RECOMMENDATION ITU-R F.757-1*

BASIC SYSTEM REQUIREMENTS AND PERFORMANCE OBJECTIVES FOR FIXED WIRELESS LOCAL LOOP APPLICATIONS USING CELLULAR TYPE MOBILE TECHNOLOGIES

(Question ITU-R 140/9)

(1992-1997)

The ITU Radiocommunication Assembly,

considering

a) that cellular type mobile radiocommunication systems are already in wide use;

b) that in some cases it may be desirable, for reasons of convenience and economy, to apply systems using cellular type mobile technologies for use as fixed wireless local loop (WLL) in both rural and urban areas;

c) that when used in fixed applications such radio links perform an equivalent access function to metallic subscriber lines;

d) that when used in fixed applications the radio links provided may form part of an international connection;

e) that the introduction of digital type cellular systems will make it possible to offer various types of service including the local grade portion of an integrated services digital network (ISDN),

recommends

1 that systems using cellular type mobile technologies in fixed applications provide services also available to subscribers by metallic lines. These services include:

– individual subscriber telephone service;

– pay-phone service of various kinds;

– 4-wire service with and without receive and send “E AND M” signalling;

– the capability to carry voice-band data signals including facsimile and other telematic services up to a data rate of 9.6 kbit/s;

2 that digital systems using cellular type mobile technologies in fixed applications should provide the same ISDN access as digital mobile cellular systems;

3 that, since such systems used as fixed WLL may form part of an international connection, the relevant G-Series ITU-T Recommendations should be met;

4 that, giving due regard to economical considerations, the grade-of-service (lost call probability) offered by such a system to a subscriber shall not normally be worse than 5% and shall be calculated employing ITU-T Recommendations E.506, E.541 and Supplement No. 1 to the E-Series Recommendations. As an objective, a service quality comparable to that already provided to fixed subscribers in urban areas should be offered, e.g. a grade-of-service better than 1%;

5 that the error performance and availability objectives of digital systems should generally be in accordance with Recommendation ITU-R F.697;

6 that analogue systems should be designed to provide voice circuits with a noise level less than 1 000 pWp (before companding improvement is taken into account) in the unfaded condition, concerning which further information is provided in Annex 1. As an objective the availability should be better than 99.9%;

7 that cellular type mobile systems operating in the bands allocated for mobile services may include fixed WLL applications;

---

* This Recommendation should be brought to the attention of Radiocommunication Study Group 8 (Working Party 8A) and the Telecommunication Development Study Group 2.

8 that fixed WLL applications using cellular type mobile technologies may also operate in bands allocated to the fixed service;

9 that Annex 1 should be referred to for the application of cellular type mobile technologies as fixed WLL.

ANNEX 1

Applications of cellular type mobile radiocommunication technologies for use as fixed (WLL)

1 Introduction

Cellular mobile radiocommunication systems are already in wide use. The technology for such systems is expanding rapidly.

It is technically feasible, and in some cases it may be desirable for reasons of convenience and economy, to apply cellular type mobile radiocommunication systems for use as fixed WLL. This Annex describes basic system requirements for such applications. In general most applications deal with the connection of subscribers to the telephone exchange and thereby into the switched network.

For brevity, the application of cellular type mobile radiocommunication systems for use as fixed WLL will be called simply “fixed cellular-WLL”.

2 General considerations

The service to be provided forms a permanent, integral part of the national telephone network and as such can be part of an international connection.

A number of administrations have already implemented such systems, for the provision of telephone service in rural areas. It is important, therefore, to establish the basic system requirements (e.g., performance objectives and frequency bands) which permit such integration as effectively as possible without degrading overall network performance.

The general goal in rural and remote areas is to establish an overall quality of service equal to that achieved by wireline systems in well served urban areas. A minimum objective towards this goal is to achieve service quality at least comparable to that offered in these urban areas, as proposed in the ITU-T Handbook on Rural Telecommunications (Geneva, 1985) and in Recommendation ITU-R F.756.

In some cases, it may be effective to use cellular type fixed systems not only in rural areas but also in urban areas e.g. where the cable infrastructure is temporarily inadequate. The radio system has the advantage that it can be deployed rapidly compared with cable systems. Also it may be another attractive feature that the facilities can be easily converted for mobile use after the cable systems become available.

2.1 Basic approach

There are two basic approaches for fixed cellular-WLL. One is to establish an entirely new fixed cellular-WLL, optimized for and dedicated to fixed use, and the other approach is to make minimum changes to the existing or planned cellular mobile systems for adaptation to fixed use.

The former approach may be justified in some cases from the viewpoint of economic considerations. However, it should be taken into account that in many cases it may be desirable that a system can accommodate both mobile and fixed subscribers. The latter approach seems preferable for these cases. It is therefore desirable that future cellular mobile systems should include in their design considerations the possible application of the systems for fixed WLL.

One complicating factor that must be taken into account is whether the cellular system is operating entirely in a fixed service mode or whether it is a mobile system with some fixed users. On the one hand, if the fixed station is part of an existing mobile system, then the service can be provided with considerable economy, since the mobile system provides the basic infrastructure in which the fixed station works. On the other hand, the mobile system will have been designed

to satisfy its own performance criteria set by the mobile environment, and may well limit the performance achievable by the fixed station. For example, one administration operates mobile systems with a carrier to interference ratio of 18 dB at the edges of the cell. This provides an acceptable level of performance for a mobile system, but could result in unacceptable performance in the fixed service where the radio link is intended to be part of the telephone network and radio is used instead of wire or cable only for convenience and economy. Another factor is that cellular systems are normally optimized for low traffic subscribers, 0.02 E, whereas fixed subscribers normally average between 0.05 and 0.09 E.

2.2 Frequency bands

Frequency spectrum is a limited natural resource. Therefore, the frequency bands suitable for mobile communication should be primarily used for the mobile services. For this reason, the application of cellular type mobile systems for fixed WLL may be justified mainly in rural areas where the demand for mobile communication is small and the provision of telecommunication services by means of wireline facilities is too costly.

If cellular mobile systems are adapted for use as fixed WLL, frequency bands for fixed cellular-WLL should be the same as those for cellular mobile systems.

Frequency bands commonly used for cellular mobile radio are in the 400 MHz and 800/900 MHz bands. Any of these bands are, in principle, suitable for the provision of a fixed service; however, the interference environment in any area where it is proposed to operate must now satisfy criteria for the fixed service as opposed to the mobile cellular service. Further study is required for preferred frequency bands for cellular type systems which have been optimized for fixed WLL.

3 System requirements

Basic requirements are examined in this Annex.

3.1 Operational aspects

As a matter of principle, all kinds of telecommunication services offered through wireline facilities could be made available by cellular type fixed systems. Most of the services are already provided by cellular mobile systems. Among the services which are not usually provided by cellular mobile systems is the pilot number service (multiple lines) which is essential for key telephones and private branch exchanges.

Some features of cellular mobile systems are not necessary for fixed cellular-WLL. Among them are roaming and hand-off capabilities. In addition, certain sub-systems of cellular mobile systems may require modifications for adaptation to the fixed WLL. Most important are the numbering plan and charging sub-system. In particular, in cases where a system accommodates both cellular mobile and fixed cellular-WLL subscribers, the numbering and charging sub-systems should be capable of handling the two categories of subscribers, unless the regulation permits a common sub-system to be applicable to both cellular mobile and fixed cellular-WLL subscribers.

One of the solutions for numbering and charging when cellular systems are introduced into an existing public switched telephone network (PSTN) might be to adopt service control points (SCP) with common channel signalling.

3.2 Basic voice channel characteristics

3.2.1 General

A full description of the voice channel would involve the specification of all voice channel parameters:

– circuit noise,

– frequency response,

– envelope delay,

– impulse noise,

– gain stability,

as well as impedance, return loss, balance, etc., at the interface.

Whilst all the above are important, only the circuit noise is discussed here, the other requirements being the subject of further study.

3.2.2 Cellular radio noise performance

Mobile cellular radio traditionally does not specify the noise level of a connection in absolute terms. Channel performance as a whole is specified in terms of mean opinion scores (MOS) which describe the level of satisfaction expressed by a group of listeners to a given circuit, as described in ITU-T Recommendations P.70 to P.79. Fixed WLL applications, on the other hand, deal with absolute values of circuit parameters, such as noise level, frequency response, etc. Hypothetical reference connections to allocate noise allowances to various parts of a circuit have not yet been established for cellular mobile systems.

Analogue cellular radios employ FM modulation and companding. In a mobile environment the performance is normally limited by the rapid fading associated with the movement of the subscriber. In a fixed environment the radio path is, by definition, comparatively stable and subject only to fading and may be designed in accordance with established principles. In particular, directional antennas are used by the subscriber station which increase system gain and help to reduce the effects of interference. Based on reported figures, a steady state (unfaded, high received signal level, no interference), noise level in the range 1 000 to 10 000 pWp is typical of cellular radio.

Companding in accordance with ITU-T Recommendation G.162 is normally employed and subjective improvements of the order of 10 to 20 dB have been reported, reducing the steady state circuit noise to 100-1 000 pWp subjective equivalent. However, ITU-T Recommendation G.143 provides guidance on the use of compandors and recommends that only a 10 dB “advantage” (improvement in subjective noise level) should be assumed for planning purposes and cautions on the possible effects of compandors used in series in the network.

3.2.3 Local loop noise performance requirements

Various performance figures for the noise contribution in the local loop have been put forward for analogue systems. For example, ITU-T Recommendation G.103, which provides recommendations for hypothetical reference connections, allows 100 to 500 pWp for the connection to the local exchange. In as much as the rural connection can be part of an international connection, these figures are applicable to the subscriber to exchange connection in a rural area. This is essential if the objective of providing urban quality service is to be achieved. This would not be inconsistent with Recommendation ITU-R F.395 which, for example, establishes a noise power limit of 350 pWp for a 50 km link and 500 pWp for a 100 km link. These distances are typical for rural subscriber connections via radio. The ITU-T Handbook on Rural Telecommunications makes reference to ITU-T Recommendation G.103 for guidance but suggests “realistic” figures such as 4 000 to 10 000 pW0p and discusses figures of 1 000 pW0p used by some administrations. Recommendation ITU-R F.754 which deals with trunk connections in rural areas, uses a figure of 1 000 pWp derived from ITU-T Recommendation G.123 (Circuit noise in the national network). However, the ITU-T Handbook on Rural Telecommunications (Geneva, 1985) also cautions (on page 28) that, in the most complex reference connection, any appreciable increase of receiving end noise will degrade the system and result in user dissatisfaction. It also discusses the importance of maintaining a proper balance between noise and loss. It is clear that the ITU-R and ITU-T do not envisage high levels of noise for rural subscriber connections where it can be reasonably and economically avoided.

Narrow-band FM systems such as mobile cellular, while offering performance that may well be acceptable in a number of applications, are limited by the residual noise inherent in these systems. They are designed for an environment where the residual equipment noise is negligible in relation to the noise caused by interference and multipath fading. Wideband techniques, such as the time division multiple access (TDMA) systems discussed in Recommendation ITU-R F.756 can offer low noise performance (typically 100 to 200 pWp) owing to, in the case of digital systems, the use of standard A and μ-law pulse code modulacion (PCM) voice encoding as specified in ITU-T Recommendation G.165.

3.3 Service requirements

The basic service requirement is typically a 2-wire connection. However, in practice, a variety of additional services is also required. For example, in rural and remote areas, the provision of a pay-phone service is a necessity, while telex, facsimile, 4-wire with "E AND M" signalling and a variety of data services represent a wide range of additional telecommunications services which may need to be provided by radio to subscribers.

3.4 Operating environment

In providing telecommunications services, consideration must be given to the likely location of the subscriber station. While it is possible to locate the subscriber terminal at the subscriber's premises, this is not necessarily the best location for the radio antenna. In hilly terrain, houses are most often built in valleys or where some shielding is provided from the weather. This must be taken into account in the system design by, for example, adapting cellular equipment to feed a 1 200 Ω loop (including the telephone set) when used in the fixed service.

Clearly there are two types of environment possible, protected and unprotected. In the unprotected case, complete environmental sealing is required, which includes protection against rain, dust, sand, corrosive atmosphere, insects, fungus, etc., and operation in high humidity and over temperature ranges from −40° to +55° C is often specified. In the protected case, while environmental protection is less demanding, the equipment must still operate over wide temperature (−10° to +55° C) and humidity (5% to 95%) ranges.

3.5 Availability

When used in the fixed service, the design of the radio path should permit an overall availability to an individual subscriber of not less than 99.9% for both propagation and equipment effects (Recommendation ITU-R F.697). This will achieve a quality of service comparable to that in urban areas served by wireline systems. Some links are often designed with a higher availability when the administration considers it necessary.

3.6 Traffic capacity – grade of service

The grade of service or lost call probability is frequently designed to be of the order of 1%, but it is seldom as high as 5%, while some administrations set requirements in the range 0.1% to 0.5%, in order not to degrade the national network beyond the ITU-T recommended objective of 1%. Care must be taken to allow for appropriate growth in the number of subscribers and the higher loss probability figures should, therefore, be avoided, since they will generally result in severe customer dissatisfaction. These probabilities are calculated in the usual manner, employing ITU-T Recommendations E.506, E.541, and Supplement No. 1 to the E-Series Recommendations, as well as Recommendation ITU-R F.756. Factors to consider include:

– the number of radio channels required,

– the number of subscribers to be served, and

– the traffic intensity per subscriber.

Average traffic intensities of 0.05 to 0.09 E per subscriber have been used frequently for rural subscribers. The loss probability for up to 6 RF channels is shown in graphical form in the ITU-T Handbook on Rural Telecommunications (Geneva, 1985), page 84, Fig. 7-4(III).

3.7 Power sources

In some rural areas, the commercial alternating current power is either unavailable or is less reliable than that in urban or suburban areas. Substantial attention must be given to provide reliable power sources for the subscriber units in rural areas.

4 Digital systems

4.1 General

Today's widespread use of digital cellular systems has provided cost-effective radio equipment for fixed WLL. Such systems have the following features:

– high system availability and good speech quality,

– shorter installation time,

– low initial cost in rural and suburban areas,

– easy maintenance and management of facilities,

– flexible access network construction to respond to changing demand,

– immunity against disasters.

Making use of the above advantages, digital fixed cellular WLLs have been extensively introduced in many countries. Services provided by fixed cellular WLLs include 2-wire telephone, public telephone, facsimile and data transmission using modems (up to 9.6 kbit/s). Future provision of ISDN (2B + D) connection is taken into account.

4.2 System configuration

System configuration of a fixed WLL system is shown in Fig. 1. The major components of the system are adapters (ADPs), cell stations (CSs) and subscriber stations (SSs). Cables or radio systems are used for connections between ADPs and CSs. ADPs are positioned between the service node (SN) and the CSs. ADPs function to implement concentration, authentication and so on. Typical interface between ADPs and CSs is the I interface. CSs are installed outdoors in such locations as at the top of poles. One CS can contain several radio units, each of which having a number of message channels depending on the technology used. A control channel is provided. Therefore, in total, 15 user channels and one control channel can be provided by one CS. One CS can cover subscribers within a cell having a radius of 5 km (typical). SSs are installed in user's homes and are connected to telephone terminals. Principal system parameters are summarized in Table 1.

FIGURE 1

Fixed WLL system using cellular type mobile technologies

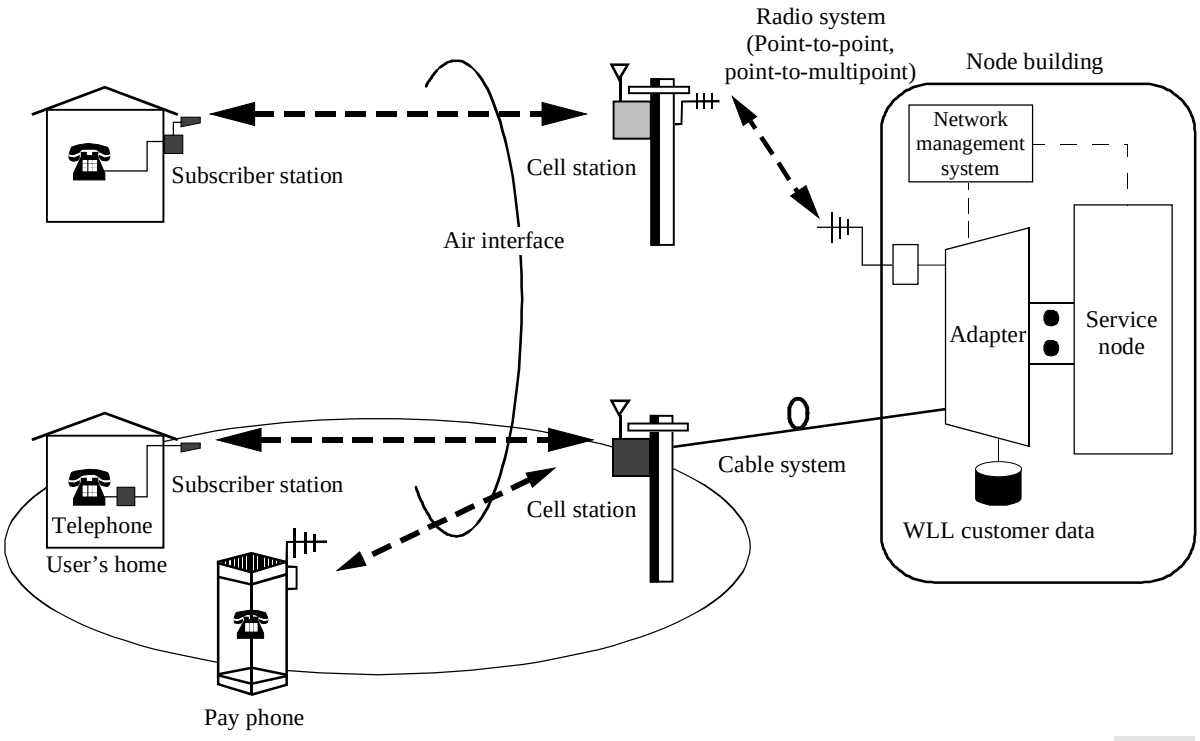


TABLE 1

Main parameters

	D-AMPS-WLL	CT2-WLL	IS-95-CDMA-WLL	GSM-WLL	CDMA/ TDMA-WLL	PHS-WLL	DECT-WLL	PACS-WLL	PDC-WLL	
Frequency band (MHz)	869-894 824-849	864.1-868.1	869-894 824-849	935-960 890-915	1 850-1 990	1 895-1 918	1 880-1 900	1 930-1 990 1 850-1 910	810-826 940-956	1 429-1 453 1 499-1 501
Access	TDMA	FDMA	CDMA	TDMA	CDMA/TDMA	TDMA	TDMA	TDMA	TDMA	
Service area radius (km)	Several tens	0.1 to 2	Up to 62.5	(1)	0.4 to 11	5	5	(1)	20 (up to 60)	
Voice coding scheme	VSELP 8 kbit/s ACELP 7.4 kbit/s(2)	ADPCM 32 kbit/s	QCELP 13.2 kbit/s	RPE-LTP 13 kbit/s	CELP like 7.2 kbit/s	ADPCM 32 kbit/s	ADPCM 32 kbit/s	(1)	VSELP 6.7 kbit/s PSI-CELP 3.45 kbit/s(3)	
Number of RF channels	832	40	20	124	28	76	10	300	640	960
Network interface	T1/E1	$n \times 2$ Mbit/s	T1/E1	2 Mbit/s	T1/E1	G964/G965 GR303/PSTN	2 Mbit/s	T1/E1	VS-1, VS-2 PSTN (analogue 2-wire)	

(1) To be provided later.

(2) Enhanced.

(3) In the case of half rate.

ACELP: Algebraic code excited linear prediction

ADPCM: Adaptative differential pulse code modulation

CDMA/TDMA-WLL: Code division multiple access/time division multiple access-wireless local loop (WLL)

CT2-WLL: Cordless telephone 2 WLL

D-AMPS-WLL: Digital advanced mobile telephone system-WLL

DECT-WLL: Digital enhanced cordless telecommunications-WLL

FDMA: Frequency division multiple access

GSM-WLL: Global system for mobility-WLL

IS-95-CDMA-WLL: International Standard-95 code division multiple access-WLL

PACS-WLL: Personnal access communications system-WLL

PDC-WLL: Peripheral digital controller-WLL

PHS-WLL: Personal handyphone system-WLL

PSI-CELP: Peripheral subsystem interface-code excited linear prediction (CELP)

QCELP: Qualcomm code excited linear prediction

RPE-LTP: Regular pulse excitation/linear predictive coding using long term prediction

T1/E1: Primary rate transmission system

VS: Videotex service

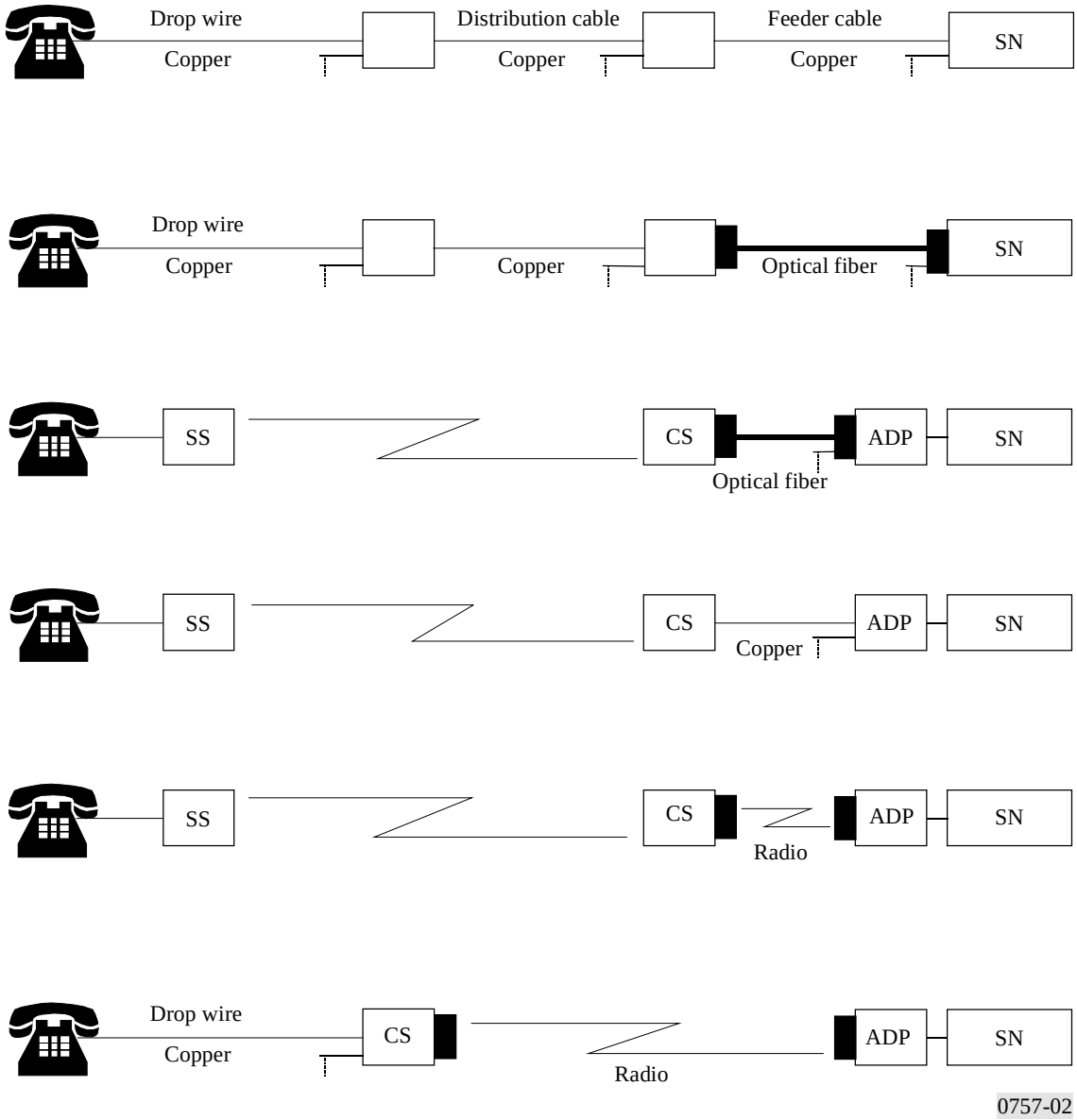
VSELP: Vector sum excited linear prediction

4.3 Implementation process

There are many possible ways to implement access facilities that include fixed cellular WLL, as shown in Fig. 2. For example, in a large area accommodated by one SN (Service Node), there will be a number of small sub-areas at different distances from the SN, having different numbers, densities, and growth-rates of subscribers. Therefore, the most important question facing network operators is how to select the optimal (i.e. lowest-cost and highest-efficiency) implementation, given the conditions in each of the sub-areas in question.

FIGURE 2

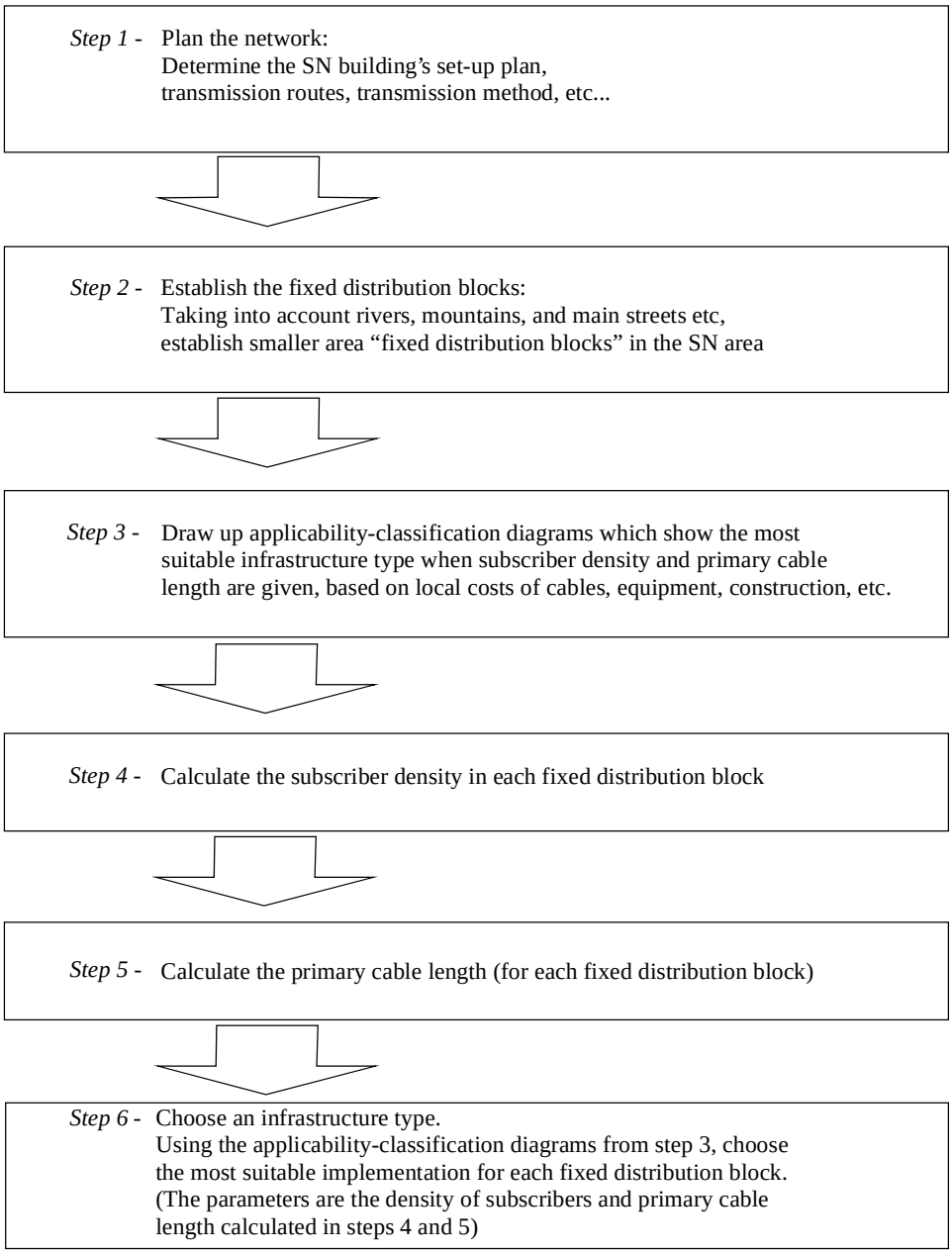
The access facility forms



An outline of choosing the most suitable facility is described in Fig. 3.

FIGURE 3

Choosing the appropriate fixed cellular WLL implementation pattern



4.4 Maintenance and operation aspects

Operators can control and manage several fixed cellular WLL systems from one operations center. There are two choices of management architectures (tree or ring) for the system. They have different characteristics in terms of cost, reliability etc. and one can switch from one architecture to the other when expanding the system, equipment, or centre.

In terms of functions, there are three systems that constitute the NMS implement functions. The functions of each system is shown below:

– network operation and maintenance system for operations center;

– facility engineering and management support system for local offices;

– service order system for customer service centre.

Each operations center holds backup data (for customers, the system, traffic, etc.) fully mirroring one or more other operations centers, to provide protection in case of accidents. If one center fails, data can be restored from another site or control can be switched to another site for continuous operations.

Relational data base management system (DBMS) provides fast and flexible searching of data, easy collection of statistics, and high-performance transaction processing for large quantities of data. It also supports various forms of data storage, such as floppy disk, magneto-optical disk, etc.

Operators can easily manipulate the NMS, determine the current system status, and take appropriate measures using graphical user interface.

5 Optimized fixed systems

Optimized fixed systems employing TDMA techniques are described in the ITU-T Handbook on Rural Telecommunications (Geneva, 1985) and in Recommendation ITU-R F.756. These systems were designed specifically for the provision of telecommunications in rural and remote areas via radio and achieve a high level of performance and quality comparable or equal to that offered by wireline services in a well served urban area, but over a distance of up to several hundred kilometres.

Most of these systems operate in certain frequency bands between 1.427 and 2.690 GHz. A variety of telecommunication services (see § 3.3) is often provided in addition to a 2-wire basic telephone service and, in future, full ISDN 2B + D basic access will also be provided. This subject is being examined under Question ITU-R 125/9. The use of radio repeaters extends the system reach to hundreds of kilometres, and provides the necessary connections to bring isolated subscriber groups to a distant exchange. Generally, most of these systems are designed to serve clusters of subscribers from one subscriber out-station, thus providing economical service to the cluster. Performance is normally specified in terms of detailed channel characteristics (noise, frequency response, envelope delay, etc.). Noise levels of the order of 100 to 200 pWp are typical and radio paths are designed to provide availabilities of the order of 99.9% or better.

6 Summary

Fixed cellular-WLL are capable of making telecommunication services available to subscribers in rural areas and, in particular, to subscribers in the developing countries.

Optimized fixed systems can offer, as should be expected, a higher level of performance and service features than might be achieved by the use of cellular radio. The level of performance offered by fixed WLL may be acceptable, in some cases, to an administration that requires a basic telephone service for a few widely scattered subscribers, especially if the service can be provided very economically within an existing mobile cell. An administration, however, should consider that the performance which can be achieved may degrade national or international connections beyond acceptable national or ITU-T objectives. As is always the case, a full evaluation of suitable radio techniques must be made which will include the consideration of ITU-T and ITU-R Recommendations, comparisons of achievable versus required performance, cost, the lifetime of the equipment, maintenance, reliability, suitability for the local physical environment, services offered, etc.

ITU-T GAS 7 (Volume II, Training Handbook of Rural Telecommunications (Geneva, 1989)) addresses many of these topics. The interest of the developing countries in this subject is also reflected in the questions submitted by the Plan Committee for Latin America (Paramaribo, 1985) and by the Plan Committee for Asia and Oceania (Bali, 1986).

In view of the apparent growing use of fixed WLL using cellular mobile technologies, it would be highly desirable if administrations could provide information on the effects they have noted on overall network performance.