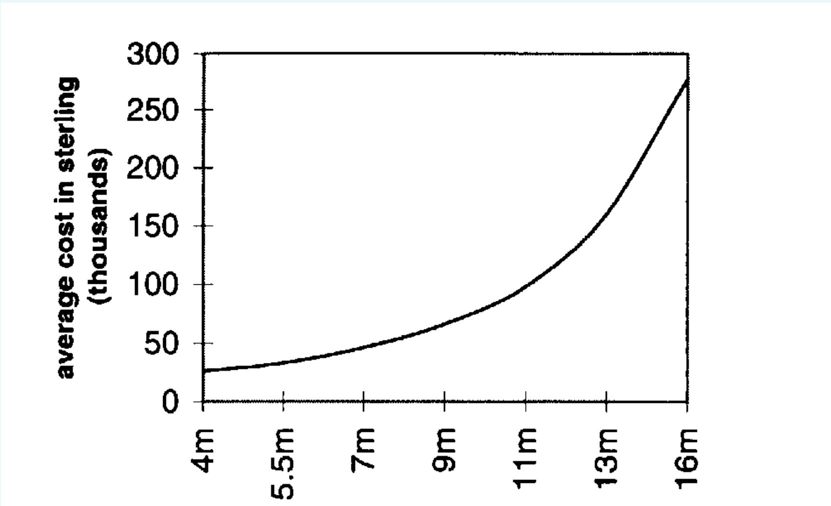
The antennas of earth stations are common to transmission and reception. The antenna beam must remain pointed towards the satellite under all environmental operational conditions and irrespective of the residual movements of the satellite.

Types of earth station for 6/4 GHz and 14/11-12 GHz bands are often classified according to the size of their antennas:

- large stations: antennas dimension more than 15 m;
- medium-sized stations: antennas of approximately 15 m to 7 m;
- small stations: antennas of 7 m to 3 m or less;
- micro-stations for VSAT (very small aperture terminal): 4 m to 0.7 m. [See Chapter 7]

The price rises steadily as the antenna diameter increases, owing to the increased amount of steel and aluminium. As well as the diameter increasing the amount of structural material required, the design wind-speed also has a key impact on cost (Figure 6-6). The graph shows costs for standard wind-speed antennas (e.g. 180 km/h) survival. An antenna designed to operate in locations subject to higher wind-speeds or hurricanes must have a significantly stronger and hence more expensive structure. Some antennas are designed to survive during high-wind periods in a stow position, to lessen the effect of the wind. In addition, the larger antennas will probably include more complex tracking arrangements.

**Figure 6-6: Average cost against antenna diameter: C-band**




### 6.2.1.2 Connection to the terrestrial network

For telecommunication services, the earth station is usually connected to the terrestrial network through a switching centre. This may be a transit centre in the case of international stations and large or medium-sized stations in national systems, or possibly a subscriber exchange in the case of small local stations within national networks. The specific equipment usually required for such a connection is a terrestrial link between the earth station and the switching centre. Generally it may use an optical or coaxial cable. However, where the geographical conditions make it necessary, radio-relay links are also used. [For these subjects see Chapters 4 and 5]

### 6.2.1.3 Power supply equipment

The satisfactory operation and service continuity of an earth station depends on the correct design of its electric power supply. There are two main sources of power:

- the main power supply, with stand-by capability;
- the uninterrupted power supply (UPS).

In addition, an auxiliary low voltage (24 V or 48 V) d.c. source may be required to supply certain automatic equipment.

The main power supply distribution network is via the station transformer unit. It is backed up by an independent generating set (or better still by two sets with 1 + 1 redundancy) driven by a fast-start (5 to 10 s) diesel engine. This generator, which for large stations would have a power of usually about 250 kVA, supplies the whole station, including the antenna motors, lighting and air conditioning. Maintaining the stand-by generator and keeping a stock of diesel fuel is one of the basic tasks in the management of the station.

The purpose of the Uninterrupted Power Supply, which receives its primary energy from the main power supply, is to provide a constant high-quality power supply (stable voltage and frequency with no significant transients), while the stand-by sets are starting up following a power cut in the distribution network. This source supplies all the electronic equipment. For a large station the power would be roughly from 50 to 100 kVA, most of which (80% to 90%) is required for the high-power amplifiers.

The three most common Uninterrupted Power Supply systems are:

- alternator motors with an inertia flywheel. The flywheel provides reserve mechanical energy which continues to drive the alternator while the diesel motors are starting up;
- alternator converter systems. In this case the reserve energy is provided by accumulator batteries. The batteries, which are kept charged by the main power supply (via rectifiers), feed an alternator which constitutes the uninterrupted source;
- static converter systems in which the alternator mentioned above is replaced by a solid-state a.c. generating unit using thyristor bridges. This is the most commonly used system at present.

The converter systems described above require a large set of electric batteries. The size of the unit depends on the installed power of the uninterrupted source but also, and most importantly, on the duration of autonomy required (permissible duration of interruption of the general source). This duration usually ranges from a few minutes to half an hour.

Clearly, if there is no adequate and reliable local electricity network, the power supply equipment may be designed quite differently. It might, for instance, be based entirely on diesel generating sets with built-in redundancy and switching systems guaranteeing continuous operation. It is often the case for small stations that no electricity supply is available and that the station must operate without technical staff. Here the engineer must endeavor to design low consumption equipment, if possible completely solid state, which can operate without ancillaries (air conditioners, etc.) in all local environmental conditions. Power supply systems should be provided that requires the least possible maintenance and replenishment (fuel, etc.). Solar power units are particularly suitable and can generally be used for power consumption not exceeding 500 W.

### 6.2.2 General infrastructure

The general infrastructure of an earth station includes all premises, buildings and civil engineering works. Its size obviously depends on the type of station.

#### 6.2.2.1 Large earth stations (mainly for international applications)

Although INTELSAT is no longer the only global international operator, INTELSAT standards are typical examples of international earth stations.

Seven standard types of earth stations are normally admitted for operation in the "INTELSAT global system", though other types ("non-standard") may be taken into consideration (at least for provisional operation) on a case-by-case basis. INTELSAT's earth stations standards (IESSs) define seven types of stations as Standards A, B, C, D, E, F, and G, each of them is cost-effective for a specific type/capacity of traffic. The characteristics of these stations can be taken as a basis for the design of the relevant infrastructure.

#### 6.2.2.2 Medium-sized stations (mainly for regional and domestic applications)

A number of earth-station types are available for regional or domestic applications. The selection of a specific type depends on the general system operation and on satellite communications payload performance characteristics.

For medium-sized stations, which require less equipment and consume less power than large stations, the infrastructure can be designed more simply and economically. It may be advantageous for ready-wired prefabricated buildings to be delivered to the site.

#### 6.2.2.3 Small stations

The term "small earth station" should be taken in a broader sense and should include a wide variety of earth stations implemented in the FSS (at 6/4 GHz, 14/10-12 GHz, 30/20 GHz) in the framework of GSO (Geostationary) or non-GSO satellite systems. In fact, this sector of the earth segment is, at the moment, in very rapid evolution in terms of technical progress and market evolution. Also small earth stations can be characterized by their technical features.

In terms of applications and services, small earth stations can be characterized by their proximity to the users. In consequence, they are generally used as access communication systems, by permitting connection to public or private communication networks or to shared information or computer means.

As concerns the earth station construction, small earth stations are characterized by a compact equipment assembly, all equipment being generally contained, either in a shelter near the antenna, or even in two "boxes", the first one (the "outdoor unit") or ODU comprising the main parts of the radio equipment) being located in the antenna system and the other one (the "indoor unit" or IDU comprising the signal processing and the interfacing equipment) being inside the user premises. Ultimately, in the case of very small terminals, the complete equipment could form a single unit;

### 6.3 General construction of main earth stations

When a decision has to be made as to a suitable location for an earth station, a number of physical considerations have to be taken into account. Typical of these are the external temperature and humidity, rainfall, snow etc., likely wind conditions, particularly corrosive atmospheric conditions, and the likelihood of earthquakes etc. The effects of some of these can be minimized by careful site selection, but other considerations may well outweigh these possible actions. Availability of sufficient space to locate the equipment, transportation to the site (e.g. good road access) and reliable electric power at the site must also be considered.

Large satellite earth stations are usually located in low-lying areas that are shielded from terrestrial RF interference by low hills surrounding the area. They are generally operating with significant traffic capacities and are equipped with medium or large antennas (typically 10 m to 18 m, but possibly even more) and are implemented with relatively large, manned, buildings. The case of small stations used in domestic or business operations (e.g. VSATs) is quite different and it is not included in this section. [See Chapter 7]

NOTE – Up to the eighties, the INTELSAT specifications for Standard A earth stations (G/T ≥ 40.7 dBi at 4 GHz) asked the use of very large antennas (up to 33 m diameter). Since then specifications have been relaxed (G/T ≥ 35.0 dBi at 4GHz) to permit the utilization of smaller, less expensive Standard A antennas. However, older stations remain operating with those previous very large antennas.

Large and medium earth stations often include within the station proper, a terrestrial microwave link connecting the station to the central area it is serving.

The earth station should be designed to provide shelter and a suitable internal environment for the telecommunications equipment, control and monitoring equipment, the station support equipment and the personnel operating the station. The basic components are:

- the civil works necessary to provide shelter and a working environment;
- the power supply providing the energy to the electronic equipment and the building services;
- the antenna system (antenna civil works).

All descriptions given in this section are to be considered only as representative of current trends in technology. In fact, project engineers and designers should, in each particular case, consider fully the local conditions and comply with the regulations, standards and requirements which are locally in force as concerns environment, construction, security, human engineering, etc.

### *6.3.1 Civil works*

The design of a satellite earth station has to cater for the following main features:

- antenna;
- telecommunication equipment;
- power supply equipment;
- mechanical equipment (heating, ventilating and air-conditioning);
- administration;
- station support services.

Additional supplementary features that should be considered are:

- access roads and parking;
- security;
- water supply and treatment;
- fire protection system;
- power entrance;
- terrestrial link telecommunication facilities.

The characteristics of the areas designated for the above features will depend upon the type of station being considered and are given below.

#### 6.3.1.1 Large multi-antenna earth stations

In a station with several antennas, each antenna is erected on a separate building which houses the equipment directly associated with it (low-noise amplifiers, tracking receiver, power amplifier and sometimes frequency converters). A central operations building, common to all the antennas, contains the actual telecommunication and operating equipment, some of which may be shared (e.g. supervisory and command equipment) or multi-purpose (e.g. the transmission and reception chains may be assigned to the various antennas according to requirements).

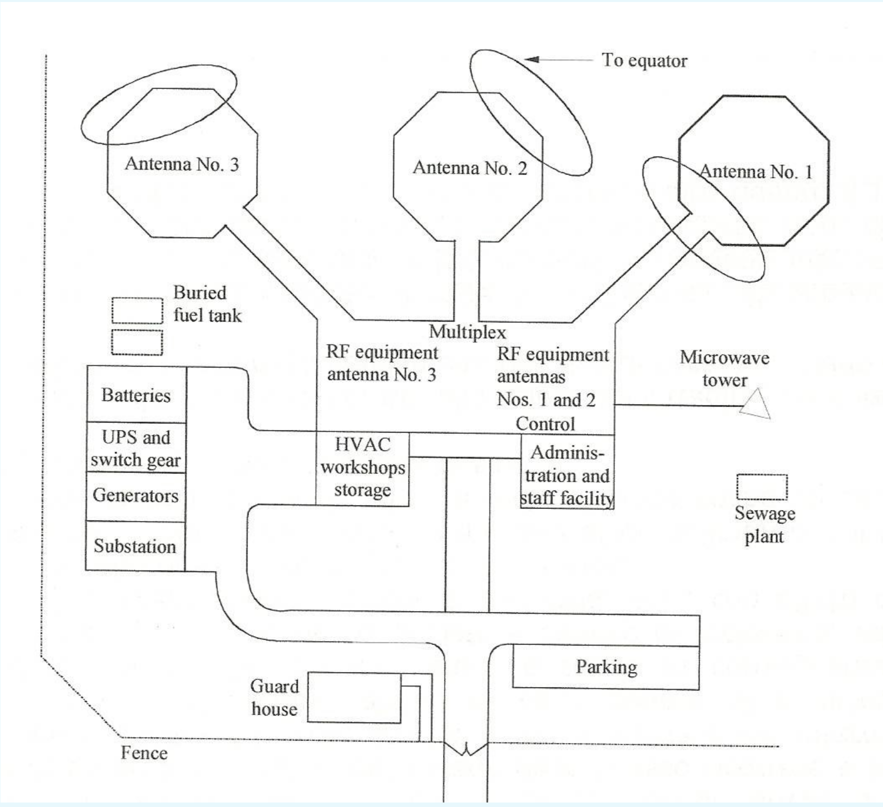
Microwave (waveguide) or intermediate frequency (coaxial cable) links, called inter-facility links, are used to connect the equipment in the antenna buildings to the equipment in the main building. The general infrastructure of a large multi-antenna station can account for a high proportion of the total cost of the centre: between 20% and 50%, or even more if additional installations and premises are necessary, as is frequently the case (conference rooms, staff accommodation, etc.). Construction costs should also cover the general preparation of the site and access (roads, etc.), supply networks (electricity, air conditioning, fluids, etc.) and miscellaneous fittings (grounding, internal communications, fire prevention, drainage, etc.).

The main features mentioned previously, apart from the antennas, should be housed in discrete areas (individual areas isolated from their neighbours by fire-resistant walls, door openings, etc.) with a central building so located as to provide the shortest possible inter-facility links between the telecommunications equipment room and the antennas. Figure 6-7 shows the layout of a typical multi-antenna station.

The location, height and orientation of the various buildings, structures and antennas should be such that no obstacles obstruct the radiation of the antennas wherever they are pointed during operations.

The main building should be designed to withstand the severest seismic shocks anticipated in the locality. After such a shock the building should have suffered only superficial damage and its support and communications systems should continue to maintain service.

**Figure 6-7: Layout of typical large multi-antenna station**




*Telecommunication equipment area*

The telecommunications equipment should be housed in a discrete area having adequate floor-to-ceiling height to permit the use of overhead inter-rack cabling. Elevated air-conditioning ducts are usually installed in the space provided between the concrete ceiling and a false ceiling.

Alternatively, the area should have a technical elevated floor (computer type) with sufficient under floor depth (0.6 m) to provide space for air-conditioning ducts and for inter-rack wiring, including power distribution cabling.

The environment of the area should be controlled to meet the requirements specified by the equipment suppliers. The air-conditioning equipment should be of sufficient capacity to adequately meet all heating/cooling loads and have ample redundancy to allow for individual unit failure.

*Power supply equipment area*

The power supply equipment (i.e. transformers, switchgear, uninterruptible power supply (UPS), stand-by generators, d.c. power supplies, etc.) should be housed in a discrete area somewhat adjacent to the telecommunications equipment room. This area should have amply resistant fire walls to prevent the spread of combustion to and from the other areas. The stand-by generators, batteries, switchgear and UPS should be housed in separate interconnected rooms within the area.

Self-closing, anti-panic, fire-resistant doors should be used throughout and all cable routes through walls or under-floor should be sealed with fire-resistant materials to prevent the spread of combustion. Sound-absorbing materials should be used in the construction of the generator room, particularly if this is the only source of continuous electrical power. If possible this room should be cooled by outside ambient air using natural convection or fans. The generator control equipment should, if possible, be housed in an adjacent room with a sound-proof window between rooms.

The battery room should have adequate ventilation to disperse hydrogen fumes. Adequate curbs, sloping floors and a cesspool for removing and retrieving accidental spillage should be provided.

The floor and lower part of the walls should be protected with anti-acid paint. For security reasons, the battery room should also be equipped with a shower/eye douche.

The d.c. power and uninterruptible power supply (UPS) rooms should be air-conditioned. The use of heat pumps in the UPS room is recommended if other station support areas required heating in the winter months as the excess heat from this equipment can thus be utilized.

The power supply area should be laid out so that the d.c. power and UPS rooms are as close as possible to the electronic equipment room to avoid long power cable runs.

An adequate underground reservoir for fuel oil of sufficient size to meet the needs of the station's power generating equipment, should be provided. The reservoir should consist of two or more interconnected tanks linked by dual fuel lines, valves, etc. to dual daytanks located in the generator room. All fuel lines should be equipped with fusible link stop valves at their entry to the generator room.

*Mechanical equipment (heating, ventilating and air-conditioning)*

The mechanical equipment (heating, ventilating, air-conditioning, HVAC) should have a separate area adjacent to the power equipment area with fire-resistant walls, doors, etc. The type of HVAC system will depend on the location of the station. It is usual for large stations to have heat exchangers (cooling towers) with a central circulating plant using either chilled water or water at a controlled temperature to individual air-conditioning units or heat pumps distributed throughout the station.

If heating is required in the winter season, the use of heat pumps between the UPS room, the electronic equipment room and the station support areas should be considered. The excess heat from UPS and equipment can thus be utilized.

The design of the building envelope (walls, roof, windows, etc.) should include a study of the local climatic conditions and environmental requirements of the station to determine the optimum design of both the envelope and mechanical system. Natural (free) cooling should be used whenever possible and consideration should be given to energy-reducing features to improve the building energy efficiency.

The cooling of the microwave HPAs should be carried out by means of either an air-cooled system or a water-cooled system depending on the size of the microwave tube that is used.

In the case of an air-cooled system, cooling of the HPA should be by means of outside air connected directly to the intakes and exhausts of the individual units by insulated ducts. Supplementary fans should be considered to assist the flow of cooling air and to overcome duct friction. In climates with large variations of seasonal temperatures the intake and exhaust ducts should be interconnected and the hot exhaust air mixed with the cold outside air by means of modulating duct dampers to give the required intake temperatures at the HPA inlet.

In the case of a water-cooled system, de-ionized pure water should be used for cooling the HPA in order to prevent blockages of the water paths in the collector and to provide low water conductivity. It is also necessary to keep the amount of diluted oxygen absorbed in the water flow as small as possible to avoid oxidization. Materials such as copper, brass and stainless steel are commonly used for water path. However, recently, water-cooled systems are seldom used.

*Administration and station support area*

The administration and station support areas can be combined in one discrete area or be in two separate discrete areas. The area should contain the offices (manager, supervisors, clerical staff), the staff personnel facilities (lunchroom, lockers, toilets, classroom/conference room, etc.), receiving, storage/warehouse area and mechanical and electronic workshops.

*Supplementary features*

Apart from the preceding main features the following supplementary features should also be considered:

- access roads and parking: access to the station, particularly during the construction stage when large heavy structural components of the antenna have to be transported, must be reviewed. Adequacy of the road bed, bridges, tunnels, etc. must be determined and corrections made where necessary. Turning areas for delivery vehicles and space for parking should be allowed.

- water supply and treatment: investigations should be undertaken before the site has been selected to ascertain the availability of potable water, or water requiring the minimum amount of treatment, adjacent to the site. The availability of this water will have a direct bearing on the design of the HVAC system, the stand-by generator cooling as well as the personal needs of the station staff. If wells have to be drilled, their capacity should be determined for all seasons of the year and a redundant system should be provided to cater for failure or maintenance of pumps and equipment.

  An adequate sewage system should be provided. This system should be connected to a main line system or consist of a septic tank with drainage field.

- fire protection system: the buildings should be protected by a zone-designated fire protection alarm system including local fire detectors. In equipment areas the protection system could consist of an automatic release of $CO_2$ gas. A portable system, associated with proper alarm announcement, could be sufficient in attended areas.

  Where the stations are located in heavily-wooded areas, a clear space to act as a fire break should be maintained between the buildings and foliage.

  A water hydrant system connected to a reservoir of sufficient capacity and with pumping facilities to maintain an adequate flow of fire-fighting water should be considered.

- power entrance: if a high voltage or commercial power source is available it should be fed via dual cables (underground and/or overhead) to a high voltage substation which can be located within the main building or exterior to it. The exterior substation should be protected by a 2.5 m chain link or equivalent type fence.

- terrestrial link telecommunication facilities: provision should be made for providing terrestrial telecommunication facilities from the station. Protected space should be provided for the electronic equipment and, if required, the location of a terrestrial microwave transmission tower should be determined so as not to interfere with the operation of the main antennas. If communication is by cable then an adequate duct or burial system should be provided.

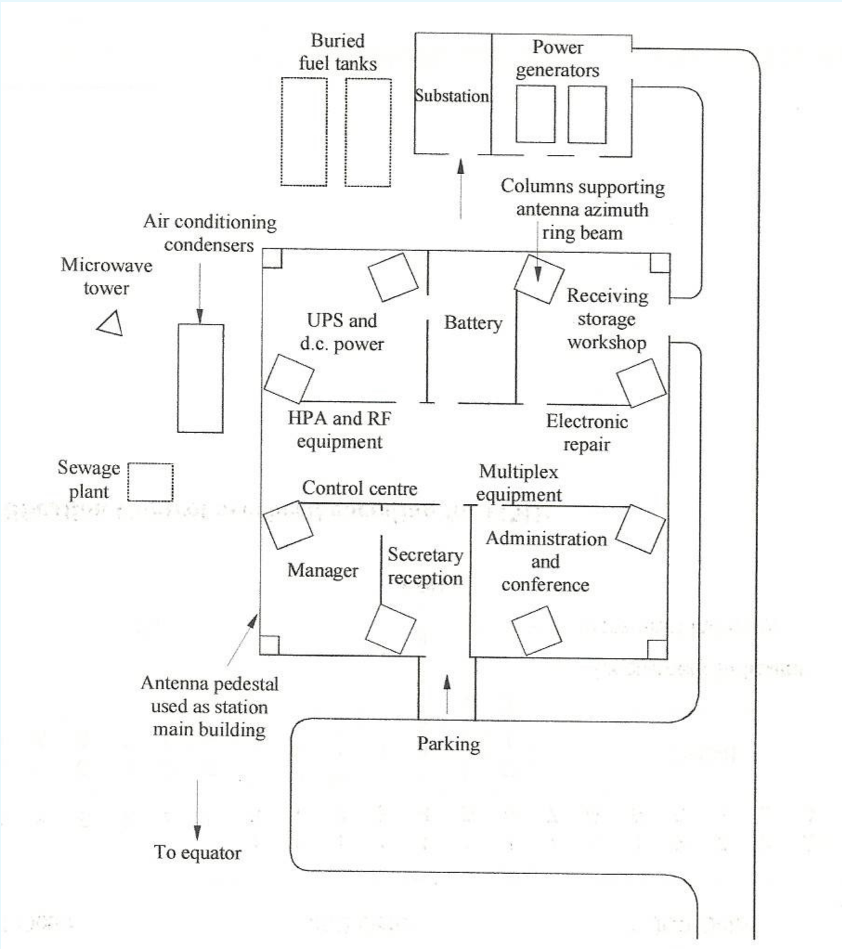
#### 6.3.1.2 Large single-antenna earth stations

In a station with a single antenna all the equipment may be installed in one building located under the antenna (apart from the power supply equipment which for sound-proofing reasons is usually housed in its own building). In this way the general infrastructure is particularly compact and economical.

This type of station is assumed to have a maximum of one antenna only, the antenna pedestal acting as the central building (Figure 6-8). The main features (antenna, telecommunication equipment, power supply, administration and support services) as given for a multi-antenna station apply equally for this type of station. The characteristics and locations of all the above quoted features should be followed, except for the following:

- mechanical equipment (HVAC): for a station of this size a separate HVAC room may not be necessary. A split unit (internal evaporator, external condenser) system should be considered for the conditioned areas with individual fan coil (evaporator) air handling units plus back-up units in each area. The condenser units should be outside and adjacent to the pedestal in an area with an adequate wind flow. The air handling units can be provided with a heating coil if seasonal changes necessitate the use of heating in the winter months.
- power generating equipment: the stand-by generators and their control equipment should be housed in a separate building some distance from the antenna. This building should be cooled by natural and/or mechanical (fans) air flow using ambient outside air. Ventilation openings should be provided with automatic louvers that will close in the event of a fire, the generators and fans should shut off automatically in this event and fire extinguishing devices should be provided. The requirement for an underground fuel reservoir remains as before.

**Figure 6-8: Layout of typical large single-antenna station**



### 6.3.1.3 Medium-sized earth stations

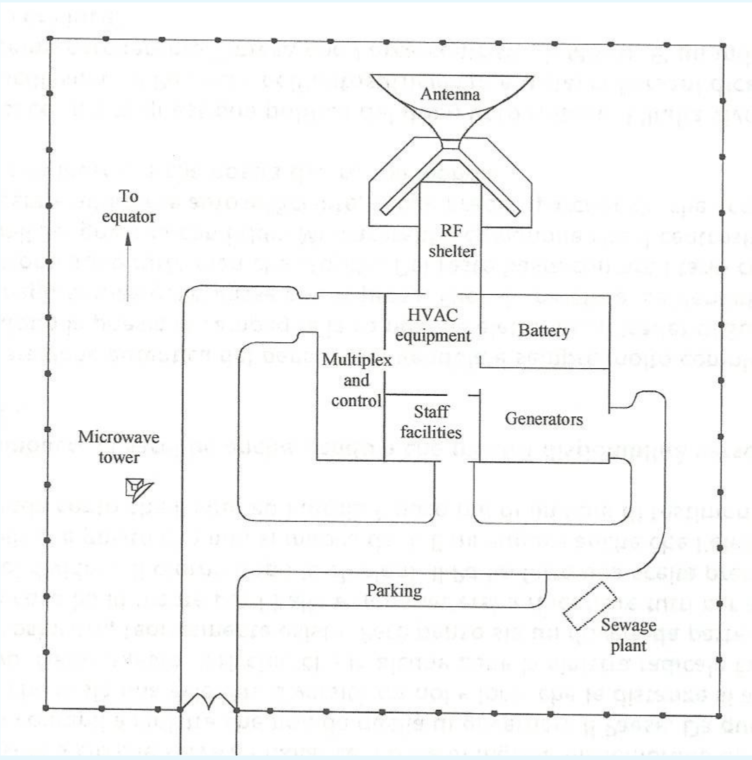
The stations considered in this subsection are domestic network type stations with a single medium-sized antenna (10-15 m). The main features detailed previously apply in general but modifications and omissions can be tolerated depending on the reliability required for this type of station (Figure 6-9).

The construction of a medium-sized station consists basically of the antenna, a radio equipment shelter and a main building. The 10-15 m antennas are usually of the limited motion variety consisting of the reflecting surface mounted on an Az-El mechanism fabricated from medium steel sections. The radio equipment shelter should be an abutment from the main building located between the support members of the antenna pedestal thus bringing the RF equipment and LNAs as close to the antenna feed as possible. The RF shelter should be well-constructed and transportable, having a removable chassis, thus permitting the RF equipment to be assembled and tested at the manufacturer's premises and transported to site ready for operation with a minimum of field labour.

The main building can be constructed of local material on a concrete slab or be of the steel frame type with a prefabricated hung panel which can be readily transported and assembled on site.

The supplementary features (access roads, parking, fire protection, etc.) as given for a multi-antenna station apply equally for this type of station.

**Figure 6-9: Layout of typical medium single-antenna station**



### 6.3.2 Power system

The power system should be designed to deliver the electrical power which is required for the communications equipment, the buildings services and auxiliary facilities.

The requirements are as follows:

- critical loads: high power amplifiers, telecommunications equipment, multiplex equipment, etc. Critical loads are normally supplied through the battery bank of the uninterruptible power supply system (UPS);
- essential loads: antenna servo system, antenna anti-icing, air-conditioning, ventilation, lighting, etc. Essential loads are normally supplied by a commercial power line and, in case of its failure, by a stand-by motor/generator at the station;
- non-essential loads: external lighting. Non-essential loads are normally supplied by a commercial power line only.

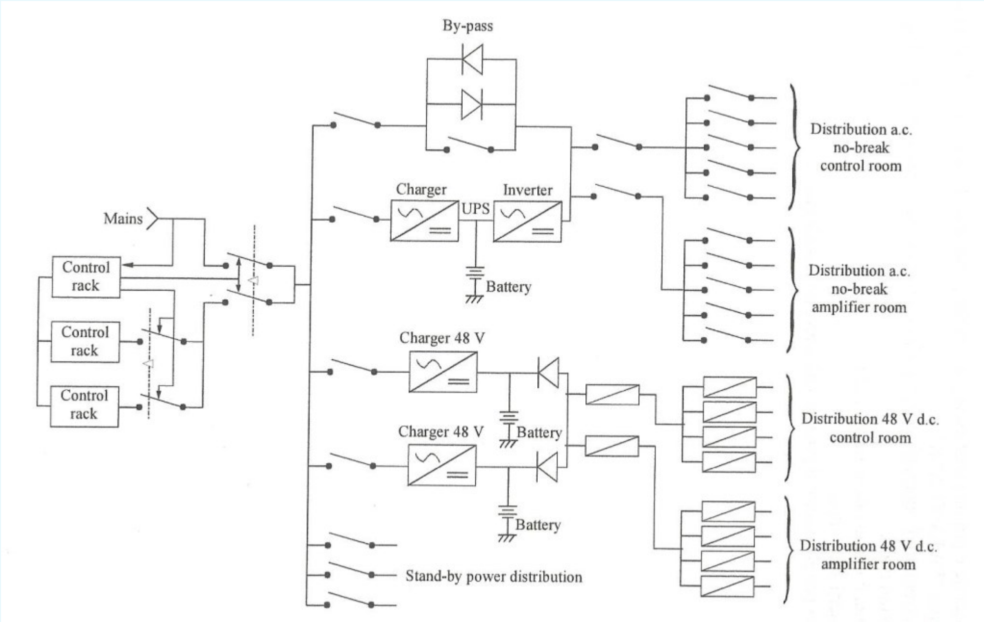
The main power subsystems are as follows:

- the power entrance facility; including the high voltage feed and transformer substation with high voltage protection;
- the a.c. power distribution; including switchgear, metering, low voltage distribution panel boards with integral low voltage protection;
- the emergency stand-by generator(s); including related auxiliary equipment and control facilities;
- the uninterruptible power supply (UPS); including rectifier, inverter and battery bank;
- the d.c. power supplies; including rectifiers, battery banks and associated distribution;
- the station grounding facilities.

A block diagram of a typical power system is shown in Figure 6-10.

The characteristics of the subsystems indicated above will depend upon the type of station being considered as given below.

**Figure 6-10: Typical block diagram of a power system**




### 6.3.2.1 Power systems for large earth stations

The main design criteria for large multi-antenna earth stations and large single-antenna stations are listed below:

i) The initial point of entry of the power supply system should be connected to a dual HV feeder each having an independent fused or circuit breaker protection fed from a common utility or commercial power source. The incoming feed to each fuse or circuit breaker should be equipped with lightning arrestors. Two main power transformers should be used to step down the incoming voltage. The transformers should have star (Y) secondary windings with the neutral grounded at the transformer and connected to the station ground. An isolated neutral can also be used (depending on local regulations). The transformers should be rated so that either transformer is capable of feeding the station load. It is preferable to utilize both transformers to feed the station via separate input circuit breakers for additional redundancy.

ii) The main switchgear should incorporate at least two main bus circuits to permit the essential loads to be separated from the non-essential loads. The bus configuration should also provide diversity of operation in that the routing of power may be derived from either or both transformers without paralleling the transformer outputs. Metering and protection facilities should be provided. Coordinated selective trip facilities are of prime importance. Coordinated ground fault protection is recommended on all three-phase circuit breakers. An isolated generator bus should be provided to permit testing of the stand-by generators. Use of a tie breaker and a dummy load feeder breaker facilitate generator operation. The rating of the main bus circuits should allow for future growth. Switchgear control power should be fed from an independent d.c. power supply backed up by batteries.

The requirement for voltage regulation is primarily dependent on the quality of the commercial power source. The majority of the station equipment will operate on the nominal voltage within ± 10%. If the required voltage tolerance cannot be met by the commercial power source, voltage regulators should be provided. Power factor correction should be incorporated in the distribution facilities; however the amount of correction required should depend upon the cost saving in operation versus the installation cost.

iii) Emergency stand-by generators are required to back up at least the essential loads. The rating of the diesel generators can be based on stand-by use but the sets must be capable of continuous use at the stand-by rating. The location of the site above sea level and the ambient temperature coupled with the choice of radiator are of prime importance in determining the continuous output capability. The requirement for multiple diesel generators is dependent on the availability and reliability of the commercial power source. The advantages of utilizing more than one stand-by generator set are numerous and if multiple sets are used, synchronizing facilities should be provided to parallel the sets. The fuel system should include dual electric transfer pumps to keep the day tanks full. The generator output voltage regulation should be ± 2% for steady-state conditions for no load to full load and the frequency regulation should be ± 1% for the same steady-state conditions.

The use of an electronic voltage regulator and an electronic governor is recommended. The generator and/or voltage regulator should incorporate an exciter current boost circuit to prevent exciter field collapse during short circuit conditions, to ensure circuit breaker fault clearing.

iv) Uninterruptible power supply systems (UPS) may employ rotary or static generation. The preferred scheme utilizes a static inverter which under normal conditions feeds the critical a.c. loads of the station and provides total isolation from commercial power interruptions and line disturbances including voltage or frequency excursions. The system employs a rectifier charger to supply current to a d.c. bus which feeds a battery and an inverter. An automatic transfer switch is used to transfer the critical load from the UPS to the UPS bus in the case of an inverter failure. The use of a static transfer switch for this function is preferable over an electromechanical type switch in cases where computer equipment is being fed. The rectifier should incorporate a delayed start and a current control facility to coordinate and limit power inrush to the working bus upon restoration of a.c. input power. The system should also incorporate adjustable output current limit facilities, the capability to parallel with additional future UPS modules and a d.c. logic power supply backed up by a separate battery. The UPS battery should be of long lifetime type (lead antimony, lead calcium, nickel cadmium).

v) d.c. power supplies consisting of rectifier chargers feeding a battery bank and its associated distribution via circuit breakers or fuses are required to feed communications equipment. The use of multiple conservatively-rated rectifier chargers suitable for load sharing is recommended. The battery bank should have local disconnect facilities with cable protection. The bank should consist of two sets of cells in parallel to permit isolation of one set for maintenance.

vi) Station grounding facilities should be provided as follows:

- An important requirement of station grounding is to maintain an equal potential across all portions of the system and the equipment to which it is connected, particularly during electrical power faults and strokes of lightning. In order to distribute the ground throughout the station, a perimeter ground system is used. This consists of a large diameter conductor (about 10 mm copper wire) buried adjacent to the walls of the building with conductors connected at intervals to the perimeter conductor and carried to the interior where they are connected to an interior copper bus bar. The bus extends internally around the building walls of rooms where equipment requires grounding. The extension of the perimeter ground to the antenna and the transformer substation is normally done using two buried ground conductors. All ground connections should utilize a cad-welded process. Ground rods are normally driven in adjacent to the perimeter conductor and connected to it. The number of ground rods required will depend upon soil conductivity.

- The antenna grounding is of special concern with regard to lightning protection. Antenna structure grounding down leads should be welded to the antenna perimeter ground with a ground rod at the same point. If the overall ground resistance is poor, consideration should be given to utilizing deep earth electrode grounds around the antenna with connections to the perimeter ground. The nature of the soil conditions determines the methods which must be used to achieve a low-resistance ground. A design goal of 5 Ω should be used.

- In an area which is predominantly rocky and soil conductivity is low, it may be necessary to utilize deep earth electrodes to meet the design goal of 5 Ω.

#### 6.3.2.2 Power systems for medium-sized stations

Power supply subsystem characteristics for domestic network type stations are listed below:

i) the initial point of entry of the power supply system should use a single high voltage fused disconnect switch feeding a step-down transformer. The transformer secondary star (Y) point should be connected to the station ground;

ii) the switchgear could consist of a Circuit Breaker Panel board (CDP) with dual bus circuits to permit essential loads to be separated from non-essential loads. The bus configuration should also permit feeding a dummy load from the stand-by generator while the working bus is fed from the commercial power source;

iii) the characteristics of the uninterruptible power supply system are essentially the same as those used on large earth-station complexes;

iv) the characteristics of the emergency stand-by generator system are essentially the same as those used on large earth-station complexes. However, less emphasis should be given to the use of redundant or multiple diesel generator sets;

v) the characteristics of the d.c. power supply system are the same as those used on large earth station complexes;

vi) the characteristics of the station ground system are essentially the same as those used on large earth-station complexes.

### *6.3.3 Antenna system (antenna civil works)*

The civil works associated with the antenna are described below.

Two types of antennas are here again considered in this section: large antennas (>15 m) used in high traffic capacity earth stations and medium-sized antennas (15 m to 10 m) used in domestic network stations.

The pointing accuracies of the antennas require that the antenna should be built on ground with stable soil conditions. The soil should be analyzed in depth to determine the actual condition on which the foundations are to be laid. These analyses are usually conducted by the antenna supplier/erector and the type of foundation is determined after a study of the soil report.

The foundation must be designed to meet the operational and survival loads imposed by the antenna, the support structure and the pedestal. These include wind loads, gravitational loads and seismic loads.

#### 6.3.3.1 Large antennas civil works

Most large antennas are mounted on an azimuth-over-elevation (Az-El) mechanical assembly of the wheel and track type. In this design, a large diameter circular rail supports the mechanical assembly and allows its rotation in azimuth, while the horizontal stresses are transmitted to a central bearing. The foundation pedestal can consist of eight columns of reinforced concrete supporting the azimuth rail tied to four columns supporting the central bearing (pintle), connected by radial beams and a top slab. The pedestal can also consist of a continuous polygonal concrete shell with a self-bearing dome-shaped roofing embedded in the circular beam, the pintle being included in this roofing. In this latter case the foundation is an integral part of the antenna building.

As the diameter of the azimuth rail ring is about 15 m to 18 m for large (30 m) antennas, the area under the top slab or the roofing is an ideal place to locate RF equipment. The internal construction and finish of this area should follow the general guidelines previously given for the main building.

The antenna foundation and pedestal should have a good drainage system which is capable of gathering and dispersing storm-water captured by the antenna and support structure.

#### 6.3.3.2 Medium-sized antennas civil works

Medium-sized antennas (10-15 m) are generally mounted on limited motion assemblies (Az-El or X-Y type) attached to a fixed support structure secured directly to the foundation by means of embedded anchor bolts.

The foundation should be designed after completion of a soil analysis. In general, it consists of footings or of a raft with piles tied in the upper part by groundsels, the whole being constructed in reinforced concrete. The foundation should have a sufficient mass, conveniently distributed to compensate for the winds, gravitational and seismic loads imposed by the antenna. A less stringent soil condition can thus be tolerated.

Small footings should also be provided for supporting an electronic equipment shelter situated, if possible, between the rear legs of the antenna support structure.

### 6.4 Maintenance

Now that the earth station is ready to go into operation it is imperative that a correctly formulated plan is in existence for keeping it in operation. To this end, supplies of spare parts must be available as well as sufficient test equipment for routine maintenance and fault finding. Maintenance instructions must be prepared for all equipment and systems as well as charts showing recommended maintenance intervals. Maintenance records, when well kept, can be an excellent indication of fault trends leading to early diagnosis of problem areas and timely corrective action. Staff must be available with the necessary skills to carry out this maintenance either on a round-the-clock attendance basis or a call-out basis for unattended sites. Full training will be required to ensure that maintenance staff are familiar with the equipment. The standby/redundancy philosophy for the earth station is a key factor here.

## Bibliography

1 – "Handbook on satellite communications", Wiley-ITU

2 – "Satellite Communication systems", B.G. Evans, IET N.38

3 – "Guidelines for implementation of satellite telecommunications for disaster management in developing countries", Report ITU-D SG2, Period 2006-2010

http://www.itu.int/dms_pub/itu-d/opb/stg/D-STG-SG02.22-2010-01-PDF-E.pdf

4 – Recommendation ITU-R S.1001 "Use of systems in the fixed-satellite service in the event of natural disasters and similar emergencies for warning and relief operations"

http://www.itu.int/rec/R-REC-S.1001-2-201001-I/en

5 – "Propagation Handbook for satellite communications system design", Robert Krane, CRC Press

6 – "Satellite communications" Dennis Roddy, McGraw-Hill

7 – "Satellite Handbook" AFRTS

8 – "Satellite communication Engineering" Michael Kolawole, Marcel Dekker Inc.

9 – "Satellite networking" Zhili Sun, John Wiley

10 – "Satellite communication applications Handbook" Bruce Elbert, Artech House

11 – "The telecommunication Handbook" Kornel Terplan, CRC Press

12 – "Telecommunications and data communications Handbook", Ray Horak, Wiley

# Chapter 7

# Outside plants of transportable fixed wireless terrestrial systems and VSAT earth stations: design and implementation

## 7 Introduction

This Chapter deals with the outside plants of two types of systems which can be rapidly deployed: transportable fixed wireless terrestrial systems and VSAT earth stations.

### 7.1 Transportable fixed wireless terrestrial systems

[For further information see ITU-R Recommendation 1105**,** http://www.itu.int/md/R12-WP5C-C-0171/enhttp://www.itu.int/md/R12-WP5C-C-0171/en]

Transportable fixed wireless equipment may be used for relief operation of either radio or cable links and may involve multi-hop applications with digital and analogue equipment. These systems may be operated in locations with differing terrain and in differing climatic zones, uncontrolled environmental conditions and/or unstable power sources.

It can be also effective to equip both a transportable mobile backhaul link and a transportable mobile base station in a vehicle and carry it to the disaster hit area when the mobile backhaul link and the base station for normal operation are both damaged by a disaster;

#### *7.1.1 Types of transportable wireless systems*

Some types of these fixed wireless systems (FWS) are shown in Table 7-1.

**Table 7-1: Types of transportable wireless systems for disaster mitigation and relief operations**

| Type | Feature | Application |
|---|---|---|
| A | A simple wireless link which can be established rapidly for telephone communication with a governmental or international headquarters | (1)<br>(2) |
| B | One or more local networks which connect a communications centre and up to about 10 or 20 end-user stations with telephone links | (1) |
| C | A telephone link for between about 6 and 120 channels or a data link up to the 6.3/8 Mbit/s over a line-of-sight or near line-of-sight path | (1)<br>(2) |
| D | A telephone link between 12 and 480 channels or a data link up to 34/45 Mbit/s over a line-of-sight or obstacle [or trans-horizon path] | (2) |
| E | A high-capacity telephone link (more than 480 channels) or high-speed data link up to STM-1 | (2) |
| Application (1): For devastated areas.<br>Application (2): For breaks in transmission links.<br>Application (3): For mitigation of disaster effects. | | |

Transportable fixed wireless systems listed in Table 7-1 could also be used for the access link to a base station in mobile communications that are operating in disaster relief and emergency situations.

### 7.1.2 System characteristics

For each type of system in Table 7-1, the channel capacities, frequency bands and path distances given in Table 7-2 are suitable.

**Table 7-2: Basic characteristics**

| System type | Capacity | Example frequency bands[1] | Transmission path distance |
|---|---|---|---|
| A | 1-2 channels | HF (2-10 MHz) | Up to 250 km and beyond |
| B | Local network with 10-20 outstations (several channels) | VHF (50-88 MHz)<br>(150-174 MHz)<br>UHF (335-470 MHz) | Up to a few km |
| C | From 6 to 120 channels<br>1.5/2 or 6.3/8 Mbit/s | UHF (335-470 MHz)<br>(1.4-1.6 GHz)<br>SHF (7-8 GHz)<br>(10.5-10.68 GHz) | Up to 100 km |
| D | From 12 to 480 channels<br>1.5/2, 6.3/8, 4 x 6.3/8 Mbit/s or 34/45 Mbit/s | UHF (800-1 000 MHz)<br>(1.7-2.7 GHz)<br>SHF (4.2-5 GHz) | Line-of-sight or obstructed paths |
| E | 960-2 700 channels<br>STM-0 (52 Mbit/s) or<br>STM-1 (155 Mbit/s) | SHF (4.4-5 GHz)<br>(7.1-8.5 GHz)<br>(10.5-10.68 GHz)<br>(10.7-11.7 GHz)<br>(11.7-13.2 GHz)<br>(14.4-15.23 GHz)<br>(17.85-17.97/18.6-18.72 GHz)<br>(23 GHz) | Up to several tens of km |

STM: Synchronous transfer mode.
[1] Many parts of these bands are shared with satellite services.

### 7.1.3 Engineering principles

#### 7.1.3.1 Low-capacity links (Type A system)

HF transportable equipment for 1 or 2 channels should employ only solid-state components and should be designed to switch off the transmitters when not in use, in order to conserve battery power, and to reduce the potential of interference.

As an example, a solid-state 100 W single-sideband terminal in a band between, say, 2 and 8 MHz operated with a whip antenna, could have a range of up to 250 km. Simplex operation (transmitter and receiver employing the same frequency) with a frequency synthesizer to ensure a wide and rapid choice of frequency when interference occurs and to facilitate setting-up in an emergency, can give up to 24 h operation from a relatively small battery (assuming that use of the transmitter is not excessive). The battery can be charged from a vehicle generator and all units can be hand-carried over rough country.

#### 7.1.3.2 Local radio networks (Type B system)

Radio networks of Type B are envisaged as local centres with single-channel radiocommunication with 10 to 20 out-stations, operating on VHF or UHF up to about 470 MHz. Single-channel and multi-channel equipment similar to types used in the land mobile service could be used.

#### 7.1.3.3 Links up to 120 channels or 6.3/8 Mbit/s (Type C system)

Equipment which is suitable for transportation by road, railway or helicopter is available. Such equipment, together with power supply equipment, can be easily and quickly installed and put into service. The equipment capacity is from about 1.5/2 to 6.3/8 Mbit/s, depending on the requirements, the topography and other factors.

d.c. operated equipment or a.c. powered equipment automatically switchable to d.c. is preferred. It can be associated with light-weight, high gain Yagi or grid antennas, giving a range of up to 100 km line-of-sight, but capable of accepting some obstruction from trees on shorter paths. Simply erected guyed or telescopic poles which can be rotated from ground level are to be preferred.

#### 7.1.3.4 Links up to 480 channels or 34/45 Mbit/s (Type D system)

Equipment which is suitable for transportation by road or railway or by helicopter is available. Such equipment, together with power supply equipment, can be easily and quickly installed and put into service. The equipment capacity is from about 12 to 480 telephone channels, depending on the requirements, the topography and other factors. The use of receivers with low noise factors and with special demodulators and of diversity reception, enables the size of the antennas, the transmitter power and the size of the power supply equipment, to be smaller than those often used for conventional trans-horizon installations.

In line-of-sight or partially obstructed path conditions, transportable equipment with similar fast deployment capability but with transmission capacities of up to 34/45 Mbit/s is available.

d.c. operated equipment or a.c. powered equipment automatically switchable to d.c. is preferred. It can be associated with light-weight grid or flat panel antennas, giving a range of line-of-sight, but capable of accepting some obstruction from trees on shorter paths. Simply erected guyed or telescopic poles which can be rotated from ground level are to be preferred.

#### 7.1.3.5 High-capacity links (Type E system)

For higher frequency bands and capacities of 960 telephone channels or STM-0 and above, it is recommended that the radio-frequency equipment is integrated directly to the antennas. For transportable equipment, preference should be given to equipment in which reflectors of diameter less than about 2 m are available. Because IF interconnection at repeaters is a desirable feature, an IF interconnection should be possible between the radio-frequency heads.

However, since the equipment which is to be bypassed in an emergency or for temporary use will most likely be at ground level, the control cable should bring the IF to the control unit at ground level. The antennas of systems used for relief operations are likely to be smaller than those of fixed microwave links and it is therefore important that the output power of the transmitters should be as high as possible and the noise factor of receivers should be as low as possible. Battery operated equipment is preferable: 12 V and/or 24 V supplies are appropriate if the batteries are to be rechargeable from the dynamos or alternators of any vehicles which are available.

An alternative arrangement would be to house the equipment in a number of containers. These would not only facilitate the transport of the equipment but each container could provide facilities for rapidly installing a number of transmitters and receivers. The maximum number of transceivers to be housed in any one container would depend on the dimensions and maximum weight adopted, allowing for transport by helicopter, aeroplane or any other means of transport. Furthermore, it is preferable to take into consideration equipment operating with ordinary commercial power supplies. Fixed wireless systems generally require line-of-sight operation. For digital fixed wireless systems, the interface should be based on the primary rate (2 Mbit/s (E1) or 1.5 Mbit/s (T1)) or 155.52 Mbit/s (STM-1).

#### 7.1.3.6 Vehicle-mounted use of transportable FS equipment (Type D or E system) in combination with transportable mobile base stations

One of the main usages of FWS (Fixed Wireless System) is for mobile backhaul link, which also can be constructed using a cable system such as optical fibre.

In a widespread disaster, not only an access link to a base station (using whether FWS or a cable system) but also a mobile base station may be damaged and become unusable. Therefore, both a portable FWS backhaul link and a portable mobile base station should be mounted on a vehicle so that both equipment would be easily interconnected at the disaster hit area. Such an operating condition makes it possible to restore the telecommunication infrastructure effectively and to provide the service to end-users quickly.

As an example, the vehicle-mounted disaster relief operation system developed for the above purpose is provided in the next section.

### *7.1.4 Specifications for vehicle-mounted use of transportable FS equipment in combination with a mobile base station for disaster relief operation*

The transportable FWS uses the different frequency bands, i.e. some of the example frequency bands in Table 7-2 (row E), depending on the interference condition and/or the transmission distance needed in the disaster hit area. In particular, the upper 4 GHz and 18 GHz band systems are light weight and small in size. Therefore they are easy to install on a vehicle and easy to use. The main specifications of these systems are shown in Table 7-3.

The main specifications of the transportable mobile base station to be interconnected to the transportable FWS are shown in Table 7-4. The overall conceptual diagram of such system is shown in Figure 7-1.

**Table 7-3: Main specifications of transportable FWS for vehicle-mounted use for disaster relief operation**

| Frequency band (*) | Capacity | Interface | Antenna type | Transmission distance |
|---|---|---|---|---|
| Upper 4 GHz band (4.92-5.0 GHz) | 7-35 Mbit/s | 100BASE-TX (**) | 36 cm flat panel | 10 km |
| 18 GHz band (17.85-17.97/ 18.6-18.72 GHz) | 155.52 Mbit/s | STM-1 | 0.4-1.2 m diameter dish | 3.5 km |

(*) The RF channel is selected within the assigned frequency band.
**(**)** Connected to the MPX (multiplexer) via Ether/ATM convertor.

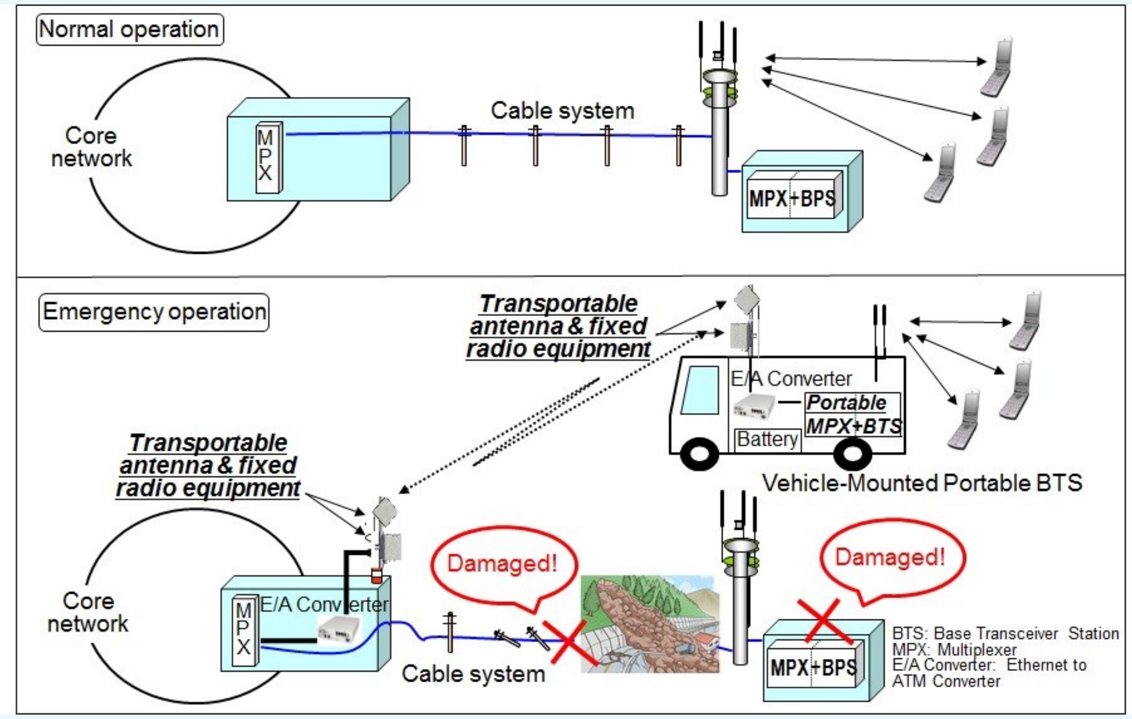
**Table 7-4: Example parameters of transportable mobile base station for vehicle-mounted use for disaster relief operation**

| Frequency band | Bandwidth (Carrier number) | Antenna type |
|---|---|---|
| 800 MHz (830-845/875-890 MHz),<br>2 GHz (1 940-1 960/2 130-2 150 MHz) | 15 MHz (3 carriers)(*),<br>20 MHz (4 carriers)(*) | Corner reflector (40 cm × 3 7cm),<br>Corner reflector (23 cm × 42cm) (**) |

(*) The bandwidth of 1 carrier is 5 MHz.
(**) Maximum aperture.

Figure 7-1 shows the conceptual diagram of the vehicle-mounted disaster relief operation system for the upper 4 GHz band.

**Figure 7-1: Conceptual diagram of the vehicle-mounted disaster relief operation system for the upper 4 GHz band**




## 7.2 Transportable VSAT earth stations

[For further information see Report ITU-R S.2151 and "Handbook on satellite communications" Wiley-ITU]

The term "Very Small Aperture Terminal", or simply "VSAT" was introduced in the eighties to designate small earth stations generally implemented in the framework of "VSAT systems" (or "VSAT networks") used for private corporate communications.

Very Small Aperture Terminal, is a two-way satellite earth station with a dish antenna that is smaller than 3 meters. The majority of VSAT antennas range from 75 cm to 1.2 m. Data rates typically range from 56 kbit/s up to 4 Mbit/s. VSATs access satellite(s) in geosynchronous orbit to relay data from small "remote" earth stations (terminals) to other terminals (in mesh topology) or master earth station "hubs" (in star topology).

VSATs designed for fixed installation are used to transmit narrowband data (point of sale transactions such as credit card, polling or RFID data, etc.), or broadband data (for the provision of satellite Internet access to remote locations, VoIP or video). VSAT networks can also support basic telecommunications infrastructure restoration requirements including the Public Switched Telephone Network (PSTN). Fixed VSAT (remote) earth stations are generally directly installed on users' premises and unattended. Their location density may be high.

VSATs are also frequently used to meet emergency telecommunications requirements and for this use so-called "transportable" systems (including vehicle-mounted and hand-carried earth stations) have been designed. Also transportable VSATs can offer high-speed Internet connections, that are independent of the telecommunication terrestrial system infrastructure, to re-establish voice, data and video connectivity. In particular VSAT networks can provide for restoration of wireless cellular nodes and WiMAX WAN (Wide Area Network) networks for public and private first responders networks. Dishes for disaster relief and recovery are often smaller to allow for rapid transportation to, and installation at, the disaster area. VSATs for this application should be quickly made operational with no special tools or test equipment for installation.

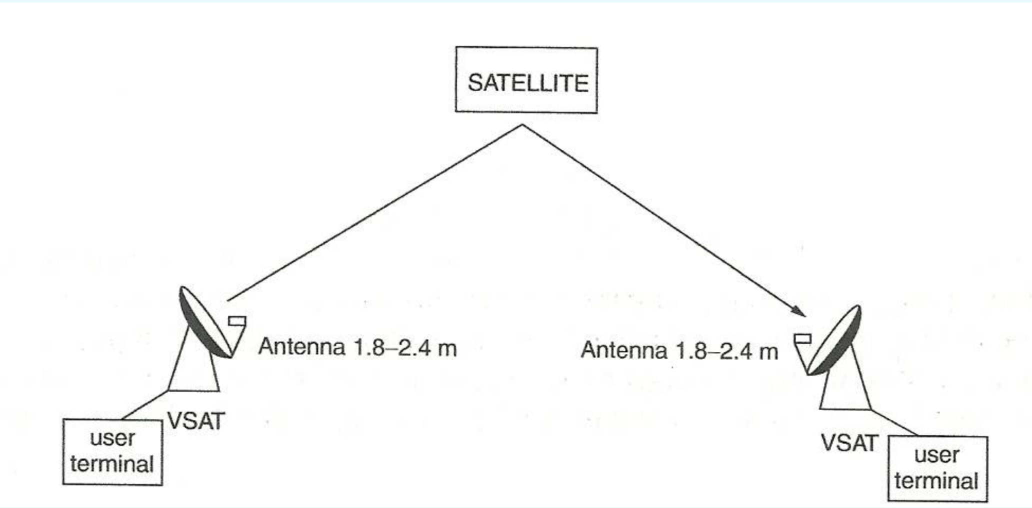
### 7.2.1 VSAT network architecture and requirements

VSAT earth stations are usually implemented to form closed networks for dedicated applications either for information broadcasting (receive only VSATs) or for information exchange (transmit/receive VSATs).

VSAT networks can be designed and managed in accordance with two architectures:

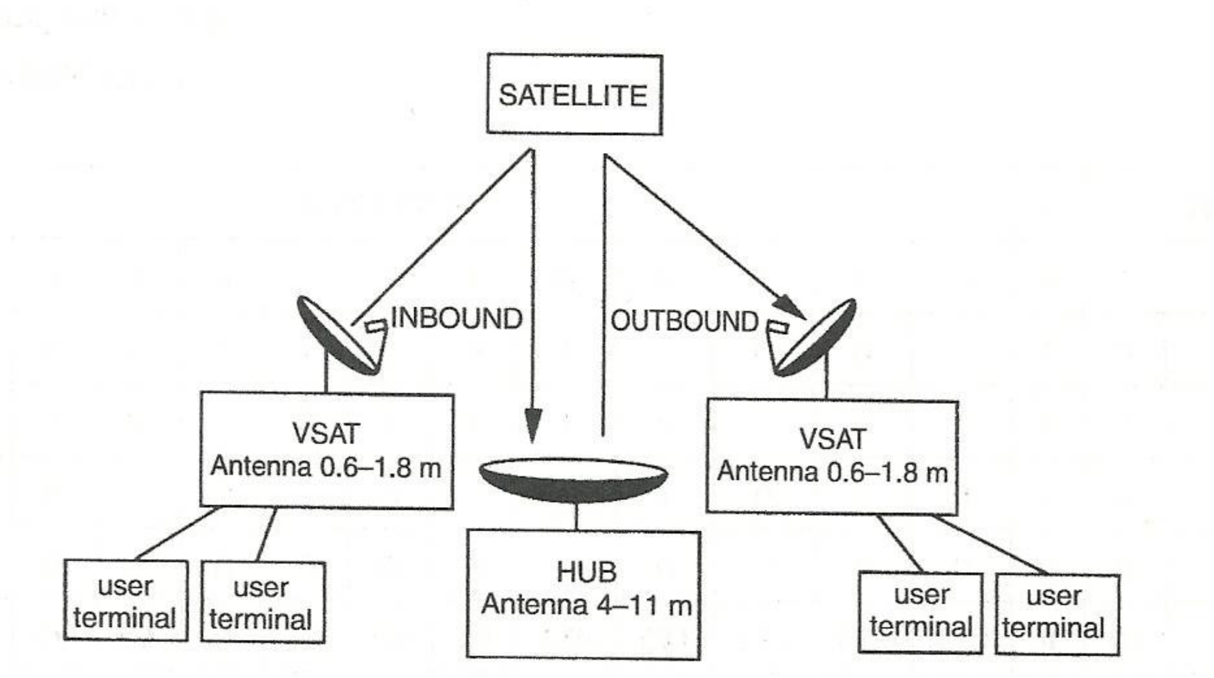
– a mesh architecture characterized by a direct link among the earth stations (Figure 7-2);

**Figure 7-2: User terminal connectivity within meshed VSAT networks**




– a star architecture in which a central earth station, usually called the "hub", is linked to a large number of geographically dispersed remote. In most applications the hub is connected, possibly through terrestrial lines, to a host computer. The block diagram of a star architecture is shown in Figure 7-3.

**Figure 7-3: User terminal connectivity using the hub as a relay in star shaped networks**




The basic telecommunication architecture for relief operations should be composed of a link connecting the disaster area and designated relief centres, supporting basic telecommunication services comprising at least telephony, any kind of data (IP, datagrams, facsimile), and video.

For relief operations, due to the essential requirement of having small antennas, it is preferable to operate the network in the 14/12 GHz band or even in the 30/20 GHz band. Although the bands such as 6/4 GHz require larger antennas, they are also suitable depending on conditions of transmission and coverage of satellite resources. In order to avoid interference, it should be taken into account that some bands are shared with terrestrial services.

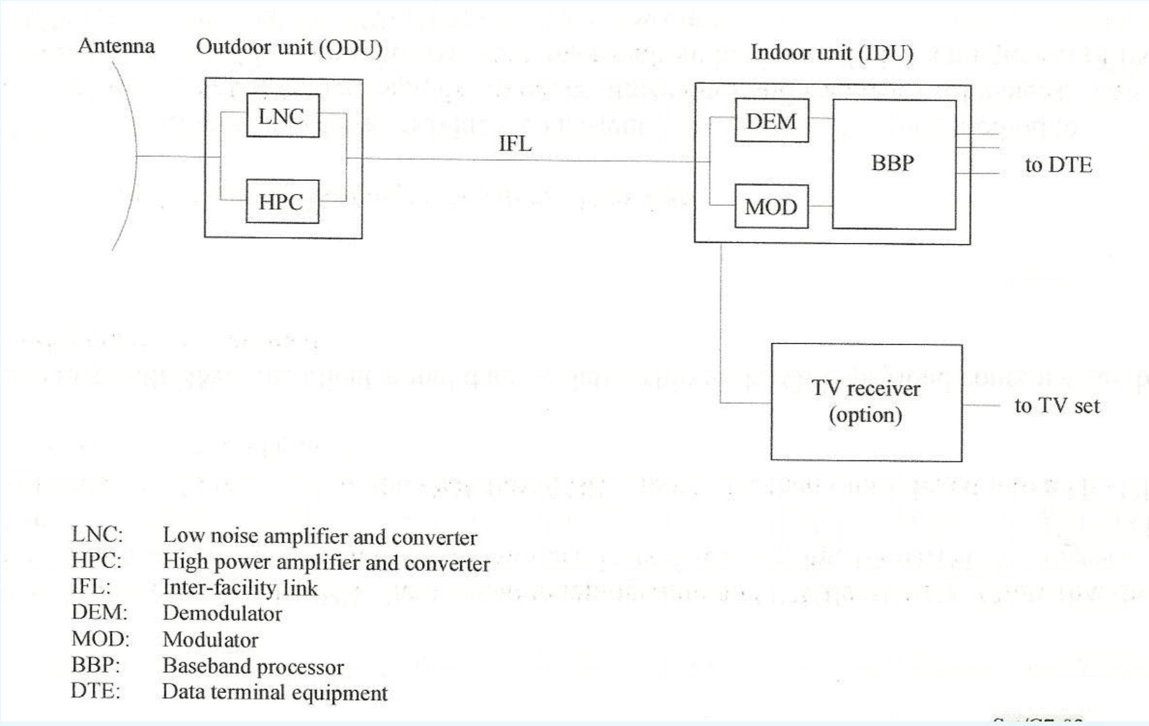
VSAT networks should offer suitable quality of service. In case the network is shared with customers having non-urgent needs, the emergency operations should have absolute priority which means a "pre-emption" class of service. A fully private network, with reserved frequency bands and facilities, could be desirable.

When the number of operational earth stations is large, a network control based on Demand Assignment Multiple Access (DAMA) may be necessary.

### 7.2.2 VSAT earth stations characteristics

A VSAT remote earth station (fixed, vehicle-mounted, hand-carried) is functionally divided into three major elements: the antenna, the outdoor unit (ODU) and the indoor unit (IDU). The typical configuration of a VSAT is shown in Figure 7-4. All three components are compact and designed for low cost mass production. This section mainly describes the configuration of VSATs for 14/12 GHz band operation. The configuration for 6/4 GHz band operation is similar except for the antenna and RF circuit.

**Figure 7-4: Typical configuration of a VSAT**




Small offset parabolic antennas with typically 1 to 2 meter diameters are widely used. The ODU typically contains RF electronics such as a low noise converter (a low noise amplifier with a down converter) and a high power converter (a high power amplifier with an up converter) in a compact weather-proof housing with an integrated antenna feed horn, and is installed behind the antenna focal point. The antenna with the ODU can be installed very easily on the roof top, on the wall, or in the car park of the user's office buildings, where the user data terminals are located.

The IDU typically contains an IF circuit, a modem and a baseband signal processor. Sometimes the modulator circuits are contained in the ODU instead of in the IDU. The IDU is usually installed near the user data terminals and connected to them directly through the standard data communication interface. Usually an optional TV receiver can be connected to the IDU to receive TV signals transmitted by another transponder of the same satellite. The ODU and the IDU are connected by inter-facility link (IFL) cable(s). The IDU can be separated from the ODU by as much as 100 m to 300 m.

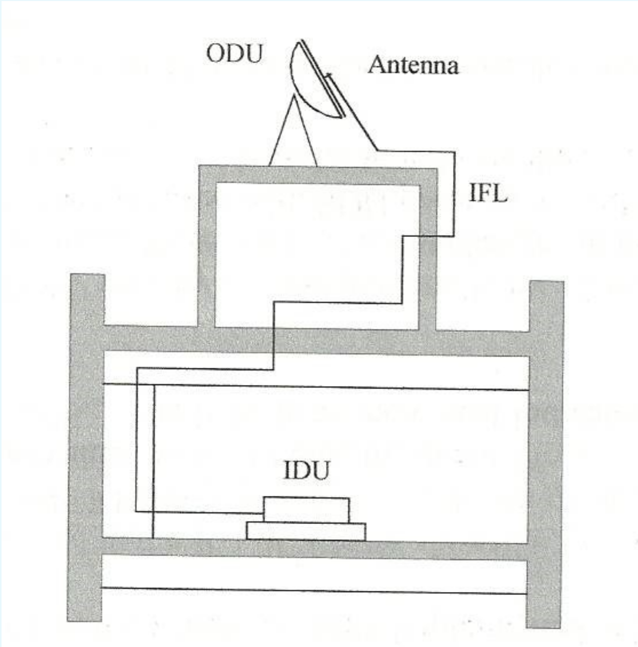
A typical installation layout of the VSAT is shown in Figure 7-5. Consideration should be given to safety aspects to protect the VSATs earth stations, such as tolerance to high winds, avoidance of electrical shock, lightning protection, and protection from radio-frequency radiation hazards.

Typical values adopted for wind speed and deicing in VSAT station are the following:

– Wind speed: operation 75 to 100 km/h survival 210 km/h;

– Deicing Electric (optional) or passive (hydrophobic coating).

**Figure 7-5: Typical installation of a VSAT**




VSATs should also include control and monitoring equipment, terminal equipment (including facsimile and telephones) and support facilities.

In order to best support requirements for disaster telecommunications management, VSATs solutions should be evaluated based on size, ease of installation and transportation, weight of materials, and frequency and bandwidth requirements.

As a result of an example of link budget calculation based on the assumption that a small earth station (a fixed VSAT, a "vehicle-mounted" earth station or a "hand-carried" earth station) operating in the disaster area communicates with a hub earth station equipped with a larger antenna, the diameters of the antennas are indicated in Tables 7-5 and 7-6:

**Table 7-5: Remote earth station antennas**

| Frequency band (GHz) | 6/4 | | 14/12 | | 30/20 | |
|---|---|---|---|---|---|---|
| Antenna diameter | 2.5 m | 5.0 m | 1.2 m | 3.0 m | 1.2 m | 2.4 m |

**Table 7-6: HUB earth station antennas**

| Frequency (GHz) | 6/4 | 14/12 | 30/20 |
|---|---|---|---|
| Antenna diameter | 18 m | 7.6 m | 4.7 m |

From this example of the link budget calculation it appears the antenna diameter of a small earth station (in particular vehicle-mounted or hand-carried) is assumed to be 2.5 m or 5 m for the 6/4 GHz band and 1.2 m or 3 m for the 14/12 GHz band and 1.2 m or 2.4 m for the 30/20 GHz band.

For 14/12 GHz and 30/20 GHz stations, smaller diameter antennas (such as 45 cm and 75 cm ) may be used if appropriate measures are adopted. However Radio Regulations (RR) including the off-axis limitation should be considered when using those antennas. The use of small antennas may not allow meeting the off-axis emission criteria, therefore the earth station transmit power should be reduced in order to avoid the interference to adjacent satellites and other services.

Considering that one of the major requirements for the antenna is ease of erection and transportation, the antenna reflector could consist of several panels made of light material such as fibre reinforced plastic or aluminium alloy. A manual or automatic pointing system may be provided commensurate with weight and power consumption,

### 7.2.3 Additional requirements for transportable earth stations

Efforts have been made to decrease the size and to improve transportability of earth stations so as to facilitate use of satellite services for many applications. For emergency applications, it is desirable that fixed, vehicle-mounted and hand-carried VSATs earth stations, with access to an existing satellite system, should be available for an easy transportation to, and installation at, the disaster area. This allows the occasional or temporary use of these earth stations for relief operations anywhere a disaster might occur.

Examples of transportable earth station realizations are in Section 7.2.4.

It is also desirable that the system relies on widespread standards so that equipment is readily available, interoperability is ensured and reliability is ensured. For the smooth operation of earth stations in the event of a disaster, regular training for potential operators and preparatory maintenance of the equipment is essential. Particularly, special attention should be given to the inclusion of autonomous battery or power systems.

#### 7.2.3.1 Requirements for vehicle mounted VSATs

An earth station in which all the necessary equipment is installed in a vehicle, e.g. a four-wheel drive van, permits operation within 10 minutes of arrival including all necessary actions such as antenna direction adjustments.

#### 7.2.3.2 Requirements for hand-carried VSATs

A hand-carried earth station is disassembled prior to transportation and quickly reassembled at the site within approximately 15 to 30 min. All the equipment, including shelters, should be capable of being packaged into units of weight which can be handled by a few persons. The size and weight of the equipment normally allow it to be carried by hand by one or two persons, and the containers are within the limit of the International Air Transport Association (IATA) checked luggage regulations, if transported by air. It is also possible to carry the equipment by helicopters.

Total weight of this type of earth station including power generator and antenna assembly is reported to be as low as 150 kg, but 200 kg is more usual. This is readily attainable with present-day technology. The allowable size and weight specifications of the various aircraft should be consulted during the design of satellite terminals for disaster relief telecommunications.

Some characteristics of small transportable earth stations in the 14/12 GHz band are shown in Table 7-7.

**Table 7-7: Characteristics of transportable earth stations for the 14/12 GHz band**

| Type of transportation | Air transportable |
|---|---|
| Antenna diameter (m) | 1.2~21.8 |
| RF bandwidth (MHz) | 20~30 |
| Total weight | 200~275 kg |
| Package:<br>• Total dimensions (m)<br>• Total number<br>• Max. weight (kg) | <br><2<br>8~13<br>20~45 |
| Capacity of engine generator (kvA) | 0.9~93 |
| Required number of persons | 1~3 |

### 7.2.4 Example of transportable earth station characteristics (from Japan)

Examples of small transportable earth stations for use with Japanese communication satellites in the 14/12 GHz band are shown in Table 7-8.

**Table 7-8: Examples of small transportable earth stations for the 14/12 GHz band**

| Example No. | 1 | 2 | 3 | 4(1) | 5 | 6 |
|---|---|---|---|---|---|---|
| Type of transportation | Vehicle equipped | | | | | |
| Antenna diameter (m) | 2.6 × 2.4 | 1.8 | 1.2 | 1.8 | 0.9 | 1.5 × 1.35 |
| e.i.r.p. (dBW) | 72 | 70 | 62.5 | 65.1-71.2<br>(95-400 W)(2) | 54-64<br>(20-200 W)(2) | 72<br>(400 W)(2) |
| RF bandwidth (MHz) | 24-27 | 20-30 | 30 | 1.4-60 Mbit/s | 64 kbit/s-60 Mbit/s | 1.4-60 Mbit/s |
| Total weight | 6.4 tons | 6.0 tons | 2.5 tons | 250 kg(3) | 70 kg(4) | 210 kg |
| Package:<br>– Total dimensions (m)<br>– Total number<br>– Max. weight (kg) | <br>–<br>–<br>– | <br>–<br>–<br>– | <br>–<br>–<br>– | <br>2.62 × 1.95 × 0.88<br>–<br>< 345 kg | <br>1.2 × 1.1 × 0.4 m<br>1<br>– | <br>2.37 × 1.53 × 0.45<br>1<br>– |
| Capacity of engine generator or power consumption | 7.5 kVA | 10 kVA | 5 kVA | ~ 4 100 W | ~ 4 100 W | ~ 4 100 W |
| Required number of persons | 1-2 | 1-2 | 1-2 | 1 | 1 | 1 |

| Example No. | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|
| Type of transportation | Air transportable | | | | | | | | |
| Antenna diameter (m) | 1.8 | 1.4 | 1.2 | 0.75 | 0.9 | 0.9 × 0.66 | 1 | 0.9 | 0.9 × 0.66 |
| e.i.r.p. (dBW) | 70 | 64.9 | 62.5 | 42.5 | 44.0 | 51.7 | 55 | 66 | 51.7 |
| RF bandwidth (MHz) | 20-30 | 30 | 30 | Up to 0.5 | Up to 0.5 | 2 | 6 | 64 k ~ 60 Mbit/s | 64 k ~ 4 Mbit/s |
| Total weight (kg) | 275 | 250 | 200 | 131 | 141 | 100 | 110 | 130 | 39 |
| Package:<br>– Total dimensions (m)<br>– Total number<br>– Max. weight (kg) | <br>2<br>10<br>45 | <br>2<br>13<br>34 | <br>2<br>8<br>20 | <br>1<br>5<br>37 | <br>1.2<br>5<br>37 | <br>–<br>–<br>– | <br>–<br>–<br>– | <br>1 × 0.6 × 1.2<br>3(5)<br>< 43 kg | <br>70 × 47 × 31 (cm)<br>1<br>39 kg |
| Capacity of engine generator or power consumption | 3 kVA | 0.9-1.3 kVA | 1.0 kVA | < 370 W | < 370 W | < 2 kVA | < 2 kVA | ~ 4 100 W | 750 W |
| Required number of persons | 2-3 | 2-3 | 1-2 | 1-2 | 1-2 | 2 | 3 | 1 | 1 |

(1) Flyaway.
(2) The amplifier size is selectable for the purpose.
(3) Total weight does not include the weight of the car.
(4) Without amplifier.
(5) There are three packages; the sizes are 72 × 60 × 26 (cm), 51 × 29 × 40 (cm) and 100 × 60 × 40 (cm) respectively.

Also several types of 30/20 GHz small transportable earth stations, which can be transported by a truck or a helicopter, have been manufactured and operated satisfactorily in Japan.

Examples of small transportable earth stations for operation at 30/20 GHz are shown in Table 7-9.

**Table 7-9: Examples of small transportable earth stations for the 30/20 GHz band**

| Operating frequency (GHz) | Total weight (tons) | Power require-ment (kVA) | Antenna | | Maxi-mum e.i.r.p. (dBW) | *G/T* (dB/K) | Type of modulation | Total setting-up time (h) | Normal location of earth station |
|---|---|---|---|---|---|---|---|---|---|
| | | | Diameter (m) | Type | | | | | |
| 30/20 | 5.8 | 12 | 2.7 | Cassegrain | 76 | 27 | FM (colour TV 1 channel)(1)<br>or<br>FDM-FM (132 telephone channels) | 1 | On a truck |
| | 2 | 9 | 3 | Cassegrain (2) | 79.8 | 27.9 | FM (colour TV 1 channel)(1)<br>and<br>ADPCM-BPSK-SCPC<br>(3 telephone channels) | 1 | On the ground |
| | 1 | 1(3) | 2 | Cassegrain | 56.3 | 20.4 | ADM-QPSK-SCPC<br>(1 telephone channel) | 1.5 | On the ground |
| | 3.5(4) | < 8.5 | 1.4 | Offset Cassegrain | 68 | 20 | Digital-TV (3 voice channels are multiplexed)(1)<br>or 1 voice channel | > 1 | On a van/SUV |
| | 0.7 | 3 | 1 | Cassegrain | 59.9 | 15.2 | FM-SCPC<br>(1 telephone channel)<br>or<br>DM-QPSK-SCPC<br>(1 telephone channel) | 1 | On a truck |

(1) One-way.
(2) The reflector is divided into three sections.
(3) Excluding power for air conditioning.
(4) Include vehicle.

### 7.2.5 Examples of VSAT emergency networks

#### 7.2.5.1 Example of an emergency network in Italy using the 14/12 GHz band

An emergency satellite network has been designed and implemented in Italy for operation in the 14/12.5 GHz frequency band via a EUTELSAT transponder. This dedicated network, which is based on the use of wholly digital techniques, provides emergency voice and data circuits and a time shared compressed video channel for relief operations and environmental data collection. The network architecture is based on a dual sub-networking star configuration, for the two services. The ground segment is composed of:

i) a master common hub station for the two star networks, which is a fixed-earth station having a 9 m antenna and a 80 W transmitter;

ii) a small number of transportable earth stations, having antennas of 2.2 m and 110 W transmitters;

iii) a number of fixed data transmission platforms with 1.8 m dishes and 2 W solid state power amplifier transmitters.

The transportable earth stations are mounted on a lorry, but if necessary, can also be loaded in a cargo helicopter for fast transportation. They are equipped with two sets of equipment each containing one 16 kbit/s (vocoder) voice channel and one facsimile channel at 2.5 kbit/s. These earth stations which are also able to transmit a compressed video channel at 2.048 Mbit/s, are remotely controlled by the master station. The major features of this *ad hoc* emergency network are summarized in Table 7-10.

**Table 7-10: Example of an emergency satellite radiocommunication network operating at 14/12 GHz**

| Station designation | Antenna diameter (m) | Primary power requirement (kVA) | Service capability |
|---|---|---|---|
| Master | 9.0 | 15.0 | 12 × 16 kbit/s<br>(vocoder)<br>voice channels |
| | | | 12 × 2.4 kbit/s<br>facsimile channels<br>1 × 2.048 Mbit/s<br>video channel |
| Peripherals (transportable) | 2.2 | 2.0 | 2 × 16 kbit/s<br>(vocoder)<br>voice channels<br>2 × 2.4 kbit/s<br>facsimile channels |
| | | | 1 × 2.048 Mbit/s<br>video channel |
| Unattended platforms | 1.8 | 0.15 | 1 × 1.2 kbit/s<br>data transmission channel |

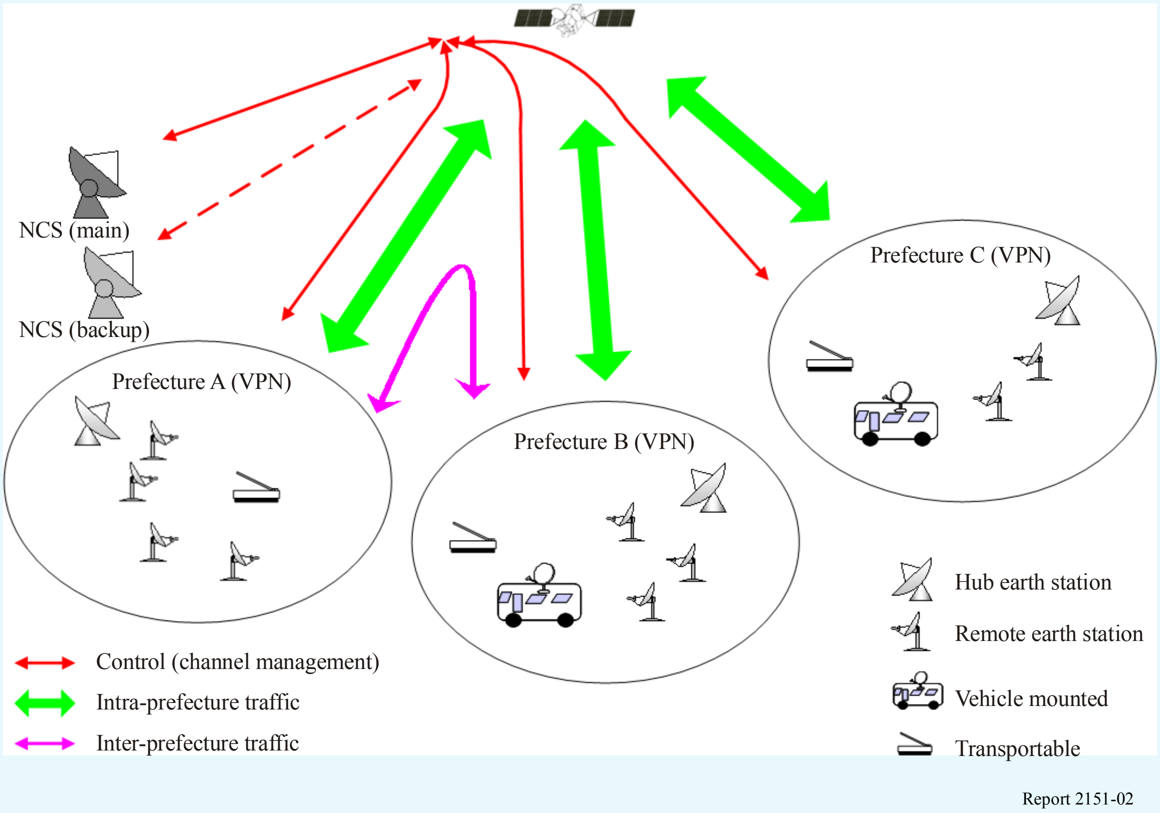
#### 7.2.5.2 Example of an emergency network in Japan using the 14/12 GHz band

In Japan, there is a satellite network operating in the 14/12.5 GHz frequency band mainly for the purpose of emergency radiocommunications that accommodates more than 4 700 earth stations including VSATs located at municipal offices and fire departments, transportable earth stations and vehicle-mounted earth stations. The network provides voice, facsimile, announcement (simplex), video transmission and high-speed IP data transmission.

As shown in Figure 7-6, the network is based on DAMA, so that satellite channels can be efficiently shared by as many as 5 000 earth stations. An earth station asks the Network Coordination Station (NCS) for the assignment of traffic channels such as voice, facsimile and IP transmission prior to its radiocommunication with other earth stations. Note that there are two NCSs, main and backup, in the network.

The network is designed to have a multi-star topology where each prefecture (note that Japan consists of 47 prefectures) configures an independent sub-network so that the principal office of the prefecture can be the hub of emergency radiocommunications in the case of an event. By virtue of the closed-group network, the satellite resources can be controlled by the NCS depending on urgency of events. For instance, the NCS can provide priorities for radiocommunications originated from a particular prefecture where an emergency event occurs over routine radiocommunications in other prefectures. The network also provides inter-prefecture radiocommunications if any.

**Figure 7-6: Configuration of the emergency network**




In order to help telecommunications from/to an area damaged by disasters, the development of smaller user earth stations with high performance is under way. Typical parameters of such earth stations are listed in Table 7-11. There are two types of vehicle-mounted earth stations. Type-A earth station is designed to transmit full motion picture based on MPEG-2 (i.e. 6 Mbit/s) and provide a voice circuit simultaneously available during video transmission. The earth station is to be mounted on a relatively large vehicle such as "Wagon" type. On the other hand, a type-B earth station is designed to transmit a low rate limited-motion picture by MPEG-4/IP (i.e. 1 Mbit/s) with a voice circuit switchable with video transmission. The earth station is to be mounted on a smaller vehicle such as "Land-cruiser" type. Similar to type-B vehicle-mounted earth stations, the transportable earth station is designed to transmit a low rate limited-motion picture by MPEG-4/IP with a voice circuit switchable with video transmission. Its video transmission rate is only 256 kbit/s.

**Table 7-11: Parameters of the vehicle-mounted and transportable earth station**

| Parameters | Vehicle-mounted earth station | | Transportable earth station |
|---|---|---|---|
| | Type-A | Type-B | |
| Description | – Full-motion pictures based on MPEG-2<br>– Simultaneous voice circuit | – IP-based low-rate motion picture based on MPEG-4<br>– Voice circuit switchable with the video circuit | – IP-based low-rate motion picture based on MPEG-4<br>– Voice circuit switchable with the video circuit |
| Antenna diameter | 1.5 m (offset parabola) | 75 cm (offset parabola) | 1 m (Flat array) |
| Number of channels and transmission rate | Video: 1 channel<br>(6 Mbit/s, MPEG2)<br>Voice/IP: 1 channel | Video: 1 channel<br>(1 Mbit/s, IP)<br>Voice/IP: 1 channel | Video: 1 channel<br>(256 kbit/s, IP)<br>Voice/IP: 1 channel |
| Type of vehicle | Wagon type | Land-cruiser type | N/A |

### 7.2.5.3 Example of an emergency network in South-East Asia using the 14/12 GHz band

An agency in South-East Asia has set up an end-to-end broadband VSAT system to improve the broadband telecommunication between its offices and enhance the e-risk management policy.

The satellite network interconnects the headquarters (redounded) with:

– 13 national offices;

– 25 county offices;

– 72 villages;

– 12 emergency vehicles.

Based on IP, it offers all the common services of an intranet such as access to web and FTP servers, electronic messaging and content distribution in multicast, e.g. streaming. In addition, it offers broadband applications relevant for crisis management (e-risks services suite): videoconferencing, collaborative working and voice-over-IP.

In normal situations, the system carries up to 8 Mbit/s:

– 2 Mbit/s shared by all voice radiocommunications;

– 3 Mbit/s for central data exchanges;

– 3 Mbit/s for data shared by other data exchanges.

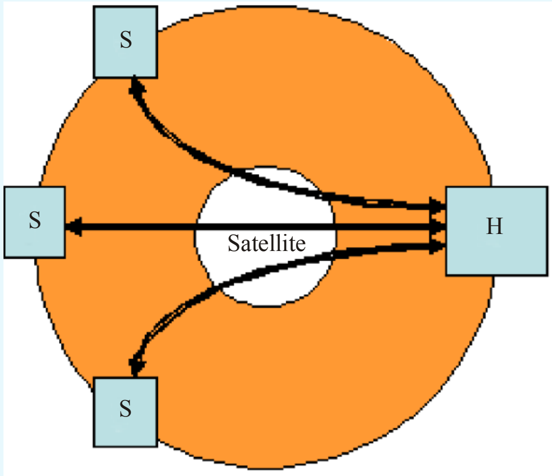
In crisis situations, the system carries up to 21 Mbit/s:

– 12 Mbit/s for two video streams;

– 9 Mbit/s for up to 16 videoconference terminals.

The topology chosen is the star topology (as opposed to the mesh one) with a hub installed at the headquarters and satellite terminals installed at the remote sites listed above (Figure 7-7).

**Figure 7-7: Star topology**




Star

Report 2151-03

This topology is the best suited to services such as videoconferencing since they are by nature point-to-multipoint with a multipoint control unit located at the hub. This one also enables access to the Internet by means of a broadband access server. It shall be located abroad from the place of the disaster and therefore there is less constraint on the facilities; for example, the antenna can be as large as necessary.

The network operates in 14/12 GHz band (the 14 GHz band for the uplinks; the 12 GHz band for the downlinks). 14/12 GHz band antennas are smaller and lighter, which eases the use and the transportation of material. The terminals are state-of-the-art with a diameter ranging from 0.6 m to 1.2 m; the diameter is chosen so as to optimize the trade-off between the signal-to-noise ratio and the ease of transportation. The RF subsystem of remote terminals is specified in the norm as the outdoor unit.

The satellite access technology on the return link is fixed multi-frequency time division multiple access (fixed MF-TDMA). Fixed MF-TDMA allows a group of satellite terminals to communicate with the hub using a set of carrier frequencies of equal bandwidth while the time is divided into slots of equal duration. The network control centre at the hub will allocate to each active satellite terminal series of bursts, each defined by a frequency, a bandwidth, a start time and a duration.

Satellites terminals can be controlled from the hub, they can be configured, faults can be detected and software can be downloaded.

## Bibliography

1 – ITU-R Recommendation 1105**,**

http://www.itu.int/md/R12-WP5C-C-0171/enhttp://www.itu.int/md/R12-WP5C-C-0171/en]

2 – Report ITU-R S.2151 “Use and examples of systems in the fixed-satellite service in the event of natural disasters and similar emergencies for warning and relief operations”

http://www.itu.int/pub/R-REP-S.2151-1-2012

3 – “Handbook on satellite communications” Wiley-ITU

4 – New Report ITU-R.S.[vsat] “Technical and operational requirements for very small aperture terminals (VSATs), WP 4B, Annex 7, (28 May – 1 June 2012)

http://www.itu.int/md/R12-WP4B-C-0028/en

5 – Document 2/245Rev.1-30 November 2009 "Guidelines for Implementation of Satellite Telecommunications for Disaster Management in Developing Countries" ,

http://www.itu.int/md/choice_md.asp?id=D06-SG02-C-0245!R1!MSW-E&lang=en&type=sitems

6 – Report ITU-D SG2 Period 2006-2010 "Manual on Satellite aspects for disasters"

http://www.itu.int/dms_pub/itu-d/opb/stg/D-STG-SG02.22-2010-01-PDF-E.pdf

7 – Rec. S.1001 "Use of systems in the fixed-satellite service in the event of natural disasters and similar emergencies for warning and relief operations",

http://www.itu.int/rec/R-REC-S.1001-2-201001-I/en

8 – "VSAT networks", Gerard Maral, John Wiley

# Chapter 8

# Risk assessment and cost/effectiveness analysis for the mitigation activities of the hazards effects

## 8 Introduction

Hazards, emergency and disasters threaten many areas of the world. Whether it is a natural disaster or a technological accident, risk management should put systems in place to prevent and reduce losses and damages. The following management strategy is known to reduce risk:

– hazard risk assessment analysis;

– mitigation strategy;

– cost/effectiveness analysis.

The first step is to prepare a hazard risk assessment analysis for the area of interest that means to identify hazards, to estimate their intensity and likelihoods, to evaluate their consequences. This is the subject of Section 8.1.

The second step is to develop a management strategy suitable to face the hazard. As already known, a hazard management strategy is based on four activities: hazard mitigation, emergency preparedness, emergency response and disaster recovery. Mitigation and preparedness take place before disasters strike. Response and recovery activities tale place after the disasters have occurred. The objective of this Handbook is mainly to look at the design criteria of the telecommunication outside plants in areas particularly exposed to natural disasters. This means that among the four above quoted activities, the attention is focused on hazard mitigation. It is clear that actions devoted to apply more stringent design criteria in order to better face future hazards can also be taken during the disaster recovery phase (e.g. during the reconstruction of the damaged plants). However for sake of simplicity reference is mainly made in this Chapter to the mitigation phase. This is the subject of section 8.2.

The third and last step is a cost/effectiveness analysis (incurred costs/achievable benefits) of the mitigation actions. This is the subject of section 8.3.

### 8.1 Hazard risk assessment analysis

[For further information see Bibliography]

Hazard risk assessment is the process through which the threat posed in the area of interest by each identified hazard is investigated. Risk is evaluated in two steps. The first is hazard identification, and description (intensity and probability). The second is the evaluation of the hazard consequences. Together these two factors inform us of how concerned we should be about the existence of a hazard. Generally, high-likelihood/high-consequence hazards are of great concern, while low likelihood/low-consequence hazards are of least concern, and all of the others full in between.

### 8.1.1 Hazard identification and description

*Hazard identification*, as the name suggest, is the process through which all hazards that have or could affect an area of interest are identified and described. This is done through a number of methods, including historical study, brainstorming, scientific analysis and subject matter expertise. For example, historical data for the past hundred years show that residents who live on the Atlantic and Gulf coast of the US are exposed to hurricanes, while people who live on the Pacific Northwest and the Hawaii are exposed to volcanoes. To be comprehensive, a hazards risk assessment effort must look not at each hazard individually and irrespective of the others, but rather at the entire hazards portfolio as interconnected and as each hazard having an influence on the effects and risks of the others.

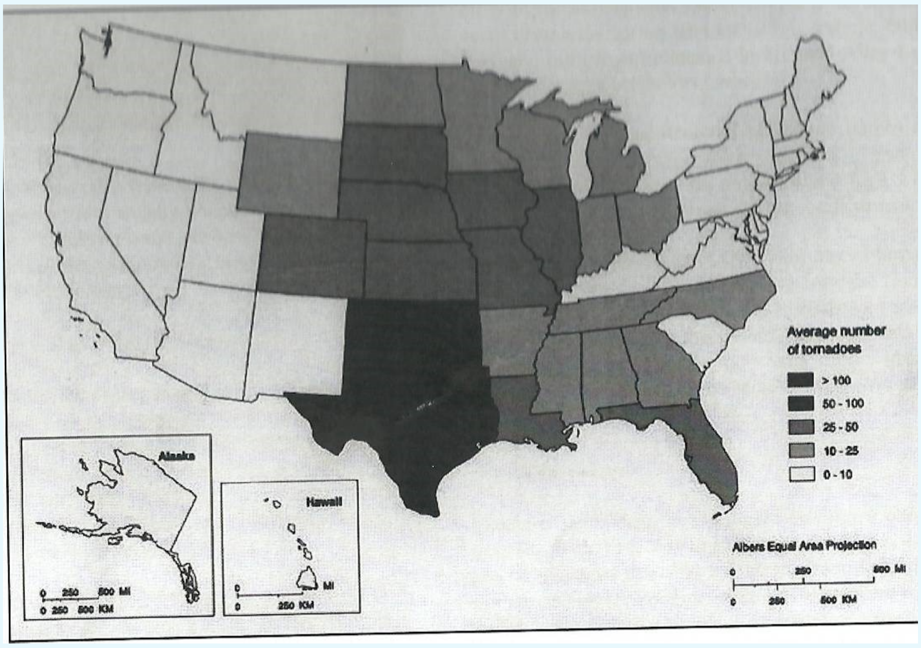
*Hazard description*, or profiling as it is also called, is a further step, where the particular characteristics of the specific natural hazard, possibly impacting the studied area, is defined.

Each hazard has the following significant characteristics:

- the *intensity* of the hazard, which is generally defined in accordance with a recognized category/scale;
- the size of the geographical area affected by disaster impacts;
- the duration of impact, which is the length of time the disaster impact persists;
- the *probability* of occurrence.

In order to carry out hazard description there are many useful sources of information that can be used. As an example related to the US, one source is the set of maps contained in FEMA Multi Hazard Identification and Risk assessment, as those shown in Figures 8-1 and 8-2.

**Figure 8-1: Average annual number of tornadoes per state in the period 1953-1993**

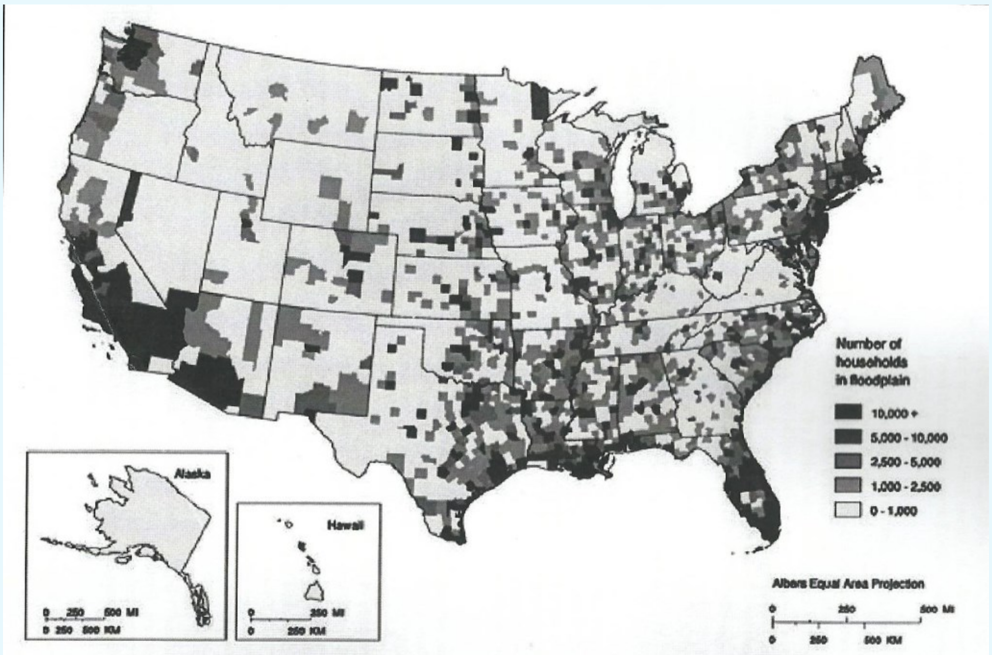



This source describes exposure to most natural hazards. These maps of natural hazards exposures can be supplemented visiting several Web site, including those belonging to the same FEMA (www.fema.gov), U.S. Geological Survey (www.usgs.gov), and National Weather Service (www.nws.noaa.gov).

However even if these maps provide a good start toward assessing the potential impact of disasters, they have some limitations:

– many of these maps are designed to compare the relative risk of large areas. This information does not tell which zones within the area of interest are most likely to be struck by a disaster. For example, a coastal region might be exposed to hurricanes, but only a small area is exposed to significant damage. Smaller scale maps are needed to assess exposure of limited areas;

**Figure 8-2: Geographic distribution by county of households in the United States in the 1-percent-annual-chance floodplain**




– these maps vary in the amount of information they provide. For example, hurricane maps identify areas that will be hit by category 1-5 hurricanes. However these maps do not provide with the probability of each category of hurricane striking the area of interest. By contrast, other earthquake maps give the probability that an earthquake will exceed a given intensity. Some maps tell which areas in a city contain buildings that are the most likely to collapse. However within each of these areas, each building probability of collapse must be assessed by structural engineers;

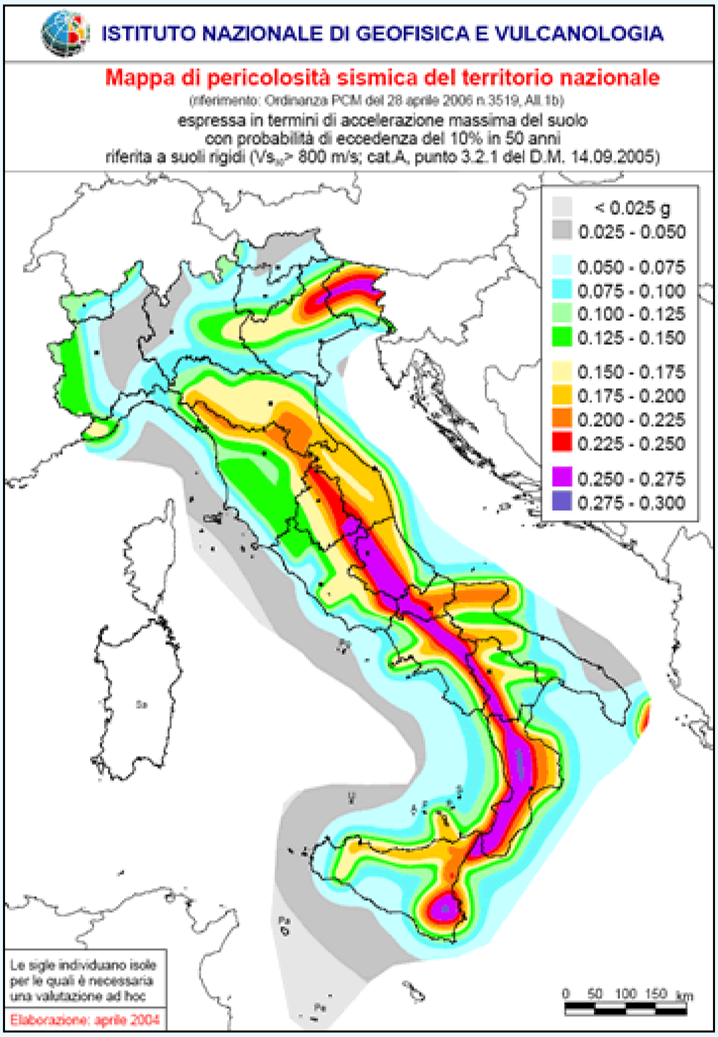
– these maps often lack important information about the relative risk of different hazards. In deciding how to allocate the available resources, it is necessary to know what is the likelihood of a flood in comparison to a tornado and to an earthquake;

– in many cases it is only possible to categorize disaster impact as high, medium or low. This provide only a rough estimate for determining which hazards need the most attention. Considering that some emergency management measures are hazard specific, the possibility of ranking hazards in the area of interest can help to allocate resources to get the biggest reduction in likely casualties and damage.

An example of natural hazards exposures is in Figure 8-3 which shows the map of seismic hazard of the Italian territory expressed as maximum acceleration of the soil with a 10% probability of exceeding the indicated values in 50 years.

An example of evaluating seismic performance of outside facilities is in Annex 8A1.

**Figure 8-3: Map of seismic hazard in Italy (http://zonesismiche.mi.ingv.it/mappa_ps_apr04/italia.html)**




## 8.1.2 Hazard consequences and methodologies for their evaluation

The evaluation of the hazard consequences is performed in order to determine the relative seriousness of hazard risks that have been identified and assessed. Using the procedures just listed to identify the hazards that threaten the area of interest, in order to determine their consequences, emergency managers will have to gather all of the information necessary to determine how these risks compare one to another. For this reason, by the time the risk evaluation process begins, each hazard must have been identified, described, mapped and analyzed according to its likelihood of occurrence.

It is also to be taken into account that a given hazard agent may initiate a number of different threats. For, example, hurricanes can cause casualties and damages through wind, rain, storm surge, and inland flooding. Volcanoes produce ash fall, explosive eruptions, lava flows, mudflows and floods, and forest fires. For this reason, by the time the risk evaluation process begins, each hazard must have been identified, described, mapped and analyzed according to its intensity and likelihood of occurrence.

Hazards consequences can be evaluated in the frame of a Hazard Vulnerability Analysis (HVA) study, which mainly looks at the following factors: physical vulnerability and social vulnerability.

The *physical vulnerability* is the human, agricultural, structural susceptibility to damage or injury from disasters and can be measured in casualties and damages.

The *social vulnerability* is the lack of psychological, social, economic and political resources to cope with disaster impacts.. This vulnerability includes effects which can develop over a long period of time and can be difficult to assess.

Complete information on the above quoted vulnerability is unlikely to be available. This might seem to be a negative view of the usefulness of HVAs, but it is not. Rather it simply recognizes the current limitations of HVA technology and the resources which can be devoted to this activity. However, it is still possible to do a good job without extremely precise data. This is because it could be sufficient to collect enough information to decide how much money to spend in different activities. That is, it could be sufficient to collect enough HVA data to decide how to allocate resources among hazard mitigation, emergency preparedness, emergency response and disaster recovery. After the relative threat from different types of hazard has been assessed, it is necessary to verify if these different types of hazard might have the same disaster demands. For example, hurricanes and inland floods might have different probability of occurrence but they require similar emergency responses such evacuation. Consequently some investments will help to prepare for multiple hazards.

The evaluation of the hazard consequences is so important because all communities face a range of natural and technological hazards, each of which requires a different degree of mitigation and risk reduction. Moreover, most communities have a range of competing budgetary pressures and are therefore unable to fully mitigate all hazard risks. The goal, as a result, is to lower the number of deaths, injuries, and damage to property and to the environment, associated with hazards, to an acceptable degree, so they must ensure them the greatest results overall.

There are various approaches to developing a study of the possible hazard consequences, ranging from qualitative to quantitative, as well as several computer-based models that have been developed for individual hazards such as earthquakes, floods, hurricanes, and landslides. The validity and utility of any risk assessment is defined by the quality and availably of data. Emergency managers must rely on a range of sources to develop accurate determinations of the possible consequences, despite the fact that these factors are constantly changing as a result of increased development, access to new information, changes in climates and community characteristics and many other factors which can complicate the equations.

Rather than relying on specific mathematical calculations to determine exact values, qualitative systems limit the possible values to a smaller defined range (typically five to seven values) into which each hazard is more easily placed. For example, it may be difficult to calculate the rate of return for an ice storm in the specific year, but it is much more possible to determine whether that storm will occur once or more every year or once every two or ten years. Qualitative systems are not exact, but they facilitate a process that might otherwise be too difficult or time-consuming and therefore disregarded. In the United States, Australia and New Zealand, for instance, various qualitative assessment systems have been developed to measure possible consequence values. Some examples of quantitative assessment methods are pointed out in the following.

#### 8.1.2.1 Hazard US-Multi Hazard (HAZUS-MH)

Hazard US-Multi Hazard (AZUS-MH) is a computer program that predicts losses from earthquakes, floods and hurricane winds. The program estimates casualties, damage and economic losses. Further information about AZUS-MH is available at www.fema.gov/hazus.

#### 8.1.2.2 Risk matrix approach

Each region is unique because of such factors as climate, geography, and development. Therefore the risks associated with hazards in each region are also relatively unique. Depending on the corresponding needs for risk assessment and associated costs, different levels of risk management can be conducted. In the risk matrix approach, both the frequency of occurrence and the magnitude (severity) of a hazard are given as qualitative measure that permits the prioritization of risk among multiple hazards.

Criteria for frequency categorization might include:

- High frequency: events that occur more frequently than once in 10 years ($>10^{-1}$/yr);
- Moderate frequency: events that occur from once in 10 years to once in 100 years ($10^{-1}$ to $10^{-2}$/yr);
- Low frequency: events that occur from once in 100 years to once in 1,000 years ($10^{-2}$ to $10^{-3}$/yr);
- Very low frequency: events that occur less frequently than once in 1,000 years ($<10^{-3}$/yr).

Criteria for severity categorization might include an examination of the potential for fatalities, injuries, property damage, business interruption, and environmental and economic impacts, rated in categories ranging from catastrophic to minor:

- Class A: High-risk condition with highest priority for mitigation and contingency planning (immediate action). Examples of losses: death or fatal injury, complete shutdown of facilities and critical services for more than one month, more than 50 percent of the property located in affected area is severely damaged;
- Class B: Moderate-to-high-risk condition with risk addressed by mitigation and contingency planning (prompt action). Examples of losses: permanent disability, severe injury or illness, complete shutdown of facilities and critical services for more than 2 weeks, more than 25 percent of the property located in the affected area is severely damaged;
- Class C: Risk condition sufficiently high to give consideration for further mitigation and planning (planned action). Examples of losses: injury or illness not resulting in disability, complete shutdown of facilities and critical services for more than one week, more than 10 percent of the property located in the affected area is severely damaged;
- Class D: Low-risk condition with additional mitigation contingency planning (advisory in nature). Examples of losses: treatable first aid injury, complete shutdown of facilities and critical services for more than 24 hours, no more than 1 percent of property located in the affected area is severely damaged.

To prepare risk analysis, emergency managers create a graph that represent risk frequency (likelihood) and severity (consequences) on the x- and y- axes, with the highest of both falling in the upper right quadrant and the lowest in the bottom left. If a quantitative system has been used, the defined values selected for each of the two risk factors are transferred into this matrix (Table 8-1). Otherwise, if qualitative representation of likelihood and consequences have been used, the minimum and maximum of all hazards analyzed represent the high and low limits of the two graph axes. Then all of the hazards are plotted into this matrix together, thereby providing a visual illustration of a community or country's hazard risks in relation to one another. Using the results of the risk matrix, a prioritized ranking of the risks is created. This list becomes the basis of the final step, which is the treatment of the identified hazard risks.

**Table 8-1: Example of risk matrix**

| | | Severity | | | |
|---|---|---|---|---|---|
| **Frequency** | | **Minor** | **Serious** | **Extensive** | **Catastrophic** |
| | **High** | C | B | A | A |
| | **Moderate** | C | B | B | A |
| | **Low** | D | C | B | B |
| | **Very low** | D | D | C | C |

#### 8.1.2.3 Composite Exposure Indicator

Another approach to assess the risk from a given hazard based on several indicator variables is the Composite Exposure Indicator (CEI) method. The output of this approach is a ranking of the potential losses in a given region or area for single or multiple hazards. Actual losses are not estimated because the approach does not include a relationship between exposure and losses, and economic data are not used. However the approach could be extended to provide estimates of losses.

Using databases provided by FEMA, 14 variables are quantified for 3,140 counties in the United States. The variables and their units of measure are expressed as densities (number or length per square mile). The variables were chosen because they are readily available and indicative of exposure and potential damage from hazards. The approach is flexible and the list of indicator variables could be modified easily. Table 8-2 shows an application to the telecommunication outside plants.

**Table 8-2: The Outside plants in an area natural disaster-prone**

| Type of outside plants | Number in the area | Characteristics | Degree of protection | Spare/redundancies | Fuel/power autonomy |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

CEI values are a measure of exposure of each type of outside plant to the considered hazard. Larger CEI values imply that more plants are exposed to potential damages from the considered natural hazard.

## 8.2 Mitigation activities for the protection of the TLC outside plants

[For further information see Bibliography]

Mitigation strategies can be classified in different ways. One of the most common is the distinction between structural and nonstructural mitigation. The most common examples of structural mitigation are dams, levees, seawalls, and other permanent barriers that prevent floodwater from reaching protected areas. Nonstructural mitigation includes activities as purchasing undeveloped floodplains and dedicating them to open space, installing window shutters for buildings located on hurricane-prone coastlines, etc.

However, the above classification of mitigation activities is still vague, so that a more precise classification was developed by FEMA based on five categories: hazard source control, community protection works, land-use practices, building construction practices and building contents protection.

– *Hazard source control* does not work for natural disasters, but there are some exceptions. Wildfire hazard can be controlled by limiting fuel loads in woodlands and controlling ignition sources. Flood hazard can be controlled by maintaining ground cover that decreases runoff by causing rainfall to infiltrate the soil.

– *Community protection works* are most commonly used to divert flood water pass areas that are located in flood plains. They can also be used to provide protection from other types of water flows such as tsunami and hurricane storm surge. Finally, community protection can protect against two types of geophysical hazards: landslides and volcanic lava flows. The four major types of flood control works are the following: i) channelization which is the process of deepening and straightening stream channels; ii) dams which are elevated barriers sited across a streambed for increasing surface storage of floodwater in reservoirs upstream from them; iii) levees which are elevated barriers placed along the streambed for limiting stream flow to the floodway; iv) floodwalls which are built of strong materials such as concrete. They are more expensive than levees, but they are also stronger.

– *Land-use practices* are defined by the ways people use the land. These include woodlands, farmland, residential, commercial and industrial structures and infrastructure facilities. The local government can influence land-use practices through the use of risk communication, incentives and sanctions.

– *Building construction practices.* Property owners can change their construction practices voluntarily because of risk communication or incentives. They can also change involuntarily because of building code requirements.

– *Building contents protection.* For most hazards, protecting buildings from damage also protects the content from harm.

As well known, this Handbook deals with telecommunication outside plants which are cables, conduits, ducts, poles, towers, antennas, repeaters, repeater huts, and other equipment located between a demarcation point in a switching facility and a demarcation point in another switching facility or customer premises.

These means that, strictly speaking, the above five general categories of mitigation activities are out of the scope of this Handbook. However, it is clear that the mitigation actions taken under these categories could in some cases reduce the amount of hazard on the TLC outside plants.

The design criteria able to mitigate the direct impact of the natural disasters on the TLC outside plants are dealt with in Chapters 4, 5, 6, and 7 and there is nothing to add in this chapter.

## 8.3 Cost/effectiveness analysis of mitigation actions

[For further information see Bibliography]

Several possible mitigation actions have been described in this Handbook in view of reducing hazard consequences. This section deals with the problem how these actions can be justified and approved from the economical point of view.

### *8.3.1 Cost evaluation of mitigation activities*

The first issue is the evaluation of the cost of the possible mitigation actions. The cost is different in each of the following cases:

i) the mitigation actions are implemented on the existing outside plants;

ii) the mitigation actions are adopted for the replacing of plants destroyed by a natural disaster;

iii) the mitigation actions are applied in the realization of new plants.

In general the cost incurred in these three cases is different. Focusing the attention on the iii) case, which is the main objective of the Handbook, the following relations apply:

- $C_N$ : Cost of an outside plant realized with a “normal” requirements;
- $C_E$ : Cost of an outside plant realized with ”more severe” requirements;
- $C_D = C_E - C_N$ Difference between “more severe” and “normal” costs.

As an example let us see the following case:

i) the plant has been realized with “normal” requirements and the disaster does not happen: no money has been lost for a “more severe” design of the plant and no damage has occurred.

ii) the plant has been realized with “normal” requirements and the disaster happens: some money ($C_R$) is necessary for the repair or an amount of money ($C_E$ or $C_N$) is necessary for the replacement of the plant. Moreover damages have been suffered.

iii) the plant has been realized with “more severe” requirements and the disaster does not happen: an amount of money equal to $C_D$ has been lost, but no damage has been suffered.

iv) the plant has been realized with “more severe” requirements and the disaster happens: an amount of money ($C_D$ ) has been necessary, but no damage has been suffered (hopefully).

These four situations are summarized in Table 8-8.

**Table 8-8: Impact of the mitigation activities**

| | The disaster does not happen | | The disaster happens | |
|---|---|---|---|---|
| **Design criteria** | **Cost** | **Damages** | **Cost** | **Damages** |
| **Normal** | No cost | No | $C_N$ or $C_E$ or $C_R$ | Yes |
| **More severe** | $C_D$ | No | $C_D$ | No |

From this elementary exercise, it is clear that an evaluation of the damages due to the disaster is a key element in order to take a decision on the adoption of the mitigation activities and of the relative costs.

### 8.3.2 The damages from a disaster

As said above, the *physical impact* of a disaster is measured in terms of deaths, injuries and property damage. These losses are the most obvious and rather easily measured. The *social impact* which includes psychosocial, demographic, economic and political effects develops over a long period of time and can be difficult to assess.

#### 8.3.2.1 Physical impact

The physical impact of a disaster can be measured in casualties and damages:

– Human vulnerability. Humans are vulnerable to extreme of temperature and pressure. These environmental conditions can cause death, injury and illness.

– Agricultural vulnerability. Like humans, agricultural plants and animals can also be hurt by hazards. However agricultural vulnerability is more complex than human vulnerability because there are more spaces. Each species has its own response.

– Structural vulnerability. Buildings are damaged or destroyed by hazards. The design and materials used in constructions determines the level of vulnerability. The construction of most buildings is governed by building codes intended to protect occupants from structural collapse. However the buildings do not necessarily provide protection from extreme wind, seismic, hydraulic loads.

In ranking the disasters, hurricanes can cause the most fatalities. Worldwide data from 1947-1980 show:

– Hurricanes produced 499.000 deaths

– Earthquakes produced 450.000 deaths

– Floods produced 194.000 deaths

#### 8.3.2.2 Economic impact

Leaving aside the psychosocial and demographic impacts in the analysis of the social impacts, let us consider only the economic impact. Telecommunication outside plants damages can be measured by the cost of repair or replacement.

In addition to direct economic losses, there are indirect losses that arise from business interruption. An earthquake in the community might have left a company's buildings, equipment and raw materials undamaged. However if electric power has been lost, workers will not be able to operate the machinery and produce the goods the company sells. to stay in business. Business interruption can be also be caused by the loss of other infrastructures such as fuel, water, sewer, telecommunications and transportations.

### *8.3.3 Cost/benefits from mitigation actions*

As said above, it is rather difficult to make a precise assessment of the cost/benefits related to the implementation of a telecommunication outside plant designed on the basis of "more severe" criteria in order to improve its resistance to a specific natural disaster, which could impact the area. However, some tools, also operating on PC (e.g. FEMA), allow estimation with an accuracy related to the precision of the available data (e.g. extension of the area, type of hazard, its intensity, its probability, estimation of casualties and damages).

In any case an evaluation of the cost/benefits is always necessary in order to have risk mitigation programs approved and implemented. Otherwise despite the best technical knowledge, historic occurrence and media attention, very often it is not recognized that TLC plants are vulnerable. Some of the reasons are denial of the risk, costs and lack of funding and taking on the risk. Recognition requires action and it could have economic consequences as business decide to locate elsewhere if they find the area is at risk. Some people are willing to try to beat the odds, but if a disaster strikes, they know someone will help them out. Gradually, however, such attitudes are changing. Potential liability issues are making responsible more aware, media attention to disasters has brought public pressure and the government have provided both incentives for and penalties for not, taking actions.

Moreover, as previously mentioned, mitigation provides long-term benefits, while very often people tend to focus on short-term rewards. Without a good risk and vulnerability analysis, it is very difficult to decide to spend money on mitigation activities. Data on vulnerability of telecommunication plants are necessary to lobby for more money. Emergency management must compete with other needs such as new TLC services, new TLC systems, etc.. In these cases, the Hazard Vulnerability Analysis (HVA) should be specific enough to persuade others that an increase will benefit the community and the telecom operators. This is not a trivial problem. Emergency management must lobby for money to solve *future* problems. TLC services and TLC network planners tend to be more successful because they request money to solve *current* problems.

## Annex 8A1: Example of evaluating seismic performance of outside plant facilities (Japan experience)

[For further information see Bibliography 4]

It is necessary to evaluate outside plant facilities in terms of the possibility of them suffering damage and to execute appropriate countermeasures according to priority assessment with a limited budget.

Figure 8A1-1 shows an example of an algorithm for evaluating the seismic performance of underground facilities. It can evaluate their earthquake resistance based on 1) information about the facilities (available from various in-house shared databases), the ground (detailed geological data about Japan) and earthquakes (magnitude, epicentre, depth, etc.) and 2) the probability of damage estimated from historical damage data.

By performing simulations, we can predict the seismic intensity and potential liquefaction areas, and utilize this information to make an effective plan for updating facilities taking account of the importance of communication lines. The results help us in making plans for surveying damage and undertaking effective restoration work after an earthquake (Figure 8A1-2).

**Figure 8A1-1: Algorithm for evaluating seismic performance of underground facilities**

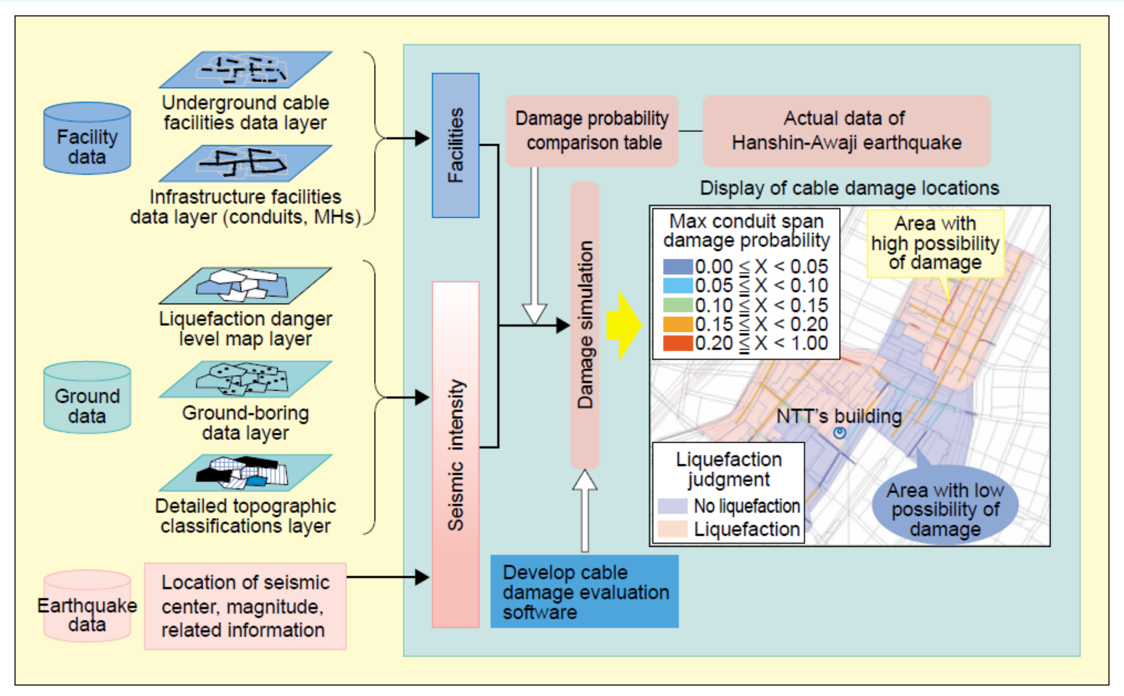
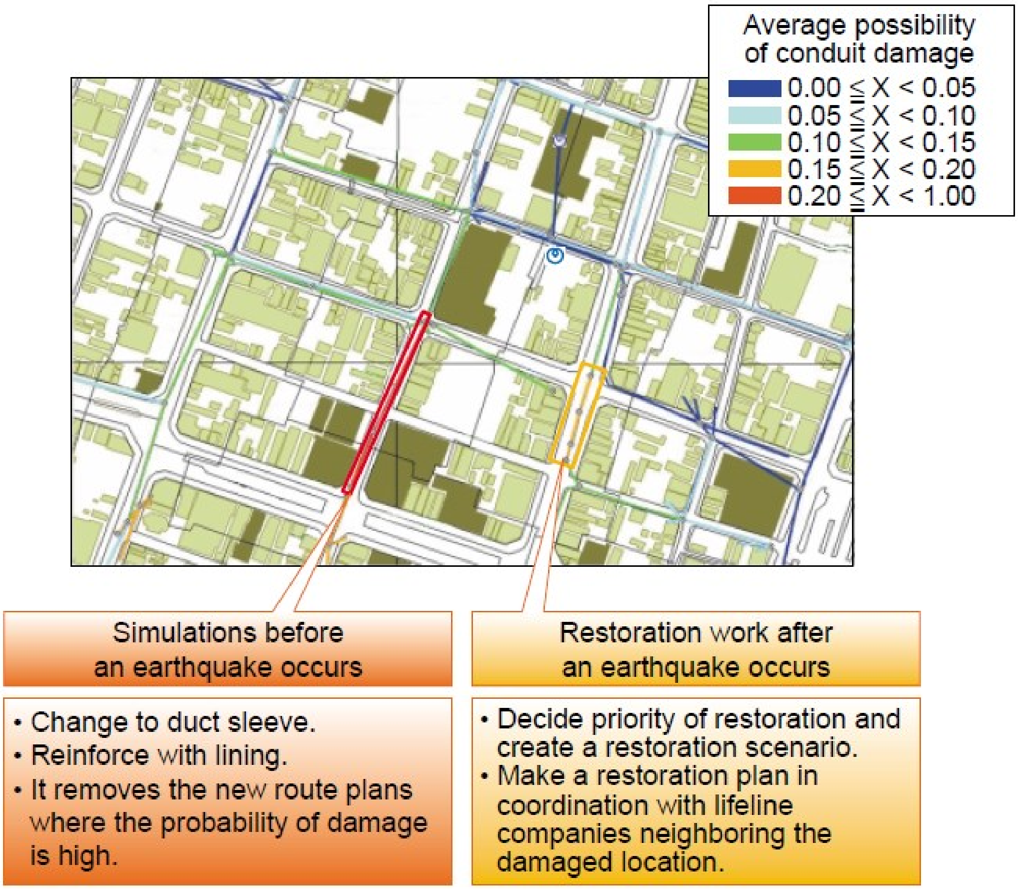


**Figure 8A1-2: Example interpretation of simulation results**




## Bibliography


1 – "Introduction to Emergency Management", Michael Lindell, Wiley 2007

2 – "Introduction to Emergency Management" George Haddow, Elsevier BH, 2011

3 – "FEMA, Multi Hazard Identification and Risk Assessment

http://www.fema.gov/library/viewRecord.do;jsessionid=BC889A879E6DBD9F621A69902C5D8854.Worker2Public2?action=back&id=2214

4 – ITU-T Recommendation L.92

# Chapter 9

# Emergency telecommunication plans with a focus on the outside plants

## 9 Introduction

In a disaster, communications is one of, if not the, primary tool in recovery. Therefore, having a communication system that is both reliable (i.e. able to withstand unusual and unexpected situations) and resilient (i.e. able to recover quickly when service is interrupted by unusual situations) is a key element in responding to disasters.

Fortunately, disasters are relatively rare events, and this leads to a tendency to put off planning for them. There are enough things that warrant attention in daily operations about without preparing for something that rarely happens. This philosophy works for some things but not for telecommunications networks. The vital role that communications plays in our everyday lives and especially in disaster situations makes preparation and practice essential. Because of the key role that communications plays in personal lives, commerce and government, National Emergency Telecommunication Plans (NEPT) for dealing with a disaster need to be established long before it happens.

A NEPT should be based on specific disaster management activities which can be grouped into the following four phases:

i) Mitigation (Prevention): Activities that actually eliminate or reduce the probability/effects of a disaster (for example, designing buildings resistant to earthquakes).

ii) Preparedness: Activities prior to disasters that are used to support the prevention of, mitigation of, response to, and recovery from disasters. In this phase, plans are developed to save lives and minimize disaster damage (for example installing early warning systems).

iii) Response: Activities following a disaster. These activities are designed to provide emergency assistance for victims, to stabilize the situation and to reduce the probability of secondary damage.

iv) Recovery: Activities necessary to return all systems to normal or better (for example, rebuilding destroyed property, or the repair of other essential infrastructure).

This Chapter gives a glance to the possible actions for mitigation (Section 9.1), Preparedness (Section 9.2) and Response (Section 9.3). Section 9.4 is dedicated to the preparation of a National Emergency Telecommunication Plan., based on the practical application of the above activities.

### 9.1 Actions for Mitigation

Communications systems are constantly under attack from nature (e.g., hurricane, flood, earthquake) and from humans, either intentionally (e.g., vandalism) or unintentionally (e.g., work errors, overloads). These are referred to as hazards. It is practically impossible for communications operators to be prepared for the next specific hazard with which they will be attacked. Fortunately, while operators may not know the next threat that they will be assailed with, they can know the vulnerabilities of their systems, and take steps to guard those.

A hazard can only have an impact on a system if it exploits an intrinsic vulnerability of that system. As an example, the need for power is an intrinsic vulnerability of communications systems, so that outages can occur by affecting the power on those systems. Operators may not know what form the hazard on power may take, but they know they need power and can take steps (e.g., dual power feeds, back-up batteries, emergency generators) to protect the power to the system, thereby mitigating the vulnerability. By examining the vulnerabilities of a system and protecting it, the operator can be prepared to face the hazard in whatever particular variation it comes in.

### 9.1.1 Telecommunication networks and their vulnerability

Telecommunication networks are based on a vulnerable infrastructure. The exchanges are interconnected by cable connections or radio links. The knowledge of the vulnerability of the various parts of this infrastructure allows us to determine the capacity to resist the hazards and to take measures to reduce this vulnerability.

- Switching exchanges

The switching exchanges are exposed to the risks of flood, fire, collapse further to the hazards of diverse natures (earthquake, landslide, volcanic eruption, etc.), of breakdown on the system power supply, blocking because of the overload of networks further to a sudden increase of the traffic.

In the implementation of exchanges, measures must be taken to reduce their vulnerabilities to these various risks.

- Local loop in wired network

The local loop, the connection between the local exchange and the residence of the subscriber, is generally a copper cable; in numerous places, these telephone lines are cables suspended from poles. Their routes are vulnerable in the disasters caused by violent winds, snow and earthquakes.

- Metropolitan and long haul networks

Metropolitan and long haul links are connections which group hundreds or thousands of circuits by the process of multiplexing. According to the necessary capacity and to the distance between the concerned cities, these connections can be by radio links, by copper and optical fibre cables. When the links are realized by cable, these cables are generally laid underground.

Whatever is the type of connection (cable or radio link), the vulnerability can be reduced by the implementation of protection links. However, the continuity of the service widely depends on the available protection capacities. In certain countries, there is a progressive decrease of the redundant capacities, these having been sold by operators subjected to a strong competition. When a connection breaks down, the protection links has no sufficient capacity to support the interrupted traffic. For that reason, it is necessary that sufficient spare capacity is maintained.

- Mobile Network

When the mobile telecommunications network is not damaged by a disaster, it is an essential tool for its management.

The mobile networks are less vulnerable in disasters, because the connections are wireless and the network is disrupted only if exchanges and base telephone stations are affected by the hazard.

- Satellite Network

Considering their positions in respect to the surface of the earth, satellites are protected from natural hazards. The earth stations are the only component of the satellite systems which are vulnerable to the natural disasters. Therefore satellite links constitute an important element for the emergency telecommunications.

### *9.1.2 Evaluation of the vulnerability of the telecommunication systems*

Communication systems can be described by eight basic ingredients; power, environment, hardware, software, network, payload, human, and policy. Using these eight ingredients, a system owner can study its system, identify their vulnerabilities, and to devise measures to protect these vulnerabilities. The eight ingredient framework has been used by various teams to help define the system under study, its vulnerabilities, and the corresponding countermeasures needed to protect these vulnerabilities.

In the United States, the communications industry, under the auspices of the Federal Communications Commission (FCC) has developed a set of Best Practices that provide guidance, based on industry expertise and experience, on making communications more reliable and resilient. In other words Best Practices are intended to help prevent communications outages from occurring (*reliability*) and to speed recovery from outages should they occur (*resiliency*).

The Best Practices can be accessed on the ATIS web site (http://www.atis.org/bestpractices) or on the FCC web site (https://www.fcc.gov/nors/outage/bestpractice/BestPractice.cfm). Best Practices cover five general areas: Network Reliability and Interoperability, Disaster Recovery and Mutual Aid, Public Safety, Physical Security, and Cyber Security. A key characteristic of a Best Practice is that it is not just a good idea – it has been implemented by at least one company and has been judged to be a Best Practice by the other companies involved, even though they themselves may not have implemented it. Best Practices are not intended to be requirements. Each Best Practice must be evaluated by a person knowledgeable in the specific area covered, and implemented only if it makes sense for a company's individual set of circumstances.

The European Network and Information Security Agency (ENISA) have also established a set of practices aimed at things such as information sharing and emergency preparedness exercises. (http://www.enisa.europa.eu/act/res/policies/good-practices-1) .

### *9.1.3 Possible actions for strengthening telecommunication networks*

As an example of the possible actions for strengthening telecommunication networks, the following can be quoted:

– land use restrictions (zoning) in order to limit people's intrusion/building's construction into the flood plain;

– definition of building codes, architecture and design criteria, and soils and landscaping considerations for the construction of new buildings resisting to earthquakes.

Other examples of the actions which can be taken for strengthening the telecommunication networks/plants are given in Annex 9A1.

Moreover Chapters 4, 5 and 6 of this Handbook are devoted to the description of the design criteria of the telecommunication outside plants, with a particular attention to those criteria able to improve the resistance of the plants to the natural disasters.

## 9.2 Actions for Preparedness

Disaster preparedness for communications systems has several components. The most important are listed in the following:

– typology of the disasters which have had an impact on the country in the past (Section 9.2.1;

– mutual aid agreements (Section 9.2.2);

– signature of agreements of mutual assistance or partnership between involved organizations (Section 9.2.3);

– spare emergency equipment (Section 9.2.4);

– training of the staff involved in emergency telecommunications and simulation exercises (Section 9.2.5);

– realization of systems of alert and of plan of alert.

### 9.2.1 Typology of the natural disasters which have had impact one the country in the past

An example of the typology of natural disasters in a country is shown in Annex 9A2.

### 9.2.2 Mutual aid agreements

Disasters, especially natural disasters, are often geographically contained, even though it might be a wide spread area. Because of this, communications companies in the same area are all likely faced with disaster recovery and may not be in a position to provide assistance to one another. To deal with this, companies should consider establishing mutual aid agreements with other operators, possibly in different areas of the country or even in different countries, as part of their disaster recovery plan. These companies may not have been impacted by the event and may be in better position to provide equipment or personnel to assist with the restoration.

What is a formal mutual aid agreement? It is an expression of intent to work together, *if both sides agree at the time*, and can spell out financial and legal agreements that have been established in a controlled negotiation rather than in the heat of the moment during a disaster. A key point is that a mutual aid agreement *does not* obligate either side to provide assistance or to accept it. It simply establishes the ground rules that will be used if both agree to implement it. In the United States, a mutual aid template has been established that is used as the foundation for mutual aid agreements by many network operators. It identifies some of the types of aid that might be considered, including equipment, vehicles, network capacity, and personnel, and calls out many of the legal and financial considerations that might be addressed in a mutual aid agreement.

The United States has experienced a number of well-known communications disaster situations over the past few years, including Hurricanes Katrina and Rita. In these, and in many other cases, mutual aid agreements have demonstrated their value to quickly and efficiently focus the full force of the communications industry on restoring communications services. At the international level, the Tampere Convention, an effort of the ITU, provides a framework for telecommunications assistance in times of disaster.

### 9.2.3 Plan for priority communications

Another thing to consider in disaster recovery preparation is ensuring that the most urgent calls can be completed. In most disaster situations, the communications network is flooded with a load for which it was not engineered, resulting in a large number of calls that don’t complete. This is not acceptable for calls from first responders and those vital to the restoration of various human and communication services. For this reason, it is imperative that a scheme be established to help ensure priority calls are completed at a rate higher than the normal completion rate. In the United States the Government Emergency Telecommunications System (GETS) and Wireless Priority Service (WPS) have been developed and been put in place to address precisely this issue. Both services provide enhanced completion opportunities to those calls identified as priority. The United Kingdom has deployed a wireless priority scheme called Mobile Privileged Access Scheme (MTPAS) as well as a Government Telephone Preference Scheme (GTPS), Australia has a Wireless Priority Service System, and an effort is underway in Spain, supported by the European Commission, to look at ways of addressing Priority Communications on Public Mobile Networks (PCPMN) in crisis situations. All currently deployed schemes have drawbacks, and a country considering deploying such a capability would be wise to examine these systems to avoid the pitfalls each has experienced. When creating and deploying a means of addressing priority calling, strong consideration should be given to the interface such a system would have with other countries. Disaster recovery often involves contacting vendors or other support organizations in different countries, and a priority communications system that doesn't span national borders will not provide the full potential that it should.

### 9.2.4 Emergency equipment

Spare emergency equipment is necessary for being used in the natural disaster areas in order to substitute the damaged equipment and/or to complement the existing ones. The type, the number and the distribution of emergency equipment on the national territory is one of the tasks of a National Emergency Telecommunication Plan.

Possible spare emergency equipment is the following:

- radio base stations on mobile tracks;
- switching exchanges on mobile tracks;
- back-up batteries;
- emergency generators;
- VSAT terminals;

Thuraya/Iridium/Immarsat/Intelsat phone/terminals.

In the areas hit by the earthquake/tsunami in Japan on 16 March 2011, the ITU deployed 78 Thuraya satellite phones equipped with GPS to facilitate search and rescue efforts along with 13 Iridium satellite phones as well as 37 Inmarsat Broadband Global Area Network terminals. The equipment can be charged by car batteries and were also supplied with solar panels to enable operations during power outages.

The ITU deployed a hybrid of 40 broadband satellite terminals in an effort to restore vital communication links in the aftermath of a tsunami triggered by a 7.7 magnitude earthquake and a volcanic eruption that hit the Indonesian archipelago in two separate incidents.

### 9.2.6 Training and exercises

Having an emergency plan, which may include mutual aid agreements, it is possible that plan may seldom, if ever, be used, but because disasters are rare events. An organization doesn't know if it has a good, up-to-date emergency plan unless it has been used recently.

Once a disaster occurs is not the time to discover that there are gaps in the emergency plan, that vital contact information has changed, or that critical items haven't been accounted for. Those discoveries should occur during periodic exercises, which should be conducted as realistically as possible. It is far better to discover gaps or errors in a plan under the controlled conditions of an exercise than during an actual event, when errors can be the difference between a successful recovery or an extended outage, between being a key recovery enabler or a recovery impediment, or even between life and death. Exercises are also an opportunity to utilize existing tools. The Database of Frequencies to Be Used in Disaster Relief [ITU-R Resolution 647 (WRC-07)] is one such tool, and ensuring that it contains accurate information and that people know where to find it and how to use it can be woven into exercises.

Emergency exercises aren't free and there is a tendency to reduce or eliminate this type of effort, especially if a disaster hasn't occurred recently and economic conditions are putting pressure on the operator. Having no emergency plan is simply unacceptable, and having an untested plan is only slightly better. When it comes to ensuring a robust and dependable communications infrastructure, nothing pays greater dividends than preparation.

## 9.3 Actions for the Response in case of a disaster

The Response is the totality of the activities following a disaster. These activities are designed to provide emergency assistance for victims, to stabilize the situation and to reduce the probability of secondary damage.

Response activities are normally in line with Preparedness activities (defined in the NETP) prepared and approved in advance. Those activities are composed of Preparedness arrangements and plans for effective measures to be taken to deal with emergencies and disasters if and when they do occur, to act during or immediately after a disaster, and to be able to manage the consequences of a disaster. This is important to ensure that the public emergency works to support search and rescue operations, emergency medical delivery and the evacuation process so as to minimize suffering and loss of life.

A pro-active approach is imperative. As soon as it becomes apparent that a disaster needs telecommunications equipment and/or expertise, emergency telecommunications planners should immediately initiate the activation of the emergency telecommunications response plan. If necessary, planners should activate their emergency operation centre. Precious time and high costs result from a reactive rather than pro-active stance.

The main activities during the response phase are the following:

– evaluate which are the available telecommunication infrastructures after the disaster;
– allow the availability of the communications between the various involved organizations;
– operate to face the disruptive effects of emergencies on telecommunications services and networks;
– facilitate the operation of international, inter-governmental and telecommunications organizations;
– facilitate the use of the spare telecommunications equipment to ensure the availability of telecommunications according to the emergency requirements;
– facilitate the tasks and the steps of deployment of equipment supplied by national and international organizations;
– facilitate the availability of the new radiofrequency necessary for the response operations;
– facilitate the deployment of the new earth satellite stations and terminals;
– collection of data from the warning systems.

## 9.4 National Emergency Telecommunication Plan (NETP)

### *9.4.1 Why a National Emergency Telecommunication Plan (NETP)*

The preparation of a National Emergency Telecommunication Plan (NETP) is the necessary completion of the activities listed in the previous Sections.

Preliminary questions to the preparation of a NETP are the following: "which is the value of a NETP?" "Why not wait until something happens, evaluate the situation, and then decide how to react?" There is an old adage that says, "Practice makes perfect." In almost any field of endeavour where people seek to perform at their best, they practice first. Why? Because while practice can't simulate all the things encountered in a game, it helps prepare people to react properly to whatever they may encounter. The same holds true for practicing for disasters.

It is impossible to know what form the next disaster will take, but individuals and organizations can learn how to respond, whatever the conditions, by practicing responding to a variety of disasters. Having completed the planning process, an organization is better able to respond quickly and efficiently to a disaster. They know the steps to take and the contacts to make to begin the recovery effort. With the stakes so high, no communications provider can afford to wait for a disaster to strike before formulating recovery plans.

A NETP consists of all the activities that aim to protect the availability, at any time, of telecommunications systems in the case of the natural disasters. This plan also includes the measures taken to guarantee the availability of telecommunication systems for the institutional structures charged with the protection of the public (Police, fire brigades, emergency medical service, etc.).

A National Emergency Telecommunication Plan is mainly based on:

– the typology of the hazards which have had an impact on the country in the past;
– the data collection concerning the resources available by identifying the infrastructures of essential and critical telecommunications;
– the identification of the vulnerabilities of the critical infrastructures and their protection;
– the reduction of the vulnerabilities of the existing infrastructures;
– the implementation of legislation/regulations which facilitates the provision of the resources of telecommunications for the prevention and the management of the disasters;
– the identification of the various actors of the emergency telecommunications.

The activities carried out within the framework of the National Emergency Telecommunication Plan involve several administrations and companies. None of the institutions involved have the mandate, in its structure, to lead all these activities. The realization of these activities can be effective only through collaboration or a dialogue between the various participants.

To bring these activities to a successful conclusion, it is thus necessary to set up a National Committee for Emergency Telecommunications (NCET) in which all the organizations involved in the emergency telecommunications are represented. The NCET establishes a platform for a dialogue among all the involved organizations in order to facilitate the implementation of the National Emergency Telecommunications Plan.

The National Emergency Telecommunication Plan is part of the National Emergency Plan (NEP) prepared by the National Committee for the Emergency Plans (NCEP).

An example of NEP is shown in Annex 9A3.

### *9.4.2 Necessary actions to put in place a National Emergency Telecommunication Plan*

The necessary actions to put in place a NETP are summarized below.

#### 9.4.2.1 Objective: Adapt the infrastructures of telecommunications to the management of the disasters and the emergencies:

Activities:

– identify the vulnerabilities of the telecommunication networks;
– implement a plan of priority of the calls in the public networks;
– set up an integrated management system of emergency calls and location of appellants;
– set up systems of premature alert;
– set up a system of communication independent from that usable public network by all the participants in case of disaster;
– set up a geographical information system (SIG) of high-risk areas;
– set up monitoring system of the natural phenomena;
– management of frequencies and control of the interferences.

#### 9.4.2.2 Objective: Adapt the legal and statutory framework to the use of Telecommunications for the management of the disasters.

Activities:

– Adapt the legislation and the telecommunication regulation to prevent and to manage the disasters;

– Amend the legislation and the regulations of the management of the disasters to take into account the role of telecommunications.

#### 9.4.2.3 Objective: Make available the necessary equipment

Activities:

– Purchase and maintenance of the emergency equipment.

#### 9.4.2.4 Objective: Coordinate the use of the resources of telecommunications for the management of the disasters

Activities:

– Create a National Committee for the Emergency Telecommunications;

– Set up the National Emergency Telecommunications Plan;

– Sign agreements of mutual assistance or partnership between stakeholders;

– Realize an inventory of the resources of emergency telecommunications.

#### 9.4.2.5 Objective: develop the human resources for the emergency telecommunications

Activities:

– Train the staff of the emergency telecommunications;

– Realize exercises of simulation.

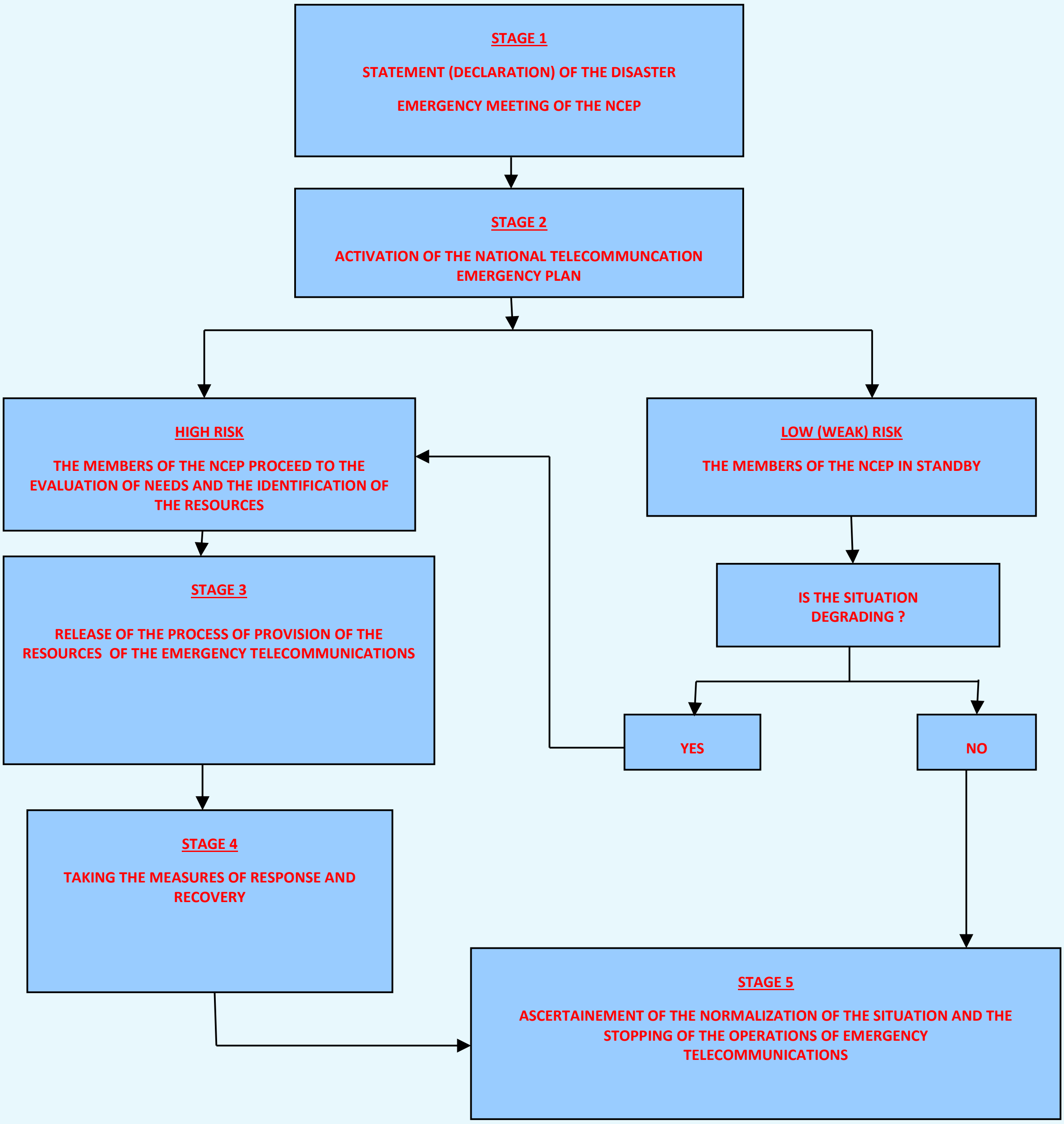
### *9.4.3 Procedure to implement the National Emergency Telecommunication Plan*

As already mentioned, the purpose of a National Emergency Telecommunication Plan is to supply guidelines for the organization and the implementation of the means of telecommunications necessary for the answer to the disasters. It describes the actions to be led to coordinate the stake measure of the resources of telecommunications for the answer to the hazards as well as for the recovery after the disaster. It is based on the legislation and the regulations in force regarding management of the disasters on one hand, and telecommunications on the other hand.

The resources of available telecommunications for the implementation of this plan are the ones belonging to all the organizations involved in the emergency telecommunications. The way to put at disposal the resources of telecommunications for the relief operations in case of emergency is coordinated by the National Emergency Telecommunication Plan which also specifies the responsibilities of the various organizations involved in the emergency telecommunications in the implementation of the above-mentioned plan.

Figure 9-1 shows an example of process for putting in operation a National Emergency Telecommunication Plan.

**Figure 9.1: Process for putting in operation a National Emergency Telecommunication Plan**




## Conclusion

Disasters are rare events, and while some may view management for such events as unnecessary overhead, history has demonstrated that although the possibility of a disaster striking is small, it is not zero. The indisputable importance of communications in today's societies requires a strong commitment to timely restoration in times of disaster. At this purpose a key element is the preparation of a National Emergency Telecommunication Plan.

## Bibliography

1 – "Plan National des Télécommunications d'Urgence au Cameroun (PNTUC)",

http://www.itu.int/md/D10-RGQ22.1.2-INF-0004/en

2 – "Disaster Planning", Alcatel-Lucent, March 2012, **[ 10 ]**

3 – "Lignes directives pour la mise en oeuvre d'un plan national de télécommunications d'urgence", Makrem Mahjoub, ITU,

http://www.itu.int/ITU-D/emergencytelecoms/events/abidjan/C6-UIT_BDT_Makrem_Mahjoub.pdf

4 – "Importance des télécommunications pour la gestion des catastrophes au Congo **[ 17 ]**

5 – "Principles de bases applicables un plan national de telecommunications d'urgence", Milot, ITU-D Workshop Sao Tomè 2009

http://www.itu.int/ITU-D/emergencytelecoms/events/sao_tome/presentations/Plans%20d'urgence%20Sao%20Tome.pdf

6 – "Elements essential pour un plan urgence" (Milot, ITU-D Workshop Sao Tomè 2009)

http://www.itu.int/ITU-D/emergencytelecoms/events/sao_tome/presentations/Elements%20essentiels%20Sao%20Tome.pdf

7 – "État des lieux de la situation de la Côte d'Ivoire en matière de télécommunications d'urgence » RGQ22-1/2/INF/3-F

8 – Use of telecommunications for disaster preparedness and response: Case of Burkina Faso **[ 90 ]**

9 – Draft Outline for Disaster Communications Plan Guidelines (Document /RGQ22-1/2/5, March 2011) **[ 5 ]**

10 – ITU-R WP 5A Disaster Relief Rapporteur's Report, Alcatel Lucent, September 2011, **[ 18 ]**

11 – "Basic Emergency Principles for a National Emergency Telecommunications Plan", Cosmas L. Zavazava Bogota, Colombia (24-26 July 2012)

http://www.itu.int/ITU-D/emergencytelecoms/events/bogota2012/presentation/PresentationZavazavaEn.pdf

12 – "National Emergency Communications Plan" US Homeland Security, 2008

http://www.dhs.gov/xlibrary/assets/national_emergency_communications_plan.pdf

# Annex 9A1: Actions in Cameroon to reinforce the resistance in the disasters

## 9A1.1 Strategic actions of the National Emergency Telecommunication Plan in Cameroon

The analysis made on the state of emergency telecommunications in Cameroon highlighted inadequacies in this domain. There are no adequate resources to manage telecommunications when there are disasters on emergency situations. This problem is related to four main causes and numerous primary causes with direct effects in the mismanagement of the disasters, with material losses and human lives.

With regard to what precedes, the following strategic actions have emerged for the National Emergency Telecommunication Plan.

### *9.A1.1.1 1st Strategic action: building networks, aid services and emergency services*

– strengthen the infrastructure, the covering and the functioning of the aid networks and services, of the electric radio services of help and safety of the human life, of the air and maritime radio navigation, of the telecommunication networks of the national safety and the protection of the public, to support and contribute to the works of mitigation of the effects of the disasters;

– strengthen the infrastructure, the covering and the functioning of the electric radio systems assistant to the meteorology, the seismic and volcanic alarm systems, and the systems of detection of the natural phenomena;

– strengthen the infrastructure, the covering and the functioning of the telecommunication networks of the operational entities of the help and the national emergency telecommunication networks, as well as the telecommunications networks of the regional and local committees of management of the disasters, in particular in the high-risk zones;

– strengthen and promote in an appropriate and effective way, the supply of the service of alert and public information, supported by the public telecommunication networks to guarantee the communication between the citizens and the authorities in case of emergency;

– strengthen and promote, in an appropriate and effective way, the supply of the priority service in case of emergency, supported by the public telecommunication networks, to facilitate the communication between the governmental authorities and between the organizations of the first aids.

### *9A1.1.2 2nd Strategic action: building telecommunication networks and services for the mitigation of disasters*

– strengthen the infrastructure, coverage and operation of public networks and promote an appropriate and effective basic public service telecommunications, such as fixed and mobile telephony, to ensure communications during an emergency or a disaster;

– strengthen the infrastructure and operation of broadcasting stations and promote in a timely and effective manner, the provision of public broadcasting service such as radio and television, to ensure the dissemination of information to the public for the prevention of disaster and for relief /disaster recovery after the disaster. This is also to promote the use of spaces for the dissemination of social programs, the proper use of mass media for prevention, relief and recovery;

– strengthen the infrastructure and operation of public telecommunications networks and promote the provision of value added services such as Internet and broadband systems, to facilitate communications in emergencies and disasters;

– strengthen the infrastructure and operation and promote the provision of services of amateur radio and citizens band, to contribute to the disaster management;

- promote and strengthen the network infrastructure of institutional and official state government entities, of the telecommunications networks to support the public service, of the telecommunication networks of strategic economic institutions and of other private networks, to ensure the availability of telecommunications in emergencies, and to protect and preserve the national infrastructure.

### 9A1.1.3 3rd Strategic action: promoting development of the sector

- promote the development of the entities of the telecommunications sector in order to facilitate the prevention of the disasters, the help in case of disasters and the recovery after the disaster.

## Annex 9A2: Natural typology of the disasters in Cameroon

Table 9A2-1 presents the typology of the natural disasters occurred in Cameroon during the last 30 years.

**Table 9A2-1: Typology of the natural disasters in Cameroon**

| Type of disasters | No. | Concerned Regions | Locality and years | Damages |
|---|---|---|---|---|
| Volcanic Eruptions | 2 | South West | Buea (Mont Cameroon), 1998 et 1999 | 300 million damages |
| Floods | 9 | Centre, Adamaoua, South West, North, Far-North | Limbe, Garoua, etc. | 10 people died, 200 Farming victims, 20 houses destroyed |
| Landslides | 9 | South-West, East, South, Center, West and Littoral | Bafaka-Balue 1995, Garoua-boulai 1996 et 1998, Mont Bankolo 1986 | 10 died, 50 destroyed plantations of cocoa, 180 million FCFA of damages. |
| Tornados, thunderstorms and lightnings | 22 | Center, East, North-West, Adamaoua, South, South-West, West, North | Nkolgal (1986), Nguelemendouka (1994), Tignere (1995), Ambam (1995), Garoua (1994), Boumnyeyebel (2000), Dibang (2000), Bamusso (2000), Ebolowa (2004) | 2272 victims, 482 destroyed houses, 100 decimated heads of cattle, 54 million FCFA of damages, fields gobbled up in waters. |
| Fire | 20 | All Provinces | Marché Mokolo 1999, Mvog-Ada 1995, Edéa 1994, Bafoussam 1999, Sangmelima 1995, Douala 1992, Batouri et Maroua 1995, Nsam Effoulan 1998, Marché de Maroua 2000 | Shops and destroyed supermarkets, losses in human lives |

# Annex 9A3: Organization of the management of the disasters in Cameroon

## 9A3.1 Management Roles

The "Ministère de l'Administration Territoriale et de la Décentralisation (Direction de la Protection Civile)» is charged with the coordination of the national and international actions in case of disasters in contact. This, of course, with the authorities and the other administrations involved in the management of crisis situations.

Other organizations involved in the management of the disasters are: the "Police Nationale, the "Ministère de la Défense (Gendarmerie et Corps National des Sapeurs Pompiers) », the « Ministère de la Santé Publique (SAMU) », the « Ministère de la Recherche Scientifique et de l'Innovation (IRGM et INC) », the « Croix Rouge Camerounaise », the « Haut Commissariat des Réfugiés (HCR) », the «Fonds des Nations Unies pour l'Enfance (UNICEF) », the « Programme des Nations Unies pour le Développement (PNUD) », the « Organisation Mondiale de la Santé (OMS) », the Fédération Internationale de la Croix Rouge et du Croissant Rouge (FICR) », etc.

The main structures of intervention and management are shown in Figure 9A3-1.

## 9A3.2 Role of the sector of telecommunications in the management of the disasters

– Ministry of Post and Telecommunications

The Ministry of Post and Telecommunications is responsible for the elaboration and for the implementation of the policy of the Government regarding the telecommunications, the technologies of information and the communication. In this framework several measures have been taken to guarantee the supply of the services of emergency telecommunications in Cameroon. In particular the creation of a department of emergency telecommunications which guides a project concerning the emergency telecommunications.

– Agency of Regulation of the Telecommunications (ART)

The Agency insures on behalf of the State, the regulation, the control and the follow-up of the activities of the operators of the telecommunications sector. In this framework it deals with license applications and prepares the related decisions. Moreover measures are taken to integrate into the technical specifications of the networks operators the requirements necessary for the supply of service of telecommunication emergency, in particular:

- the free emergency calling services (17, 117, 18, 118);
- the commitment of the operators to arrange measures of prevention and mitigation of the effects of the hazards;
- the attribution of authorizations to the radio bands;
- the organization of seminars and conferences to make sensitive and insure a better supply of the service of emergency telecommunications. The Agency has among others missions, the management of the coastal station of Douala to protect and insure the safety of the offshore human lives.

– Operators of the telecommunication networks

The operators of the telecommunication networks are called to collaborate with the Government for the deployment of their networks to guarantee the continuity of service in case of disaster.

– Media

In a general way, in case of disaster, the information is broadcasted on the Television and on the Radio. Several organs of media are involved.