RECOMMENDATION ITU-R F.755-1

POINT-TO-MULTIPOINT SYSTEMS USED IN THE FIXED SERVICE

(Question ITU-R 125/9)

(1992-1994)

The ITU Radiocommunication Assembly,

considering

a) that different applications of point-to-multipoint systems share common features;

b) that there are different services provided by point-to-multipoint systems with various requirements, operating in a number of frequency bands;

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 point-to-multipoint systems can use similar performance objectives to those used for other systems;

e) that point-to-multipoint systems commonly use wide beam or multiple antenna configurations at the central station and directive antennas at the terminal, repeater or subscriber stations, and that system configurations are adjusted according to geographical coverage requirements;

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 several applications of point-to-multipoint systems are possible, examples of which are given in the annexes and in the texts referred to below,

recommends

1. that for TDMA point-to-multipoint systems used as radio concentrators, Recommendation ITU-R F.756 should be referred to;

2. that for radio-frequency channel arrangements for analogue and digital point-to-multipoint radio systems operating in frequency bands in the range 1 427-2 690 GHz, Recommendation ITU-R F.701 should be referred to;

3. that for single channel or multi-channel 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 point-to-multipoint systems used in the local grade portion of an ISDN connection, reference can be made to Recommendation ITU-R F.697.

ANNEX 1

An example of single-channel and multi-channel multipoint distribution services (MDS)

1. System description

The multipoint distribution service provides, for one-way point-to-multipoint 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 multi-channel 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: channel number = 1, 2, 3, 4.

The system design approach for the multipoint distribution service was selected to allow randomly sited transmitters to re-use 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 point-to-multipoint system used for MDS is shown in Table 1.

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:

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

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.

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

2.2 *Co-channel interference*

Frequency re-use 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 re-use 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*

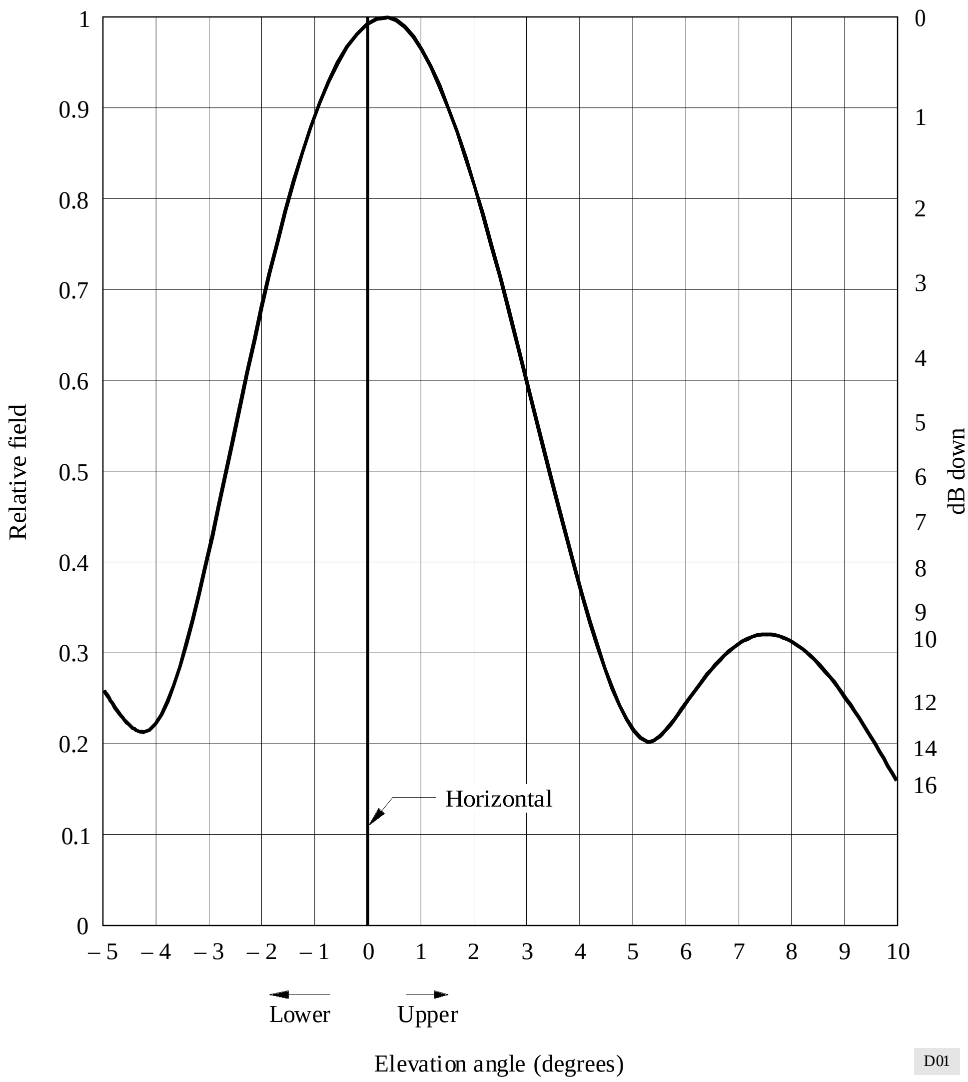
Adjacent-channel interference is controlled by imposing conditions on both the multipoint distribution service transmit and receive sites. An objective of 0 dB C/I was chosen for this condition. In order to help achieve this condition in a practical manner, multipoint distribution service stations serving 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 point-to-multipoint 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



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 time division multiple access (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 (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 point-to-multipoint data transmission systems, it has been observed that block retransmission techniques are superior to forward error correction.

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 bit error ratio 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

Point-to-multipoint systems utilizing time division multiple access techniques for data transmission in urban areas

1. Introduction

The general principles of point-to-multipoint systems using TDMA are discussed in Annex 1 of Recommendation ITU-R F.756.

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 point-to-multipoint 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 Table 3a and 3b.

2. Principles of operation

The principles of operation are discussed in Annex 1 to Recommendation ITU-R F.756 particularly with regard to radio concentrator systems. However, all TDMA point-to-multipoint 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 3 and 4 of Recommendation ITU-R F.756 show a typical system schematic and TDMA frame arrangement.

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 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.756 gives details of typical point-to-multipoint configurations, a block diagram and a time-slot sequence. These features are equally applicable to urban data systems.

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 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 (FS-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.

TABLE 3a

Examples of point-to-multipoint 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 27 dBi at 2.4 GHz	Conical: gain 17 dBi	Parabolic (φ ≥ 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 point-to-multipoint 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

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.