Brief Description

of

Switching and Transmission Systems

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CONTENTS

1. INTRODUCTION

In this chapter, we are briefly going to deal with the specifications of switching and transmission systems that are needed in network planning. Telephone set technical characteristics will not be looked at.

In a telephone call, the paths between subscriber to exchanges and exchanges-to-exchanges constitute the transmission paths. Figure 1 is a schematic representation of the facilities (telephone sets, transmission paths and switching systems) involved in a call.

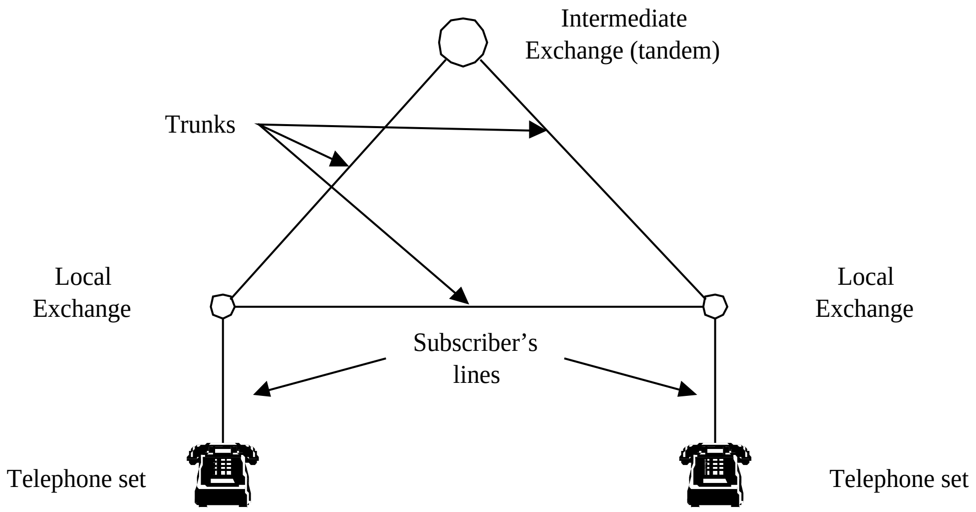

Figure 1

Although there are a variety of switching systems in use, we are going to look only at the very general common characteristics of electromechanical (conventional) and SPC digital switching systems. As regards transmission facilities, only the most common in use are going to be considered.

2. SWITCHING SYSTEMS

2.1 General

The basic function of any switching system is to interconnect communication paths. The two essential groups that are common in all switching systems are:

- switching network made up of individual switching device and used to connect paths together;
- a control section to operate the right switching device at the proper time.

The earlier type of switching network which is still quite common in some countries is space-division network (SPC or electromechanical), in which the speaking paths are physically separated.

Modern SPC digital switching systems use the time-division network in which more than one conversation may share the same physical path.

2.2 Space Division Switching Systems

In this type of switching system, there are conventional and electronic SPC systems. Both systems have more or less the same main blocks. The main differences can be detected to the fact that the components of SPC exchange are almost electronic and the call processing is controlled by a central part which is a computer often called a data processor.

In old electromechanical exchanges (strowger systems), control is performed in a straight-forward way. The switches are controlled by using pulses from the subscribers dial and are driven to the right contacts.

In modern electromechanical exchanges (common control systems), the control is performed by rapidly working more or less centralized special equipment. This equipment can be of relay type, as in many crossbar systems.

In Figure 2, a schematic representation of a space-division switching system is shown.

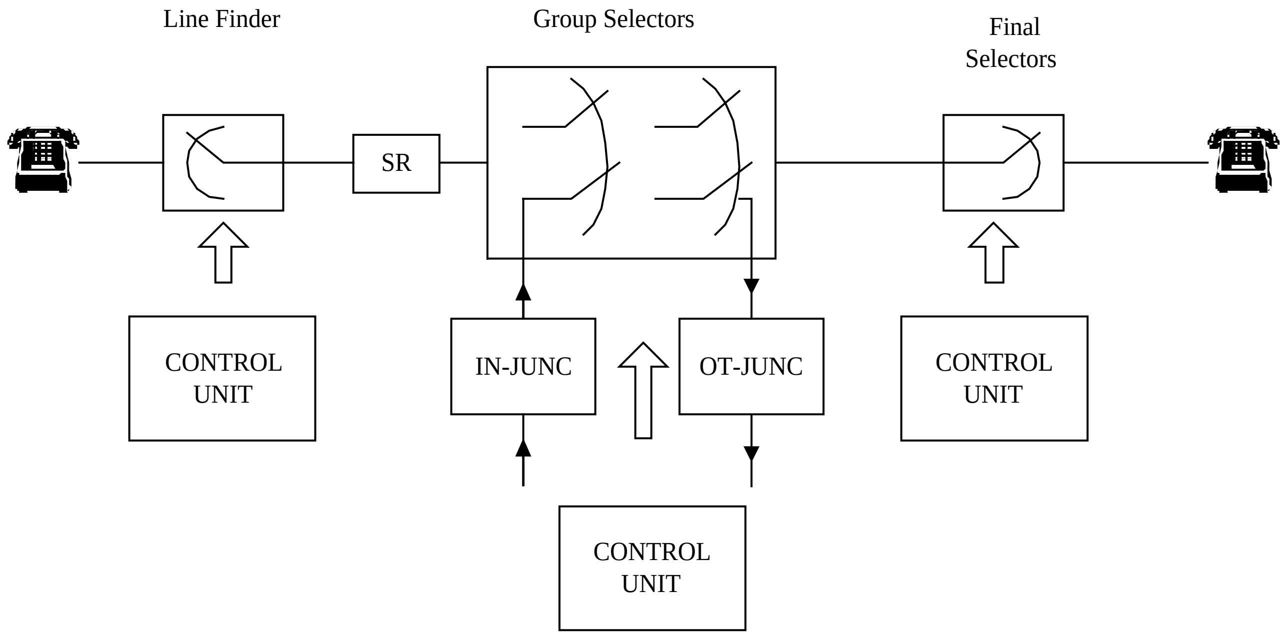

Figure 2

The main function of:

- line finder is to detect the calling subscriber and to ensure feeding current;
- group selector is to connect paths of different directions;
- incoming and outgoing junctors is to interface the trunk circuits with regard to different types of signalling;
- final stage is the selection of the last two digits until the called subscriber is found;
- control device is to control the switches.

The above stages can be detected to all types of switching systems (conventional or SPC).

2.3 Time Division Switching Systems - Digital Systems

The signals processed are PCM (time Division Multiplexed signals). The group selectors are of digital type which can be very easily connected to PCM transmission environment. It is, of course, possible to connect the exchange to analogue network with FDM or voice frequency transmission. As said in the previous paragraph, the main stages of an analogue exchange outlined earlier are also distinguished here.

2.3.1 *Analogue environment*

Figure 3 shows a block diagram of a digital exchange connected to analogue environment. Since the environment is analogue, we need an analogue-to-digital converter (PCM) so that analogue signals to and from the exchange are changed to digital inside the exchange. For European systems, the CEPT (2048 bit rate), PCM specifications are used. As regards junctors, they are of conventional type. The signalling is handled by code senders (CS) and code receivers (CR) in a conventional way. Signals from other exchanges are extracted from the line relay sets and multiplexed into the control system while signals to other exchanges are injected into the line relay sets by the control.

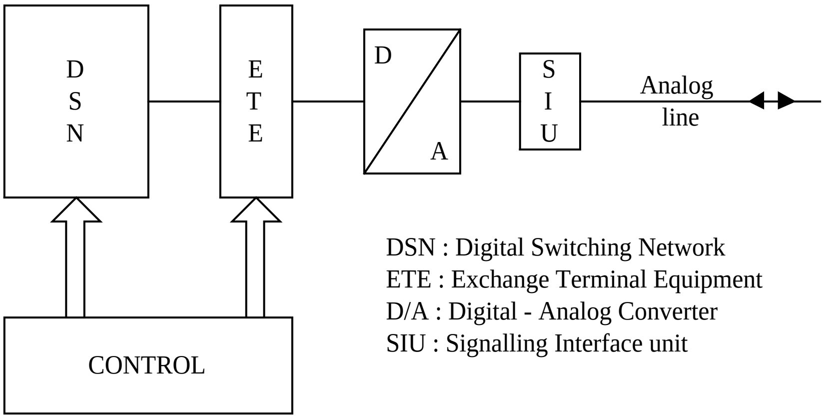

Figure 3

2.3.2 *Digital environment*

Figure 4 shows a block diagram of digital exchange connected to digital environment. The essential differences between this and the analogue environment is that in digital environment the analogue-to-digital conversion is no more needed.

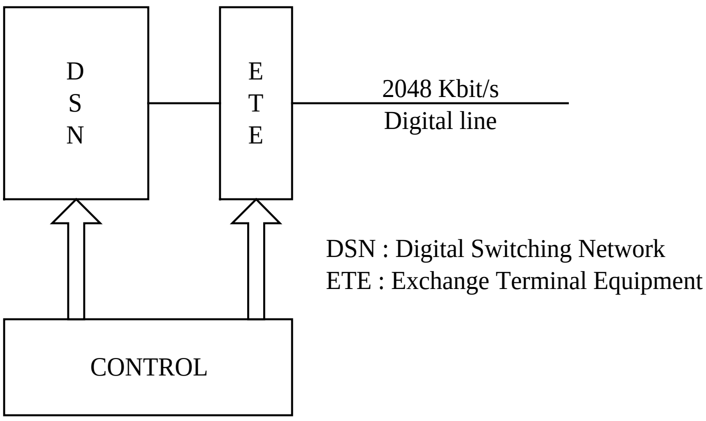

Figure 4

As regards signalling, the common channel signalling is used. The information in the signalling channel (time slot-16) can be extracted or injected directly by the exchange terminal before switching, or taken via the switching network.

The stages common to analogue and digital environment are:

- Digital Switching Network. The switching network performs switching between the time-multiplexed signals. It consists of digital, electronic components.

- Exchange Terminal. The purpose of the exchange terminal is to arrange the time slots coming from different PCM multiplexers, in phase with the exchange time slots.

- Regional and Central Control. The purpose of this unit is to perform the control of the system with some type of processor system. The regional control takes care of frequent and simple functions whereas the central control handles the more complex functions.

2.4 *Exchange specifications*

We are going to outline all those Exchange specifications which are required in network planning. For all kinds of exchanges in the network, i.e. local, tandem and transit, the necessary data are listed below:

- name of the exchange;
- superior tandem/transit;
- type of switching system (e.g. Strowger-EMD);
- type of availability (full or restricted).

Other types of data regarding also switching systems, which should be provided, are:

- grade of service;
- transmission and signalling requirements;
- routing principles;
- marginal switch cost.

For the exchanges with restricted availability, the following should be defined:

- possible availability;
- number of outlets per group selector;
- maximum number of outgoing routes.

3. SUBSCRIBER PAIR GAIN SYSTEMS

3.1 Background

In the recent years, the cost of subscriber pair gain system, i.e. a system which enables L subscribers to be served by K (L>K) cable pairs, has decreased significantly in comparison with cable. Moreover, the operating expenses, associated with an all-cable loop network, have increased along with the cost of labor, particularly in areas of high subscriber mobility and uncertain growth. For these reasons, the application of pair gain systems has become an important consideration in loop plant design.

The basic structure of a subscriber pair gain system is illustrated schematically in Figure 5.

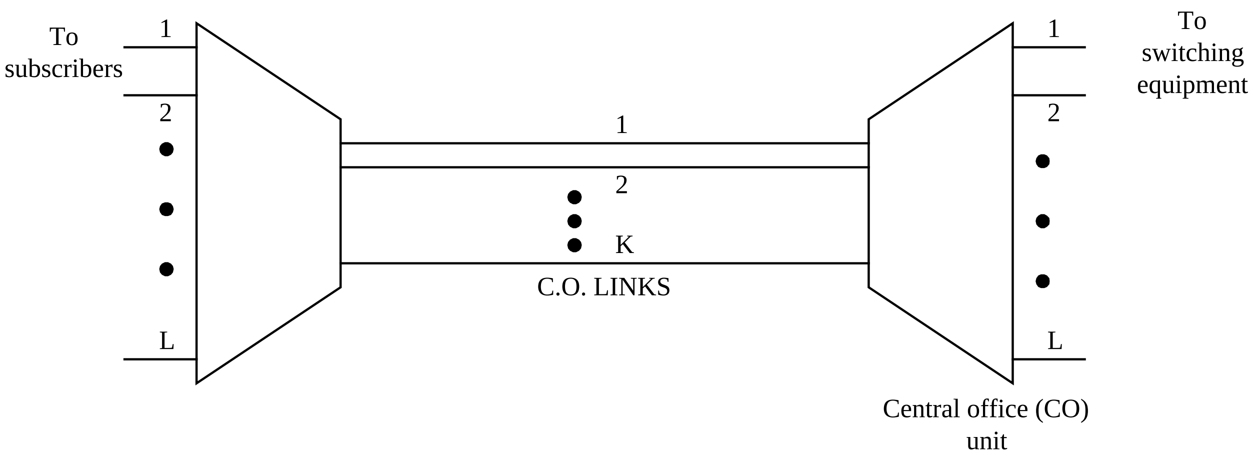

Figure 5

The system consists of a central office (CO) unit, located in the central office building, and a remote unit, located in the field. A given number, say L, of subscribers are connected to the remote unit by individual wire pairs which will be called subscribers lines. The remote unit is connected to the CO unit by K wire pairs (K<L), which will be called CO links. The CO unit effectively converts the K links into L lines at the central office. The pair gain, which is defined as the difference L-K, is the net reduction in cable pair requirements achieved by the pair gain system.

There are two basic approaches to achieving pair gain systems:

- Carrier system, time or frequency division multiplexing. These systems are used to derive additional voice and signalling channels over each CO link. For example, the single channel carrier derives a second line from a single pair (K = 1, L = 2).

- Line concentrator. For example, type 27/6 enables 27 subscribers to be connected over 6 pairs to CO (K = 6, L = 27).

3.2 Pair Gain Systems Application

Par gain systems reduce the need for subscriber cable pairs and, therefore, the obvious application of pair gain is an alternative to additional cable. However, the determination of an economic policy for pair gain application is not simply a matter of deciding whether to use pair gain or cable.

Consider a route which is experiencing growth and whose existing capacity is exhausted. Any of the following alternatives may be appropriate:

(1) Place a new cable.

(2) Place one or more pair gain systems, using existing cables as links.

(3) Place one or more pair gain systems initially, using existing cable pairs as links. When these systems are exhausted, remove them and place a new cable.

Alternative (1) is the classic “all cable” solution. Alternative (2) is often called a permanent pair gain solution since the pair gain systems are not removed. Alternative (3) is called temporary pair gain solution, in which the relief cable is deferred, but once it is placed the pair gain are removed. Generally speaking, the cost of the pair gain system relative to cable must be lower to justify (2) rather than (3). This (2) is prevalent primarily on long rural routes while (3) is more characteristic for suburban applications.

3.3 Line Concentrator

A line concentrator is essentially a switching device. The links between the remote and central office units can be either physical lines or carrier or multiplex channels.

A line concentrator uses a sharing scheme in which some numbers of input channels share a smaller number of output channels on demand basis. Consequently, it is not possible to have all concentrator subscribers using the telephones simultaneously. For this reason, the originating traffic from the subscribers play an important role in the planning and use of concentrators in an attempt to ensure that links are available when needed.

The number of subscribers that can be served by a concentrator is also dependent upon the type of service offered. For example, a concentrator system with 1 % busy hour congestion designed to serve 96 single-party subscribers, under certain traffic conditions, may only accommodate 72 two-party lines.

To minimize the number of cable pairs between a remote location and the central office, it is possible for a concentrator system to include a multiplexing technique transmitting more than one signal on the same transmission channel. For example, a line concentrator that requires 30 cable pairs can serve the same number of subscribers, with only 4 pairs if the concentrator is used in conjunction with a 30 channel PCM system.

In general, requests for service between two subscribers belonging to the same concentrator are carried out by the equipment of central office, although there are some concentrators designed to serve the subscriber internal traffic without the control of the central office. When planning line concentrators, the loop resistance between central office unit and remote unit, remote unit and subscribers should be considered. Care must also be taken so that the maximum permitted loop resistance of the exchange should not be exceeded for any subscriber.

A properly dimensioned line concentrator will not degrade the service, whatsoever. Therefore, to determine whether a line concentrator can be used advantageously or not, it is sufficient to study the economical aspect only.

3.4 Line Concentrator Specification

For the line concentrators, the following data should be provided:

- type and name of line concentrator;
- maximum number of subscribers that can be served for the specific type;
- marginal cost for a subscriber line;
- marginal cost for a link;
- maximum number of links needed.

4. REMOTE SUBSCRIBER UNIT

The application of remote subscriber unit (RSU) is the same as the subscribers pair gain systems. The RSU are electronic digital devices designed to be connected to SPC digital exchanges. These units are remote subscribers stages, namely the subscriber's stage of the exchanges is taken out of the exchange and installed close to subscribers.

The size of RSU varies from a few hundreds to few thousands lines. The optimum size depends on technological and geographical factors such as the subscriber density distribution.

Because of the large capacities of RSU, the installation calls for housing, local power supply and control equipment. The links between RSU and parent exchange should be solely PCM, since the voice signals processed are digital. In Figure 6 (a, b), a typical connection of subscribers local exchange and RSU is shown.

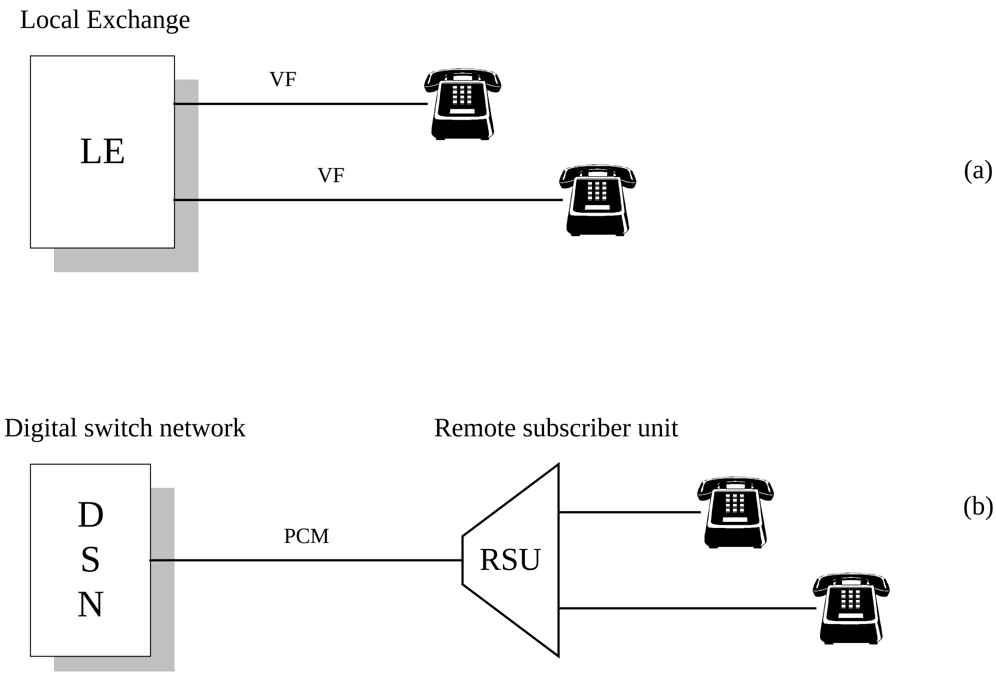

Figure 6

The connection of subscribers to RSU is assumed to be analogue. In general, RSU's of small capacities have not got possibilities of local switching. This is performed in parent exchange. As a result of this, there is an isolation of subscribers of RSU in case the links are out of service. It is convenient to ensure alternative links to avoid this unpleasant situation. For RSU of larger capacities, there is a decentralization of control which can ensure local switching. In that case, we speak about satellite exchanges. Remote subscribers units are connected only to digital SPC exchanges, and subsequently (in optimization studies) these units should be considered only when digital switching systems are involved.

We must be very careful when specifying the marginal cost of an RSU, with respect to subscriber's stage cost, because the major part belongs to the marginal cost of the parent exchange. Only the additional costs associated to subscribers of RSU should be considered.

5. TRANSMISSION SYSTEM

5.1 Introduction

The problem of planning, providing and using the facilities needed to satisfy subscriber demand requires a proper balance between service and cost. The most significant factors to be considered in the selection of transmission facilities are:

- service demand;
- technical specifications;
- number of channels required and where they terminate;
- geographical conditions;
- system compatibility;
- economic feasibility.

In general, a number of different types of transmission facilities will be available, which will satisfy requirements. The problem is to select from this array of available facilities, the most economical type for the immediate needs and for future requirements.

5.2 Voice Frequency Transmission

5.2.1 *General*

Voice frequency systems transmit information over the line at frequencies within the useful portion of the audible spectrum. The media used to transmit this information can be classified into:

- open wire;
- multipair cables.

Open wire economically competes with multipair cable when initial circuits requirements are low (less than about 12 circuits), along with distance and low growth. In rural areas, resistance considerations may require that open wire are installed to permit satisfactory supervisory signalling. The use of open wire as a voice frequency media in the long distance network and backbone routes is very much limited because of economic, traffic and technical considerations.

Open wire is very much susceptible to electrical interference. Its maintenance costs are higher than for multipair cables.

5.2.2 *Multipair cable*

The media consists of insulated copper or aluminium conductors and the insulation is either paper or plastic. The conductors are cabled in pairs or in quads and assembled into layers or units. The twist pitch in these cabling operations is carefully controlled in order to reduce crosstalk between circuits.

The most common copper conductor sizes are 0.4, 0.6, 0.8, 0.9, mm, although we quite often encounter sizes such as 0.41, 0.51, 0.64, 0.91.

For unloaded multipair cable pairs, and for frequencies in the audio band (300 to 4000 HZ), an approximate formula for the calculation of attenuation, α, per kilometer, is given by:

$$\alpha = \sqrt{\pi f R C}$$

where:

f:	frequency
R:	is the loop ohmic resistance of the pair per kilometer
C:	is the capacitance of the line per kilometer
π:	3,14

The attenuation of line for a length “*l*” kilometers is given by:

$$a = \alpha \cdot l$$

The attenuation of cable pairs is higher than for open wire, but its value is less susceptible to variation. Typical attenuation values at 800 HZ for unloaded cables are illustrated in Table I.

Conductor	Diameter ∅	Capacity in nF/km	Loop resistance in OHM/Km	Attenuation in dB/Km
Copper	0.4	45	280	1.55
“	0.6	50	130	1.11
“	0.6	55	130	1.16
“	0.6	120	130	1.72
“	0.8	38.5	72	0.73
“	0.9	55	56.6	0.77
“	0.9	120	56.6	1.14

Table I : Cable Parameters

Loading is used to reduce the loss of cable pairs. The most significant factors to be considered in the choice of a loading system are: desired bandwidth, mutual capacity of cable pairs, attenuation requirements, desired image impedance, velocity of propagation and relative costs.

The typical loading coils are 88 with inductance 88 mH, 66 with inductance 66 mH and 44 for 44 mH inductance. As far as coil spacing are concerned, we have H type with spacing 1830 m which is the most common spacing, D type with spacing 1362 m and B type with spacing 915 m. Thus, loading H88 means spacing type H with 88 mH coil inductance.

Loaded pairs electrically behave like a low band filter, so apart from attenuation, a, another parameter of importance is the cut-off frequency. For frequencies, f, greater than f_o, the attenuation of the pair becomes extremely high and the band $f > f_o$ almost remains constant. An approximate formula for loaded cables, giving the attenuation per kilometer, is:

$$\alpha = \frac{R}{2}\sqrt{\frac{SC}{L_p}}$$

where:

R: is the kilometric loop resistance,
C: the kilometric capacitance;
S: the loading spacing in kilometers
L_p: the loading coil in Henry.

As regards cut-off frequency, an approximate formula is:

$$f_o = \frac{1}{\pi}\sqrt{sL_pC}$$

In Table II, some electrical parameters for loaded cables at medium frequencies (300 ≤ f ≤ 3000) are given.

LOADING	DIAMETER	CAPACITY in nF/Km	ATTENUATION in dB/Km	IMPEDANCE in $\underline{\Omega}$	BANDWIDTH in KHz
H88	0.8	38.5	0.30	1150	4.00
H88	0.9	50.0	0.27	1000	3.55
H88	0.9	38.5	0.24	1140	4.00

Table II : Loaded Cable Parameters

CCITT recommendations dealing with loaded cables include:

- G522: Audio frequency cables-use of different types of loading;
- G451: Specification of factory lengths of loaded telecommunication cables;
- G542: Specification of loading coils for loaded telecommunication cables;
- G543: Specification for repeater sections of loaded telecommunication cables.

In addition to loading, amplifiers are used to further reduce losses on the longer circuits. Location of amplifying devices must be consistent with the maximum level differences permitted between pairs. The most common types of multipair cables are:

- aerial cable
- buried cable
- cable in ducts

Aerial cable installation requires the minimum capital investment for mountainous terrain. It is more flexible (when additions or changes are required) and fault location is less costly, but it is more vulnerable than the other two types to electrical, mechanical interference. Its transmission characteristics are more susceptible to temperature variations.

Buried cable is relatively free of interference when compared to aerial cable, and it has lower annual operating and maintenance costs. Cable in ducts has the highest initial cost per circuit as compared with the other types. Subscriber loops exceeding the loss requirements imposed by the transmission plan can be loaded with H66 or H88, use coarser gauge amplifying devices or subscriber carrier in order to bring them within limits. Subscriber and junction pairs should be in separate cable sheaths unless costs are significantly lower when combination cable is used.

Junction cables are normally buried or underground. From the planning, technical and operational point of view, it is desirable to limit the number of gauges used in the junction plant of a given area to a minimum, preferably one but not more than two.

This selection will depend on the transmission plan, interoffice signalling requirements, distribution of junctions and the relative cost of providing such an arrangement. A desirable alternative to consider in the establishment of a fundamental facility plan is the use of PCM systems in multi-exchange areas. Intercity cables may be aerial or buried. They may consist of pairs, star or multiple twin quads. Normally, they are only used on relatively short routes or for a complete cable being installed primarily for carrier operation.

5.3 Frequency Division Multiplex

Frequency division is a method of multiplexing in which signals from a number of channels are translated to separate frequency bands by a modulation process, so that they are combined and transmitted over a single medium.

Channels are arranged in groupings in order to make up a carrier link. Several groupings can be combined to constitute a grouping of higher capacity and this operation can be repeated several times by means of translating equipment.

The capacity and transmission media of the FDM carrier for subscriber purposes are illustrated in Table III.

No.	TYPE	CARRIER CAPACITY	TRANSMISSION MEDIA
1	Single channel	1	Symmetrical cables or open wire lines
2	3-channel	2	Open wire
3	12-channel	3	Symmetrical cables or open wire lines

Table III : Typical Carriers for Subscriber Purposes

5.3.1 Open Wire Carriers

FDM carrier, as commonly applied to open wire facilities, increases the capacity of existing open wire lines up to 12 voice channels per pair. The signal is applied to one open wire pair, and is transmitted by using the split band frequency.

It is possible to use on the same pair one twelve channel and one three channel carrier. In this case, the maximum capacity of the line is increased up to 15 voice channels. The CCITT recommendations dealing with this subject are: G311, G312, G313, G314 & G361. Crosstalk caused by inductive couplings between parallel wire pairs is one of the main problems in open wire carrier transmission. An effective solution is the use of transposition technique. The main application of open wire carrier is in those areas where the rate of growth is small and the open wire facilities are already installed. In general, its use is decreasing as these systems are being phased out in favor of cable systems.

5.3.2 Multipair Cable Carrier

The most common type of FDM systems on cable pairs provided 12 or 24 voice channels per system.

The pertinent CCITT recommendations dealing with this subject are: G321, G322, G323, G325 & G326.

If a large number of systems are used in the same cable sheath, then a special care must be taken in the cable and pair selection process, and also in the engineering and installation procedures. It is not advisable to mix different carrier systems within the same cable, but if it is necessary, frequency and level compatibility must then be assured.

5.3.3 Technical Specifications required for Network Planning

In order to make an optimal choice between the various transmission systems that fulfill the transmission requirements, their costs and technical properties must be specified. To this end, for frequency division multiplex, the following data should be provided:

- Multiplex system
  - signalling system
  - channel capacity of the system
  - cost of multiplex equipment
  - cost of portion of racks
  - installation cost

- Line system
  - type of transmission media
  - distance between repeaters
  - capacity of repeater housing
  - capacity of the line system
  - cost of line terminal equipment
  - cost of repeaters
  - cost of housing
  - cost of installation

5.4 Pulse Code Modulation

Pulse code modulation (PCM) samples each voice channel 8000 times per second and transmits the result of each sampling by means of coded pulses. At the receiving end, the pulses are decoded and the information is used to reconstruct the signal in that respective channel. Each separate signal value has a unique arrangement of pulses and only the presence or absence of pulses, not their shape, determines the receive quality for a given coding arrangement. Regenerative repeaters, spaced at fixed intervals, detect the presence or absence of pulses and replace them with perfect new ones. Theoretically, this concept of regeneration would make it possible to transmit messages for unlimited distance, but in practice, small timing errors tend to add up, placing a limit on system length. There are basically two types of PCM systems in use today:

- The (30+2) channel system consisting of 30 voice channels, plus one for signalling and another for synchronization. This system has been standardized for European application by CEPT (Conférence Européenne des Postes et Télécommunications); it also has been recognized by the CCITT as the standard for international communications.

- The 24-channel system is widely used in North America and Japan. In Table IV, the basic parameters of the two systems are illustrated: PCM systems operate on a physical four-wire basis with the two directions of transmission on separate pairs within the same cable or in separate cable sheath.

The main cable factors controlling the design of a PCM line are attenuation, crosstalk and impulse noise.

The common regenerating spacing is the coil interval for H88 loading. The end repeaters are located at a distance half the intermediate spacing, in order to minimize the effect of impulse noise which is very high close to the switching systems.

PCM systems can operate in an analogue or digital network (integrated digital network). In analogue network, PCM operates between conventional central offices or connecting conventional line concentrators to conventional central offices or analogue subscribers to analogue exchanges. All these cases are illustrated in Figure 7.

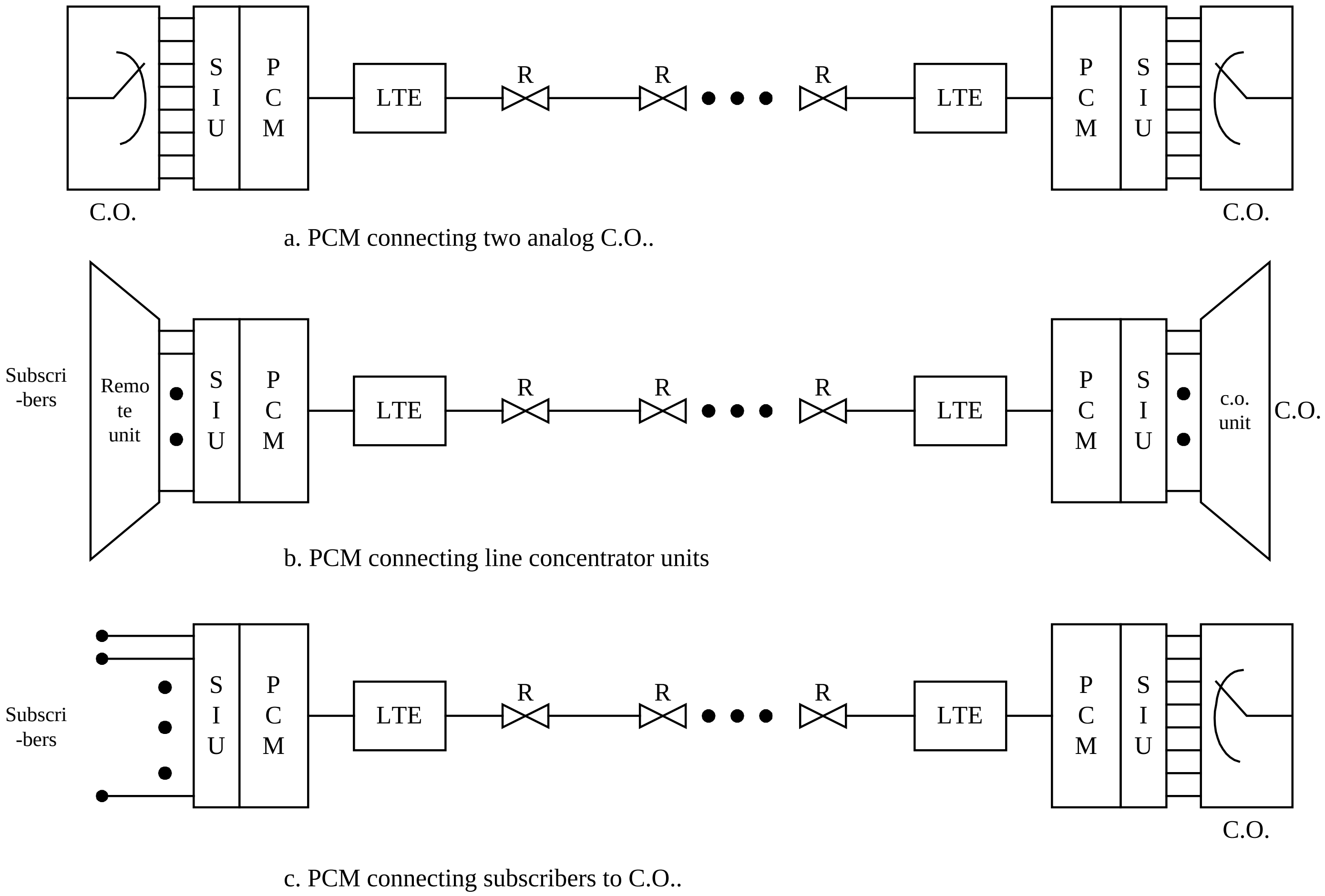

Figure 7

SIU:	signalling interface unit
PCM:	PCM terminal
LTE:	line terminating equipment
CO:	central office
R:	regenerator

Every aforementioned case necessitates a signalling interface and a PCM terminal to each end. The former unit is required for signalling and the latter to convert the voice digital signals to analogue ones.

In an integrated digital network (IDN) where there is synergy between switching and transmission, only digital signals are treated, the PCM terminals, for junction purposes, are completely eliminated.

Data required for optimization studies for PCM systems are the following:

- Multiplex system
  - Technical properties
  - Signalling system
  - Channel capacity
  - Cost for: A/D converters
    - multiplex equipment (2/8, 8/34, 34/140, etc. multiplexers)
    - racks
    - installation

- Line system / Transmission media
  - Type of multipair cable
  - Type of coaxial cable
  - Type of radio link
  - Type of fiber optics
  - Channel capacity
  - Distance between repeaters
  - Capacity of housing
  - Cost for: line terminal equipment
    - repeaters
    - transmission media
    - housing
    - racks
    - installation

5.5 Coaxial Cable

5.5.1 *Background*

Coaxial cable is an appropriate base band transmission medium for wide band FDM or PCM signals. There are two types of coaxial cables recommended by CCITT. One type is the large diameter 2.6/9.5 mm and the other type is the small diameter 1.2/4.4 mm coaxial cable. Table 6-5 comprises the transmission systems, FDM and PCM, that are used on coaxial cables. Coaxial tubes are laid in a cable sheath together with several symmetrical pairs which may be used for maintenance and supervision of the carrier system over the coaxial pairs, and also for providing additional circuits over a small carrier system or at VF. Generally, the capacity of a coaxial cable varies between two and twenty tubes. The most common sizes are 4, 6, 8, 12 and 20.

The coaxial cable transmission media are basically free of radio frequency interference. Noise contribution by the cable itself is almost negligible. Losses between two points are almost constant in contrast to line- of -sight microwave systems which undergo fading, and the small loss variations occurring are mainly due to temperature changes along the system.

The main advantages of coaxial cable systems are:

a) High flexibility, for instance:

- Possibility to plan for an ultimate system. The existing spare tubes planned to allow for new FDM systems may be successfully used for PCM systems for which there is a demand due to the penetration of digital switching.
- Channel dropping and inserting.
- Equipment additions to or removal from working systems.
- Ease of interconnection with different types of transmission systems.

b) High reliability and availability

c) Low maintenance cost.

Major items contributing to the initial cost of a system are:

- Route survey;
- cost of the cable itself;
- cost of installation. This represents a substantial percentage of the total cost;
- repeaters, housing and power requirements;
- supervision and fault detection equipment;
- terminal equipment.

The 960- channel system on a small diameter cable is used for medium and long distances to connect areas of high telephone density.

The 12, 18 and 60 MHz systems operating on large coaxial cable are basically used for long haul circuits to connect areas of high telephone density. As regards digital transmission, small coaxial cable is suitable for fourth order. In recent years, the fifth order (7680) has appeared which can be installed on large coaxial cable (regenerating spacing 1.55 km).

Table IV provides some technical characteristics of transmission systems used on coaxial cables.

Type of Coaxial Cable	**F D M**				**P C M**			
	Type of Trans. System	Base Band MHz	Channel Capacity	Repeater Spacing Km	Type of Trans. System	Bit Rate Mb/s	Channel Capacity	Repeater Spacing Km
2.6/9.5	2.6	2.6	600	9.0	34	34	480	9.0
	4.0	4.0	960	9.0				
	6.0	6.0	1260	9.0				
	12.0	12.0	2700	4.5	140	140	1920	4.5
	18.0	18.0	3600	4.5				
	60.0	60.0	10800	1.55	565	565	7680	1.55
1.2/4.4	1.3	1.3	300	6 or 8				
	4.0	4.0	960	4.0	34	34	480	4.0
	6.0	6.0	1260	3.0				
	12.0	12.0	2700	2.0	140	140	1920	2.0

TABLE IV : TRANSMISSION SYSTEMS FDM, PCM, USED ON COAXIAL CABLES

5.6 Fiber Optics Cables

5.6.1 *Introduction*

In recent years, the use of fiber optics for the transmission of large amount of information has been getting wider and wider. In spite of the fact that optical transmission systems can be designed to operate utilizing analogue or digital technique, the major field of application is the digital technique. The extensive use of fiber optics came about with the advent of integrated digital network (IDN), in conjunction with the much greater repeater spacing that can be achieved when transmitting digital signals.

The major advantages of fiber optics can be summarized to:

- low loss transmission;
- wide bandwidth;
- immunity to electromagnetic interference;
- small bending radius.

Fiber optics are very promising. Few problems, which are still remaining, will be solved very shortly. This technique with reduced cost due to wide utilization is a very competitive transmission medium for telecommunication purposes.

The commonest digital transmission systems used on fiber optics are 34 and 140 Mb/s PCM systems (3rd and 4th order PCM). This fact, in conjunction with the possibility of achieving in small cables in size a considerable number of pairs, enables the transmission of tremendous quantities of information in digital form over a single cable.

Referring, in particular, to junction and trunk networks, all the above-mentioned advantages make fiber optics suitable transmission systems. The low losses allow central offices to be linked without intermediate repeaters, and the small size of optical cables permits a more efficient utilization of ducts, thus resulting in noticeable cost savings.

5.6.2 *Application to junction network*

Average values of interoffice link length, range from 2 to about 12 km. These values correspond to repeater sections easily achieved by using first window (800 nm) fiber optics transmission systems. For link exceeding 15 km, optical transmission system operating at 1300 mm could be used. In interoffice links, the installation of repeaters should be avoided. The introduction of digital switching in metropolitan areas will result in the need for large number of digital circuits. The only way to meet these requirements is the implementation of fiber optics links.

5.6.3 *Application to trunk network*

The trunks network concerns links between long distance exchanges. Trunk can vary considerably in length from 20 to over 300 km and in some instances over 1000 km. Because trunk routes are major routes carrying large traffic, the need for high capacity transmission systems is obvious. In such cases, the installation of higher order PCM on fiber optics is economical (above 3rd order). On routes where the length exceeds the design repeater spacing, it is necessary to have intermediate repeaters. We have to avoid to remotely power the repeater. The best solution to install repeaters is in surface buildings along the route where power is available. In Table V, some practical data for fiber optics transmission systems are tabulated.

Such tables should be consulted when planning transmission systems.

SYSTEM FIBER TYPE		GRADED INDEX MULTIMODE			MONOMODE
BIT RATE (Mbit/s)		34		140	140
SOURCE DETAILS	wave length (nm)	850	1300	1300	1300
	device type	Laser	Laser	Laser	Laser
	spectral width (nm)	≤5	≤10	≤10	≤10
	mean launch power (dBm)	- 1	- 3	- 3	- 6
FIBER DETAILS	Attenuation (dB/km)	≤3.5	≤1.0	≤1.0	≤0.7
	Bandwidth (MHz.km)	≥400	>800	>800	-
DETECTOR DETAILS	Device type	APD	PIN FET	PIN FET	PIN FET
	Sensitivity for BER 10^{-9} (dbm)	- 48	- 45	- 41	- 41
SYSTEM PARAMETERS	Available power ratio (db)	47	42	38	35
	Overall system Bandwidth (MHz)	≥40	≥40	≥100	≥100
	Repeater spacing (Km)	10	22	18	≥30

TABLE V : SOME USEFUL SYSTEM TECHNICAL DATA

5.7 Line-of-sight Microwave Links

Microwave links can transmit up to 2700 voice channels using frequency division multiplexing, and up to 900 channels, using time division multiplexing on each radio carrier.

To meet noise requirements, the number of baseband repeaters must be limited. Baseband repeating should be used only on short sidelegs and end links off a main radio route. Intermediate frequency (IF) repeaters are recommended for backbone main routes at sites where no drop- insert requirement exists. “IF” repeating contributes less noise than “baseband” because the number of modulation/demodulation steps are reduced.

Radio link repeaters are separated by distances in the order of 50 km. The separation depends on terrain configuration and transmission medium characteristics, namely the continuous variation of the atmospheric refractive index with height.

The main items to be considered in the planning and engineering of terminal at repeater stations are:

- path engineering, radio frequency interference and frequency planning;
- land acquisition, buildings, access road and station layout;
- site by site decision on “IF” or baseband, repeaters, power requirements and stand-by equipment;
- towers for antennae;
- alarm requirements;
- diversity requirements.

High capacity systems are normally used for long haul backbone or main routes. Low capacity systems are normally used as side- legs off main high capacity routes or as independent for thin routes. The decision as to whether to use radio or fiber optics systems is a management decision coupled with traffic requirements, technical specifications and economic feasibility.

5.8 Multiplex Systems

The main features of PCM and FDM multiplex systems were provided in the previous paragraphs. Here, we will present the various hierarchies of multiplex systems.

5.8.1. *PCM multiplex systems*

The basic multiplex system for PCM is the PCM of 30/32 (2048 kb/s) for CEPT countries and 24 (1544 kb/s) for worth America and Japan. The basic PCM constitutes higher order multiplex, the so-called PCM “hierarchy”.

The time multiplexing of four 30/32 PCM’s provides the “second order” PCM which consists of 120 telephone voice channels at a bit rate 8440 kb/s. The multiplexing of 4 second order PCM constitutes a third order PCM of 480 telephone channels with a bit rate of 34 Mb/s. This way of building the various PCM orders is applicable to up to fifth order.

In Figure 8, all PCM multiplex systems are shown.

It is worthwhile observing that the connection of a digital exchange is carried out on the basis of 2048 kb/s (IDN) while the connection of an analogue exchange is made on channel basis. This fact is significant for cost comparison purposes.

5.8.2 *FDM multiplex systems*

Twelve audio frequency channels (300-3400 Hz) may be translated into the CCITT primary group (60-108 KHz) by means of direct modulation or pre-group modulation. A 60- channel super group is formed of five 12-channel groups in the 312-552 KHz frequency band. A basic master-group is five 60- channel basic super groups in the 812-2044 KHz. A 900- channel basic super master-group is formed of three basic master-groups in the 8516-12388 KHz. The different order groups are shown in Figure 9.

PCM MULTIPLEX SYSTEMS

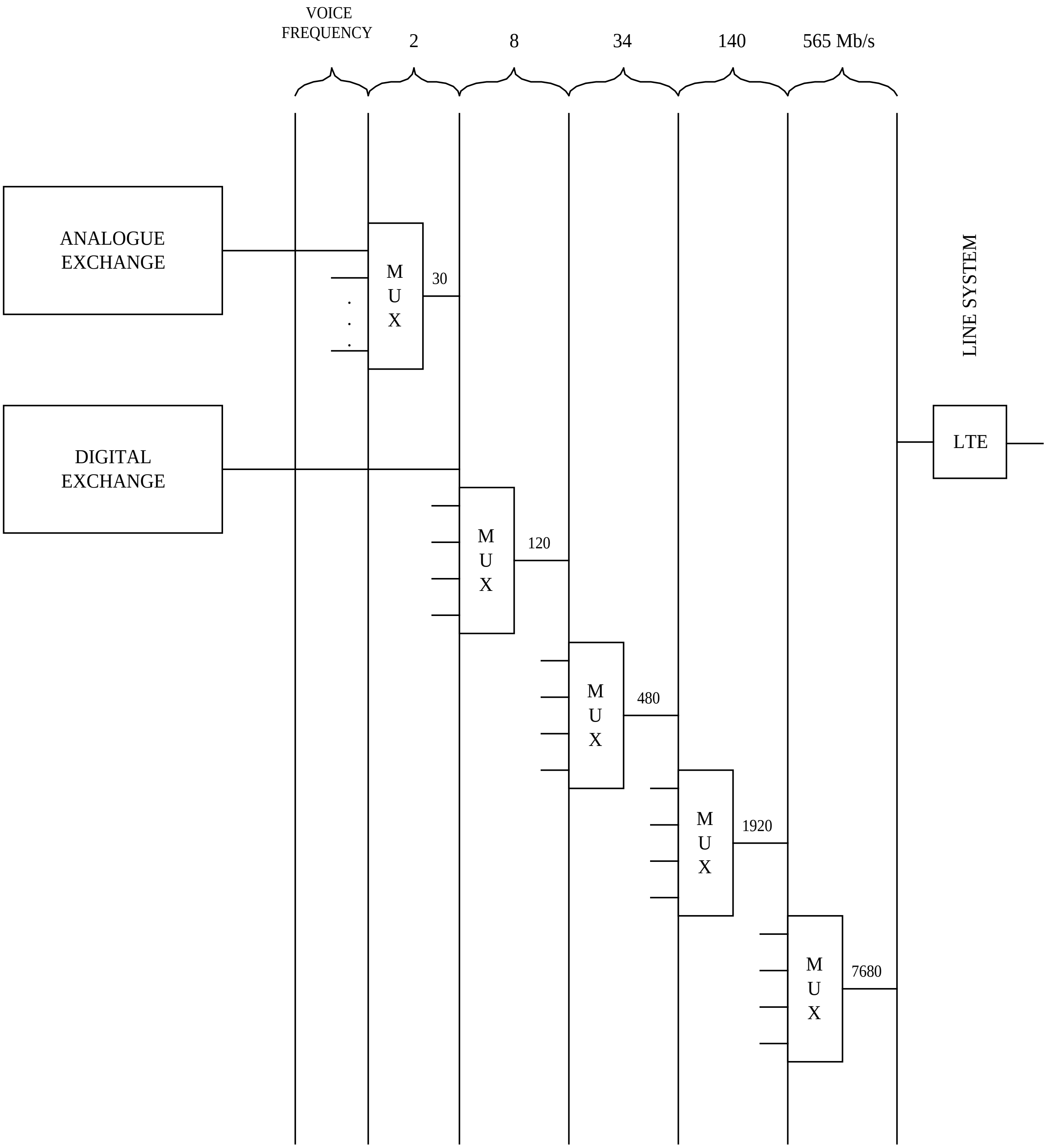

Figure 8
PCM Multiplex Systems

FDM MULTIPLEX SYSTEMS

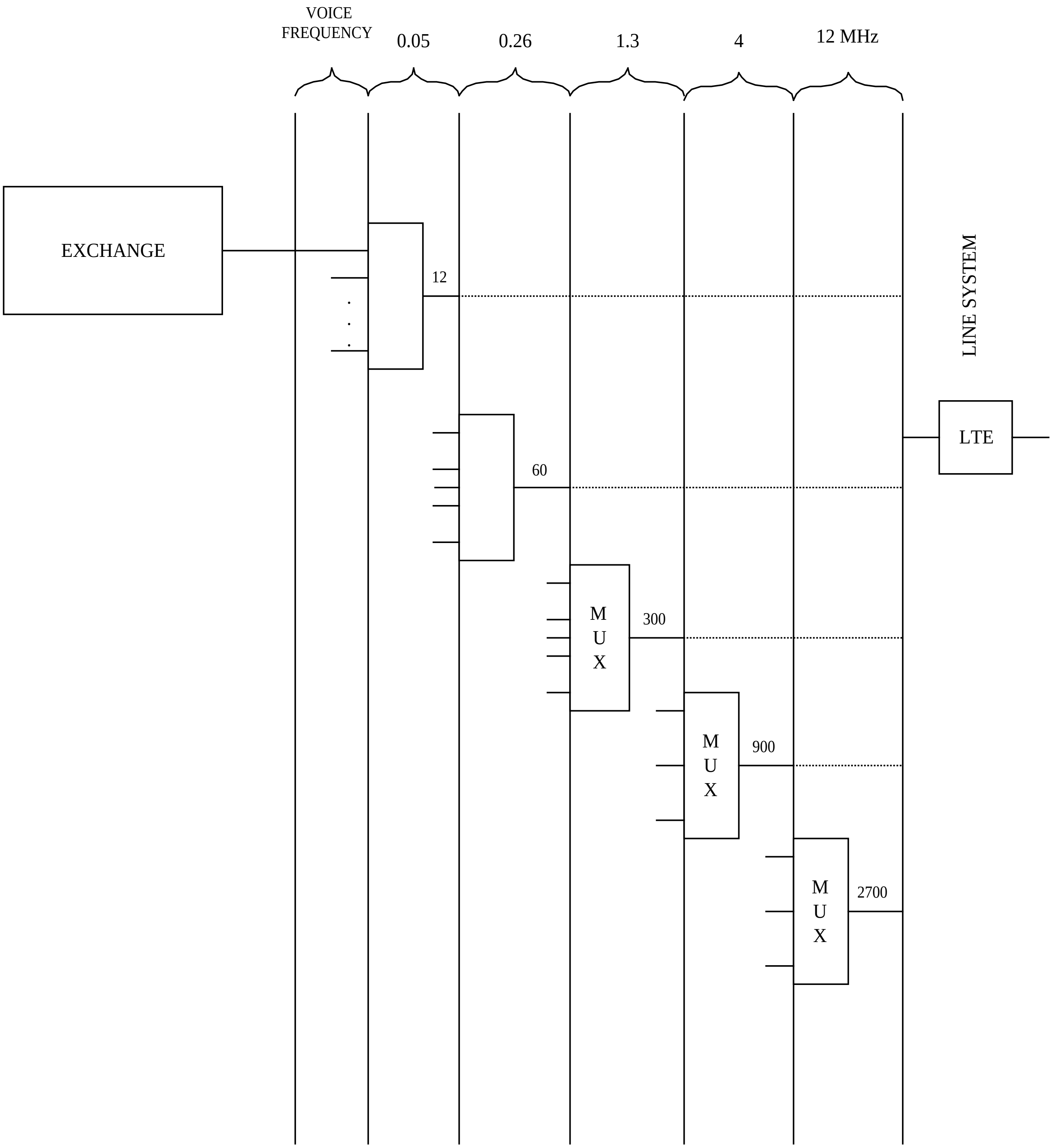

Figure 9
FDM Multiplex System

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