International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R F.755-2

(05/1999)

Point-to-multipoint systems in the fixed service

F Series

Fixed service

International Telecommunication Union

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SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
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Note*: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2010

RECOMMENDATION ITU-R F.755-2*, **

POINT-TO-MULTIPOINT SYSTEMS IN THE FIXED SERVICE

(1992-1994-1999)

Scope

This Recommendation deals with point-to-multipoint systems, including concept and basic system characteristics of high-density applications of the fixed service (HDFS) in the 25 GHz to 32 GHz band. Also technical information on point-to-multipoint systems operating in 3.5 GHz, 10.4 GHz, 26/28 GHz and 32 GHz is contained.

The ITU Radiocommunication Assembly,

considering

a) that there are different applications, services and deployment scenarios which require various point-to-multipoint (P-MP) system configurations;

b) that different P-MP systems in the fixed service (FS) are used in various frequency bands depending on the services transported and the deployment scenario envisaged;

c) that minimization of interference and optimization of spectrum usage can be achieved by proper emission control, appropriate access techniques and efficient modulation;

d) that P-MP systems can provide comparable performance and availability objectives with those used for wired systems;

e) that P-MP systems commonly use omnidirectional or sectorized antennas or multiple antenna configurations at the central station and directive antennas at the terminal station, and/or repeater station;

f) that various applications are suited to different parts of the spectrum dependent upon capacity, area coverage, path length and location (rural, suburban, urban, etc.);

g) that P-MP systems are suitable for high density deployment;

h) that operating characteristics of P-MP systems are required in order to determine appropriate intra-service interference criteria and sharing criteria with other services,

recommends

1 that for time division multiple access (TDMA) P-MP systems used as radio concentrators, Recommendation ITU-R F.1103 should be referred to;

2 that for radio-frequency channel arrangements for analogue and digital P-MP radio systems operating in frequency bands in the range 1 427-2 690 MHz, Recommendations ITU-R F.701, ITU-R F.1098, ITU-R F.1242 and ITU-R F.1243 should be referred to;

3 that for single channel or multichannel multipoint video distribution services, Annex 1 can be referred to for a description of a particular implementation;

4 that for packet radio systems, Annex 2 can be referred to for some specific examples;

5 that for TDMA systems for data transmission, primarily in urban areas, Annex 3 can be referred to for information on various systems;

6 that for some requirements for P-MP systems used in the local grade portion of an ISDN connection, reference can be made to Recommendation ITU-R F.697;

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* This Recommendation should be brought to the attention of Radiocommunication Study Groups 3 and 7.

** Radiocommunication Study Group 5 made editorial amendments to this Recommendation in December 2009 in accordance with Resolution ITU-R 1.

7 that for performance requirements of P-MP systems which provide to the end-user a connection at or above the primary rate, reference can be made to the access section of the national portion of Recommendation ITU-R F.1668;

8 that Annex 4 can be referred to for applications of frequency division multiple access (FDMA) P-MP systems operating in the frequency bands 3.4-3.6 GHz, 3.6-3.8 GHz, 10.15-10.3 GHz paired with 10.5-10.65 GHz, 26/28 GHz and 32 GHz;

9 that Annex 5 can be referred to for technical and operational aspects in the 25-32 GHz frequency range;

10 that for radio-frequency (RF) channel arrangements for digital P-MP radio systems operating in the frequency bands 26 and 28 GHz, Annex 1 and Annex 2 of Recommendation ITU-R F.748 can be referred to.

ANNEX 1

An example of single-channel and multichannel multipoint distribution services

1 System description

The multipoint distribution service provides, for one-way P-MP transmission, at approximately 2 GHz, up to four channels of voice, video and data signals to geographically distributed communities of interest. These signals may be used for entertainment, business, social or community purposes. A typical multipoint distribution service system consists of an omnidirectional transmit antenna and a combiner to combine the output of each transmitter at the transmitting site, a directional receive antenna, down converter and a video receiver at each receive location. The transmit site is generally limited in output power, typically 200 W e.i.r.p., and normally drives an antenna with either an omnidirectional or a cardioid radiation pattern with gains of 10 to 16 dBi. In some instances pairs of back-to-back cardioid antennas are driven by a single transmitter. The received signal is changed by the down converter from the transmission frequency to an unused channel frequency compatible with the video receiver.

In the case of multichannel multipoint distribution services, a narrow-band channel (125 kHz bandwidth) is provided for an audio response to the transmitter site.

A typical frequency plan for a four-channel multipoint distribution service operating in the 2.5 GHz band with a maximum transmit bandwidth of 6 MHz is given below:

Transmit frequencies

$f_n = f_0 - 128 + 24\,m + 12\,n$ for $m = 1, 3, 5, 7$

$f_n = f_0 - 146 + 24\,m + 12\,n$ for $m = 2, 4, 6$

Response frequencies

$f_n = f_0 + 89.9375 + 0.125\,m + n$

where:

f_0 : frequency of the centre of band = 2 595 MHz

m : group number = 1, 2, 3, . . ., 7

n : group number = 1, 2, 3, 4.

The system design approach for the multipoint distribution service was selected to allow randomly sited transmitters to reuse optimally the same or adjacent channel as often as possible and provide a reasonable size of protected area surrounding each transmit site. This approach required trading off high transmit power against the availability of high gain receive antennas and limiting service to only those receive sites that have line-of-sight paths to the transmit site.

An example of the technical characteristics of a typical 2.5 GHz P-MP system used for multipoint distribution services is shown in Table 1.

TABLE 1

Transmitter		Receiver	
Modulation	VSB/AM	Antenna characteristics	Rec. ITU-R F.699
Antenna gain (dBi) (relative to omnidirectional)	13	Antenna gain (dBi)	20
Transmitter power (dBW)	10	Noise figure (dB)	8
e.i.r.p. (dBW)	23	Typical receiver antenna height (m)	9.1
Signal type	TV	Carrier/interference (dB) (unfaded)	45

2 Interference considerations

2.1 Protected area

In the multipoint distribution service, receivers are protected from harmful interference if they are located within the protected area around their associated transmit station. The protected area is defined by the maximum distance from the transmitter at which a reliable signal is provided. This maximum distance in the worst propagation area of the North American continent is 25 km for a transmit site with an e.i.r.p. of 200 W and a down converter having a 10 dB noise figure. A reliable signal for this purpose is defined to be a signal sufficient to provide a 23 dB or better signal-to-noise ratio for 99.9% of the time.

For stations using a directional transmit antenna, the protection distance D_b from the transmitter can be calculated by the following relationship:

$$D_b = D_{bmax} \cdot 10^{-\frac{(G_{max} - G)}{20}}$$

where:

D_{bmax}: distance in the direction of maximum antenna gain (km)

G_{max}: maximum antenna gain (dBi)

G: antenna gain in the direction of interest (dBi).

For either directional or non-directional antennas, the maximum protection distance, assuming a standard receive height of 9 m, is further limited to the radio horizon.

2.2 Co-channel interference

Frequency reuse in an area is controlled by ensuring that the carrier-to-interference ratio *C/I* owing to co-channel interference is greater than 45 dB.

This *C/I* offers reasonable protection from harmful interference to receivers in this service while not unnecessarily restricting the ability of new stations to provide a service to unserved areas.

The achievement of this *C/I* in actual systems relies upon the angular and cross-polarization discrimination characteristics of the receive antenna. The specific antenna used as a reference is instrumental in determining the amount of frequency reuse in a given area. The characteristics of a typical 0.6 m (2 ft) parabolic antenna were selected for the purpose of making such *C/I* calculations. In certain cases where the actual receive antenna has better performance characteristics, that antenna is used when performing *C/I* calculations.

2.3 Adjacent-channel interference

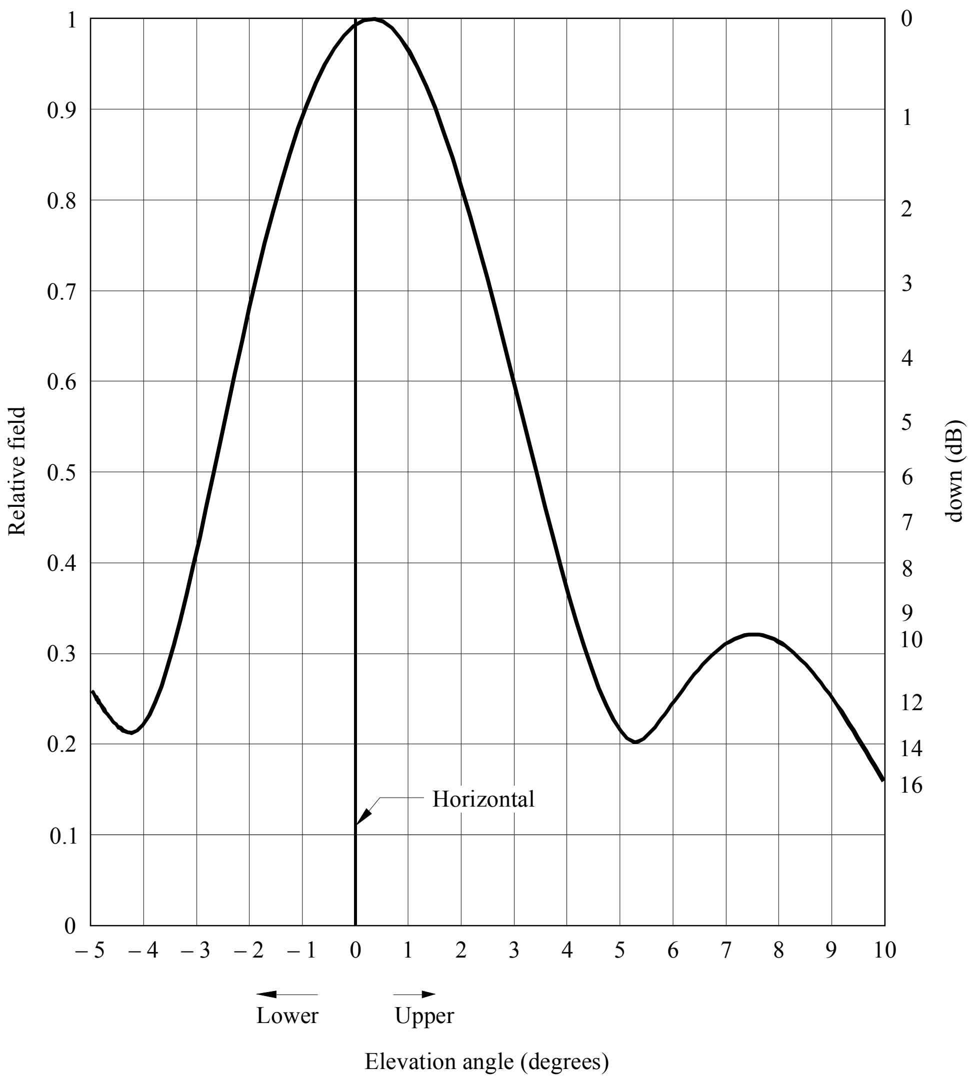
Adjacent-channel interference is controlled by imposing conditions on both the multipoint distribution service transmit and receive sites. An objective of 0 dB *C*/*I* was chosen for this condition. In order to help achieve this condition in a practical manner, multipoint distribution service stations serving the same area are encouraged to co-locate transmit antennas as close as physically possible (0.5 km, or less separation) and to transmit on orthogonal polarization, but with signals of equal power. Further study is required as to the effects of propagation on polarization stability in the 2 GHz band.

2.4 Sharing considerations

The vertical pattern for the typical omnidirectional transmit antenna used in 2.5 GHz P-MP system is shown in Fig. 1. Figure 1 and Table 1 are appropriate to use in determining sharing considerations with other services.

FIGURE 1

Typical transmit antenna pattern in the vertical plane



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ANNEX 2

Examples of packet radio systems

1 Introduction

This Annex describes packet radio technology and systems. Packet radio techniques are now being successfully used in a number of countries.

2 System application

Packet radio systems function most effectively when the data traffic they must handle is in the form of bursts. Systems operated below 1 GHz normally carry low data rates up to 9.6 kbit/s. Above 1 GHz, higher data rates can be used. For example, a packet radio network can provide the interconnection means in a computer communications network. Communications may be between host computers and end user terminals, and between end terminals.

In addition, such systems are often installed in rural areas, where the cost of adding new cables between the customer's node and the nearest network facility can be prohibitive. In other cases, a chronic shortage of copper loops makes such systems attractive in urban areas.

3 System description

The basic concept in packet radio is that the data are transmitted in packets. Systems employing TDMA and carrier sensed multiple access (CSMA) have been designed. These systems allow simultaneous access to one radio channel by either a CSMA or a TDMA protocol, and both permit individual stations to act as store and forward repeaters to handle traffic locations farther from the central site. Alternatively, two frequency duplex regenerative repeaters can be used to provide additional flexibility in system design.

Packet switching conveys with it superior error control techniques and a CRC-16 check sum can be appended to each block of data (reference ITU-T X.25 standards). To achieve very low bit-error ratios (BERs) (better than 1×10^{-11}) on transmission of large blocks of data, more than one CRC-16 check sum can be used in the block. In P-MP data transmission systems, it has been observed that block retransmission techniques are superior to forward error correction (FEC).

Since packet data systems do not operate in real time because of padding delays, special techniques can be used to keep the overall delay to a minimum, such as commencing transmission before the complete packet is received and using high network transmission rates such as 4.8 to 9.6 kbit/s. Clearly, not being "real time" offers significant benefits in spectrum conservation, since data are sent at the highest possible speed on the network even though the destination is a low speed device.

In one TDMA system configuration, network management is conducted by a unit called a station. Such a station has a number of radios in its subset and it determines the overall link connectivity of the network. In environments composed of fixed and possibly mobile units, each radio collects possible link connections, stores the information in memory, and sends it to the station. Using these data, the station establishes a final connectivity network. Network architecture can be varied to include configurations without stations or a broadcast configuration.

4 Efficiency and modulation methods

CSMA systems have the advantage of being able to use standard land mobile radio transceivers employing frequency modulation. This provides the capability to carry up to 9.6 kbit/s of data and achieve a BER of 1×10^{-6} at receive carrier levels of –107 dBm. Measurements have shown that, in a well designed CSMA system, up to 40% of the channel capacity can be used. Typical channel capacities in a CSMA operating between 130 and 960 MHz are given in Table 2.

TABLE 2

CSMA channel capacity

Average message characters	Messages/minute /user	Maximum number of users	Average delay per message (s)
60	30	16	0.26
60	20	28	0.24
60	10	52	0.23
60	5	100	0.23
60	2.5	240	0.23
60	1	400	0.22

At some point, as the number of messages/minute/user increases (for example, at 30 messages/minute/user) the traffic may no longer be considered as being in the form of bursts and another type of system may be more appropriate.

The use of direct sequence spread spectrum modulation with minimum shift keying (MSK) of the carrier frequency has been proposed for a TDMA system in the 2 GHz band. This technique can minimize interference to other systems using the same frequency and frequency bands while enabling the packet radio to reject interference and function satisfactorily with a lower signal-to-interference ratio than an analogue receiver. However, spread spectrum equipment is generally more complex and costly than analogue receivers.

5 Summary

Packet radio systems employing CSMA and TDMA techniques have demonstrated their ability to provide high performance and efficient transmission of data traffic.

ANNEX 3

P-MP systems utilizing TDMA techniques for data transmission in urban areas

1 Introduction

The general principles of P-MP systems using TDMA are discussed in Annex 1 of Recommendation ITU-R F.1103.

Considerable development has taken place in recent years in the use of this technique to provide digital terminations in urban areas.

The principles and applications of these P-MP systems using TDMA techniques for provision of data services in urban areas are discussed within this Annex and a summary of the details of a number of systems is contained in Tables 3a and 3b.

TABLE 3a

Examples of P-MP radio systems using TDMA techniques
(Frequency below 3 GHz)

System	150, 450, 800 MHz	890 to 960 MHz	1.5, 2.4 and 2.6 GHz		1.5 and 2.4 GHz	1.5 to 2.6 GHz	2 GHz
1. Channel capacity (typical) (kbit/s)	2 × 32 or 4 × 16	64 × 1.2	10 × 64	30 × 64	30 × 64	60 × 64	48 × 64
2. Aggregate bit rate(kbit/s)	26 × 64	240	832	2 304	2 432	4 864	3 088
3. Modulation method	16-DPSK	Offset 4-PSK	2-FSK	4-PSK	4-PSK	Offset 4-PSK	4-PSK
4. Central station (CS) antenna	Omnidirectional: gains up to 10 dBi or Yagi	Omni or wide beam: gain 10 dBi	Omnidirectional: gain 10 dBi Yagi: gain 16-21 dBi Horn: gain 13 dBi		Omni or wide beam: gain 10 dBi	Omni or wide beam: gain 10 dBi	(45°) wide beam: gain: see Fig. 4 of Report 1057 (Düsseldorf, 1990)
5. Out-station (OS) antenna	Yagi: gain 10 dBi	Loop Yagi: gain 20 dBi	Yagi: gain 16-21 dBi Horn: gain 13 dBi		Yagi: gain 17 dBi at 1.5 GHz Parabolic: gain 22 dBi at 1.5 GHz gain 27 dBi at 2.4 GHz	Conical: gain 17 dBi	Parabolic ($\varphi \geq 1.2$ m)
6. Customer data rates (kbit/s)	Up to 1.2	1.2-64	64	1.2-19.2 64 144 (ISDN)	a) Up to 9.6 b) Standard: 64	2.4-64	64-1 544
7. Customer assignment	Fixed or demand assignment	Fixed assignment	Fixed or demand assignment		Fixed or demand assignment	Fixed or demand assignment	Fixed assignment
8. Operational range (km)	Up to 60	Up to 30	Up to 70		Up to 50	Up to 72	Up to 50

TABLE 3b

Examples of P-MP radio systems using TDMA techniques
(Frequency above 3 GHz)

System	10.5 GHz	19 GHz	23 GHz	26 GHz	26 GHz
1. Channel capacity (typical) (kbit/s)	30 × 64	90 × 64 47 × 144 (2B+D)	10 × 64	192 × 64	96 × 64
2. Aggregate bit rate (kbit/s)	2 100	8 192	832	14 300	4 × 2 048
3. Modulation method	4-PSK	2-FSK	2-ASK	FSK (CS-OS) DFSK (OS-CS)	2-FSK
4. Central station (CS) antenna	90° or 120° wide beam: gain 13 dBi	90° or 120° wide beam: gain 18 dBi	90° or 120° wide beam: gain 10 to 15 dBi	90° wide beam: gain 20 dBi	90° wide beam: gain 20 dBi
5. Out-station (OS) antenna	Parabolic: gain 34 dBi	Parabolic: gain 35 dBi	Parabolic: gain 35 dBi	Cassegrain: gain 35 to 47 dBi	Parabolic: gain 30 dBi
6. Customer data rates (kbit/s)	64 Others available	12.8 and 64 initially, expandable to include ISDN rates of 80 or 144	64	64 to 6 144	64
7. Customer assignment	Fixed or demand assignment	Fixed or demand assignment	Fixed or demand assignment	Fixed assignment	Demand assignment
8. Operational range (km)	Up to 10	Up to 10	Up to 5	Up to 7	Up to 2

2 Principles of operation

The principles of operation are discussed in Annex 1 to Recommendation ITU-R F.1103 particularly with regard to radio concentrator systems. However, all TDMA P-MP systems use the same basic transmission philosophy. Data signals are transmitted from the central station in a time division multiplex (TDM) format, using bit or byte interleaving. The information for the various out-stations is transmitted sequentially. In the reverse direction, each out-station is allocated a time slot within which it transmits its information. Great care must be taken to ensure that the bursts of data arrive at the central station sequentially. This is generally achieved by careful design of the control system and by the provision of absolute delay equalization. In urban applications, propagation time variations are short in relation to the baud period of the system and pre-set equalization is generally adequate. Figures 2 and 3 of Recommendation ITU-R F.1103 show a typical system schematic and TDMA frame arrangement.

In general, the connection of P-MP systems to the network is effected at the central station, and it is preferable that the P-MP system appears to be transparent to the network with the provision of standard hierarchical interfaces. Furthermore, the use of a conventional interface allows the central station to be placed at some distance from the connection point to the network, as the link to this point can be made by conventional radio or cable systems.

Normally the regenerated signal received at each out-station is used to provide timing information for the out-station. Synchronization information for the burst mode transmissions is obtained from the supervisory bits received from the central station.

Hence, each burst contains preamble information and, consequently, bursts with long frame periods are desirable for efficient use of the system. However, this approach can lead to overall delays that are unacceptable in a public switched network. Consequently the relationship between transmission efficiency and permitted system delay must be carefully considered.

3 Frequency allocations

Typically, systems which provide data to urban out-stations use frequencies in the SHF bands (Table 3b). However, many systems designed for rural telephony or long range non-urban use can carry data as shown in Table 3a, and can also be used in urban areas.

It is necessary for systems operating at SHF frequencies to have an unobstructed propagation path free of tall buildings which may cause many shadow regions. Propagation path visibility, defined in terms of the percentage of subscribers in line-of-sight from the central station, can be increased by an overlapped cell configuration using several central stations. With UHF and VHF systems operating in rural areas, some diffraction loss is generally allowable.

Further studies, taking into account the characteristics of urban propagation, are needed in order to define the optimum assignment pattern.

4 Antennas

At the central station, either a directional or an omnidirectional antenna may be used, depending on the characteristics of the system and the required service area. Normally, directional antennas are used at out-stations, while repeater stations use a mixture of directional and omnidirectional antennas, as required.

To minimize interference, the central station may use directional antennas facing groups of out-stations. The beamwidth should, however, be sufficiently wide to cover the required service area.

A high front-to-back ratio is required to allow frequency re-use with other systems and to provide high antenna gain for low power transmitters and associated economical low power facilities.

To maintain the required ratio of desired to undesired signal levels, a dynamic antenna switch may be used in synchronization with the frame time to switch out the antenna receiving the undesired signal.

5 System configuration

Annex 1 of Recommendation ITU-R F.1103 gives details of typical P-MP configurations, a block diagram and a time-slot sequence. These features are equally applicable to urban data systems.

In the simpler P-MP systems, each time slot is pre-assigned to a specific out-station which has access to the time slot at all times. This arrangement is used to provide a continuous service to a customer and the spectral efficiency is similar to that of an equivalent point-to-point digital radio-relay system.

Where the out-station does not require permanent connection to the central station, more efficient usage of the spectrum can be achieved by assigning time slots to out-stations on a demand basis.

One system (shown in Table 3b) employs demand assignment and a frequency selective TDMA scheme whereby radio channels are assigned to a number of lower power different carrier frequencies (typically 4) at each out-station. This system operates at 26 GHz providing 96 radio channels, each of 64 kbit/s to serve about 500 subscribers with a call loss probability of 0.01. Frequency switching can be carried out on a call by call, frame by frame, or burst by burst basis. This is one method to reduce problems, such as required high output power for a single carrier TDMA system, or high frequency stability for an SCPC system, which are associated with operation in the 20 to 30 GHz band.

To carry data traffic efficiently at bit rates lower than 64 kbit/s, the whole 64 kbit/s trunk need not be used. By using multi-frame techniques, each 64 kbit/s trunk can be subdivided to increase the number of lower speed demand assigned trunks available for data transmission. Such systems are shown in Table 3a at 1.5 to 2.6 GHz and in Table 3b at 19 GHz, for example.

One system designed specifically for data transmission, described in Table 3a, provides continuous 2-way data communications between up to 64 remote points and a central node with any mixture of standard bit rates between 1.2 and 64 kbit/s and a total aggregate of 76.8 kbit/s in both directions. To simplify radio hardware and RF frequency assignments, a single frequency scheme is used to transmit both from the central node to the subscribers and to the central node from the subscribers in alternate transmission bursts. The actual transmission rate is 240 kbit/s.

ANNEX 4

Digital P-MP systems using FDMA

1 Introduction

Digital P-MP systems are used worldwide in rural as well as in suburban and urban areas.

The application depends mainly on the telecommunication services transported.

For rural coverage, frequency bands below 3 GHz are suitable to be used on the basis of Recommendation ITU-R F.746. The low frequency bands allow for a huge coverage using repeater stations between the central station and the terminal stations. On the other hand the user bit rates are rather limited due to the overall small frequency bands available and due to the restricted propagation conditions hindering higher capacities. Thus, mainly telephony and low data services are transported to remote areas also taking into account the possible switching functions at the repeater and terminal stations to improve the overall efficiency of such rural P-MP systems.

For applications in suburban and urban areas higher capacities, up to $n \times 2$ Mbit/s for ISDN, high data rates, Internet services and leased line connections have to be transported to the terminal stations, in order to cover the necessities of the new network operators competing with the incumbent in the post deregulated (liberalized) telecommunication market. For such types of P-MP systems in the access network the switching functions are provided in major switching centres outside the access network reducing the cost of the overall access network and the P-MP systems respectively.

Due to the different applications, coverage and frequency bands envisaged, the operational frequency bands of P-MP systems in the access network vary from about 3 GHz up to about 38 GHz for the time being and will further extend up to about 70 GHz later, especially where high density applications in the FS are intended to be deployed using P-MP systems as one possible solution.

P-MP systems apply different access methods which are based on the physical parameters of frequency, time and power (code). This leads to the access methods of FDMA method, TDMA method and code division multiple access (CDMA) method.

Each of these access methods is used depending on the application, the service and the deployment scenario envisaged.

Due to signal processing technologies with clock rates of up to 200 MHz, FDMA P-MP systems provide a highly flexible process to transport signals with bit rates of up to $n \times 2$ Mbit/s in the access network to the terminal stations (TS) in an economical and frequency efficient way.

FDMA systems are able to adapt the bit rate from 64 kbit/s up to $n \times 2$ Mbit/s, the modulation scheme, the code for FEC and the carrier frequency within the RF-channel bandwidth. Thus, according to the requirements of the user, the RF-channel bandwidth assigned for the network operator and the interference scenario in the multi-cellular environment (architecture) of the access network, the FDMA P-MP system enables the network operator to allocate on demand the necessary capacity to the customer. The FDMA system is transparent in respect to the service and digital signals transported and provides user-network interfaces (UNI) and network node interfaces (NNI) standardized by ITU-T.

The system can be operated in different frequency bands applying the same technique in respect to the signal processing, baseband processing, but with the radio frequency outdoor unit according to the frequency bands in use. Thus an access network architecture may be built up covering suburban coverage by using frequency bands below 11 GHz (e.g. 3.4 to 3.6 GHz, 3.6 to 3.8 GHz and 10.15 to 10.65 GHz) allowing link ranges between the CS and the TS of about 10 to 15 km. At the same CS site using the microwave outdoor unit in the frequency bands above 11 GHz (e.g. 26 GHz, 28 GHz (see Annexes 1 and 2 of Recommendation ITU-R F.748) or 32 GHz; high density applications in the FS) where link ranges of up to 5 km can be achieved for urban coverage.

In any case P-MP systems have to fulfil at least the performance and availability objectives comparable with that of the wired transport media used in the access network, in order to enable the network operator using fixed wireless access systems to compete with the incumbent.

2 Capacity and cell planning aspects

As mentioned above the high flexibility of the FDMA system allows a multi-cellular architecture where the necessary traffic capacity in a given service area and within an assigned RF-channel block (e.g. 28 MHz) can be provided by a given number of cells. Each cell uses the same RF-channel block. The sectorization at the CS applying sector antennas integrated in the outdoor unit is a further means to increase the traffic per cell proportional to number of sectors (e.g. 4 sectors) at the CS. The sectors are decoupled using different polarization in adjacent sectors.

In a multi-cellular network the link capacity per cell is about 3.8 bit/s/Hz/cell assuming 4 sectors per cell.

The link capacity may be increased by installing more sectors in the cells, up to 8 sectors in the bands above 10 GHz (up to 6 sectors are useful in the band 3.5 GHz). Another way to increase the capacity is to increase the number of cells and consequently reducing the cell radius of each cell. A third means to increase the traffic capacity in a given area is to apply more RF-channel blocks (e.g. 2×28 MHz). The above-mentioned means may be combined depending on the traffic distribution within the envisaged service area, the accessibility of the sites for the CS and the availability of RF-channel blocks.

The interference between the cells and within each cell is controlled by adapting the modulation scheme, the carrier frequency of each transmitted signal within the RF-channel block, by the automatic transmitter power control (ATPC) of both the CS transmitter and the TS transmitter. The level of interference is thus kept low to be able to provide a BER $< 10^{-10}$ during clear air conditions and to fulfil the performance and availability objectives for access networks during adverse propagation conditions. The computer aided cell planning for the FDMA system provides the necessary information for controlling the interference scenario during installation, operation and extension of a given network.

It is worth mentioning that in the bands above 3 GHz line-of-sight (LOS) conditions are very useful in order to fulfil the performance and availability objectives and the grade of service and to control the interference scenario.

Due to the flexibility of the FDMA system overlapping cell structures (e.g. sectors of different cells) can be readily handled by cell-planning without restriction in the overall transport capacity of the P-MP system.

3 Technical characteristics

3.1 CS and TS

The characteristics of the CS and the TS are given in the Table 4 for different frequency bands.

TABLE 4

Characteristics of CS and TS

Frequency band (GHz)	3.5/3.7	10.4	26/28	32
Total transmitter power (dBW)	–6	–6	–12	–12
Single carrier power (dBW)	–20	–20	–5	–5
Total e.i.r.p./*X*° sector antenna	+8 dBW/60°	+10 dBW/45°	+2 dBW/45°	+2 dBW/45°
2 Mbit/s carriers/RF-channel block	Max. 16/14 MHz	Max. 33/30 MHz	Max. 32/28 MHz	Max. 32/28 MHz
Modulation scheme	QPSK 8 TCM/16 TCM	QPSK 8 TCM/16 TCM	QPSK 8 TCM/16 TCM	QPSK 8 TCM/16 TCM
Bit rate per carrier	64 kbit/s to $n \times 2$ Mbit/s $n < 4$	64 kbit/s to $n \times 2$ Mbit/s $n < 4$	64 kbit/s to $n \times 2$ Mbit/s $n < 4$	64 kbit/s to $n \times 2$ Mbit/s $n < 4$
Receive level (RL) (dBW) BER: 10^{-3} 2 Mbit/s carrier QPSK 8 TCM 16 TCM	 –130 –129 –123	 –130 –129 –123	 –125 –124 –118	 –124 –123 –117

TCM: Trellis coded modulation.

The CS may be divided into two parts, the central base station system (indoor unit) containing the baseband signal processing and the central controller and the outdoor unit containing the transceiver with the integrated sector antenna (planar antenna).

The TS may have the same mechanical design, featuring indoor unit with the modem and the outdoor unit with the integrated narrow beam antenna (planar) for the bands in use, or a parabolic antenna for the bands above 20 GHz in order to achieve longer link ranges.

For carriers transporting bit rates other than 2 Mbit/s as stated in Table 4, *RL*s can be calculated from the formulas below.

For QPSK: RL (dBW(for BER 10^{-3})) $= X + 10 \log_{10} b$

For 8-TCM: RL (dBW(for BER 10^{-3})) $= Y + 10 \log_{10} b$

For 16-TCM: RL (dBW(for BER 10^{-3})) $= Z + 10 \log_{10} b$

b: bit rate (Mbit/s).

The values *X*, *Y*, *Z* for the different frequency bands are stated in the Table 5.

TABLE 5

Values for *X*, *Y* and *Z* (see formulas above)

	3.5/3.7 GHz	10.4 GHz	26/28 GHz	32 GHz
X	–133	–133	–128	–127
Y	–132	–132	–127	–126
Z	–126	–126	–121	–120

The *RL* values for BER 10^{-6} are 2.5 dB higher than the above RLs.

3.2 Antenna characteristics

The antennas used by P-MP systems for the access network, serving suburban and urban areas are mainly sector antennas at the CS in order to provide sufficient transport capacity within a cell.

Adjacent sectors may use different polarization in order to provide additional decoupling between sectors (see Annex 4, § 2).

The different sector angles (sector beamwidth at –*X* dB) such as 15°, 45°, 60°, 90° or 120° are used to adapt the cell coverage to the traffic and to the distribution of the TSs within the cell. The 15° sector antenna may be used to achieve a higher link range for some outer TSs located nearby each other. A mixture of sectors with different sector widths within one cell is a useful means too, to adapt the distribution of sites of the TSs.

The gain of the sector antenna mainly depends on the sector width. Table 6 gives typical values for some sector widths applying planar antenna technology.

TABLE 6

Typical gain of sector antennas

Typical sector width (azimuth) (degrees)	Typical gain (dBi)	Typical elevation beamwidth (degrees)
15	18	7
45	15	7
60	12	15
90	12	7
120	9	15

When down tilting the antennas of the CS, to reduce the interference into other cells the maximum link range may be affected negatively. On the other hand the elevation beamwidth of the sector antenna makes it also necessary to carefully calculate the link budget for the TS which is very close to the CS because they may fall outside the elevation beamwidth of the CS.

The TS antenna applies a narrow beamwidth, thus the gain depends mainly on the frequency and the size. Typical values for the gain of planar antennas are stated below.

TABLE 7

Typical gain of planar antennas used at TS

Frequency band (GHz)	Typical gain (dBi)
3.5/3.7	17
10.4	25
26/28	28
32	30

At the TS, the usage of antennas which are intended to be applied for point-to-point radio-relay systems may also be foreseen in some cases for P-MP systems especially where longer hop lengths between the CS and the TS in the frequency bands above 10 GHz are envisaged.

ANNEX 5

P-MP systems in the frequency band 25-32 GHz

1 Introduction

High density P-MP systems operate between terrestrial stations as fixed wireless systems for the delivery of voice, video, and data services. These applications typically provide a communications path for commercial and residential communications for the last few kilometres of a distribution network as an alternative to coax, fibre, or twisted pair solutions.

System parameters are taken from the link margin characteristics given in Tables 4 through 9. It should be noted that the maximum hub station transmit power may be adjusted on a geographic basis to meet grade of service goals.

The link has a BER equal to or better than 1×10^{-8} with clear-air conditions, and 1×10^{-6} under degraded propagation conditions for all but a small percentage of a year as meets the link availability criteria. (This means that under clear-sky conditions these carriers will be operated with enough margin to ensure that the link margin criterion is met.) These BERs are attained by the specified e.i.r.p. and by rate 3/4 FEC techniques using convolutional coding and Viterbi decoding. In addition, rate 1/2 and 7/8 coding may also be used for lower or higher margin conditions, respectively.

The following assumptions are made concerning the antennas. The hub station antenna will normally have its main beam pointed 1° below the local horizontal. The subscriber station (remote terminal) antenna will be pointed at the hub station antenna. Also, the hub station antenna will typically be mounted 100 m higher than the subscriber stations. For a subscriber station located 200 m from the hub station, the gain roll-off of the hub station antenna is typically 18 dB for a 15° × 90° (*El* x *Az*) horn antenna and 29 dB for a 3° × 45° horn antenna.

Sufficient fade margin is necessary to mitigate rain fades. In case of significant path attenuation due to rainfall, the subscriber stations will exceed the clear-air e.i.r.p. power spectral density limits to compensate (one-for-one) for the excess path attenuation. Link availability will vary with rain climate region and path length. Table 8 provides the (minimum) fade margin required for various cumulative probability values at 28 GHz. These precipitation losses were calculated using the rain climate regions in Recommendation ITU-R P.837-1 (Characteristics of precipitation for propagation modelling, Geneva, 1994) and the equations in Recommendation ITU-R P.530-6 (Propagation data and prediction methods required for the design of terrestrial line-of-sight systems, Geneva, 1995). As a worst-case local multipoint communication systems (LMCS)/local multipoint distribution systems (LMDS) scenario, the link assumes horizontal polarization.

TABLE 8

Minimum fade margin (dB) for the required cumulative probability as a function of path length (km) for various ITU-R rain climatic zones

Link	ITU-R rain climate regions and path length (28 GHz, horizontal polarization)									
Cumulative probability	E		F		K		M		N	
	2.5 km	5 km	2.5 km	5 km	2.5 km	5 km	2.5 km	5 km	2.5 km	5 km
0,999	3.5	6.4	4.3	8.0	6.3	11.8	9.3	16.6	12.9	21.8
0,9995	4.7	8.7	5.9	11.0	8.7	16.0	12.6	22.6	17.8	29.7
0,9999	9.1	16.6	11.5	21.0	17.2	30.7	25.0	43.4	35.0	57.0
0,99995	11.6	21.3	15.0	27.0	22.3	39.4	32.5	55.7	45.4	73.2

2 Technical characteristics

Technical characteristics depend on fade margin requirements. Two cases are considered: clear-air and faded conditions.

Downstream systems operate with fixed transmit power while upstream transmitters operate with automatic power control.

Report ITU-R F.2108 describes characteristics for systems operated at +8 dB(W/MHz) hub e.i.r.p. power spectral density in the 25.25-27.5 GHz band and requiring 37 dB of fade margin at 5 km range.

Report ITU-R F.2108 also describes characteristics of systems operated at +30 dB(W/MHz) hub e.i.r.p. power spectral density, up to +42 dB(W/MHz) subscriber station e.i.r.p. power spectral density in the 27.5-28.35, 29.1-29.25 and 31.0-31.3 GHz bands, and requiring 57 dB of fade margin at 5 km.

Technical characteristics, i.e. transmit power, are normally adjusted for systems designed for various fade margin requirements at a specific range.

3 Antenna characteristics

The LMCS/LMDS systems use antennas designed for various sector sizes and hub applications. Various antennas can be used to accommodate terrain, link margin, and performance requirements.

Recommendation ITU-R F.1336 should be referred to for relevant antenna radiation patterns. These antenna patterns assume orthogonal polarization in adjacent sectors.

4 Subscriber station e.i.r.p.

Subscriber stations use automatic power control to minimize self-interference within the LMCS/LMDS system. This upstream power control is also referred to as remote terminal power control (RTPC). The transmit power of the subscriber station varies with path loss so as to keep the bit energy-to-noise power spectral density ratio, E_b/N_0, received at the hub station's demodulator at a constant level. Subscriber stations close to the hub station transmit with much lower power than distant subscriber stations. For clear-air conditions, subscriber stations will transmit only enough power necessary to meet the hub receiver threshold E_b/N_0 requirements.

When events such as rain add attenuation to the path between the subscriber station and the hub station, the power of the affected subscriber stations is increased as compensation to maintain a constant hub station receiver threshold E_b/N_0. Any rain attenuation between the hub station and the observer will further attenuate this signal below the clear-air level. The apparent e.i.r.p. of the subscriber station is always the clear-air value or less when viewed from a distant observer looking towards the hub station (i.e., the upstream link maintains no fade margin, $FM = 0$ dB).

Upstream automatic power control is necessary to mitigate self-interference and make the LMCS/LMDS concept viable for two-way service. Subscriber stations transmit only when pointing at a hub. The transmit power level depends on the distance to the hub. Subscriber stations transmit with only the minimum power necessary to meet the hub station receiver threshold E_b/N_0 for a given modulation format. When operating properly, interference between LMCS/LMDS subscriber stations should degrade the hub station receiver threshold E_b/N_0 by 0.5 dB or less.

It should be noted that each subscriber station within a sector operates on a different channel at any instant in time. From a distant observer's point of view, the main beam from only one subscriber station per sector radiates from a cell towards a distant observer at a given frequency and time.

At a sector boundary, a maximum of two contributors on the same channel may occur. The subscriber station in one sector will be horizontally-polarized, while the subscriber station in the other sector will be vertically-polarized. The probability of having a sector boundary pointed at the observer and having two subscriber stations in that narrow region both on the observer's frequency is very small.

5 Operational characteristics of P-MP systems

Operational characteristics affect the probability of emissions on a given channel. Factors include but are not limited to e.i.r.p. as a function of rain zone, multi-access protocol channel utilization, band loading in general, percentage of hub capacity utilized, service mix, economics, politics, agency policy, cell-size, and deployment overlap factor. Each of these factors limits potential interference to less than the interference using gross hub densities and system emission capability. Further study of these factors is required.