TELEPHONE NETWORK

A telephone network is a telecommunications network used for telephone calls between two or more parties.

There are a number of different types of telephone network:

- A landline network where the telephones must be directly wired into a single telephone exchange. This is known as the public switched telephone network or PSTN.
- A wireless network where the telephones are mobile and can move around anywhere within the coverage area.
- A private network where a closed group of telephones are connected primarily to each other and use a gateway to reach the outside world. This is usually used inside companies and call centers and is called a private branch exchange (PBX).

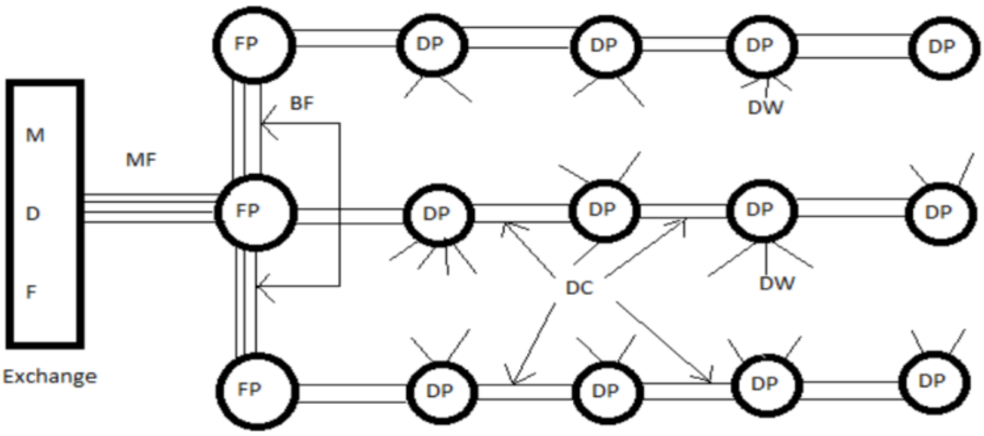
Public telephone operators (PTOs) own and build networks of the first two types and provide services to the public under license from the national government. Virtual Network Operators (VNOs) lease capacity wholesale from the PTOs and sell on telephony service to the public directly.

A telecommunication network may be categorized into major systems:

1. Subscriber end instruments
2. Subscriber loop systems
3. Switching systems
4. Transmission systems
5. Signaling systems

Subscriber loop system

In a telephone network every subscriber is connected generally to the nearest switching office by means of dedicated pair of wires. Its very difficult to connect each individual pairs from every subscriber premises to the exchange. So, generally four levels of cabling are used as shown below



MDF=main distribution frame MF=main feeder FP=feeder point BF=branch feeder DP=distribution point DC=distribution cable DW=drop wires

Fig. 24: Cable hierarchy for subscriber loops

In a communications network, a drop is the portion of a device directly connected to the internal station facilities, such as toward a telephone switchboard, toward a switching center, or toward a telephone exchange. A drop can also be a wire or cable from a pole or cable terminus to a building, in which case it may be referred to as a down lead. These cables may be reinforced to withstand the tension (due to gravity and weather) of an aerial drop (i.e., hanging in air), as in "messenger" type RG-6 coaxial cable, which is reinforced with a steel messenger wire along its length. These wires are individual pairs that run into subscriber premises and they are connected to wire pairs in the distribution cables at the distribution point. This cable can also be used as an external grade telephone cable and be clipped to the side of a building. A drop wire is over head telephone wire or cable used from a telegraph pole to a house or a building, drop wire no 10 has 2 pairs (4 wires) with 3 straining wires to withstand the tension (due to the long length of the cable and weather) along its entire length.

Fig.25: Drop wire no 10

Thus, many such distribution cables from nearby geographical regions are terminated on a feeder point where they are connected to branch feeder cables which are thus connected to main feeder cable. These DC carry only 10-500 pairs while MF cables large numbers i.e. 100-2000 wire pairs. So, such MF cables are terminated on a MDF at the exchange and moreover the subscriber cable pairs emanating from exchange also gets terminated on MDF.

MDF:The MDF is a termination point within the local telephone exchange where exchange equipment and terminations of local loops are connected by jumper wires at the MDF. All cable copper pairs supplying services through user telephone lines are terminated at the MDF and distributed through the MDF to equipment within the local exchange e.g. repeaters and DSLAM. Cables to intermediate distribution frames (IDF) terminate at the MDF. Trunk cables may terminate on the same MDF or on a separate trunk main distribution frame (TMDF). Like other distribution frames the MDF provides flexibility in assigning facilities, at lower cost and higher capacity than a patch panel. The most common kind of large MDF is a long steel rack accessible from both sides

Each jumper is a twisted pair. The MDF usually holds telephone exchange protective devices including heat coils, and functions as a test point between a line and the exchange equipment. Due to its flexibility it is very useful in reallocating cable pairs and subscriber numbers. For example: when any subscriber moves his house to a nearby served by same exchange but different DP then he can be allowed to have the same number or if he releases his wires then he can be given a new number and that number is given another subscriber. Moreover feeder and distribution points have flexible cross point connection capability in newer installations which helps in easy reconnection of subscriber drop wire to any pair of wire in the distribution cables and there after any pair from DC to any other pair of feeder cable at FP. These helps in utilization of the cable pairs efficiently as well as management during faults for e.g.: if particular cable is faulty then important subscribers assigned to this cable can be reassigned to free pairs in other cables.

From economy point of view it is desirable that the subscriber loop lengths are as large as possible so that single exchange can serve large area. But there are two factors that limit their length.

(1) Signaling

(2) Attenuation

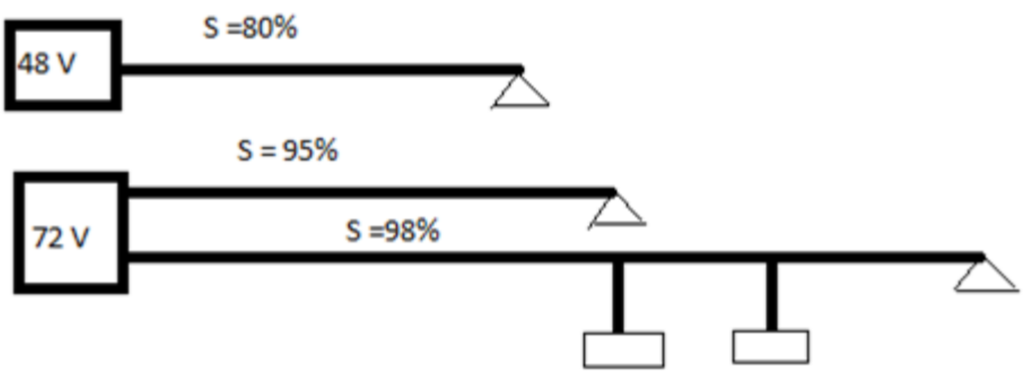
Signaling: as discussed before dc signaling is used for subscriber lines like off-hook signals and dial pulses. A certain minimum current is required to perform these signaling functions properlyand thus exchanges must be designed so that they can deliver such a current. A bound on loop resistance also limits the loop length for a given gauge wire. So, the dc loop resistance Rdc for copper conductors is $Rdc = 21.96/d^2$ ohms/km

Where d = diameter of conductor in mm

As resistance is a function of temperature equation holds good for resistance values at 20°C. So, smaller gauge wires use thicker conductors and often less dc resistance per unit length

Attenuation:its limit arises from ac response of the loop and refers to loop loss in decibels. The criteria here are to ensure that the quality of reception at the subscriber end is satisfactory.

- A need arises to connect to existing subscribers who are located beyond the maximum prescribed distance. For example: it is uneconomical to install a new exchange for alone or a few remote subscribers in such cases special technique is used to meet the resistance and attenuation constraints.
  So, the dc resistance constraint is met by:
  (1) Use of higher diameter(lower gauge)
  (2) Use of equalized telephone sets wire
  (3) Unigauge design or use of higher supply voltage.
  And attenuation constraints are overcome usually by the use of loading coils
  Moreover as significant portion (30-40%) the cost of telecommunication network comes from cost of copper in the subscriber lines so a larger value of loop resistance is acceptable.



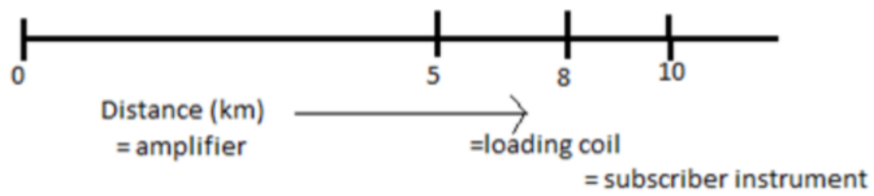


Fig.26: Unigauge design of subscriber loops

This design attempts to use wire with as small a diameter as possible while retaining the resistance and attenuation limits. For both long and short distances, the same gauge wire is used and hence the name unigauge design.

- Loading coils are identified by using a standard convention as 19-D-44, 24-A-88 etc. Here the 1st number indicates with which coil the wire gauge is used,the letter specifies the spacing between the coils and the last number specifies the inductance value in mH. This table 3 below shows the standard letters and their associated spacing and the most commonly used spacing is B,D and H.

Table 3- Loading coil spacing

Letter code	A	B	C	D	E	F	H	X	Y
Spacing (km)	0.21	0.92	0.28	1.37	1.7	0.85	1.83	0.2	0.65

- In rural places subscribers are generally dispersed and so it is both unnecessary and expensive to provide a dedicated pair for every subscriber. Hence, 3 techniques are used to gain on number pairs:
  (1) Party lines
  (2) Concentrators
  (3) Carrier systems

Party lines: here two or more subscribers are connected to one line termed as party line. This technique is generally not used due to many drawbacks. Only one subscriber can be used at a time. Selective ringing is difficult and privacy is not maintained and dialling between two subscribers on the same line is not possible.

Concentrator: here a concentrator expander is used near the cluster of users and another one at exchange end as shown

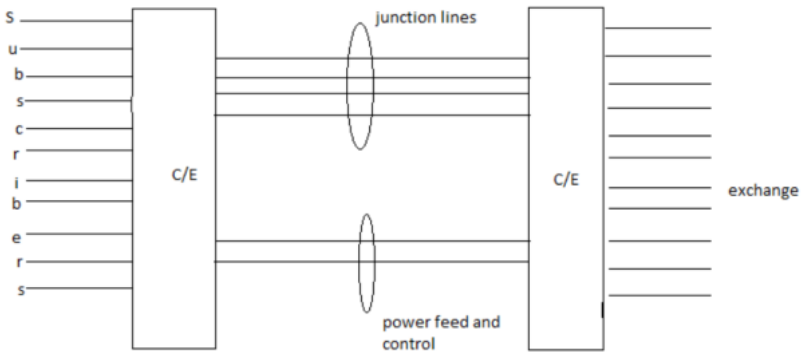


Fig. 27: Concentrator-expander connection for dispersed subscribers

Only few junction lines are run between the CEs which have switching capability. A ratio of 1:10 between the junction lines is used and the CE at the exchange end remotely powers and controls the CE at the subscriber end.

Carrier systems: they employ multiplexing techniques and enable all the users to access the exchange over a single line, analog FDM and digital TDM systems are used.

Signalling and voice transmission of the subscriber lines requires that the exchange performs a set of functions. These functions are performed by an interface at the exchange end called as subscriber loop interface.

The complete set of functions is known by an acronym BORSCHT which stands for:

B = battery feed
O = overvoltage protection
R = ringing
S = supervision
C = coding
H = hybrid
T = test

Functions B and R are well known. Overvoltage protection deals with equipment and personnel protection from lightining strikes and power line surges. Detection of off-hook condition is a supervisiory function. Functions C and H are exclusive to digital switch interfaces. As we know, digital switching demands that analog to digital and digital to analog conversions and some form of coding/decoding be done. Subscribers are connected to the exchange via 2-wire circuits.these circuits use balanced connections as shown below:

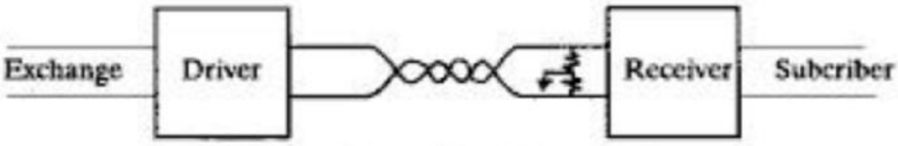


Fig.28: balanced circuit connection

Balanced connections overcome many drawbacks of unbalanced circuits. The transmission lines have equal impedances to ground and hence don't act as an antenna to pick up signals. Since the ground is not a part of the signal path and hence is eliminated. Differential inputs improve noise immunity as any interface affects both lines equally and does not introduce differential currents.

Digital exchanges require receive and transmit signals on separate 2-wire circuits. This call for 2-wire to 4-wire conversion and the circuit that performs it is called hybrid. Such a conversion is normally required for trunk transmissions in analog exchanges. The circuit is shown below. The main function of a hybrid is to ensure that there is no coupling of signal from the input to the output in 4-wire circuit.

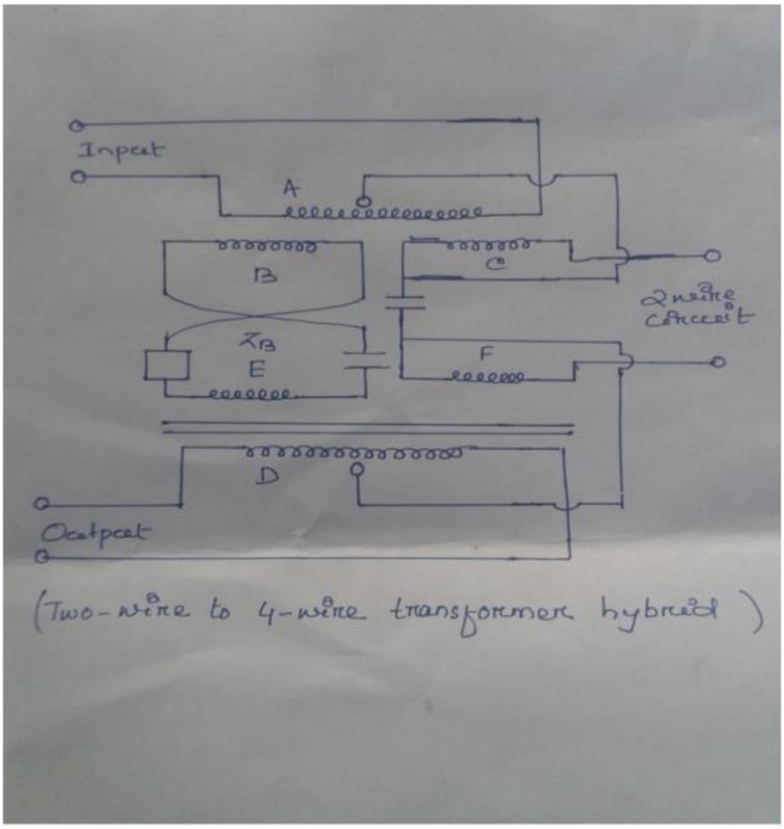


Fig.29: two- wire to 4-wire transformer hybrid

The operation of the circuit is as follows: The input signal is coupled to the B and F windings equally. Through the C winding, the input is coupled to the 2-wire circuit. The same signal when it flows the balanced 2-wire couples the signal to winding D through winding C. The signal induced in B flows through E and induces a current in D that opposes the current induced by F. If the impedance Z_B exactly matches that of the 2-wire circuit, the effect of input signal from the subscriber end is completely nullified from coupling into the winding A.

Integrated circuit manufacturer have successfully developed a single chip called subscriber loop interface circuit (SLIC) and an all-electronic telephone automatic redialing is feature that enabled in the telephone instrument if we use a microprocessor.

18. Switching Hierarchy and Routing

- Telephone networks require some form of interconnection of switching exchanges to route traffic effectively and economically. Exchanges are interconnected by groups of trunks called as trunk groups that carry traffic in one direction.
- Between any Two exchanges 2 trunk groups are required and 3 basic topologies are adopted for interconnecting exchanges: mesh, star and hierarchy. Where mesh is a fully

connected network which is used mostly in heavy traffic among exchanges i.e. in metropolitan area as the number of trunk groups are proportional to the square of exchanges being interconnected.

- A star connection utilizes an intermediate exchange called a tandem exchange through which all other exchanges communicate.
- An orderly construction of multilevel star networks leads to hierarchical networks.

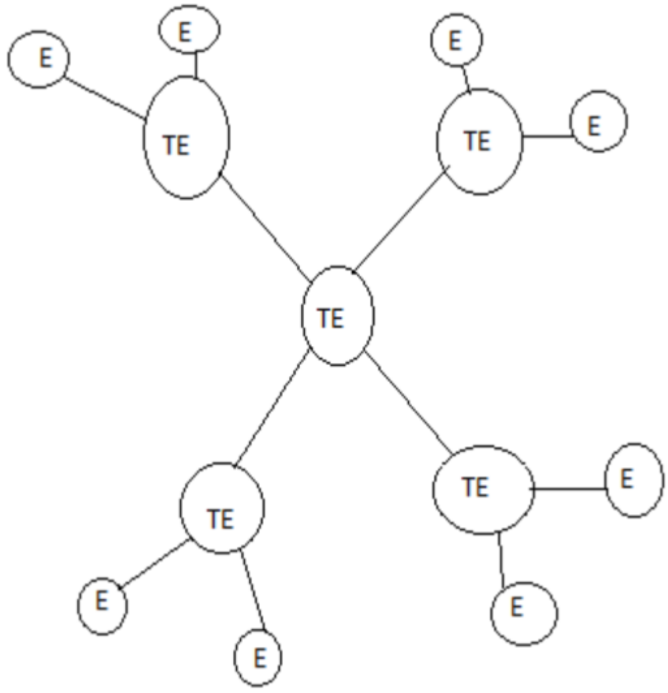


Fig. 30: Two level star

Hierarchical networks are capable of handling heavy traffic where required, and at the same time use minimal number of trunk groups. A 5-level switching hierarchy is recommended by CCITT as shown fig. 27 below. In a strictly hierarchical network, traffic from subscriber A to subscriber B and vice versa flows through the highest level of hierarchy, viz quaternary centers in fig.27 below. A traffic route via the highest level of the hierarchy is known as final route. However, if there is high traffic intensity between any pair of exchanges, direct trunk groups may be established between them as shown in figures below. These direct routes are known as high usage routes.

Three methods are commonly used for deciding on the route for a particular connection:

1. Right-through routing
2. Own-exchange routing
3. Computer-controlled routing

In right-through routing the originating exchange determines the complete route from source to destination. No routing decisions are taken at the intermediate routes.Own-exchange routing or distributed routing allows alternative routes to be chosen at the intermediate nodes. Thus the strategy is capable of responding to changes in traffic loads and network configurations.Computers are used in networks with common channel signaling (CCS) features. With computer in position, a number of sophisticated route selection methods can be implemented.

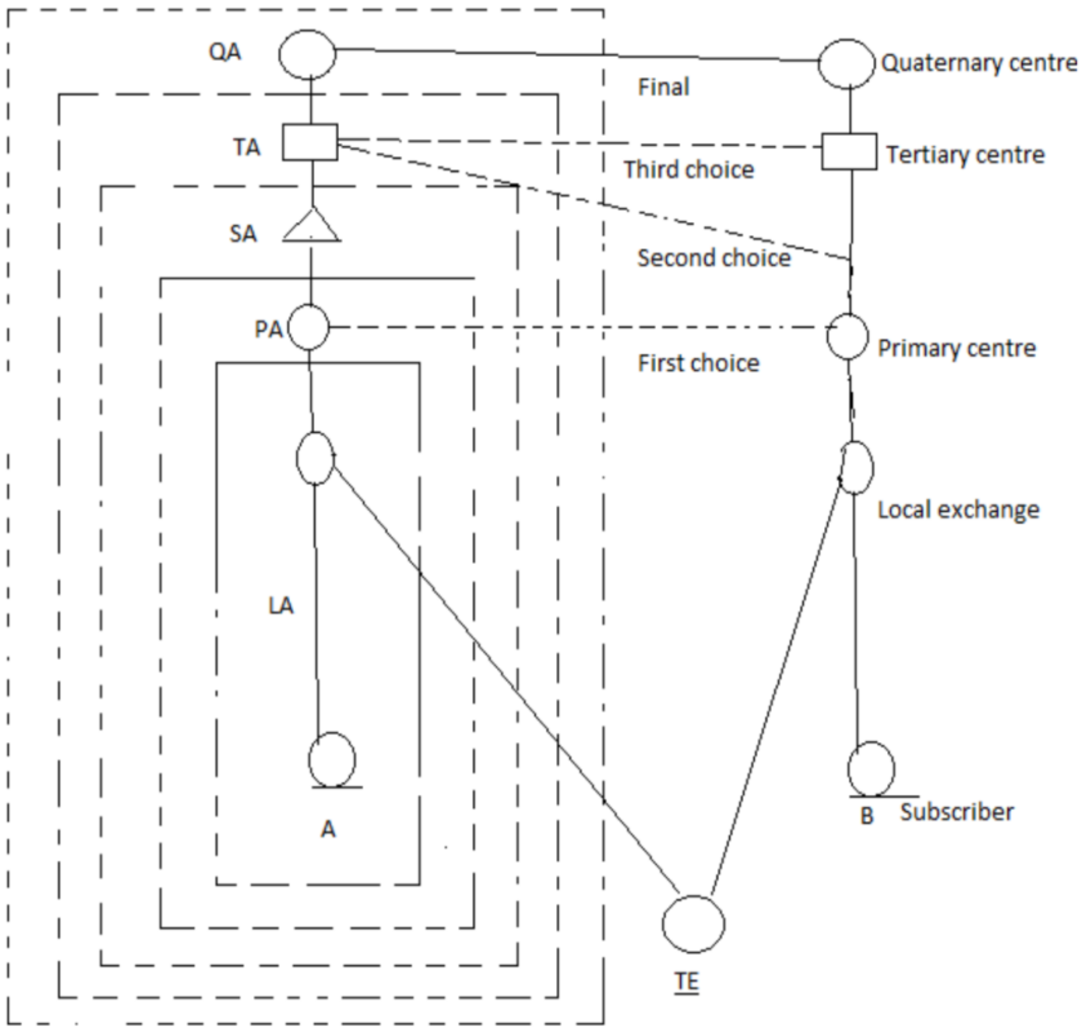


Fig.31: A five level CCITT hierarchical structure

Transmission Plan

For reasons of transmission quality and efficiency of operation of signalling, it is desirable to limit the number of circuits connected in tandem. In a tandem chain, the apportionment of links between national and international circuits is necessary to ensure "quality" telecommunications. CCITT guidelines in this regard are:

1. The maximum number of circuits to be used in an international call is 12
2. No more than 4 international circuits to be used in tandem between the originating and the terminating international switching centers.

3. In exceptional cases and for low number of calls the total number of circuits may be 14, but even in this case, the international circuits are limited to a maximum of 4.

Taking guidelines 1 & 2 we have 8 links available for national circuits, which implies a limit of four for each national circuits.

The transmission loss is defined in terms of reference equivalents of TRE, ORE and RRE. CCITT recommends that for 97% of the connections the maximum TRE is limited to 20.8dB and RRE to 12.2dB between the subscriber and the international interface in the national network. This gives an overall reference equivalent ORE of 33 db. From one country to another the OREs range is from 6 to 26 db.

Transmission losses budget should provide for 2 factors other than line and switch losses:

1. Keeping echo levels within limits
2. Control singing.

In analog exchanges, local calls are established on 2 wire circuits. But long distance calls require 2 wire to 4 wire conversion at the subscriber line trunk interface. Due to long distance involved, the bearer circuits need amplifiers or repeaters at appropriate intervals to boost the signals. The amplifiers are almost invariably one way devices. Since for long distance circuits need separate for each direction, leading to conversion into a 4 wire circuits.

The important function of the hybrid is to ensure that the received signal is not coupled. The coupling is zero only when the 2 wire circuit and the 4 wire circuit impedances are perfectly matched. However impedance mismatch occurs in most of the connections at the subscriber line trunk interface. The effect of such mismatch results in echo. If the distance are short , the round trip delay experienced by the echo is small and becomes unnoticeable.

The echo suppressors are voice attenuators. Normally the echo suppressors remain in a deactivated state. Speech in one channel activates the echo suppressor in the return path. One drawback of echo suppressors is that they may clip the beginning portion of speech segments. New designsof echo suppressors attempt to minimize the time required to reverse directions. Typical reversal times are in the range of 2-5 ms.

The operation of a system with echo suppressors is clearly half duplex. When telephone lines are used for data transmission full duplex operation is required. Echo suppressors are usually turned off for data transmission as it is very difficult to organize data transmission. This is done by providing a disabler feature in the echo suppressor and triggering the same with a special signal. Usually a 2025 Hz or 2100 Hz tone transmitted for at least duration of 300 ms with a signal not less than -5 dB is used to trigger the disabler.Once the time increases the echo becomes noticeable and annoying to the speaker.

Short delay echo are controlled byusing attenuators and the long delay ones by echo suppressors or echo cancellers. CCITT recommends use of the echo cancellers if round rip delay exceeds 50 ms. For delay up to 50 ms simple attenuators in the transmission path limit the loudness of echo to a tolerable level. The attenuation increases as the delay increases.

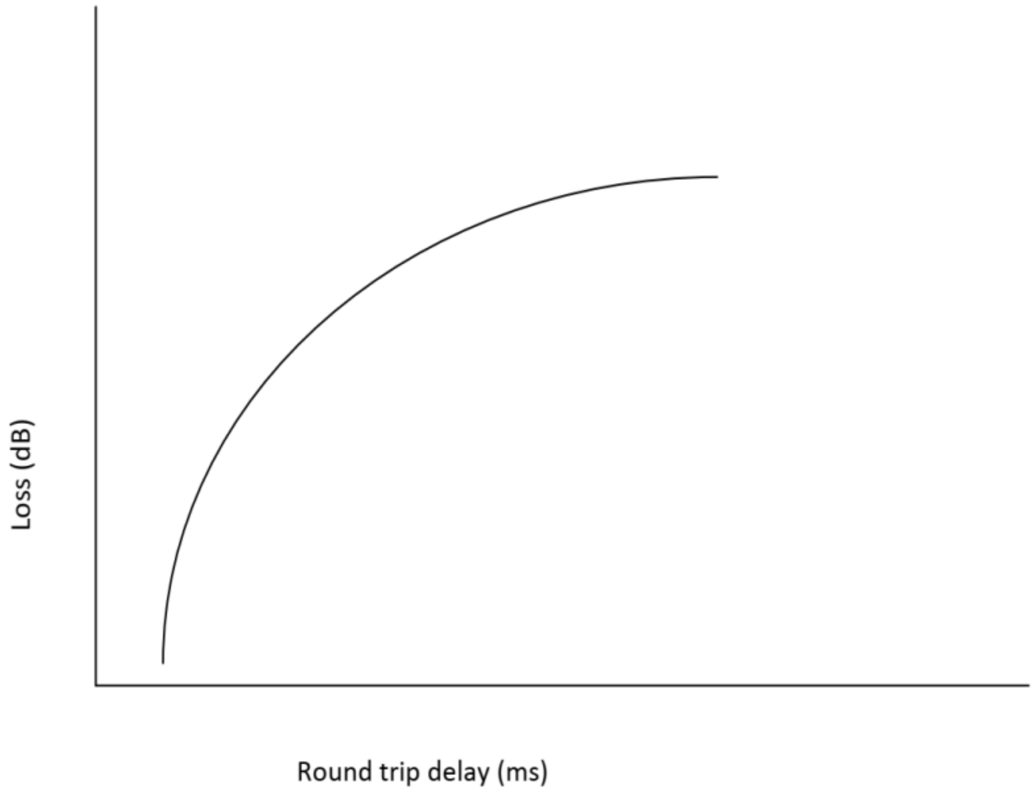


Fig.32: Transmission systems

Long distance transmission system can be placed into 3 categories:
(1) Radio systems
(2) Coaxial cable system
(3) Optical fiber system

- A radio communication system sends signals by radio. Types of radio communication systems deployed depend on technology, standards, regulations, radio spectrum allocation, user requirements, service positioning, and investment.
- The radio equipment involved in communication systems includes a transmitter and a receiver, each having an antenna and appropriate terminal equipment such as a

microphone at the transmitter and a loudspeaker at the receiver in the case of a voice-communication system.

- The power consumed in a transmitting station varies depending on the distance of communication and the transmission conditions. The power received at the receiving station is usually only a tiny fraction of the transmitter's output, since communication depends on receiving the information, not the energy that was transmitted.

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