RECOMMENDATION ITU-R F.756*

TDMA point-to-multipoint systems used as radio concentrators

(Question ITU-R 125/9)

(1992)

The ITU Radiocommunication Assembly,

considering

a) that analogue and digital TDMA point-to-multipoint systems are now widely used, particularly in frequency bands between 1.427 and 2.690 GHz, primarily for the provision of subscriber voice and data services in rural and sometimes urban areas;

b) that Recommendation ITU-R F.701 describes the channelization of the various frequency bands used by TDMA point-to-multipoint systems in the range 1.427-2.690 GHz;

c) that such systems may be an integral part of switched telecommunications networks and that it is desirable that such systems meet certain minimum performance standards which will ensure their integration into these networks;

d) that such systems should have radio characteristics which use the spectrum efficiently and facilitate band sharing,

recommends

1 that TDMA point-to-multipoint systems should provide services also available to subscribers by metallic lines. These services may include:

– 2-wire individual subscriber telephone service;

– payphone service of various kinds;

– 4-wire service with and without E&M signalling;

– the capability to carry voiceband data including facsimile and other telematic services up to a data rate of at least 9.6 kbit/s;

2 that digital systems should have the capability:

– to carry data at rates up to and including 64 kbit/s;

– to provide, in the future, an ISDN basic rate access of 2B + D;

3 that since point-to-multipoint systems may form part of an international connection, the relevant ITU-T G-Series Recommendations should be met;

* Radiocommunication Study Group 9 made editorial amendments to this Recommendation in 2002 in accordance with Resolution ITU-R 44.

4 that giving due regard to economical considerations:

a) the grade-of-service (lost call probability) offered by such a system to a subscriber should not normally be worse than 1% and shall be calculated employing ITU-T Recommendations E.506, E.541 and Supplement No. 1 to the E-Series Recommendations (Note 1);

b) the error performance and availability objectives of digital systems should generally be in accordance with Recommendation ITU-R F.697, for subscriber connections. For systems operating in the medium grade portion of an ISDN, Recommendation ITU-R F.696 is applicable;

c) analogue TDMA systems should be designed to provide voice quality with a noise level in accordance with ex-Recommendation ITU-R F.395 and an availability the same as for digital systems in b) above;

5 that digital systems have an RF-channel efficiency of at least 1 bit/s/Hz in the allocated channel bandwidth;

6 that voice encoding methods employed in digital systems be such that the integration of the point-to-multipoint system into the switched network is straightforward and introduces as few limitations as possible. Recommended encoding methods are 64 kbit/s PCM in accordance with ITU-T Recommendation G.711 and 32 kbit/s ADPCM in accordance with ITU-T Recommendation G.721 (Note 2);

7 that Annex 1 be referred to for the implementation of TDMA point-to-multipoint systems.

NOTE 1 – Some administrations may adopt other values for the grade of service, e.g. as much as 5%, depending on local conditions.

NOTE 2 – 32 kbit/s ADPCM systems have limitations with respect to the upper limit of the data transmission rate.

ANNEX 1

TDMA point-to-multipoint systems used as radio concentrators

1 Introduction

This Annex provides information on point-to-multipoint systems operating as radio concentrators using time division multiple access (TDMA). Such systems can also generally operate in a non-concentrating mode such as for pre-assigned low capacity data circuits.

These systems are now widely used to provide a subscriber voice data service primarily in rural/suburban areas and less frequently in urban locations.

2 General description

The basic purpose of these systems is to provide a radio link that will extend services to rural subscribers where wireline systems are more costly or severely restricted by terrain. As far as practicable these services should provide a transmission quality and range of facilities that are normally provided to subscribers in urban areas.

Radio concentrator systems provide multiple access to subscribers by the use of either multiple frequencies (frequency division multiple access, FDMA) or by the use of multiple time slots (time division multiple access, TDMA). Digital radio concentrators naturally use TDMA which is described here.

Multiple access systems give subscribers access to several circuits, the number n of which is smaller than the number N of subscribers ($n < N$). As this is a concentrator system, a certain grade of service in respect of attempts to set up calls must be accepted. The grade of service depends on the number n of circuits, the number N of subscribers and the traffic that is originated.

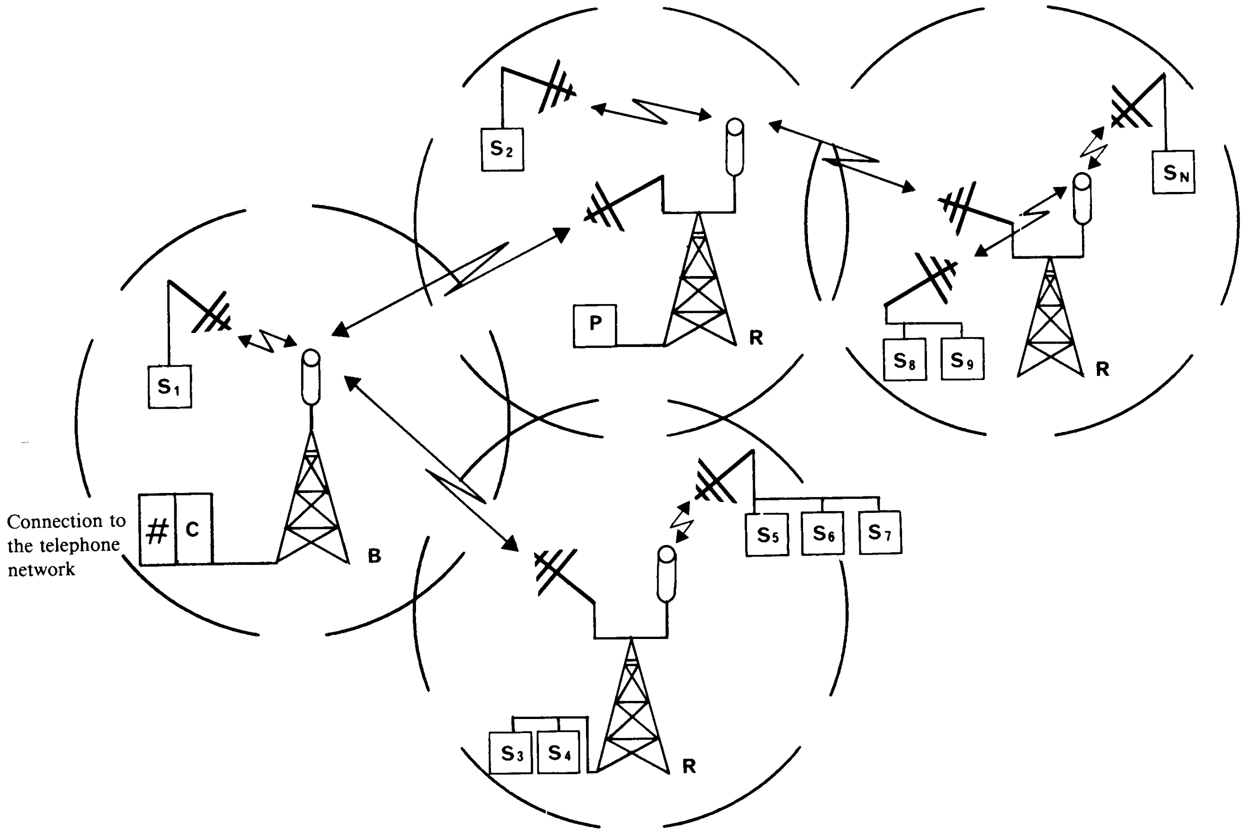
A time division multiple access radio concentrator system (TDMA-RCS) consists of a single transmitter-receiver unit at the central station and at each subscriber station. The transmitted signal consists of n time slots multiplexed in time, with each capable of providing a telephone channel. Any subscriber station has access to any of the n time slots which are allocated on a demand basis by the central station.

In the case of both analogue and digital TDMA systems, it is possible to introduce repeater stations to extend the service from the exchange to far-distant subscribers. Repeater stations consist of two transmitter-receiver units connected back-to-back through appropriate equipment. Repeaters may serve local subscribers and operate as two-way RF translators that retransmit the signal into the adjacent radio zones (see Fig. 1), thereby eliminating the need for interconnecting links between cells.

In one possible implementation using repeater stations with local switching, the signalling information, the routing requirements, and information on the operational status of the multiple access network are conveyed over supervisory channels which are continuously monitored and, if necessary, updated at all stations. Unutilized subscriber channels or time slots are allocated on demand on a drop and insert basis to the individual subscribers via the local switches and the supervisory channels are updated with information on new connections and disconnections. The same channel or time slot can be re-used several times along the network due to the local switch facility. No central switch is required. A central station must be provided as a gateway to the public network. Fig. 2 shows a possible configuration of a local switching system with typical layouts of a repeater station and a central station.

FIGURE 1

A possible configuration for a TDMA radio concentrator system for rural subscribers



#: telephone exchange
S_i: subscriber interface
R: repeater station
B: central station
P: public telephone
C: switching unit

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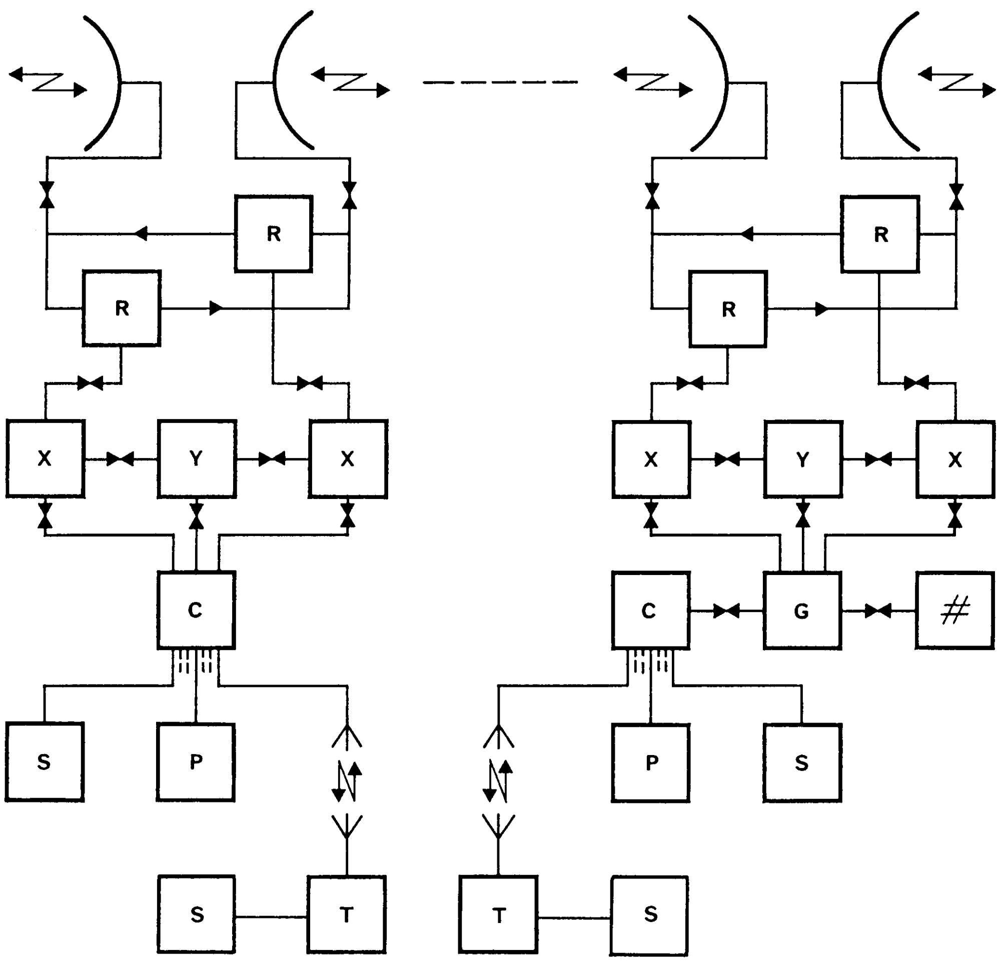
3 Principles of operation

All TDMA point-to-multipoint systems use the same basic transmission philosophy. Data or digitally encoded speech signals are transmitted from the central station in a time division multiplex (TDM) format, using bit or byte interleaving. Alternatively, 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. Such equalization is either pre-set or dynamically adjusted depending on the design objectives for the system. When propagation time variations are short in relation to the baud period of the system, pre-set equalization is generally adequate. Figures 3 and 4 show a typical system schematic and TDMA frame arrangement.

FIGURE 2

A possible configuration for a multiple access system with local switching for rural subscribers



T: radio terminal
R: repeater station
X: drop and insert multiplexer/demultiplexer for supervisory channels and traffic
Y: supervisory processor
C: local switch
G: gateway switch
#: telephone exchange
S: subscriber interface
P: public telephone

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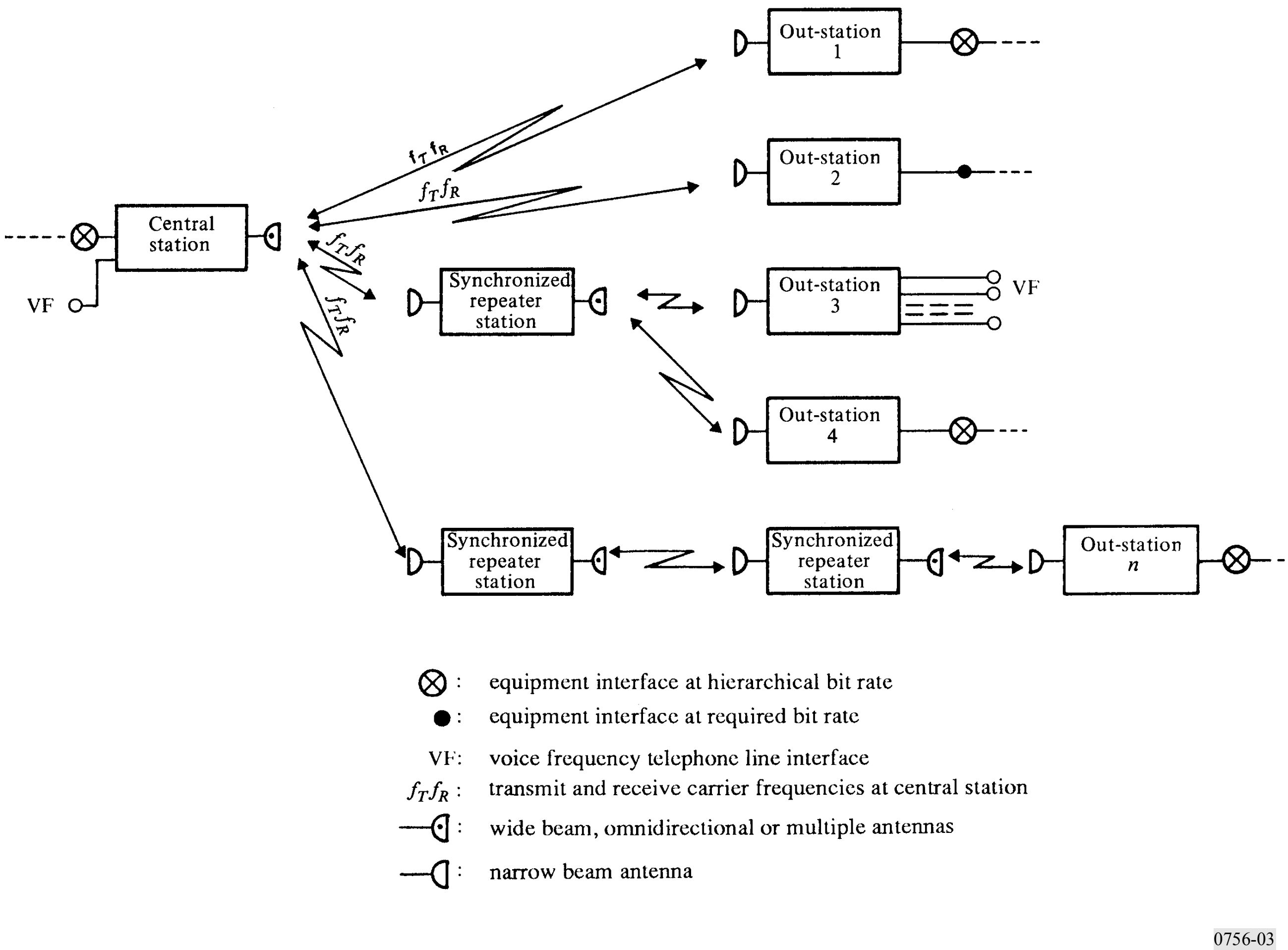
In general, the connection of point-to-multipoint systems to the network is effected at the central station and it is preferable that the point-to-multipoint system appears to be transparent to the network without any constraints imposed by the use of TDMA. Furthermore, the use of a conventional interface 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.

FIGURE 3

A typical configuration of a point-to-multipoint TDM fixed wireless system



4 Frequency, interference and modulation considerations

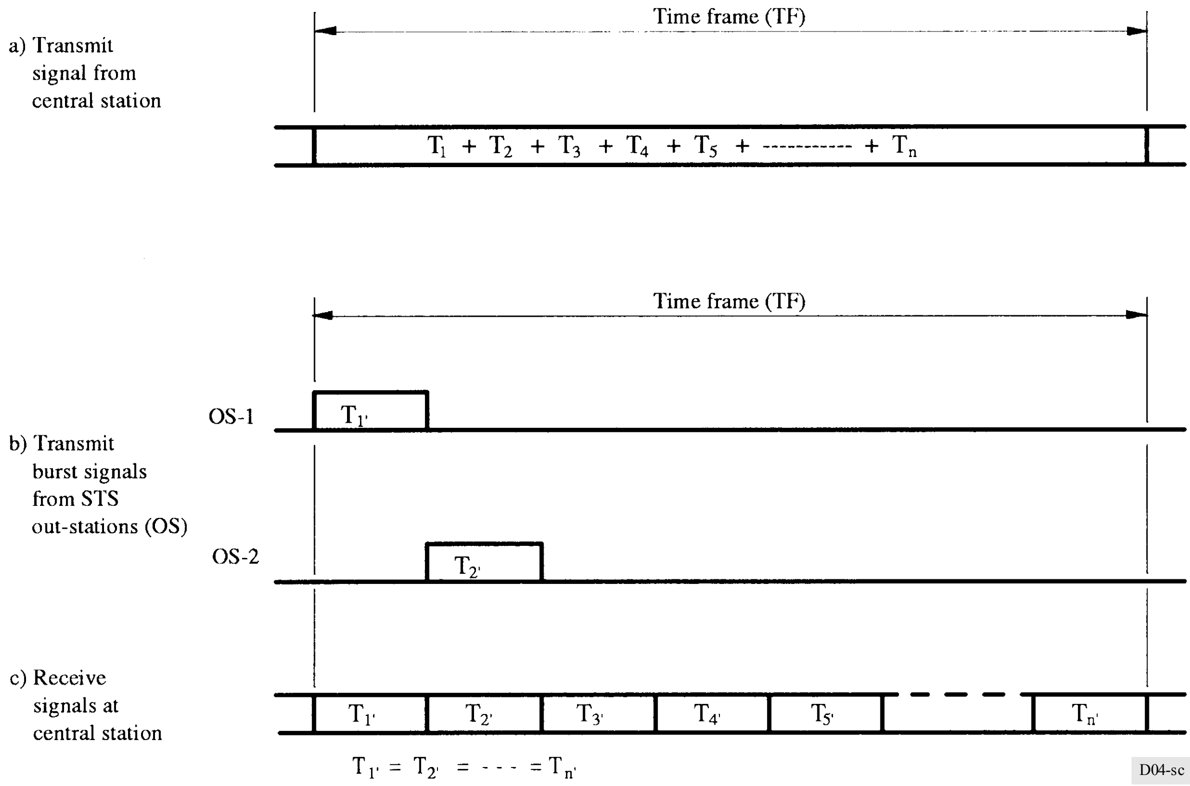
With due regard to the mode of propagation and the present state of the art, the frequency band should be chosen from those bands which have been allocated to the fixed service. The lower bands are preferred mainly when propagation is by diffraction (mountainous regions) and the higher bands are preferred in cases where there is a risk of interference. It should be noted that the 1.5 GHz band, the 1.7 to 1.9 GHz band, and the 2.3 to 2.6 GHz band, are being used by some administrations for this application.

In multiple access systems, the frequencies of the radio channels should be chosen taking into account the bandwidth of the equipment and the limitations imposed by the various sources of interference.

When several radio systems are to be operated in the same rural area, frequency coordination will require careful analysis and multiple access systems will be found to have certain points in common with mobile systems.

FIGURE 4

Typical relationship of allocated time slots of a TDMA system



More efficient use of the available radio spectrum can be achieved by taking advantage of the fact that subscriber stations are fixed and that directional antennas can be used, thereby minimizing mutual interference.

4.1 Frequency planning

Point-to-multipoint systems generally use more than one central station to obtain adequate geographic coverage, according to the number of subscribers able to be connected to one system. To limit the cost of the infrastructure, the original central stations remain used when the number of subscribers increases and more central stations are added. It is therefore necessary to multiplex the radio channels before the antenna feeder.

It is necessary for systems operating at SHF to have an unobstructed propagation path (line-of-sight), otherwise tall buildings 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.

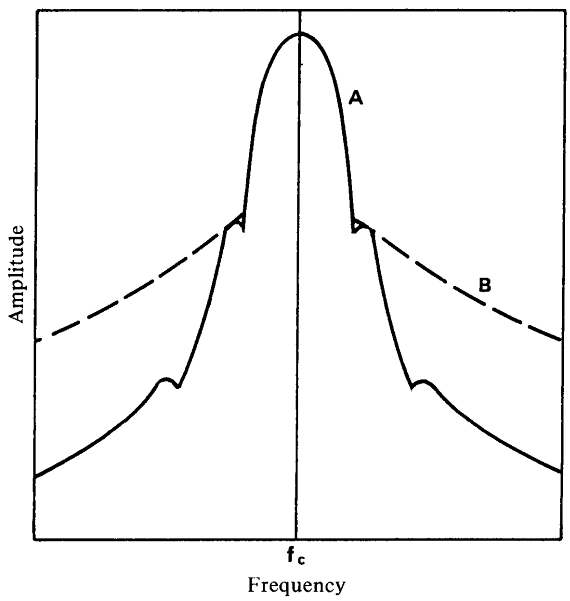
4.2 Spectrum shaping and adjacent-channel interference

The transmitted signal waveform of a digital radio system is usually shaped to minimize the sideband spectrum and to suppress adjacent-channel interference.

A TDM system which transmits burst signals must maintain a controlled symbol waveform throughout the burst period and correct gate timing is essential. Fig. 5 shows a TDM burst signal spectrum distribution for cases of correct and incorrect gate timing (curves A and B respectively).

FIGURE 5

TDM spectrum distribution



Curves A: normal spectrum of burst signal with correct gate timing
B: spectrum of burst signal with incorrect gate timing

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4.3 Modulation techniques

Frequency or phase modulation seem to be the preferred methods for analogue systems, and frequency shift keying (FSK), phase shift keying (PSK) or quadrature amplitude modulation (QAM) for digital systems. The use of class C amplifiers is conducive to low power consumption, but in practice they are only used for FSK or PSK (2 and 4 states).

The 32 kbit/s ADPCM studied by ITU-T Recommendation G.721 might be employed to make the most efficient use of frequencies while maintaining transmission quality (Note 1).

One system has been developed which provides four simultaneous voice circuits on one single 25 kHz RF channel. This system uses a 16 kbit/s coding algorithm to provide the necessary voice compression and requires the use of an echo canceller because of the codec time delay.

An offset QPSK modulation technique which is free of intersymbol interference and jitter has been developed to provide a spectrum and power efficient high capacity TDMA system.

NOTE 1 – ITU-T Recommendation G.728 gives a standard for 16 kbit/s coding.

4.4 Frequency plans

TDMA systems have been developed in band 9, based on different frequency plans with a channel spacing depending on the capacity and type of modulation. Some typical examples are shown in Table 1.

Recommendation ITU-R F.701 provides details of the radio-frequency channel arrangements for point-to-multipoint systems operating between 1.427 and 2.690 GHz.

TABLE 1

Typical frequency plans for point-to-multipoint systems

Frequency band centre (MHz)	No. of trunks	Modulation technique	Channel spacing (MHz)
1 500	15	FM	3.5
	60	OQPSK	3.5
	15	BFSK	2.0
	10	FSK	2.0
	30	QPSK	2.0/2.5
1 800	15	FM	3.5
	60	OQPSK	3.5
2 000	48	QPSK	4.0
	15	FM	3.5
	60	OQPSK	3.5
2 400 to 2 600	15	FM	3.5
	60	OQPSK	3.5
	10	FSK	2.0
	30	QPSK	2.0/2.5

TDMA systems have also been developed in the 150, 450 and 800 MHz bands that provide for narrow radio channel operation. These systems utilize channel spacings of 25 kHz and 30 kHz and share spectrum with land-mobile operations. Multiple RF channel systems using FDMA have been developed, with each radio channel supporting two or four fully trunked voice circuits.

The total number of trunk circuits that are provided is given by the product of the number of the available RF channels and the number of voice circuits per RF channel. As an example, one system in the 450 MHz band using four circuits per RF channel and 26 RF channels provides 104 trunks, but the number of subscribers served can be much greater than 104 depending on the desired grade of service.

4.5 Interference

The following interference cases need to be considered when determining cell arrangements and frequency plans:

– interference to a subscriber station caused by the repeater and subscriber stations in the adjacent cell (Fig. 6a));
– interference to a repeater station caused by the repeater and subscriber stations in the adjacent cell (Fig. 6b));
– interference to a repeater station caused by the repeater station itself (Fig. 6c));
– interference to a repeater station caused by the subscriber stations within the cell (Fig. 6c));
– co-channel interference caused by the same frequency being used in a distant cell.

At a repeater station, spurious radiation and spurious responses need to be considered.

5 System economy and spectral efficiency

5.1 General

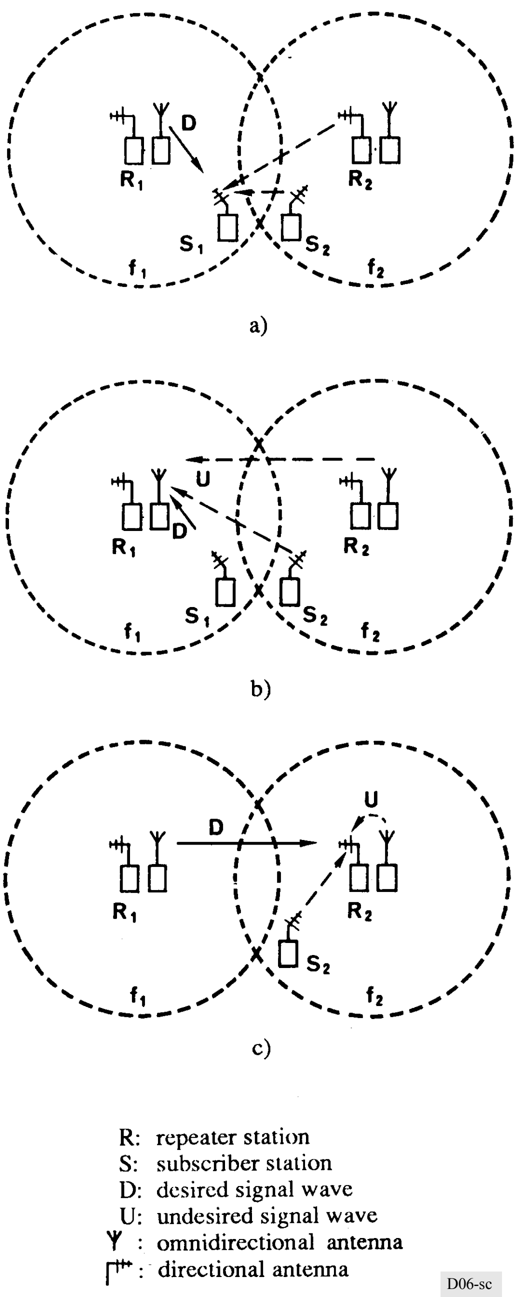
In the simpler point-to-multipoint systems, each time slot is pre-assigned to a specific out-station which has access to the time slot at all times. This arrangement is used for providing continuous service to a customer and the spectral efficiency is similar to that of an equivalent point-to-point digital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

For telephone subscriber systems, and other systems 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. Under these circumstances, the system provides a concentrating function and the proper ratio of subscribers served to trunks offered and the corresponding grade of service provided can be derived from ITU-T Recommendations E.506, E.541 (§ 3.1) and Supplement No. 1 to the E-Series Recommendations taking into account such factors as the future growth of telephone traffic.

The equipment at the central station consists of one set of transmit and receive equipment. This results in an economical system compared with systems using individual low capacity fixed wireless circuits to more than three stations. In the example shown in Fig. 1, synchronized repeaters may be utilized for certain applications between the central station and out-stations.

FIGURE 6

Interfering model



Transmit and receive equipments at both central stations and out-stations are similar to point-to-point fixed wireless equipment, except for the ability to transmit and receive burst signals by the inclusion of burst carrier control clock and frame timing equalization circuits.

5.2 Considerations for data transmission

For telephony, the message part of a TDMA burst contains a packet of 64 kbit/s PCM bits stored during one TDMA frame interval. 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.

6 Type of path and characteristics of the radio equipment

6.1 General

The most economical solution appears to be a line-of-sight or near line-of-sight (diffraction) path, making it possible to use transistorized equipment with transmitter powers of about 0.5 W to 5 W. A higher transmitter output power may be necessary in certain cases, particularly at the central station in the multiple access system.

The use of microprocessing techniques facilitates the supervision of multiple access systems, a factor which is of vital importance for the operation of such systems in rural areas. It would also be desirable for supervision at the exchange or elsewhere to include the possibility of monitoring the subscriber stations and lines.

6.2 Frequency stability

The tolerance should be in conformity with the Radio Regulations. This should be possible preferably without the use of thermostatic control.

6.3 Antennas

The antennas at the subscriber stations should be simple, sturdy and with a small surface area exposed to the wind. When considering the difficulties of access to remote sites, the need for reliability is paramount. Yagi antennas, if well constructed, are a good solution at frequencies up to about 1.5 GHz. At higher frequencies, other types of antenna such as a helix or a dipole array with a reflector may be used, depending on the gain required and the frequency used. Horn antennas have proved to be a good compromise between gain, reliability and cost at frequencies at or above 1.5 GHz.

The use of the same antenna for transmission and reception is generally more economical, but in such cases a larger frequency separation must be adopted to avoid blocking the receiver (e.g. 3% to 5% of the mean frequency). However, technical difficulties might arise from the adoption of too large a frequency separation because of the bandwidth limitation of some antennas.

In a multiple access system, the antenna(s) at the central station (where all the subscribers in the service area are concentrated) should be chosen so that their radiation characteristics are as closely matched as possible to the geographical area to be covered.

Repeater stations have two antennas. The most common configuration would be a directional antenna directed towards the exchange end and an omnidirectional or possibly a wide-beam antenna to serve local subscriber stations, and if necessary, for linking with other repeaters.

The use of directional antennas at the subscriber end provides for more efficient use of the available radio spectrum by minimizing mutual interference.

6.4 Signalling

In general, systems should be transparent to signalling.

The equipment must be fitted with appropriate signalling apparatus, comprising all calling and controlling devices, for the modes of operation required.

Recommendation ITU-R M.257 describes a selective calling system which might be envisaged for multiple access analogue systems. Digital TDMA systems would normally use a combination of common channel signalling and channel associated signalling.

In general, radiotelephone systems for rural subscribers should provide for the transmission of charge and public telephone signalling.

6.5 Power supply

The ITU-T published a document entitled “Primary Sources of Energy” (1985 edition) which discusses the related problems.

In general, dynamic sources of energy (generator sets) should not be used owing to the amount of maintenance required.

Solar energy is particularly attractive, although its use may be ruled out by the climatic conditions prevailing in certain areas.

For a TDMA system, power saving is achieved because the transmitter is switched on only for the duration of the active time slots. Additional power savings can be achieved if the receiver is switched off when idle, although this would require the use of working cycles compatible with the signalling philosophy adopted.

7 Installation

The radio equipment may be placed in a cabinet either at the top of the support structure carrying the antennas, which reduces cable losses, but makes installation and maintenance more difficult, or at the foot of the support structure so as to facilitate these functions. If the cabinet contains both radio and line interface equipment, then installation at the foot of the support is the only practical solution. In general, the equipment should be small, lightweight, robust and easy to install.

Equipment for outdoor installation should operate reliably over a wide temperature range. Alternatively, the equipment may have to be installed in shelters above or below the ground.

The above information is applicable to the installation of equipment at the subscriber locations or at the repeater site in multiple access systems. However, the infrastructure required for the radio equipment of the central station may be greater since the base equipment is more bulky, the power consumption higher, etc.

8 Maintenance

Since it may often be difficult to obtain access to equipment providing service in rural areas, the equipment should be as reliable as, or more reliable than, land lines. Some administrations have used systems that have been found to have a mean time between failures of more than 10 years for subscriber stations.

In addition, since the technical skills available to maintain the equipment in remote locations may be limited, design should be such that field maintenance can be carried out by card or complete unit replacement. Field adjustment should be minimized, if not eliminated.

9 Performance and availability objectives for telephony provided by VHF and UHF local subscriber radio over long distances

Recommendation ITU-R F.697 discusses the performance and availability objectives for digital fixed wireless systems used in the local grade portion of the ISDN between the subscriber and the local exchange. These systems typically are used for both point-to-point and point-to-multipoint distribution of telecommunication services to the premises of mainly business customers. Recommendation ITU-R F.697 is also used as a general guide to error performance.

It is important to consider separately the requirements and circumstances surrounding digital fixed wireless systems used in rural local networks. These systems are characterized by very long distances (up to several hundreds of kilometres), low telephone densities (typically less than 0.1 subscribers per square kilometre), operation in VHF and UHF bands and an overriding need to provide economic telephony services. As far as practicable, these systems should provide the same transmission quality and range of facilities that are normally provided to subscribers in urban areas. However, with due regard to economic considerations, they need not necessarily be strictly aligned with ITU-T Recommendation G.821. Nevertheless, it is desirable that any new Recommendations on performance and availability adopt the existing definitions and performance criteria whenever appropriate.