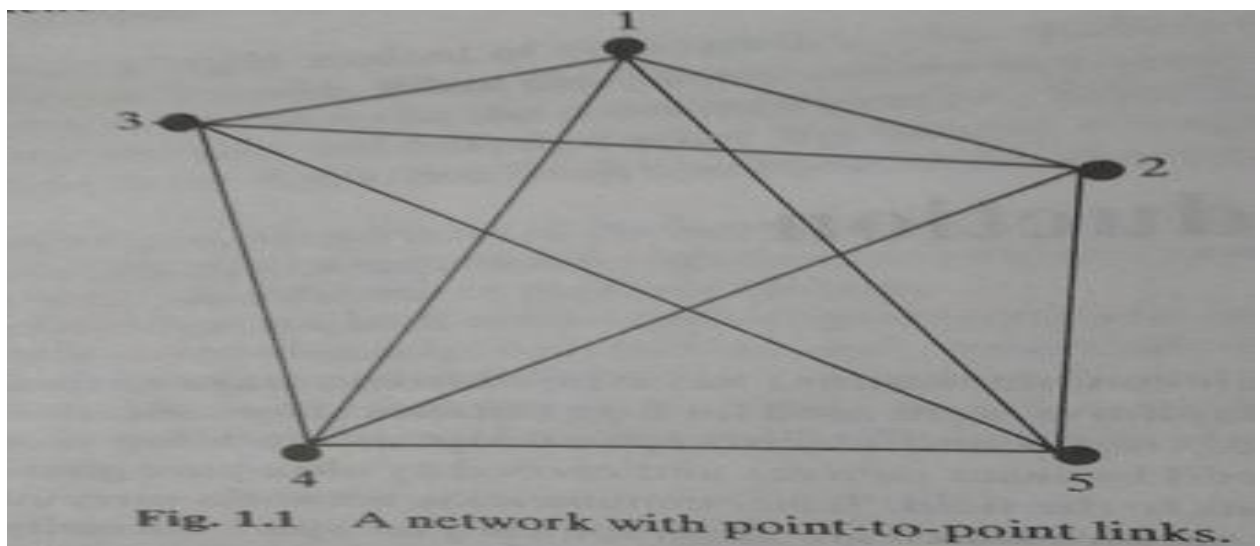


UNIT-I

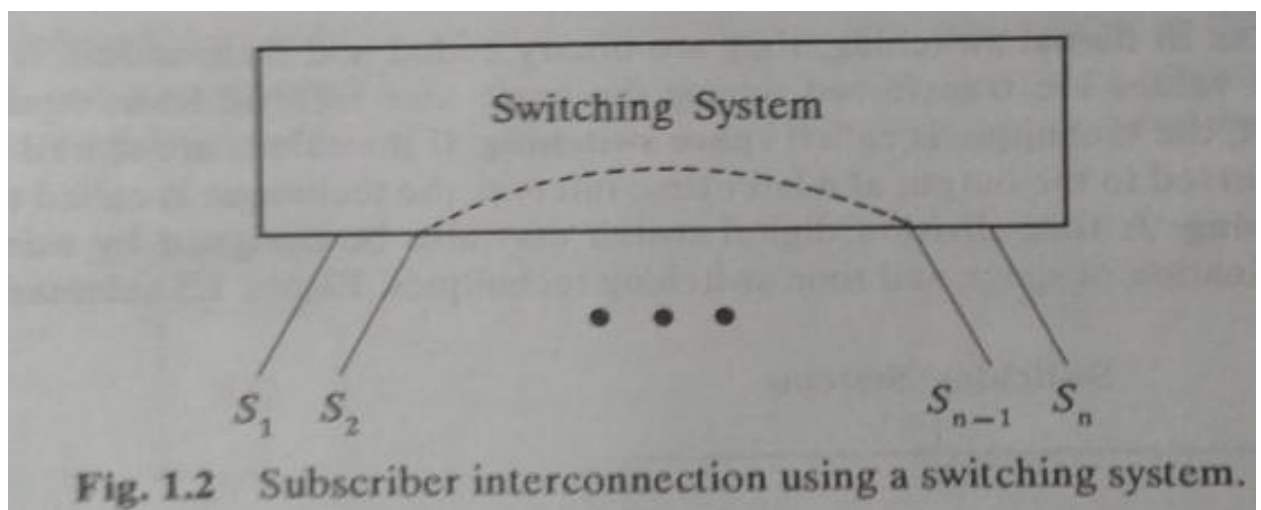
1.1.Evolution of Telecommunications

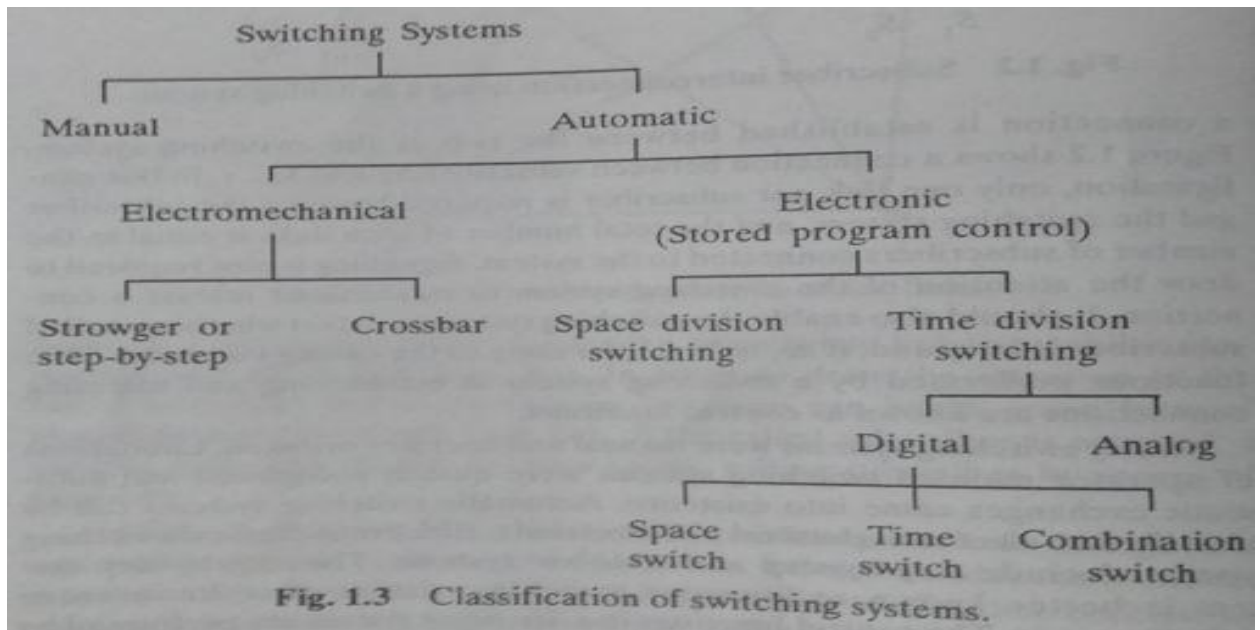
- Telecommunications is the transmission of signs, signals, messages, words, writings, images and sounds or information of any nature by wire, radio, optical or other electromagnetic system.
- Historically, transmission of telegraphic signals over wires was the first technological development in the field of modern telecommunications.
- Telegraph was introduced in 1837 in Great Britain and in 1845 in France.
- In march 1876, Alexander Graham Bell demonstrated his telephone set and the possibility of telephony, i.e long distance voice transmission.
- Graham Bell demonstrated a point to point telephone connection. A network using point to point connections is shown in below figure



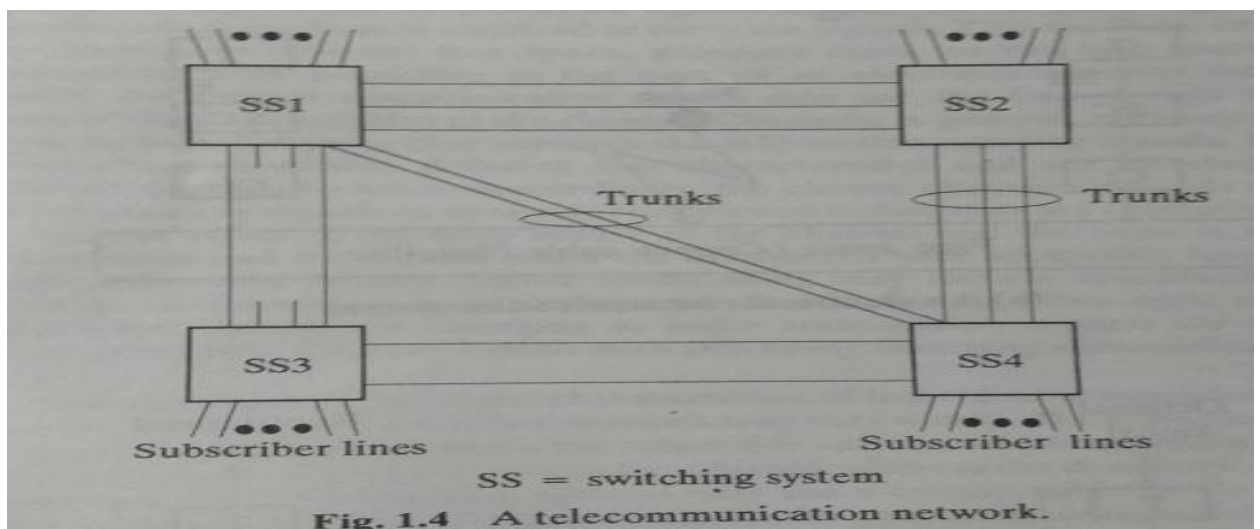
- In such network, a calling subscriber chooses the appropriate link to establish connection with the called subscriber.
- In order to draw the attention of the called subscriber before information exchange can begin some form of signaling is required with each link.
- If the called subscriber is engaged a suitable indication should be given to the calling subscriber by means of signaling.

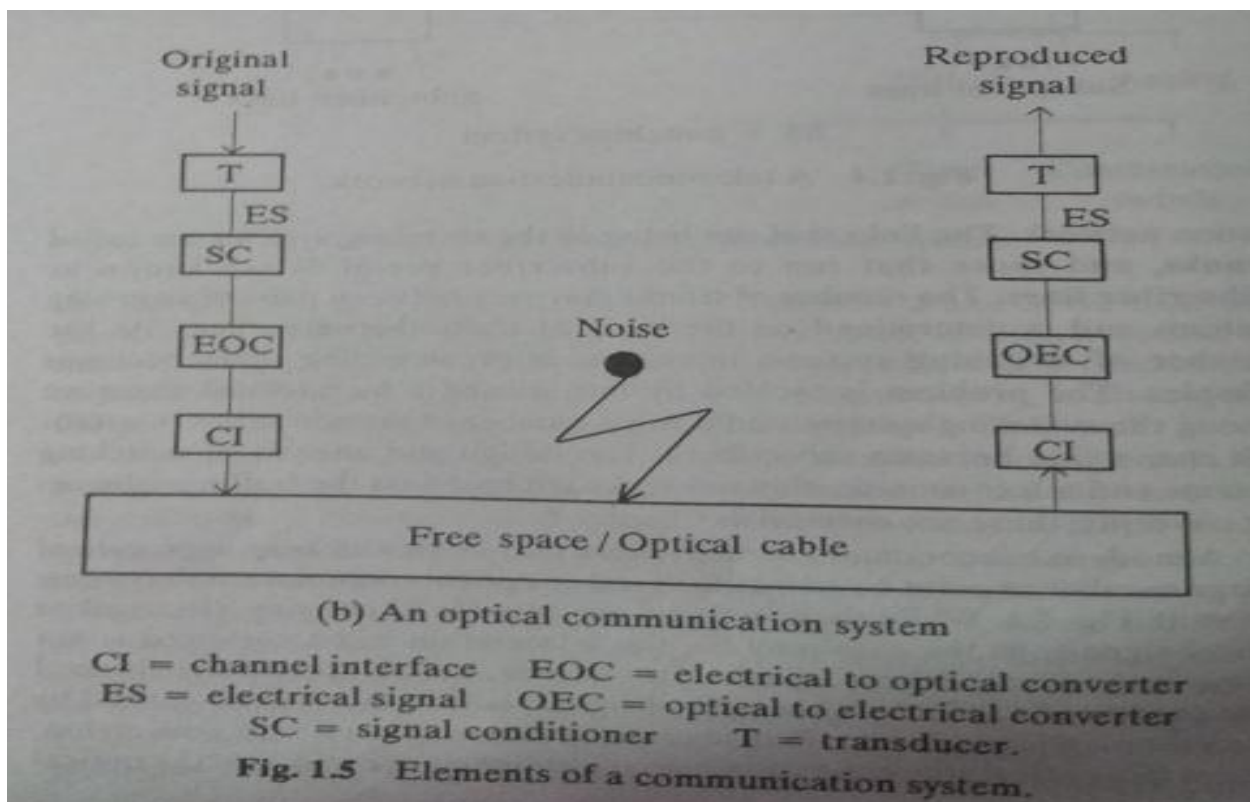
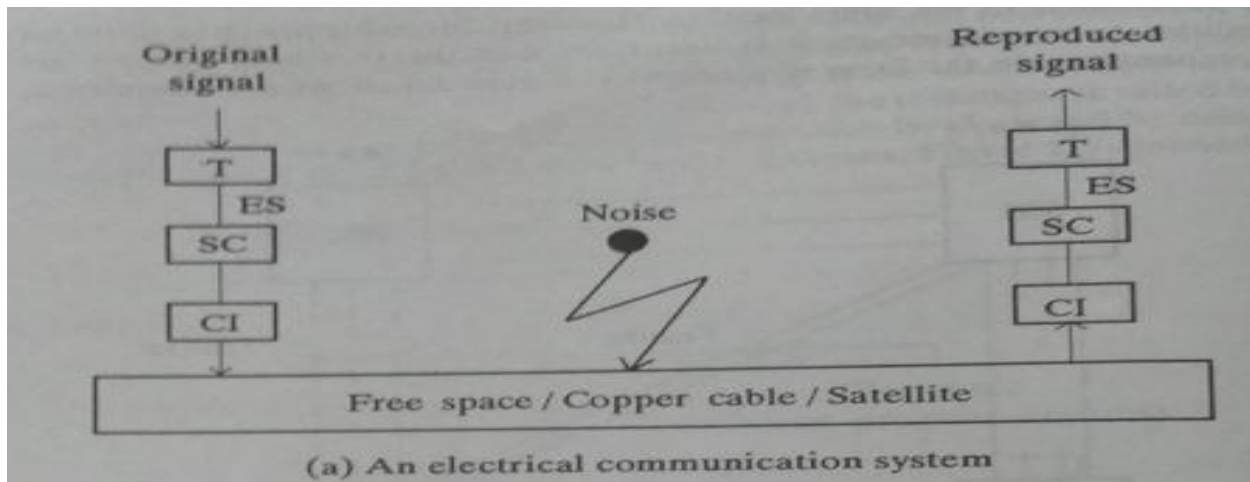
- In above figure there are five entities and 10 point to point links. In general case with 'n' entities, there are $n(n-1)/2$ links.
- $L=(n-1)+(n-2)+\text{-----}+1+0= n(n-1)/2$
- Networks with point to point links among all the entities are known as fully connected networks.
- The number of links required in a fully connected network becomes very large even with moderate values of n.
- For example we require 1225 links for fully interconnecting 50 subscribers.
- Hence, a system of switching the networks is needed in-between these subscribers. Alexander Graham Bell recommended the Switching between the subscribers using a switching office that maintains the telephone connections.
- This network connection cannot be simply made with telephone sets and bunch of wires, but a good system is required to make or break a connection. This system is known as the Switching System or the Switching Office or the Exchange..
- With the introduction of the switching systems, the subscribers are not connected directly to one another instead they are connected to the switching systems as shown in below figure.
- When a subscriber wants to communicate with another a connection is established between the two at the switching system. The below figure shows a connection between subscriber S2 and Sn-1.
- The functions performed by a switching in establishing and releasing connections are known as control functions.





- Subscribers all over the world cannot be connected to a single switching system unless we have a gigantic switching system in the sky and every subscriber has a direct access to the same.
- Subscribers in different localities to communicate, it is necessary that the switching systems are interconnected in the form of a network.
- Below figure shows telecommunication network. The links that run between the switching systems are called trunks, and those that run to the subscriber premises are known as subscriber lines.
- The number of trunks may vary between pairs of switching systems and is determined on the basis of traffic between them.



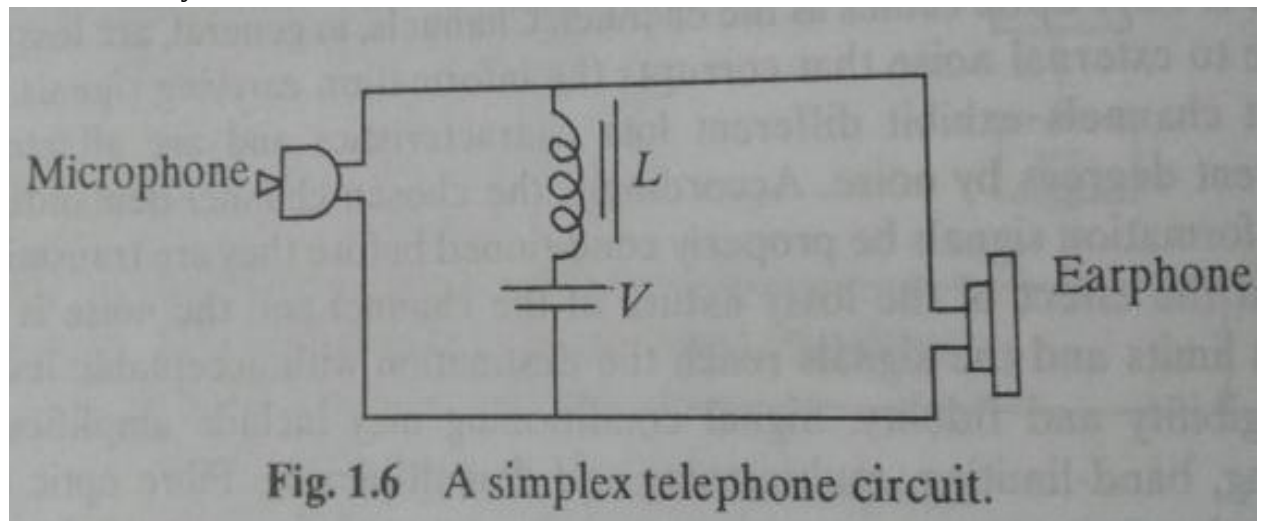


- A modern telecommunication network may be viewed as an aggregate of a large number of point to point electrical or optical signals, as the case may be the information to be conveyed is not always in the form of these signals.
- For example human speech signals need to be converted to electrical or optical signals before they can be carried by a communication system. Transducer perform these energy conversion.

- Present day optical sources require electrical signals as input and the optical detectors produce electrical signals as output.
- Hence the original signals are first converted to electrical signals and then to optical signals at the transmitting end of an optical communication system and at the receiving end optical signal are converted to electrical signals before original signal is reproduced.

1.2 Simple Telephone Communication

- In the simplest form of a telephone circuit there is a one way communication involving two entities, one receiving (listening), and the other transmitting (talking).
- This form of one way communication shown in below figure is known as **simplex communication**. ex: Radio
- The microphone and the earphone are the transducer elements of the telephone communication system.



- Microphone converts speech signals into electrical signals and the earphone converts electrical signals into audio signals.
- Most commonly used microphone is a carbon microphone. In carbon microphone certain quantity of small carbon granules is placed in a box.
- carbon granules conduct electricity and the resistance offered by them is dependent upon the density with which they are packed.
- When sound waves impinge on the diaphragm, it vibrates causing the carbon granules to compress or expand thus changing the resistivity offered by the granules
- When the sound waves impinge on the diaphragm, the instantaneous resistance of the microphone is given by

$$r_i = r_0 - r \sin \omega t \quad (1.2)$$

where

r_0 = quiescent resistance of the microphone when there is no speech signal

r = maximum variation in resistance offered by the carbon granules, $r < r_0$

r_i = instantaneous resistance.

- The negative sign in above equation indicates that when the carbon granules are compressed the resistance decreases and vice versa.
- In the above figure without loss of generality the instantaneous current in the microphone is given by

$$i = V/(r_0 - r \sin \omega t) = I_0(1 - m \sin \omega t)^{-1} \quad (1.3)$$

where

$I_0 = V/r_0$ = quiescent current in the microphone

$m = r/r_0$, $m < 1$

By binomial theorem, Eq. (1.3) may be expanded as

$$i = I_0(1 + m \sin \omega t + m^2 \sin^2 \omega t + \dots) \quad (1.4)$$

If the value of m is sufficiently small, which is usually the case in practice, higher-order terms can be ignored in Eq. (1.4), giving thereby

$$i = I_0(1 + m \sin \omega t) \quad (1.5)$$

- The earphone is usually an electromagnet with a magnetic diaphragm which is positioned such that there is an air gap between it and the poles of the electromagnet.
- When the electromagnet is energized by passing a current, a force is exerted on the diaphragm.
- The instantaneous flux linking the poles of the electromagnet and the diaphragm is given by.

$$\phi_i = \phi_0 + \phi \sin \omega t$$

where

ϕ_0 = constant flux due to the quiescent current or the permanent magnet

ϕ = maximum amplitude of flux variation, $\phi < \phi_0$

ϕ_i = instantaneous flux

Equation (1.6) assumes that the vibrations of the diaphragm are too small to affect the length of the air gap and that the reluctance of the magnetic path is constant. The instantaneous force exerted on the diaphragm is proportional to the square of the instantaneous flux linking the path. Therefore,

$$F = K(\phi_0 + \phi \sin \omega t)^2 \quad (1.7)$$

where K is the constant of proportionality. Expanding the right-hand side of Eq. (1.7), we have

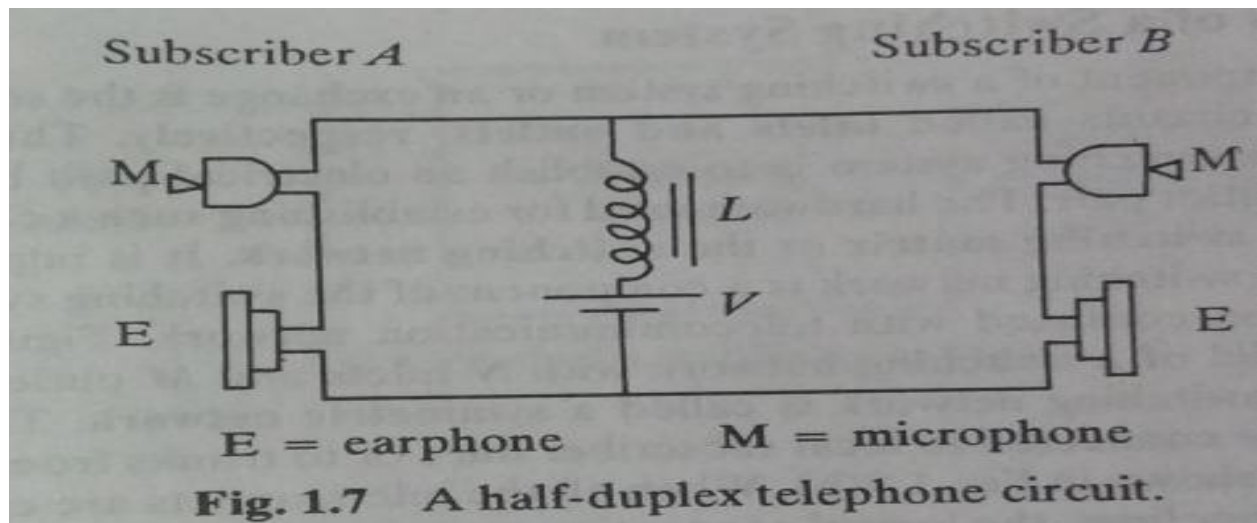
$$F = K(\phi_0^2 + \phi^2 \sin^2 \omega t + 2\phi_0\phi \sin \omega t) \quad (1.8)$$

When $(\phi / \phi_0) \ll 1$, we can ignore the second-order term in Eq.(1.8). We then have

$$F = K\phi_0^2(1 + K_1 I_0 \sin \omega t) \quad (1.9)$$

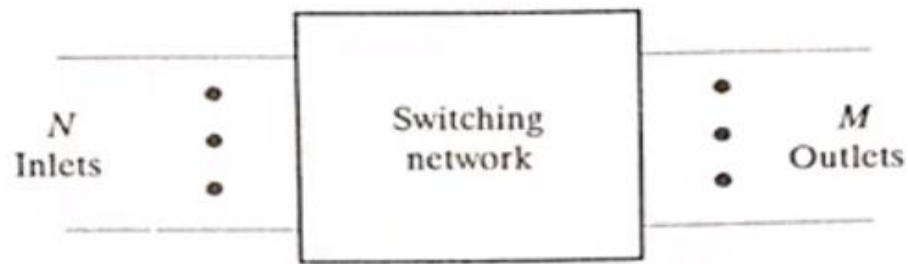
where $I_0 \sin \omega t$ is the current flowing through the coil. We thus see that the force experienced by the diaphragm is in accordance with the signals produced by the microphone.

- In normal telephone communication system, information is transferred both ways. An entity is either receiving or sending at any instant of time. When one entity is transmitting, the other is receiving and vice versa.
- Such a form of communication where the information transfer takes place both ways but not simultaneously is known as **half duplex communication**. ex: walkie Talkie
- If the information transfer takes place in both directions simultaneously then it is called **full duplex communication**. ex: Telephone
- The below figure shows half duplex communication.

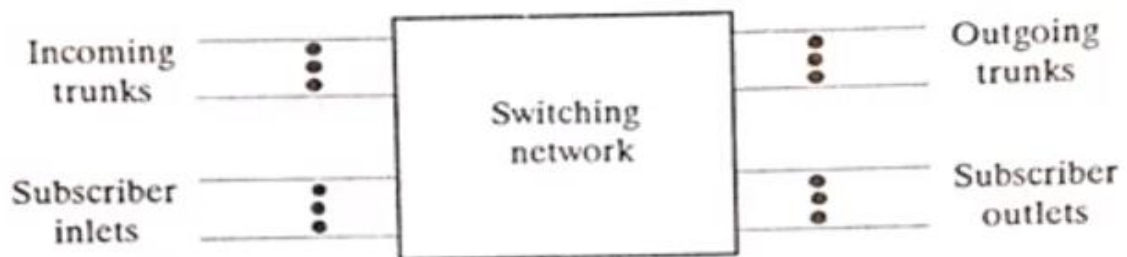


1.3 Basics of Switching System

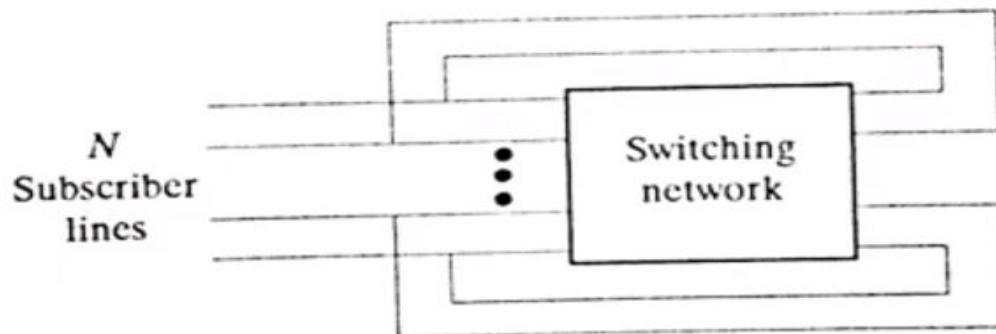
- ❑ Major components of the switching system or an exchange is the set of input and output circuits called **inlets** and **outlets**.
- ❑ Primary function of the switching system is to establish an electrical path between a given inlet-outlet pair.
- ❑ The hardware used for establishing such a connection is called the Switching Matrix or the Switching Network.
- ❑ Figure shows a model of switching network with **N inlets** and **M outlets**. When $N = M$ the switching network is called a Symmetric Network.
- ❑ The inlets/outlets may be connected to local subscriber lines or to trunks from/to other exchanges as shown in fig (b)
- ❑ When all the inlets /outlets are connected to the subscriber lines, the logical connection appears as shown in (c).



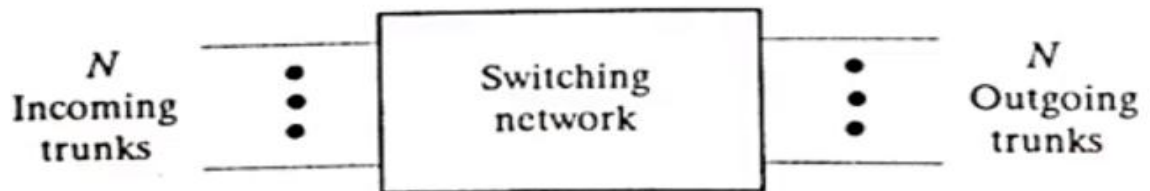
(a) Model of a switching network



(b) Inlets/outlets connections



(c) Folded network



(d) Nonfolded network

In this case the output lines are folded back to the input and hence the network is called a **Folded Network**.

In Fig (b) Four types of connections may be established:

1. Local call connection between two subscribers in the system
2. Outgoing call connection between a subscriber and an outgoing trunk.
3. Incoming call connection between an incoming trunk and a local subscriber
4. Transit call connection between an incoming trunk and an outgoing trunk.

In folded network with N subscribers, there can be a maximum of $N/2$ simultaneous calls or information interchanges. Switching network may be designed to provide $N/2$ simultaneous switching paths, Network is said to be **Non-blocking**.

In Non-Blocking network , as long as a called subscriber is free, a calling subscriber will always be able to establish a connection to the called subscriber. In other words , a subscriber will not be denied a connection for want of switching resources.

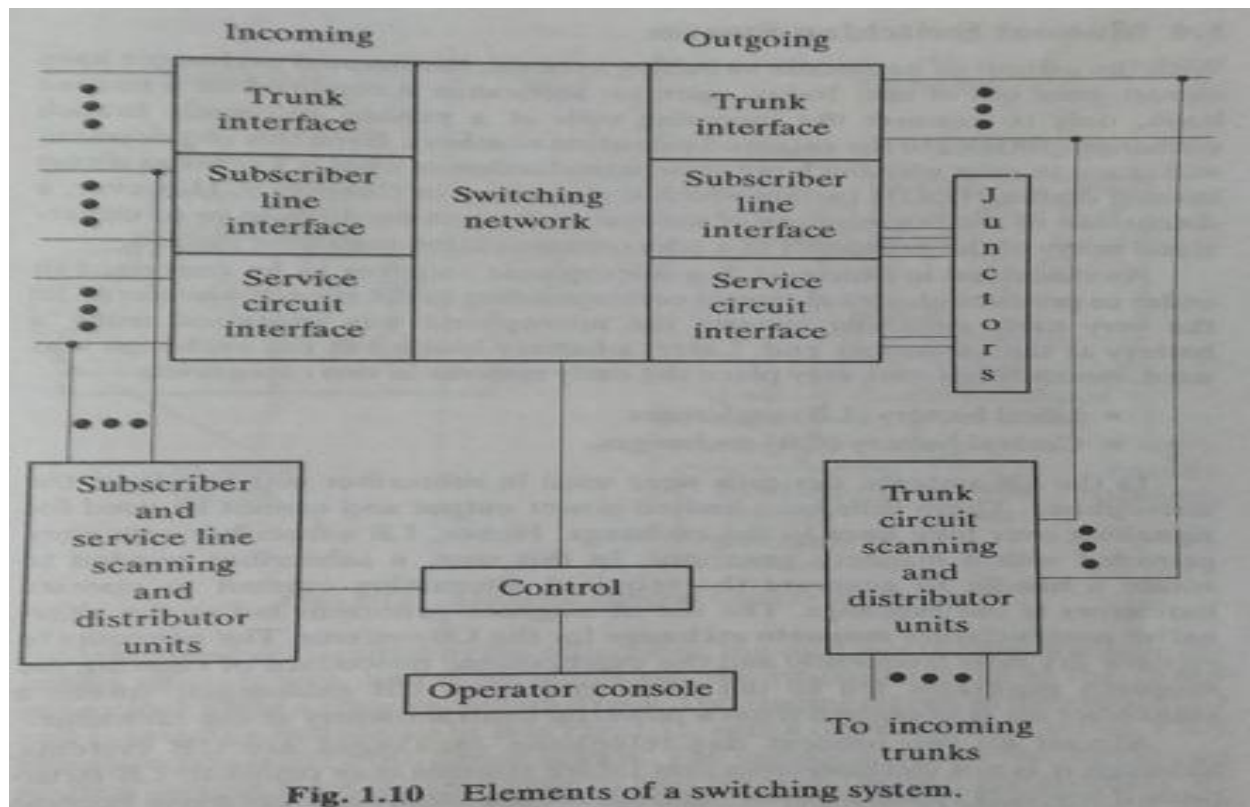
On the other hand when a subscriber requests a connection, there are no switching paths free in the network, and hence he is denied connection. In such an event , the subscriber is said to be blocked and switching network is called a **Blocking Network**.

- In a blocking network, the number of simultaneous switching paths is less than the maximum number of simultaneous conversations that can take place.
- The probability that a user may get blocked is called **blocking probability**.
- All the switching exchanges are designed to meet an estimated maximum average simultaneous traffic, usually known as **busy hour traffic**.

- The traffic in a telecommunication network is measured by an internationally accepted unit of traffic intensity known as **Erlang (E)**. One erlang is the equivalent of one call (including call attempts and holding time) in a specific channel for 3600 seconds in an hour

Elements of Switching System

- ☐ The subscriber lines are terminated at the subscriber line interface circuits, and trunks at the trunk interface circuits.
- ☐ There are some service lines used for maintenance and testing purposes.
- ☐ Junctor circuits imply a folded connection for the local subscribers and the service circuits.
- ☐ Line scanning units sense and obtain signalling information from the respective lines.
- ☐ Distributor units send out signalling information on the respective lines.
- ☐ Operator console permits interaction with the switching system for maintenance and administrative purposes.
- ☐ **Direct Control Switching Systems(DCSS)**: Control subsystem may be an integral part of switching N/W
- ☐ **Common Control Switching Systems(CCSS)**: Control subsystem is outside the switching N/W.
- ☐ Strowger Exchanges are DCSS
- ☐ Crossbar Exchanges are CCSS



1.4. Manual Switching System

Manual Switching System

With the advent of the automatic switching systems, the manual exchanges have almost gone out of use. Today operator assistance is required on a routine basis, only to connect the incoming calls at a **Private Automatic Branch Exchange(PABX)** to the required extension numbers.

Earlier microphone requires to be energized in order to produce electrical signals corresponding to the speech waveform. In the very early switching systems the microphone was energized using a battery at the subscriber end. Later a battery located at the exchange was used

So early systems were categorized as:

(1)Local battery(LB) exchanges

In LB systems , dry cells were used in subscriber sets to power the microphones. These cells have limited power output and cannot be used for signaling over long lines to the exchange

(2)Central battery(CB) exchanges : Have Powerful central battery(Magneto generators are used to produce Alternating Current)

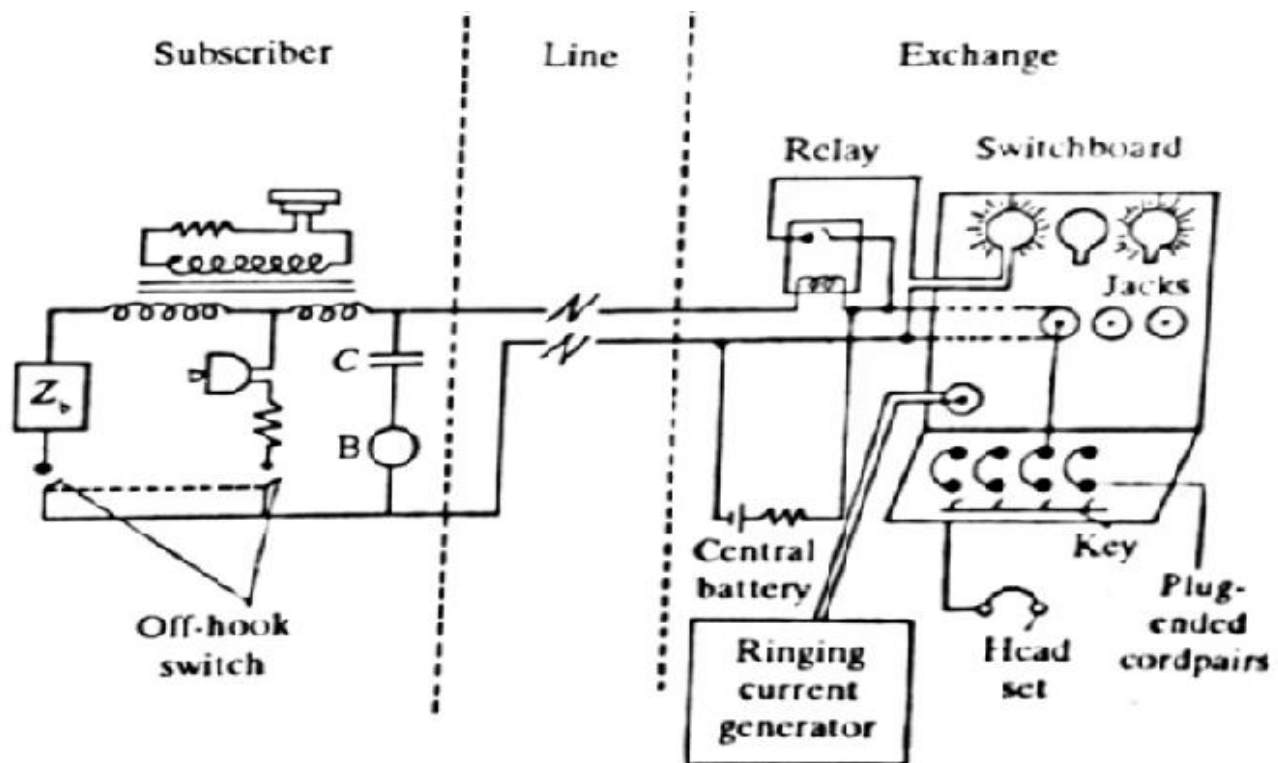


Fig: Manned Central Battery Exchange

- ❑ Almost all the present day telephone exchanges are CB systems. The system consists of one or more switchboards manned by operators.
- ❑ The subscriber lines are terminated on Jacks mounted on the switchboard.
- ❑ There is one jack for every subscriber line.
- ❑ Associated with each jack is a light indicator to draw the attention of the operator.
- ❑ When a subscriber lifts the handset, the off-hook switch is closed, causing a current to flow through the handset and the lamp relay coil.

- Lamp relay operates and the indicator corresponding to the subscriber lights up. The operator establish contact with the subscriber by connecting the head set to the subscriber line via the headset key and plug ended cord pair.
- Plug ended cord pair has two cords that are connected internally and terminated with a plug each at the external ends.
- **B** is the ringing circuits at the subscriber end.
- Capacitor **C** allows the Alternating ringing current from the exchange to pass through the bell but prevents the loop direct current.
- When called party is busy , the calling subscriber is told about the same.
- When the called party answers , his indicator lamp lights up. The operator then establishes a connection between the calling and the called party.

Types of Switch Boards

When the number of the subscriber increases, multiple switchboards and operators are required to handle the traffic. The subscriber switchboards at the exchange are of two types:

(1)Single termination switchboards

(2)Multitermination switchboards

In the single termination scheme, a subscriber is terminated on only one board, whereas in the multitermination scheme , he is terminated on more than one switchboard.

In single termination boards, subscriber are split into groups and connected to the different switchboards. Each switchboard is handled by a separate operator. When a subscriber wishes to call another in the same group, the operator concerned establishes the call. Transfer lines are provided to connect two switchboards.

In multitermination boards every subscriber is terminated on all the switchboard. Such a arrangement has the advantage that a single operator can establish a call between any two subscribers connected to the system.

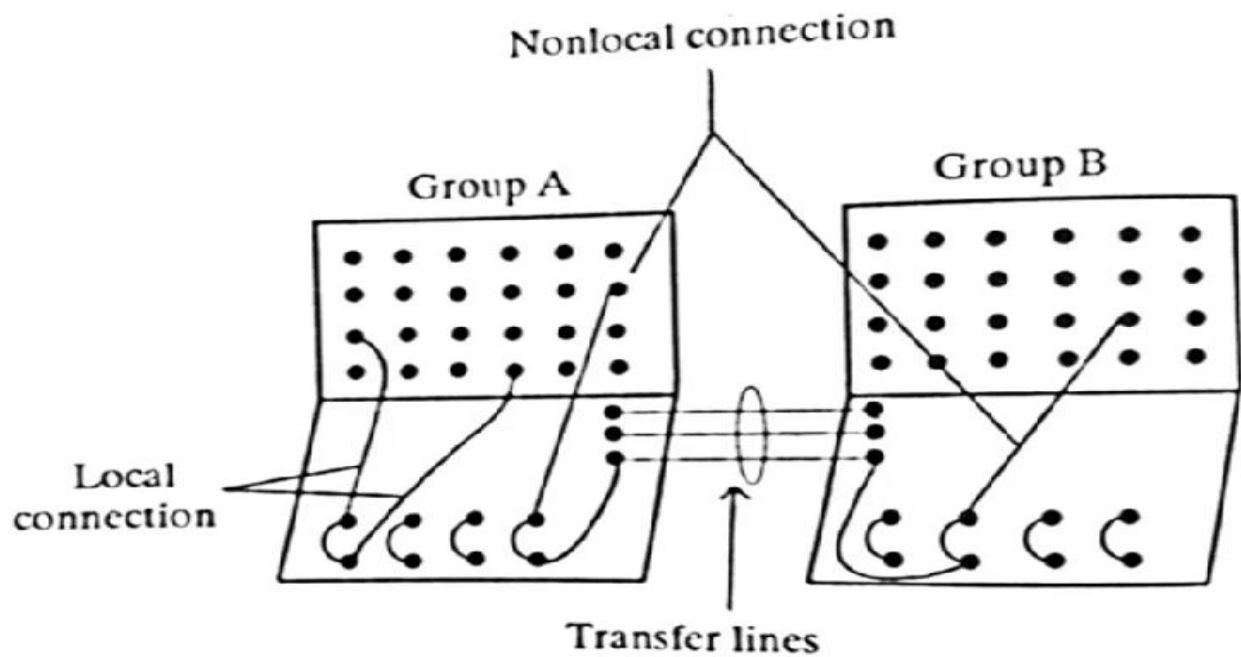


Fig : Single Termination Switch Board

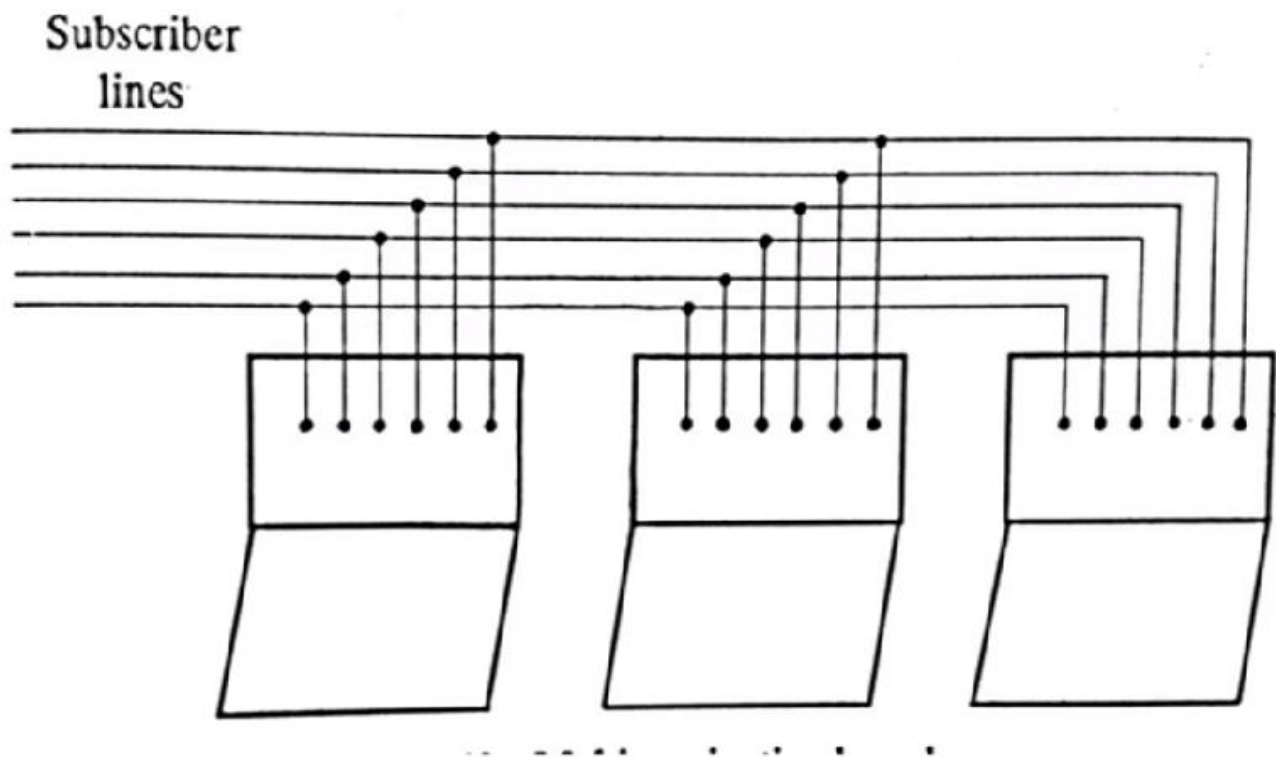


Fig: Multitermination Switch Board

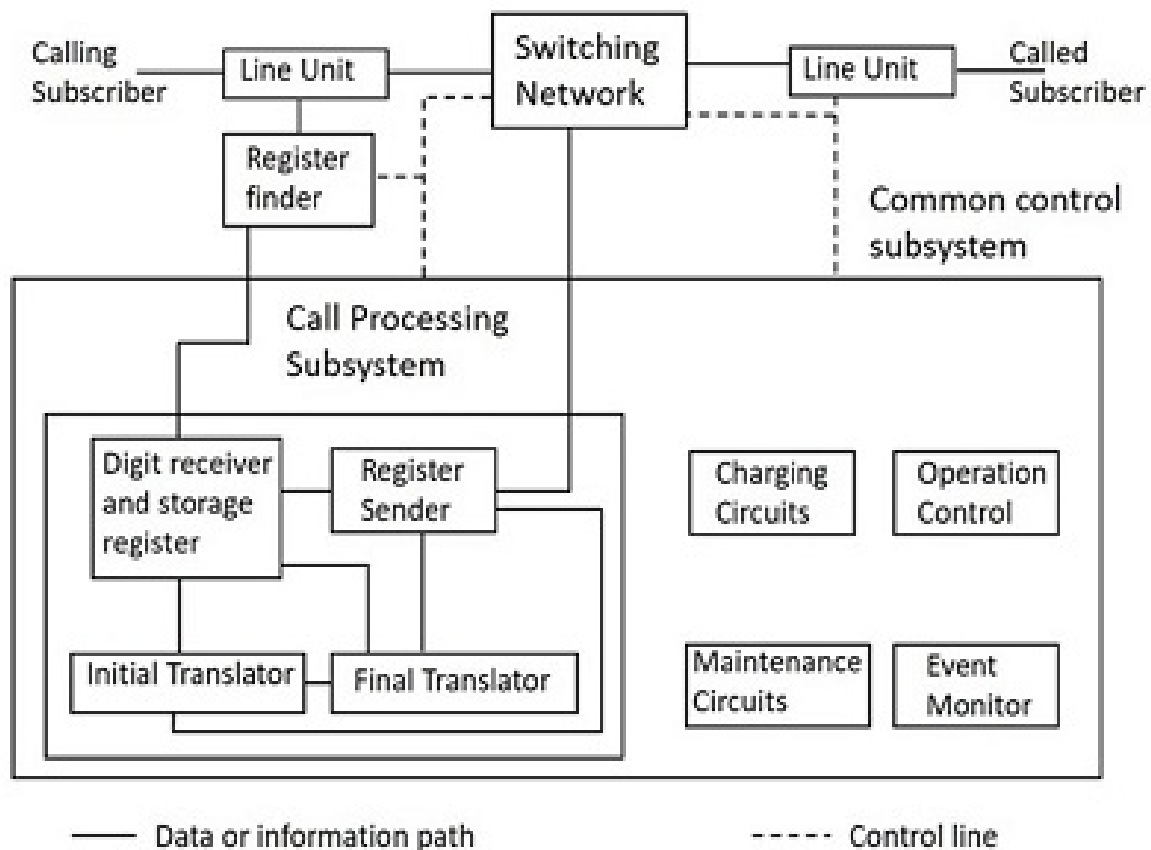
1.5. PRINCIPLES OF COMMON CONTROL

- In order to establish calls between different exchanges, which may further lead to a long distance trunk call, the Crossbar switching system was developed and the first patent was given in 1915. However, AT&T developed the first Crossbar switching system in 1938. The Crossbar switching system introduced the Common Control Subsystem in its switching system.
- In order to avoid the complication and to make it easier for a subscriber to place a call, two main ideas were implemented by the Common Control Sub system. The ideas are listed below –

1. The routing of the call should be done by the exchange, but not by the numbers dialed.

2. A Unique Identification Number should be allotted to the subscriber. The UIN contains the number of the exchange of the subscriber and the number indicating the line of the subscriber.

- **Exchange Identifier + Subscriber Line Identifier**
- This is a combination of STD (Subscriber Trunk Dialing) code and the subscriber's number; consider this as the physical line address. Every user is assigned a logical number irrespective of the physical line number.
- An Address translation mechanism translates the logical address to actual physical address for connection establishment. The call processing takes place independent of the switching network.
- A Director system is employed in the common control sub system. As soon as the translated digits are transmitted, the Director is free to process another call and is not involved in maintaining the circuit for the conversation.
- The following figure shows the diagram of the Common Control Switching system, which contains Call Processing Sub system, Charging Circuits, Operation Control, Maintenance Control and Event Monitor.



- The above block diagram is a simple indication of the common control switching system. The control functions in a switching system can be categorized as the following.

Event Monitoring

- Event Monitoring Section of the Control Subsystem monitors the events occurring outside the exchange at the line units, trunk junctures and inter exchange signaling and sender/receiver units.

Call Processing

- The Call Processing units contain digit receiver and storage register, which receive and store the dialing number from the calling party. The units also contain the initial and final translators.
- The Initial translator is the Office Code translator that determines the route for the call through the network or charging method or rate.
- The Final translator is the Subscriber Code translator which determines the line unit to which a call must be connected and category of the called line.

- The Register Sender transfers the route digit and dialed digit using proper signaling, depending on the requirements of the destination exchange.

Charging

- This is related to the charges levied on the calls made. It depends upon the type of subscriber and the service of the subscriber.

Operation and Maintenance

- The control and operation of the switching network with two main techniques known as Map-in-memory and Map-in-network.

Map-in-Memory

- The path in this technique is determined by marking the switching elements at different stages in accordance with a set of binary data defining the path, whereas the control unit supplies the data.
- At this stage, the command for the actual connection of the path is given. This Map-in-memory technique is present in Stored Program Control.

Map-in-Network

- In this technique, the Path finding may be carried out at the level of common control unit, where it marks the inlet and outlet to be connected and the actual path is determined by the switching network. This Map-in-Network technique is common in Crossbar exchanges using markers for control.

1.6. TOUCH TONE DIAL TELEPHONE

Need for Touch-Tone

- In rotary dial telephone, it takes about 12 seconds to dial a 7 digit number, from the subscriber point of view, a faster dialing rate is desirable.
- The step by step switching elements of strowger systems cannot respond to rates higher than 10-12 pulses per second.
- With the introduction of common control in crossbar system, a higher dialing rate is feasible
- Hence, a new system called the **Touch-tone dialing** was developed in Telephony to replace the Rotary dial; this was considered to benefit the customer with higher speed. This has also removed the disadvantages of limited usage and limited signaling capacity along with lower speed.

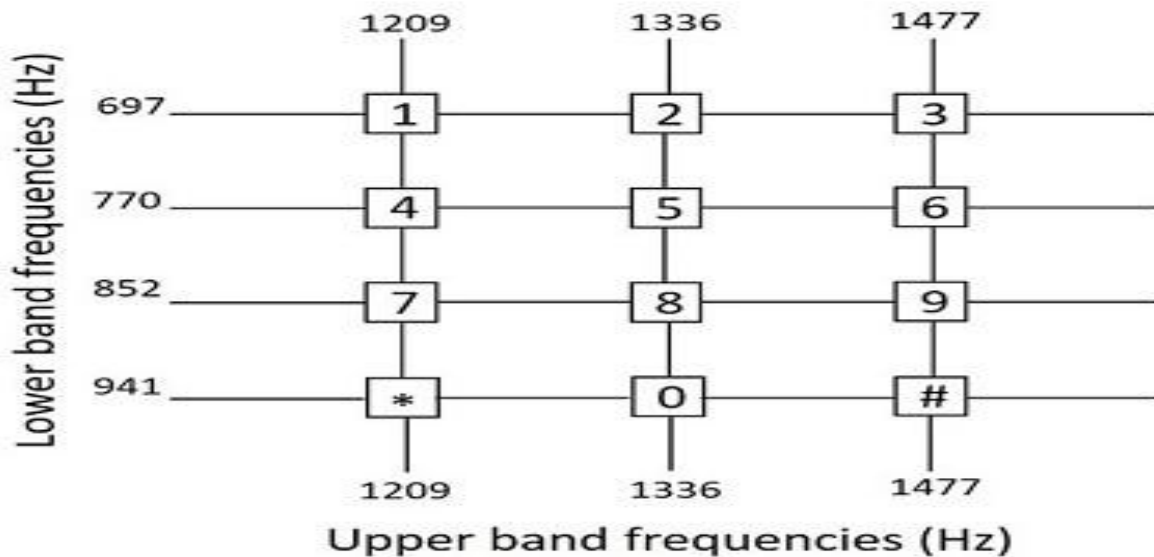
- The Pulse dialing is limited to signaling between the exchange and the subscriber, but not between two subscribers, which is called End-to-End signaling.
- **End-to-End signaling** is a desirable feature and is possible only if the signaling is in voice frequency band so that the signaling information can be transmitted to any point in the telephone network to which voice can be transmitted.



- The above figure shows a practical touch-tone dial telephone
- The above figure will help you understand that the rotary dial is replaced with a push button keyboard, where the buttons, if touched to “press” the button will generate frequencies related to the number dialed.
- The hassle-free rotation was replaced and a feature to redial the number was added to this push button keyboard, where the dialed number is stored until another number is dialed. This eased the process of redialing a 7- digit number all over again.

Touch-tone Dial Telephone Operation:

- The press of a button on the touch-tone dial telephone indicates the number dialed using certain frequencies. “**Touching**” or light pressing of a number generates a “tone” which is a combination of two frequencies, one from lower band and the other from upper band.
- For example, by pressing the button 9, two frequencies such as 852 Hz the lower frequency and 1477Hz the upper frequency are produced. The design of touch-tone dialing producing two frequencies is as shown below.



- The DTMF (Dual-tone Multi-frequency) dialing can be done through the touch-tone dialing technique as shown above. As two frequencies, one being higher and the other being lower are transmitted at the same time in the touch-tone dialing technique, it is called the Dual-tone Multi Frequency (DTMF) dialing.

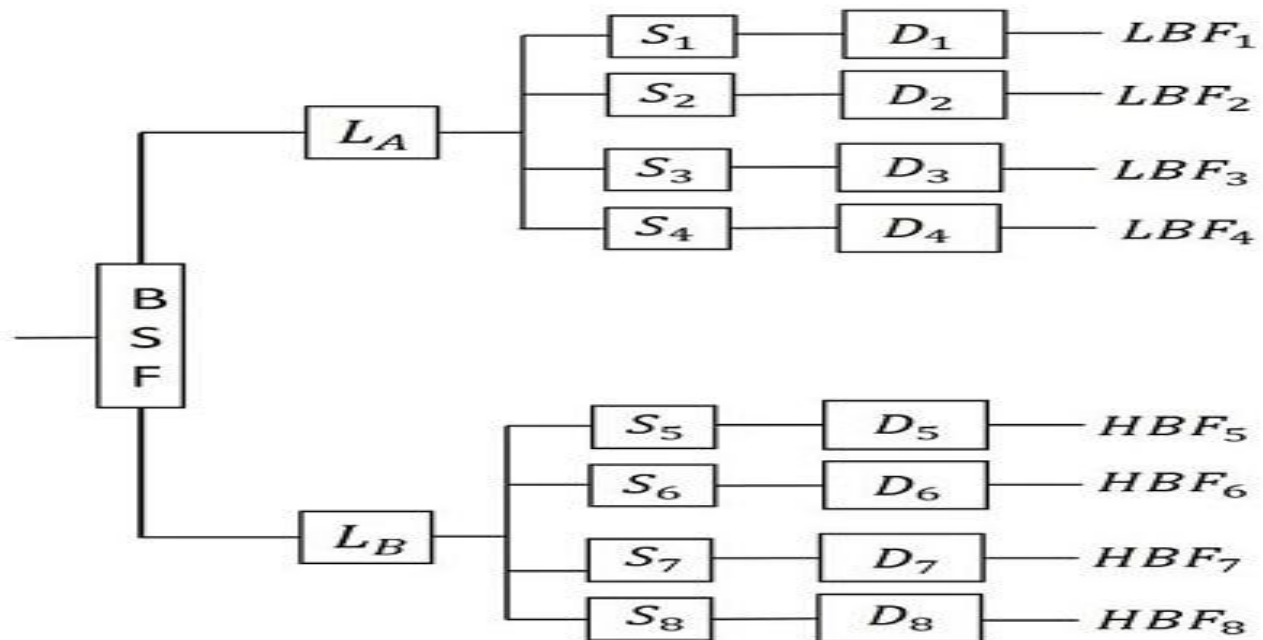
The design considerations are

- ❖ Choice of Code
- ❖ Band Separation
- ❖ Choice of Frequencies
- ❖ Choice of Power Levels
- ❖ Signaling Duration
- The **choice of code** for touch-tone signaling should be such that the imitation of code signals by music and speech must be difficult.
- Consider the following reasons for separating the **band** of two frequencies –
 - ❑ At the receiver, band filtering is used to separate the frequency groups; this helps to determine the specific frequencies in a simple way.
 - ❑ Easy amplitude regulation of each frequency component separately.
 - ❑ Limiters can be used to guard the action of each frequency separately.
 - ❑ The probability of false response is reduced.

- ❑ The attenuation and delay distortion characteristics of the telephone network circuits determine the **choice of frequencies**.
- ❑ A flat amplitude response with a very low attenuation and a uniform delay response with a low relative delay value are desirable. Though the design is high enough for reliability, the **choice of power levels** should be planned according to attenuation characteristics of the channel. The **signal duration** although inefficient is longer and helpful to combat talk-off.

Internal Mechanism

- ❑ The internal mechanism of the touch-tone receiver can be explained by a simple block diagram



- Above block diagram contains Band Separation Filter (BSF), Limiters (L), Selector Circuits (S) and Detectors (D) which give out Low Band Frequency (LBF) signals and High Band Frequency (HBF) signals,
- The Band separation filter present at the receiver is used to separate the frequency groups. This helps to determine the specific frequencies, separately.
- In addition, the filter also regulates the amplitudes of each component. Then the signal reaches the limiter, which has two of the frequencies at its input. It allows the dominant signal through it bypassing the weak signal. If both of the signals have the same strength, the limiter output is much below the full output and neither of the signals dominates.

- The selectors present in the circuitry, are designed to recognize the signal when it falls within the specified narrow pass band and has an amplitude within the range of 2.5dB of full output of the limiter.
- Both of the limiter and selector circuits are efficient in recognizing the difference between the **touch-tone** and the **voice signal**, to avoid talk-off. For further improvement, Band Elimination filters are sometimes used in place of Band Separation filters as they permit a wide spectrum of speech to pass through the filters.
- The high and low band frequency signals reach the output separately through the detector outputs.

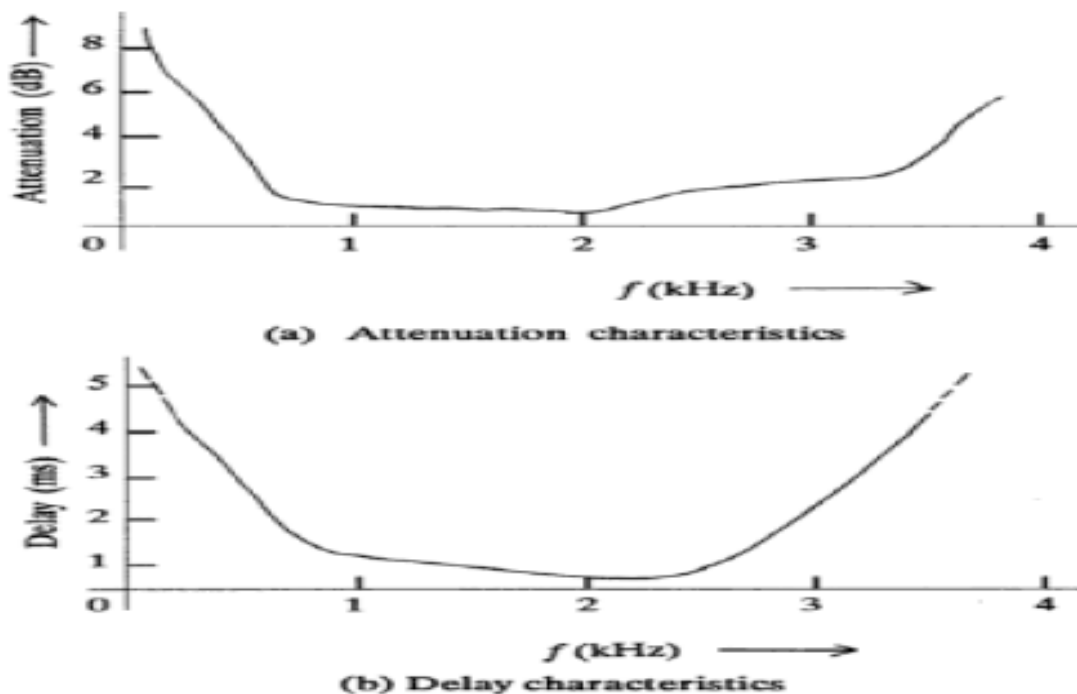
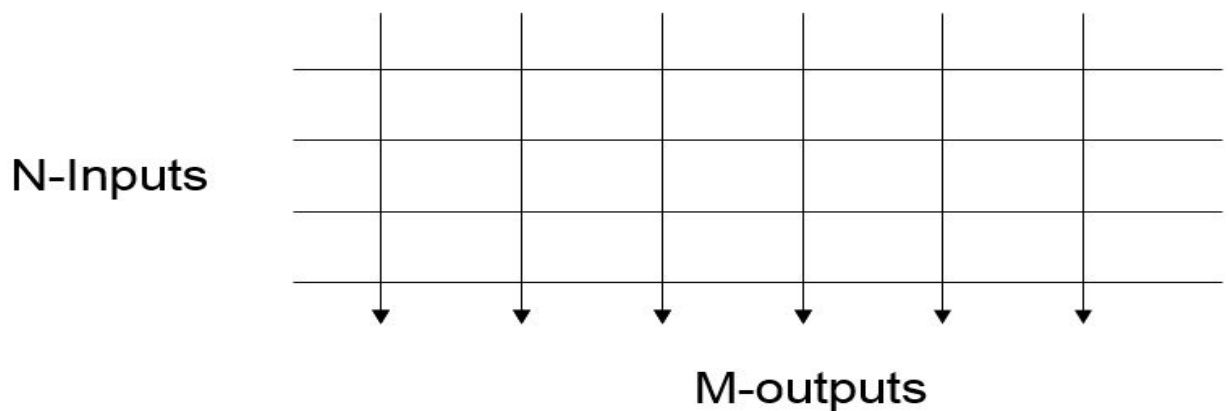


Fig. 3.5 Typical attenuation and delay characteristic of telephone networks.

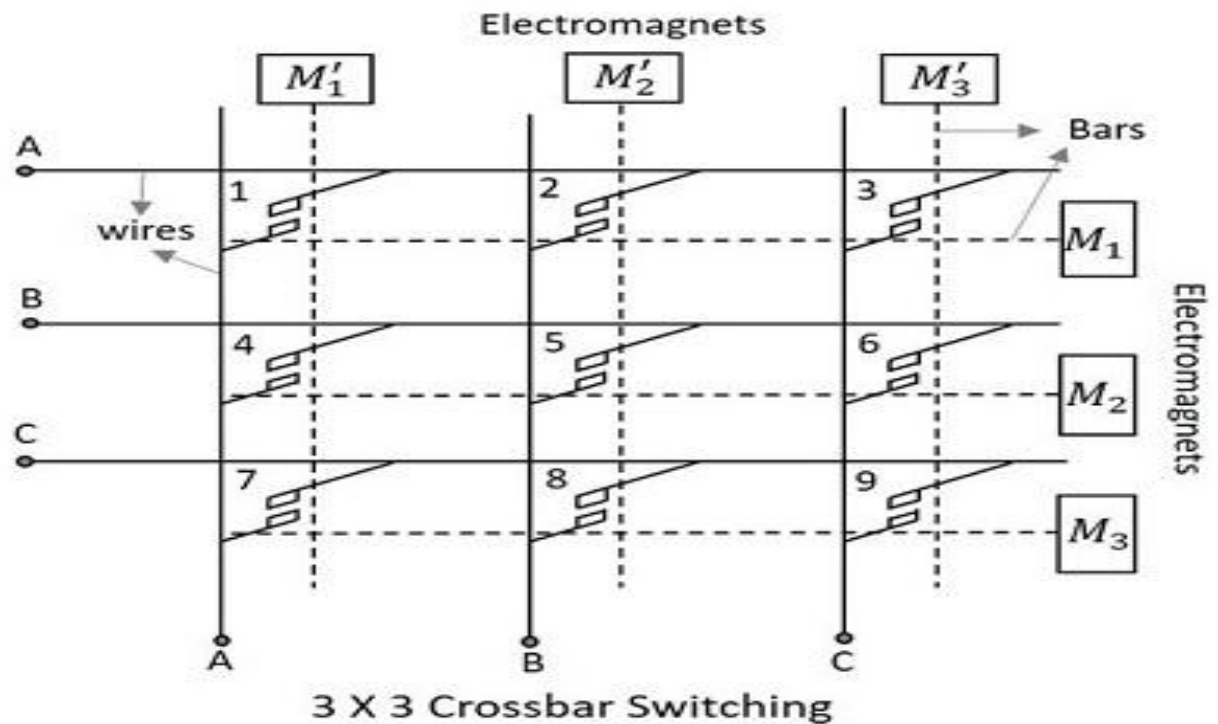
1.7. Principles of Crossbar Switching

- In telecommunications, a crossbar switch is a switch connecting multiple inputs to multiple outputs in a matrix manner.
- The basic idea of crossbar switching is to provide a matrix of $n \times m$ sets of contacts with only $n + m$ activators or less to select one of the $n \times m$ sets of contacts.
- This form of switching is also known as **coordinate switching** as the switching contacts are arranged in a xy-plane.
- The below figure shows the crossbar switching matrix.

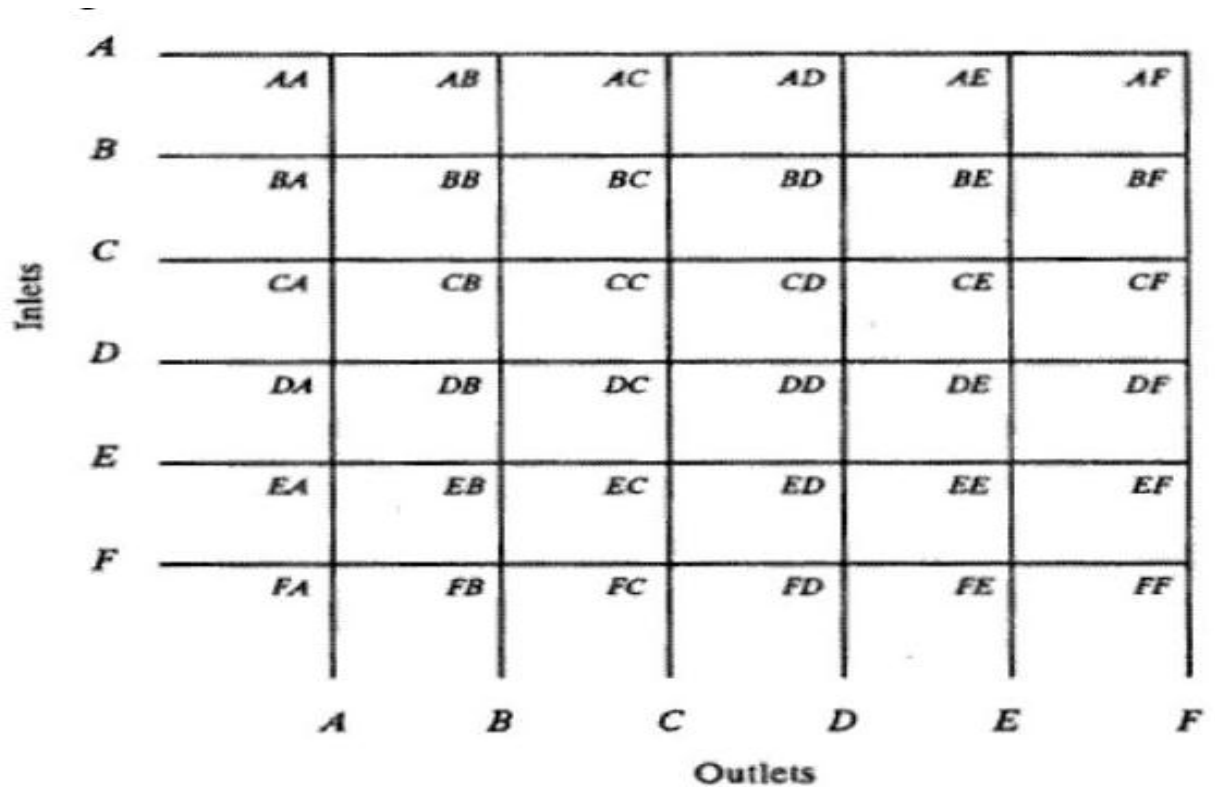
- There is an array of horizontal and vertical wires shown by solid lines. A set of vertical and horizontal contact points are connected to these wires.
- The contact points form pairs, each pair consisting of a bank of three or four horizontal and corresponding bank of vertical contact points.
- A contact point pair acts as a cross point switch and remains separated or open when not in use.
- The contact points are mechanically mounted on a set of horizontal and vertical bars shown as dotted lines. The bars, in turn are attached to a set of electromagnets.



- **Figure 1.** Cross-bar switch as an nxm matrix



- In order to understand the working of the crossbar switching, let us consider a 6x6 crossbar schematic shown in below figure



- The above schematic shows six subscribers with the horizontal bars representing the inlets and the vertical bars representing the outlets.
- Now consider the establishment of the following connections in sequence: A to C and B to E.
- First horizontal bar A is energised. Then the vertical bar C is energised.
- The crosspoint AC is latched and the conversation between A and C can now proceed.
- Suppose we now energise the horizontal bar of B to establish the connection B-E, the crosspoint BC may latch and B will be brought into the circuit of A-C.
- This is prevented by introducing an energising sequence for latching the cross points.
- A crosspoint latches only if the horizontal bar is energised first and then the vertical bar (the sequence may well be that the vertical bar is energised first and then the horizontal bar).
- Hence the cross point BC will not latch even though the vertical bar C is energised as the proper sequence is not maintained

- In order to establish the connection B-E, the vertical bar E needs to be energised after the horizontal bar is energised
- In this case , the cross point AE may latch as the horizontal bar A has already been energised for establishing the connection A-C.
- This should also be avoided and is done by de-energising the connection A-C. this should also be avoided and is done by de-energising the horizontal bar A after the crosspoint is latched and making a suitable arrangement such that the latch is maintained even though the energisation in the horizontal direction is withdrawn.
- The cross point remains latched as long as the vertical bar E remains energised. As the horizontal bar A is de-energised immediately after the crosspoint AC is latched the crosspoint AE doesnot latch when the vertical bar E is energised.
- Thus the procedure for establishing a connection in a crossbar switch may be summarized as:
 - Energise horizontal bar
 - Energise vertical bar
 - De-energise horizontal bar
- (or)
- Energise vertical bar
- Energise horizontal bar
- De-energise vertical bar

1.8.Crossbar Switch Configurations

- As all the stations are allowed to be connected with all possible connections as long as the called party is free, this Crossbar Switching is called the Non-Blocking Crossbar configuration.
- In a non-blocking crossbar configuration, there are N^2 switching elements for N subscribers. When all the subscribers are engaged, only N/2 switches are actually used to establish connections.
- Table 1 shows the values of different design parameters for four non-blocking switches. Unit cost is assumed for each cross-point switching element.

Table 3.1 Nonblocking Crosspoint Switch Systems: Design Parameters

N	S	SC	EU	C	CCI
4	16	2	12.50	16	0.5
16	256	8	3.13	256	0.5
64	4096	32	0.78	4096	0.5
128	16384	64	0.39	16384	0.5

N = No. of subscribers S = No. of switching elements
 SC = switching capacity C = total cost
 EU = equipment utilisation factor CCI = cost capacity index

- Providing N^2 cross-points even for moderate number of users leads to impractical complex circuitry. A 1000-subscriber exchange would require 1 million cross-point switches. Therefore ways and means have to be found to reduce the number of switch contacts for a given number of subscribers.
- Three ways have been tried successfully.
 1. Use of only one crosspoint switch for a given pair of subscribers
 2. Reducing the number of crossbars.
 3. Designing blocking configurations.
- The crosspoint matrix reduces to a diagonal matrix with $N^2 / 2$ switches. A diagonal connection matrix for four subscribers is shown in below figure

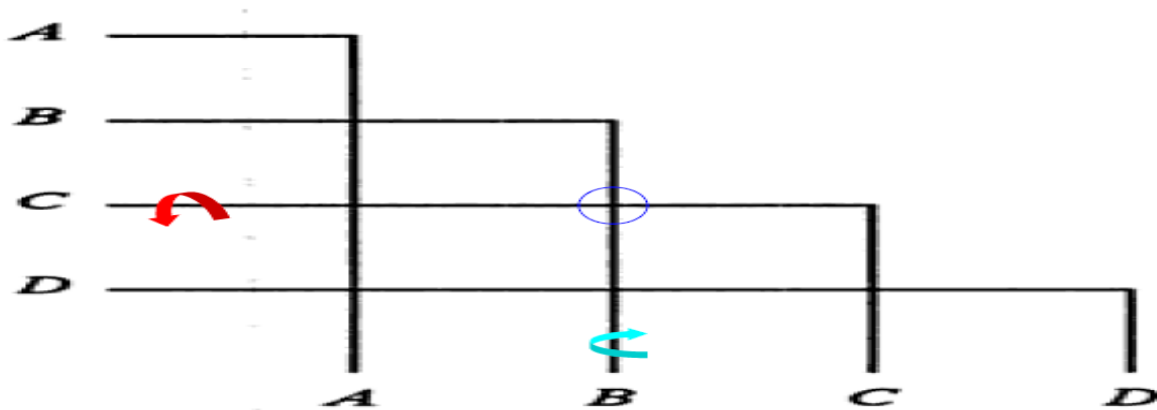


Fig. 3.8 Diagonal crosspoint matrix .

- The cross-points in the diagonal connect the inlets and the outlet of the same subscriber. This is not relevant. Hence, these are eliminated.

- The number of crosspoints then reduces to $N(N-1)/2$. Actually $N(N-1)/2$ represents the number of links in a fully connected network.
- The diagonal crosspoint matrix is fully connected. The call establishment procedure here is dependent on the source and destination subscribers.
- When subscriber D initiates a call, his horizontal bar is energised first and then the appropriate vertical bar. If subscriber A initiates a call, the horizontal bar of the called party is activated first and then the vertical bar of A.
- A diagonal cross-point matrix is a non-blocking configuration. Even $N(N-1)/2$ cross-point switches can be a very large number to handle practically. The number of cross-point switches can be reduced significantly by designing blocking configurations. These configurations may be single stage or multistage switching networks.

3.4 Crossbar Switch Configurations

□ Blocking crossbar switches

- Aiming to reduce the number of crosspoint switches.
- Category: Single stage / Multistage
- Methodology:
 - Two subscribers share one vertical bar
 - ✓ Number of bars reduced
 - ✓ Number of crosspoint switches remains the same.
 - All subscribers share a number of vertical bars
 - ✓ Numbers of bars and crosspoint switches reduced

Blocking crossbar switches

□ Scheme 1

■ 2NK switches

- N denotes the number of subscribers
- K is the number of simultaneous connections
- Operate four bars to establish a connection (e.g. A-B).
 - Energize horizontal bar A
 - Energize free vertical bar P
 - De-energize horizontal bar A
 - Energize horizontal bar B
 - Energize free vertical bar P' (associated with P)
 - De-energize horizontal bar B

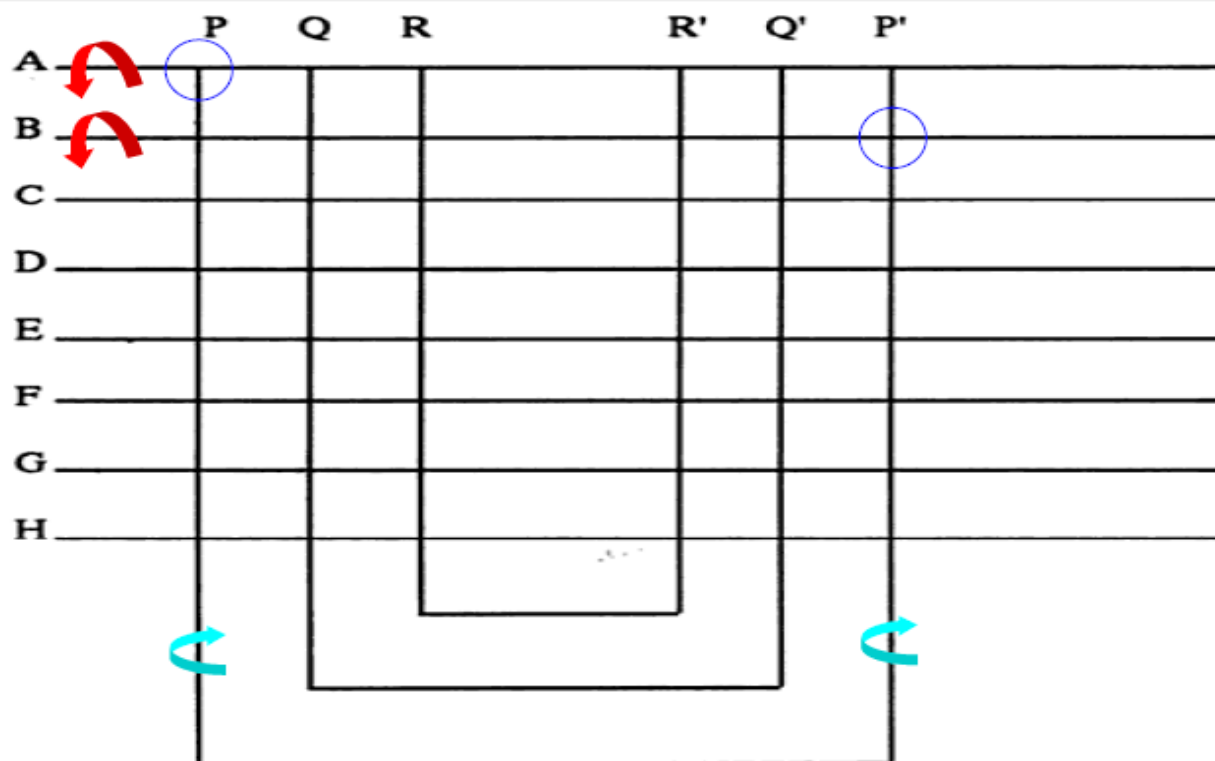


Fig. 3.9 Blocking crossbar switch.

Blocking crossbar switches

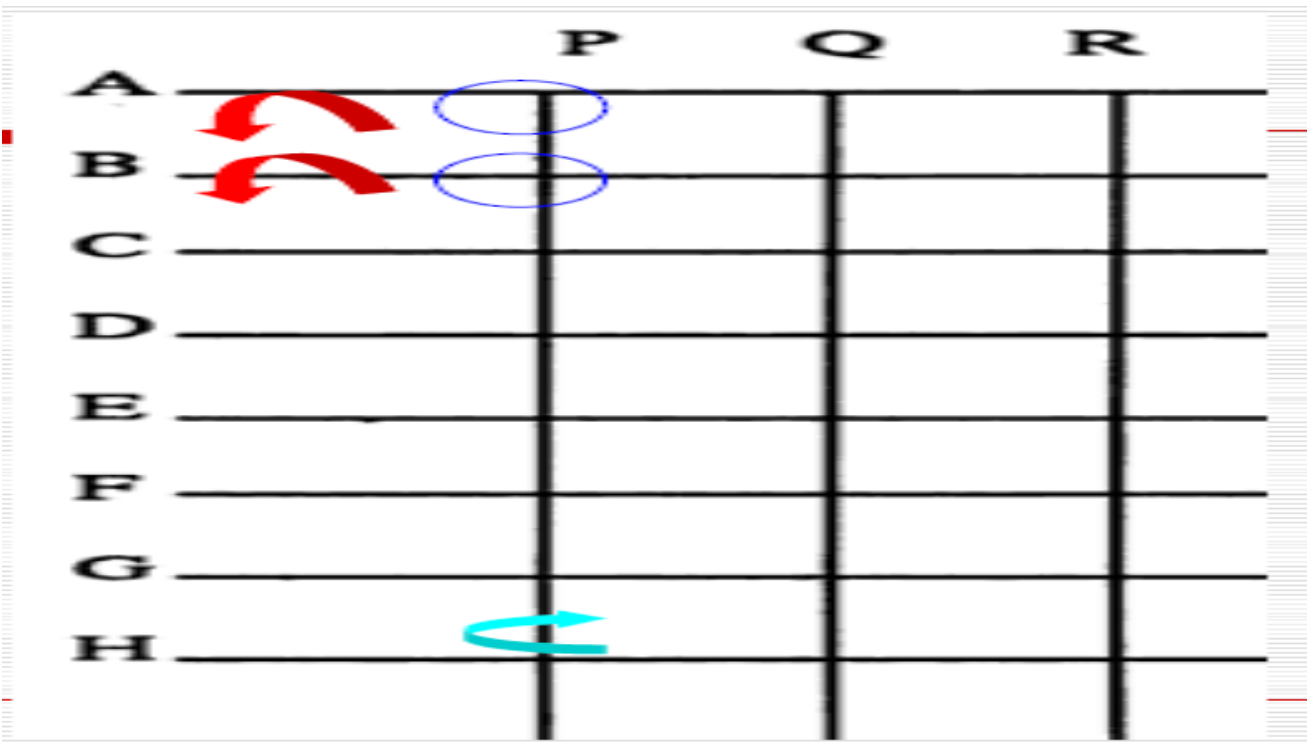
□ Scheme 2

■ NK switches

- N denotes the number of subscribers
- K is the number of simultaneous connections

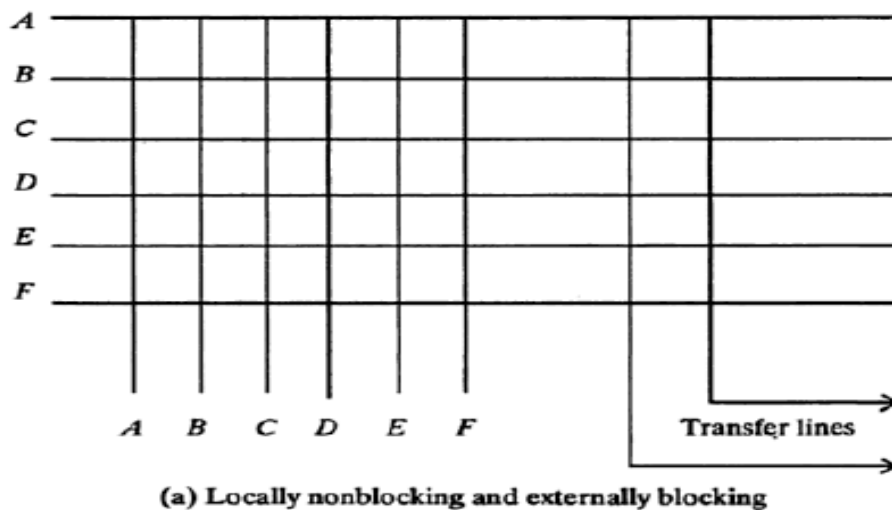
■ Operate three bars to establish a connection (e.g. A-B).

- Energize horizontal bar A and B
- Energize free vertical bar P
- De-energize horizontal bar A and B



- Both blocking and non blocking type crossbar switches can support transfer lines. This is done by introducing additional vertical crossbar and crosspoint switches as shown in below figure. The figure shown below is non blocking locally and has two transfer lines.

Locally nonblocking and externally blocking



- The switch shown in below figure is blocking, both locally and externally with two simultaneous local and two simultaneous external calls.
- The number of crosspoint switches in the first case is $N(N+L)$ and in the second case $N(2K+L)$, where N is the number of subscribers, L is the number of transfer lines and K is the number of simultaneous calls that can be supported locally.

Transfer line support

❑ Blocking both locally and externally

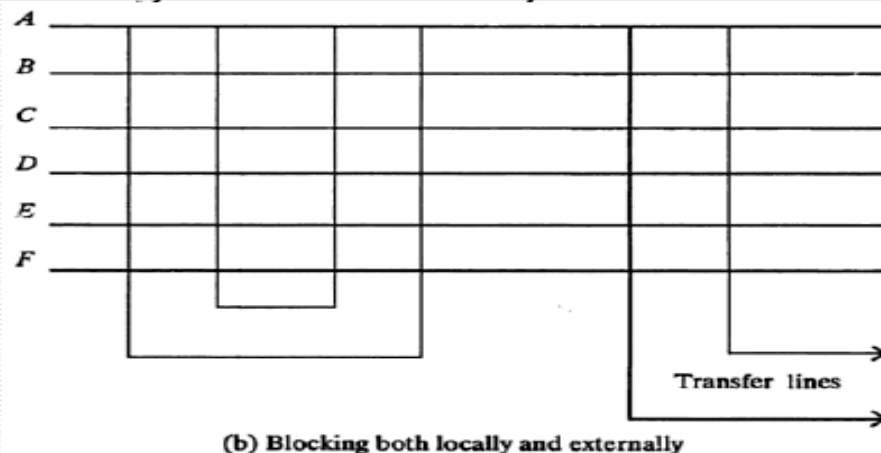
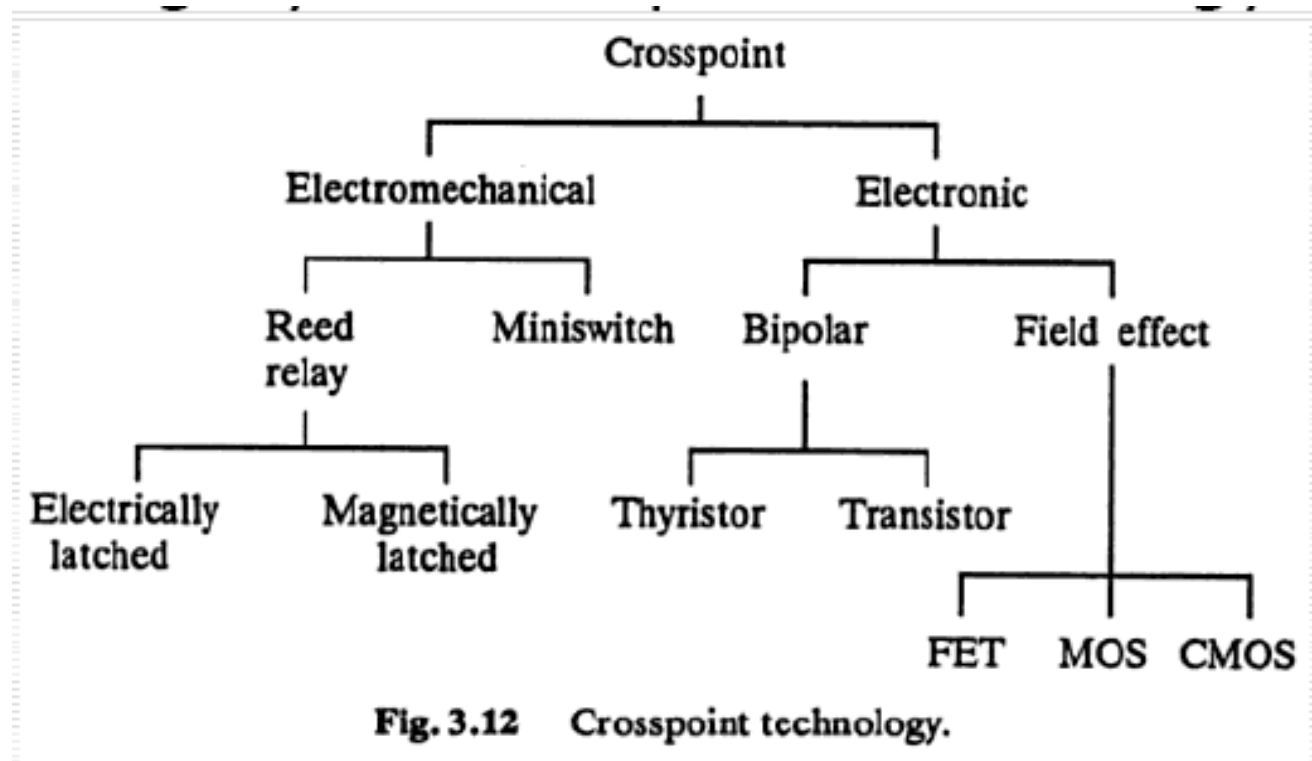


Fig. 3.10 Crossbar switches with transfer lines.

1.9. Cross-point Technology

- The Crossbar system mainly consists of the Cross point switches, which increases the cost of the system. The cost of the Crossbar system increases in direct proportion to the number of Cross points in the system.
- **Challenges for the Cross point Technology**
 - ❖ Reduction of the size of a crosspoint
 - ❖ Reduction of the cost of a crosspoint
 - ❖ Improvement of switching time
- The flowchart given below shows the different categories of the Crosspoint technology –



Electromechanical Crosspoint Technology

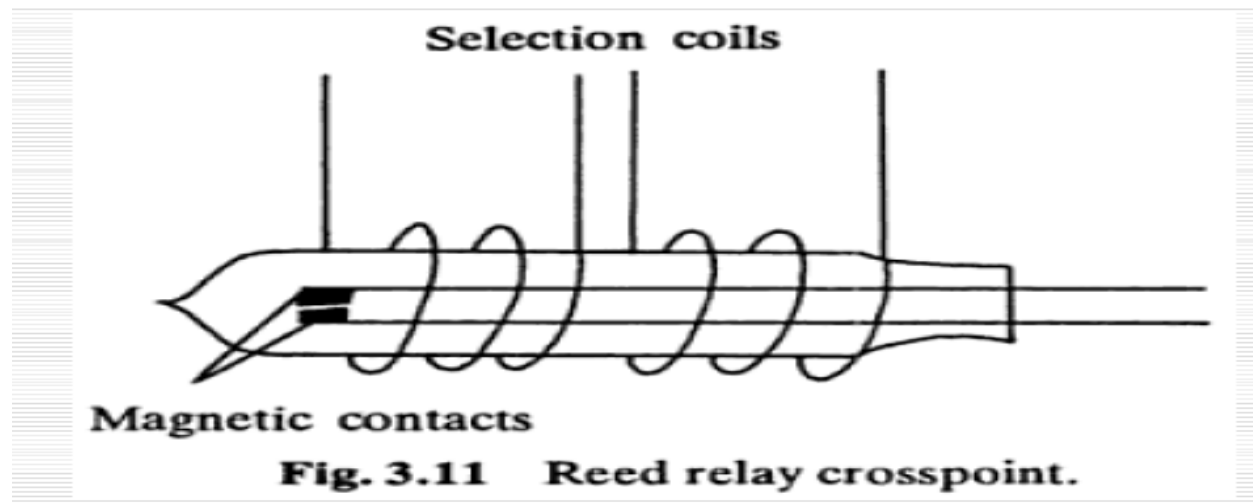
- The Electromechanical Crosspoint switches which are capable of making and breaking contacts in 1-10ms of time duration for several million times without any wear and tear are being extensively used even today. The two types of switches widely used are **Mini switches and Reed relay**.

Mini Switches

- These switches are made up of a precious metal like Palladium, which makes the contacts work quieter, with their bifurcated design and high resistance to corrosion for long lasting design. Mini switches are mechanically latched and use “V” notches for this purpose and are highly reliable in Crossbar switching systems.
- These switches mounted on Crossbars move horizontally and vertically to establish and release contacts with a switching time of 8-10ms.

Reed Relay Switches

- In order to reduce the usage of mechanical switches and increase the operating life of the switches further, the Reed relay switches were introduced. These switches are made up of magnetic material contacts sealed in a glass tube; this protects the contacts from getting contaminated.
- The following figure illustrates the design of a reed relay switch.
- A reed relay switch may be electrically or mechanically latched; it contains the contacts very close to each other having a displacement of 0.2mm resulting in a fast switching speed of 1ms.
- The construction of this relay is such that the glass tube is surrounded by a pair of coils and when current is passed through both the coils simultaneously, a field is created.
- This further leads to the reed contacts moving together. As long as it is switched on, the electrical connection is latched and current passes through the coil.



- In magnetic latching, the hysteresis of the magnetic material decides the performance.

- The magnetic pole pieces required may be placed outside the glass or the contacts may act as poles by choosing an appropriate ferromagnetic material. The reed relay is called the remreed due to the remnance property of the contact strips.
- The residual magnetism in the poles keeps the contacts closed even after the currents are withdrawn from the coils and hence a demagnetizing current needs to be applied to coils, to open the contacts.
- These reed relays are placed at each Cross point to construct a Cross point matrix.
- Cross point selection is achieved by connecting one of the coil windings of each relay in series with its vertical neighbor and the other winding in series with its horizontal neighbor.
- The reed relay is excited when the required Cross point is selected by pulsating the corresponding vertical and horizontal bars simultaneously.

1.10. CROSSBAR EXCHANGE ORGANIZATION

- The organization of a Crossbar exchange consists of three basic building blocks such as link frames, control markers and registers.
- Link frames consist of a number of crossbar switches arranged in two stages called primary and secondary stages with links between them as shown in below figure.
- This two-stage arrangement with links has the effect of increasing the number of outlets for a given number of inlets. If the number of outlets is high, the selectivity is higher too.
- Markers Control the connections between the inlets and the outlets via primary section, links and the secondary section.

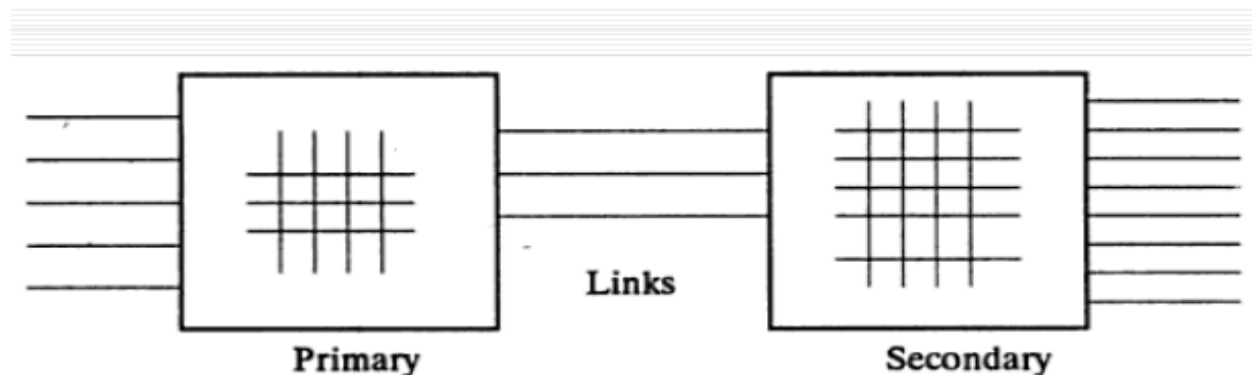
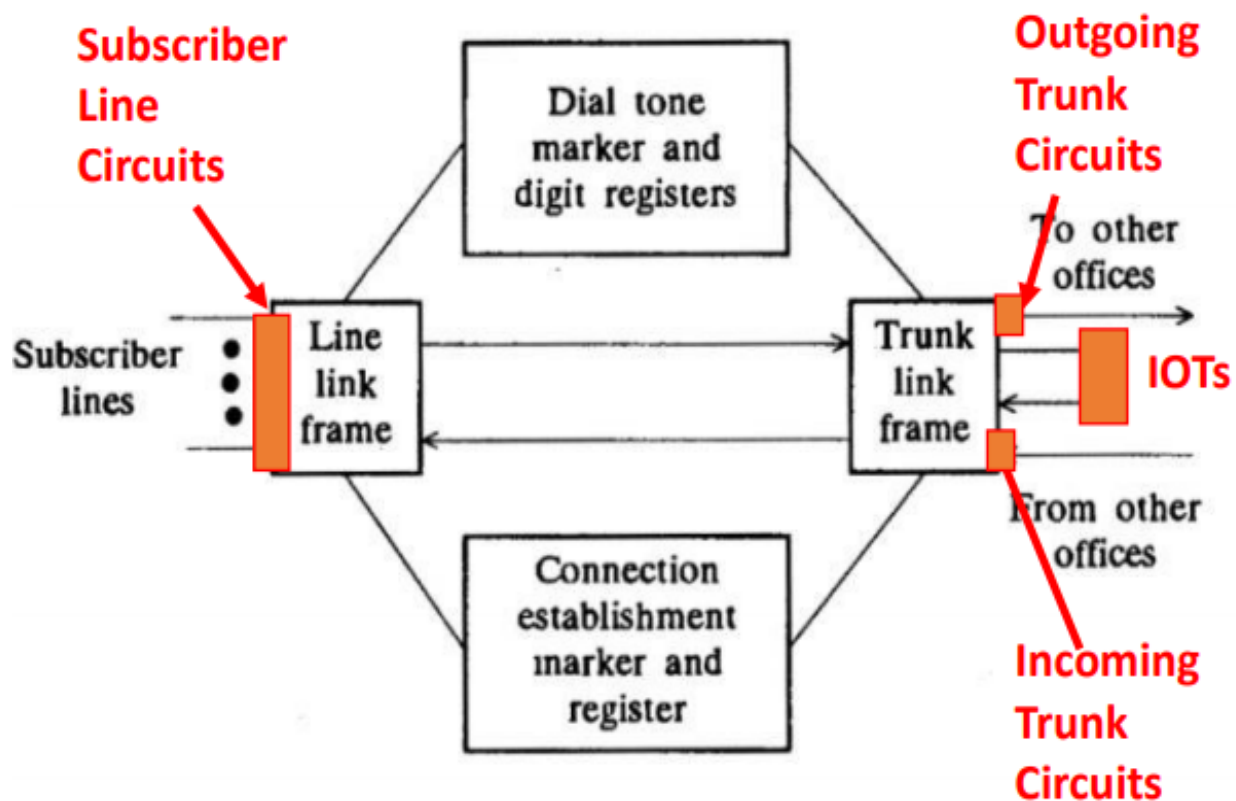


Fig. 3.13 A link frame and its control by a marker.



- The two main sections of the Crossbar Exchange organization are

Line Unit

- The line link frames along with associated markers and registers can be termed as Line Unit.
- The line units are two-way units that help in the origination and termination of calls. Because of its two-way capability, the secondary section in the line link frame is called the terminal section. The subscriber lines are terminated on the outlets of the terminal section frames.

Group Unit

- The trunk link frame along with its associated circuitry can be termed as the Group Unit.
- The trunk link frame may be sub-divided into two or three link frames like local office link frame and incoming link frame, etc. Group unit is a uni-directional device that receives the calls from the line unit or from distant exchanges. It is capable of handling local, outgoing, incoming, terminating and transit calls.

- The call processing in a Crossbar exchange is done in three stages, named as Pre-Selection, Group Selection and Line Selection.

Pre-Selection

- The originating marker does the pre-selection. When the calling subscriber lifts the handset, the dial tone is heard. The register send this tone. This stage that stars from lifting the handset to sending the dialed tone is called Pre-Selection.

Group Selection

- Once the dial tone is heard, the number can be dialed. The call is switched through the desired direction as decided, in accordance with the code given by the translator. This stage of selecting the desired group for making a call is called Group Selection.

Line Selection

- Once a number is dialed, the calling subscriber is connected to the called subscriber by the terminating marker. The line of the called party is controlled by the terminating marker which also sets up ringing on the line. This stage of selecting the line of the desired subscriber can be called as the Line Selection.
- With these three sections, a call can be connected and processed in a Crossbar exchange

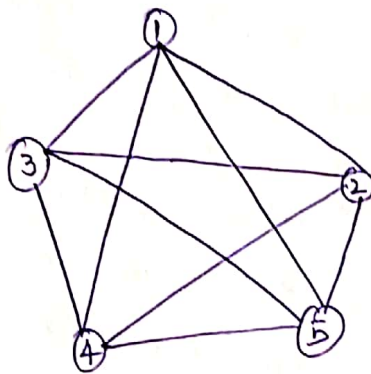
Introduction to Telecommunication

①

Evolution of Telecommunication:

- The field of telecommunications has evolved from a stage when signs, drum beats, and semaphore were used for long distance communication to a stage when electrical radio and electro-optical signals are being used.
- Telecommunication networks carry information signals among entities which are geographically far apart. An entity may be computer, a human being, a fax machine, a teleprinter, a data terminal and so on.
- In a telephone conversation, the one who initiates the call is referred as the calling subscriber and whom the call is destined is the called subscriber.
- The communicating entities are source and destination.
- The full potential of telecommunication is 'universal connectivity', it is achieved by switching systems.
- Historically, transmission of telegraphic signals over wires was the first technological development in the field of modern communication.
- Telegraphy introduced in 1837, and 1845 by Britain and France, and in 1876 A. Graham Bell demonstrated his telephone and possibility of it.

- Graham Bell demonstrated a point-to-point telephone connection. A N/w using point-to-point connection is shown below.
- In N/w a calling subscriber chooses a appropriate link to establish connection with the called subscriber
- In order to draw the called subscriber before information exchange can begin, some form of signalling required with each link.



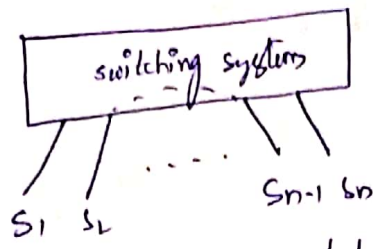
A N/w with point to point

- There are five entities and 10 point-to-point links. In general case with n entities there are $n(n-1)/2$ links. i.e

$$L = (n-1) + (n-2) + (n-3) + \dots + 1 + 0 =$$

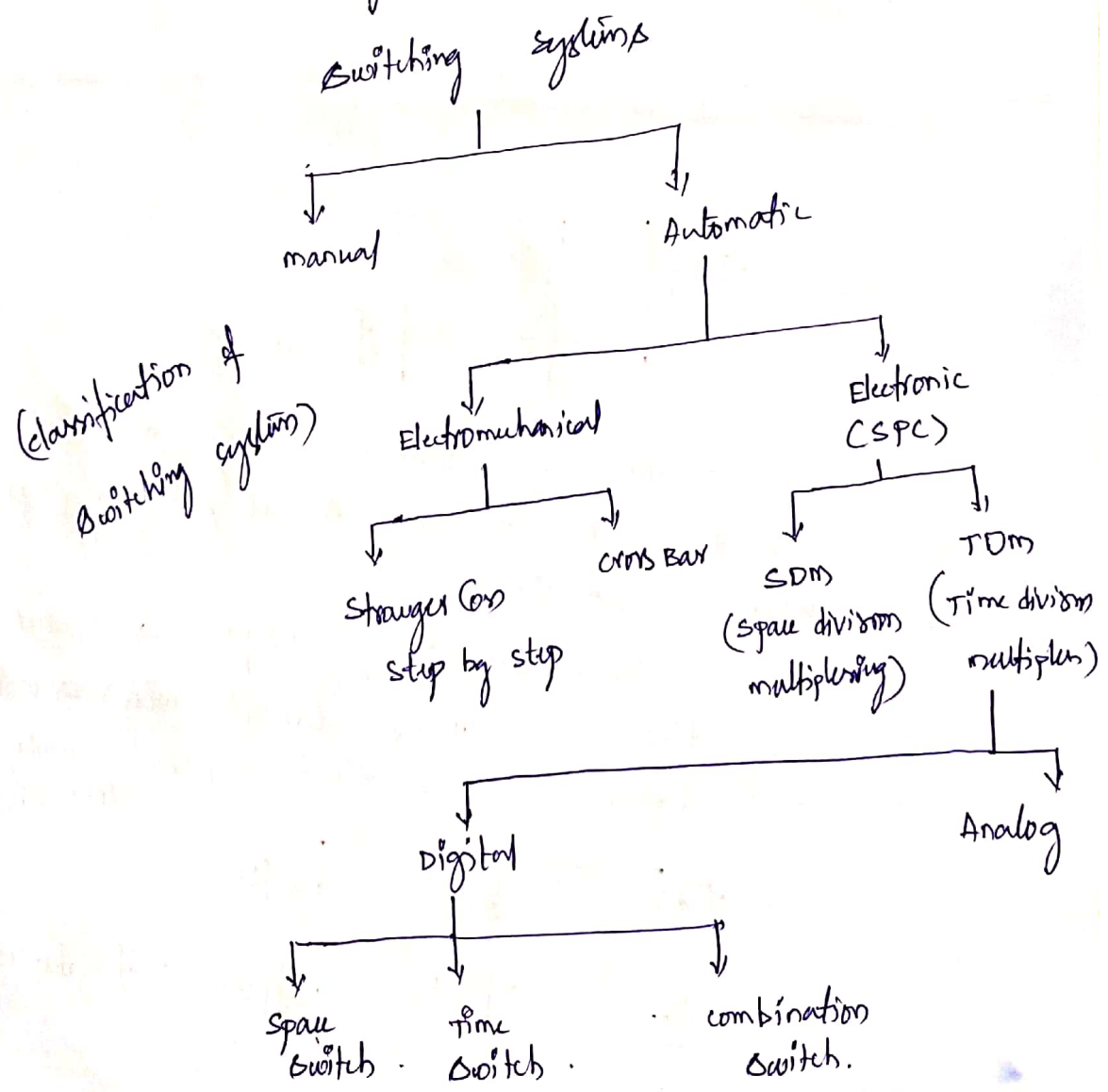
$$L = \boxed{\frac{n(n-1)}{2}}$$

- with the introduction of switching systems, the subscribers are not connected directly to one-another instead they are connected to switching systems.

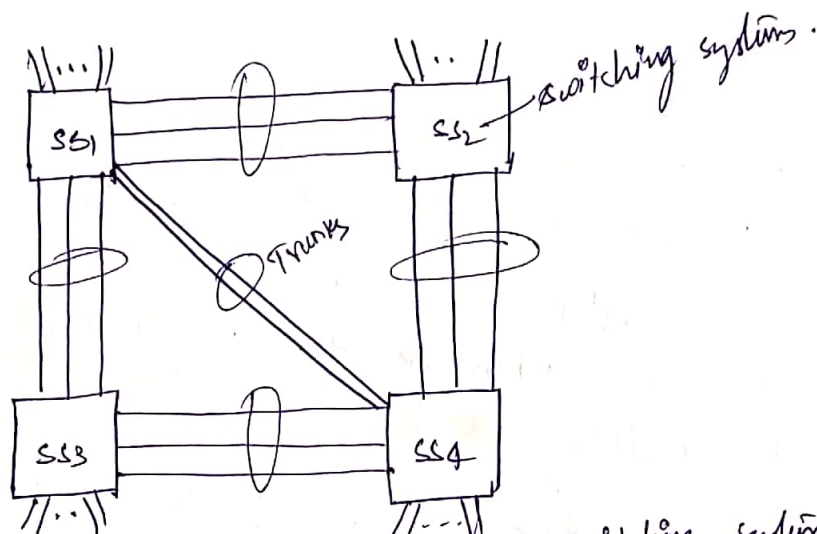


→ only one connection is needed for subscriber that is with switching system. The switching system will establish a connection between subscribers. If n subscribers the n links one connection to switching system.

- The functions required to connection and release of subscribers are called control functions.
- The switching systems are categorize into following

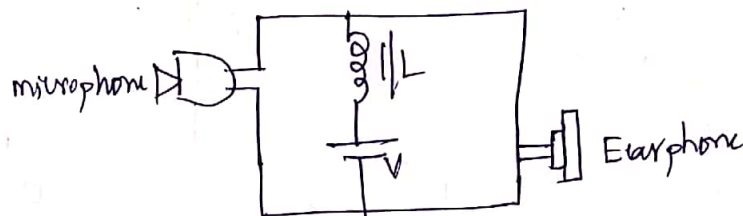


A telecommunication Network.



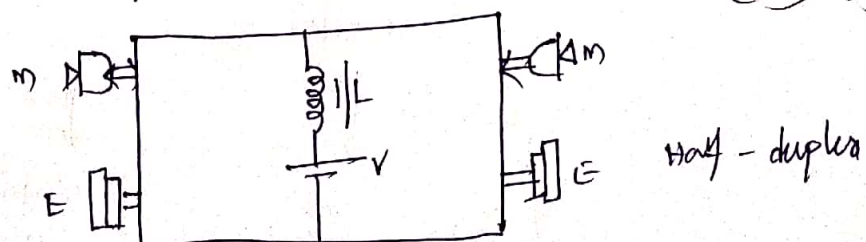
→ The links that run between the switching systems are called trunks, and those that run to subscriber premises are known as subscriber lines.

⇒ Simple telephone communication.



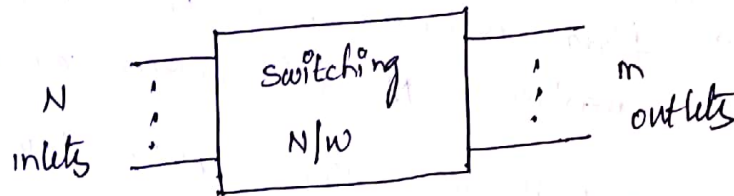
In the simplest form of telephone circuit, there is one way communication involving two entities, one receiving (listening) and other transmitting.

- Simplex communication (only Tx/Rx) → speaker
- Half duplex (Tx/Rx simultaneously) → walkie talkie
- Full duplex (Both directions, simultaneously) → (phones) (cell)

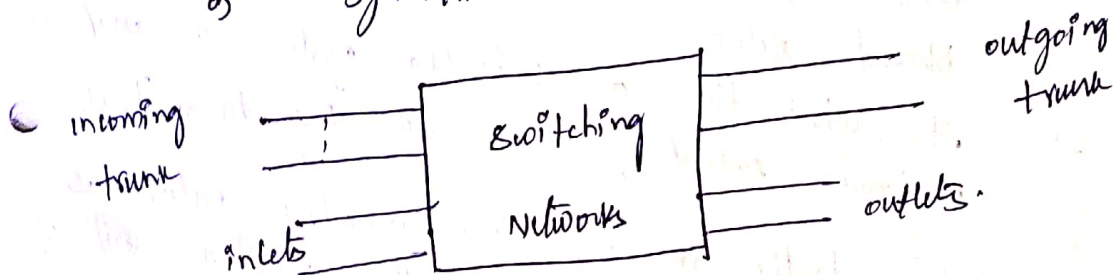


Basics of Switching System!

- A major component of switching system or exchange is the set of input and output circuits called inlets and outlets
- The primary function of switching system is to establishing such a connection ~~ix~~ between given inlets and outlets, to make this switching matrix
- (or) switching networks
- switching network is a component of switching system



- when no. of inlets = no. of outlets called it symmetric networks.



- If outlets are folded back to the inlets that N/w is called folded n/w.

→ four types of connections may be established.

- 1) Local call between two subscribers in the system
- 2) outgoing call connection between a subscriber and an outgoing trunk
- 3) Incoming call connection between an incoming trunk and local subscriber
- 4) Transit call connection between an incoming trunk and an outgoing trunk.

→ In a folded network with 'N' subscribers there can be maximum $N/2$ simultaneous calls.

→ when a switching system doesn't have switching paths to give a connection, the subscriber who request is denied that case is called blocked network

→ At what time a switched system is used its maximum extent, it is called 'Busy hour Traffic'

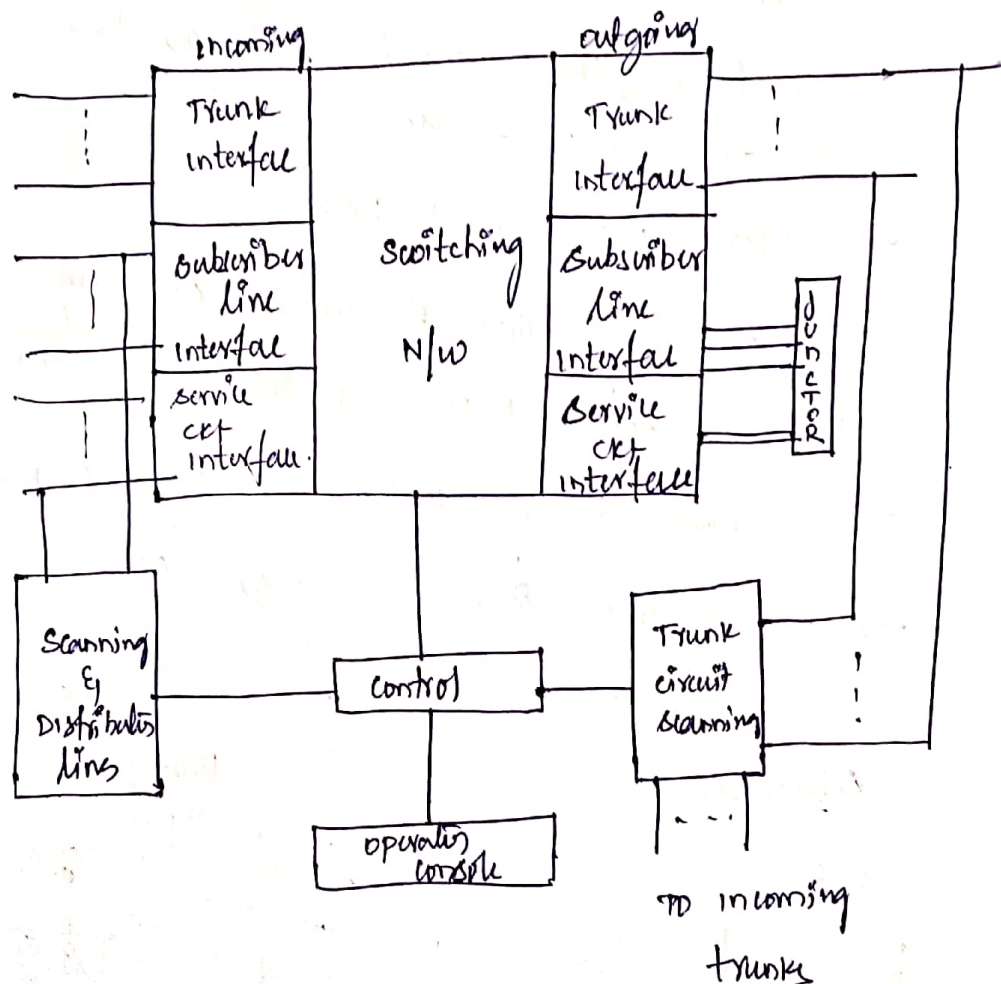
→ The traffic in a telecommunication network is measured by an internationally accepted unit of traffic intensity known as 'Erlang' (E).

→ The signalling in telecommunications in different formats depend on requirement of subscriber, the trunks and the subsystems differ significantly

→ The three different forms of Signalling are

- 1) Subscriber loop Signalling
- 2) Inter exchange Signalling
- 3) Inter Exchange or register Signalling.

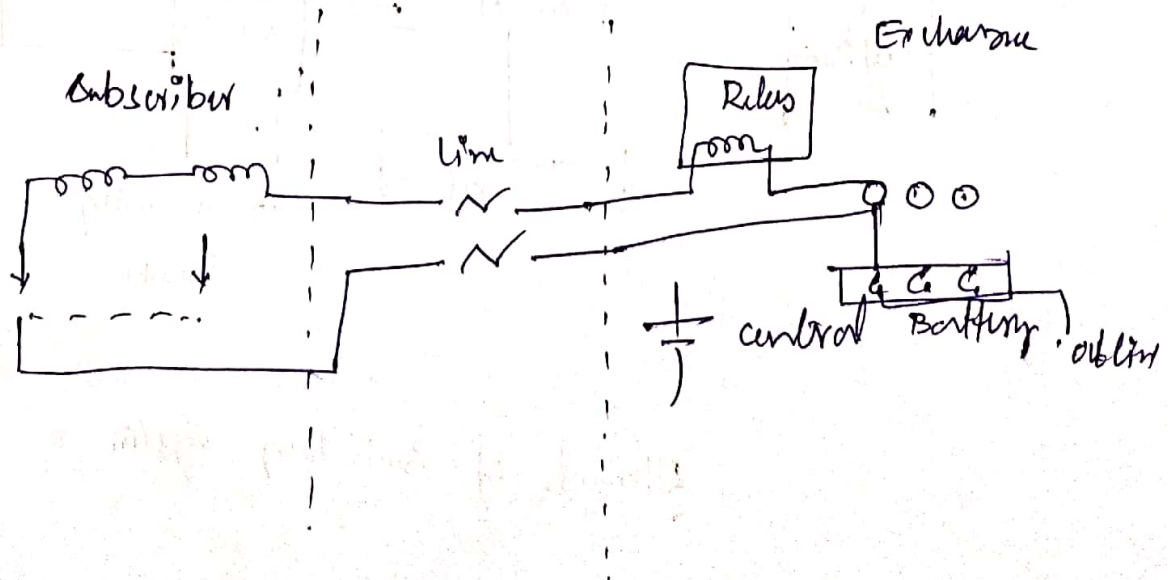
→ A Switching system is composed of elements that perform control and Signalling functions:



Elements of Switching system

- In some switching systems the control subsystem may be an integral part of the switching network.
i.e. direct control switching system.
- If control subsystem may be outside of the N/w i.e. common control.
- ⇒ Manual Switching system:

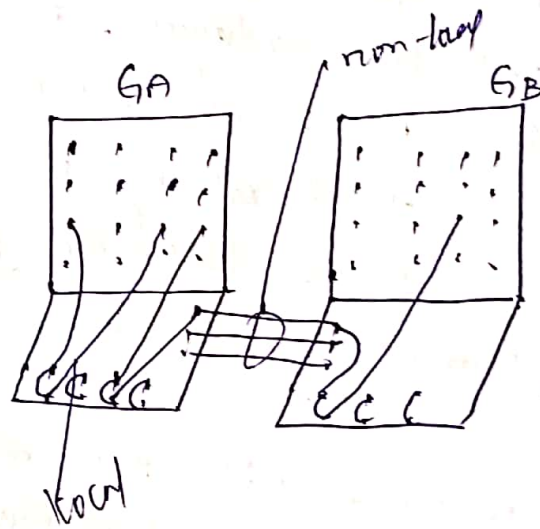
- @ with the advent of automatic switching systems, the manual exchanges have almost gone out of use.
- used only in PABX
- In early stage of manual switching to energize the microphone, battery systems are used
- Local Battery (system) exchanges (LB)
- central Battery Exchanges (CB)



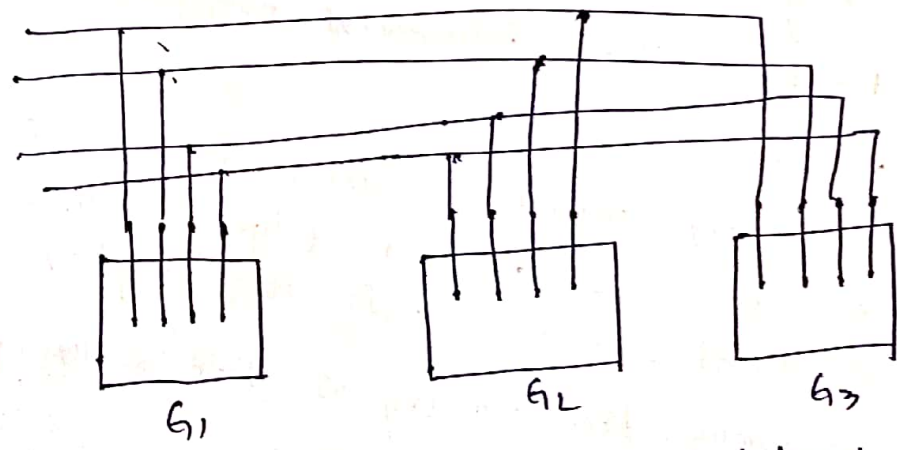
⑤

→ when the number of subscribers increase, multiple switch boards and operators are required to handle the traffic.

- single termination switch boards
- multi termination switch boards.



single termination switch board.



multi termination switch board

Major Telecommunication networks:

Telecommunication networks may be categorized according to their coverage of geographical area which have distinct telecommunication requirements

- Towns and cities have high subscriber densities and relatively heavy traffic per subscriber. They are characterised by many local exchanges. For these traffic metropolitan networks or urban
- Rural areas are characterised by low subscriber densities, widely dispersed subscribers, lighter traffic per subscriber. These areas are served by rural networks
- Long distance or toll (or) wide area networks act as backbone networks. Interconnect metropolitan and rural networks.
- The most stupendous telecommunication n/w in existence is the public switched telephone network (PSTN) or sometimes known as plain old telephone system.
- Telecommunication industry is both in the private and govt sector.
- USA had more no. of privatised telecommunication companies
- The Administration usually known as post, telegraph, telephone (PTT).
- In India a single govt department known as P&T posts and telegraph & up to 1984 december

- From Jan 1985 the responsibility was divided between two departments i.e. Department of post which dealing with mails and Department of Telecommunications dealing with telephone and telegraph and data (DAT) communications.
- No. of different agencies involved in providing telecom services. The coordination is provided by ITU - International Telecommunication Union.
- CCITT - International Consultative Committee for Telegraph and Telephone.
- ISDN - Integrated service Digital network is the major telecommunication N/W, ISDN is a envisaged single common network capable of carrying multimedia services like voice, data, video and facsimile.
- The key to ISDN is the digitalization of services transmission switching and signalling.

⇒ CROSS BAR SWITCHING

Crossbar switching is a electromechanical switching system have hard-wired control subsystems which use relays and latches. This system had limited capability and it is virtually impossible to modify them to provide additional facilities.

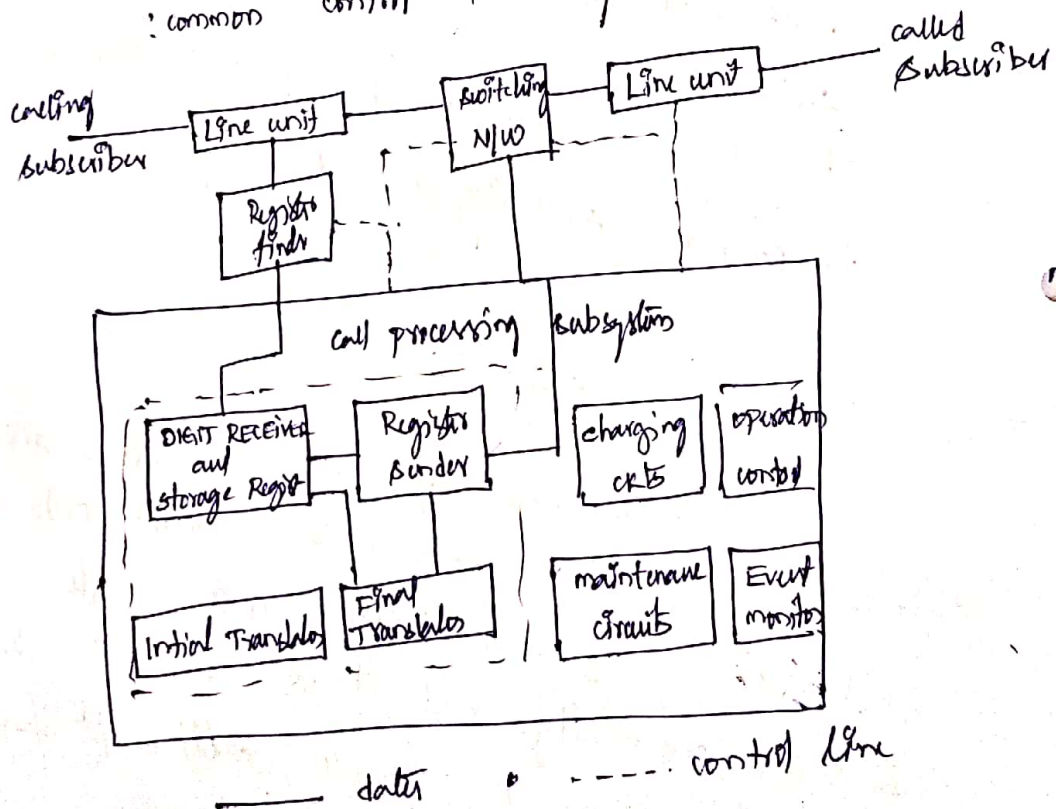
⇒ principles of common control!

to overcome the difficulties in the design of switching, crossbar switching introduced to make switching mechanism and events more easier.

→ The control functions in a system may be placed under four broad Areas.

- 1) Event monitoring
- 2) call processing
- 3) charging
- 4) o & m - operation and maintenance.

: common control switching system :



→ Events occurring outside the exchange of the line units, trunk junctions and inter exchange signalling Rr/P_r units all are monitor by the control subsystems.

* call Request, call Release - main events.

→ The control subsystem may operate relays in the junctions, Rr/P_r units and the line units and thus command these units to perform certain functions.

→ when the event is sensed, the calling location is determined and marked for dial tone, and the register finder is activated.

→ Identify the calling line is used to determine the line category and COS, (class of service)

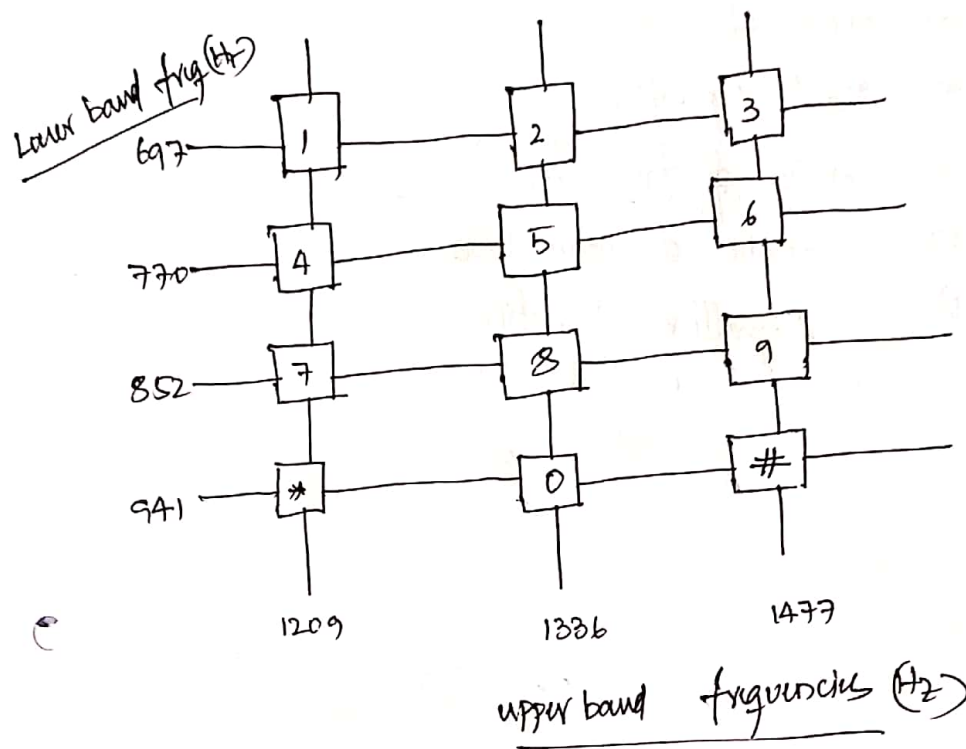
→ As soon as the initial digits which identify the exchange are received in the register. They are passed on to the initial translator for processing.

→ The initial translator determine the route for the call through the network. It also determines the charging method and the rate applicable to the subscriber. Such decisions are based on the class of service.

→ The final translator determines the line unit to which a call must be connected and the category of the called line.
i.e. call barring, call priority, call charging, origin based routing, no dialling calls

Touch Tone dial telephone:

- In rotary dial telephone, it takes about 12 seconds to dial a 7-digit number from the subscriber post of view, a faster dialling rate is desirable.
- with the introduction of common control in crossbar system, a higher dialling rate is feasible.
- pulse dialling is limited to signalling between the exchange and subscriber.
- End-to-End signalling is a desirable feature and possible only if the signalling is in the voice frequency, so that the signalling information can be transmitted to any point.
- A more convenient method of signalling than rotary dialling is preferable from the point of human factors.
- Touch tone dial telephone developed in 1964 after field trials. The rotary dial is replaced by the push button keyboard.
- Touching a button generates a tone, which is a combination of two frequencies, one from lowerband and another from upperband.
Ex. pressing push button '9' transmits 852 Hz and 1477 Hz.



⇒ Design considerations:

→ The need for touch tone signalling frequencies to be in the voice band brings with it the problem of vulnerability to "talk-off", which means the speech signals may be mistaken for touch tone signalling and unwanted control actions such as terminating a call may occur.

→ The main design considerations for touch tone signalling stem from the need for protection against talk-off which include the following factors.

- 1) choice of code
- 2) Band allocation
- 3) choice of frequency
- 4) choice of power levels.
- 5) Signalling duration.

9

⇒ principles of crossbar switch:

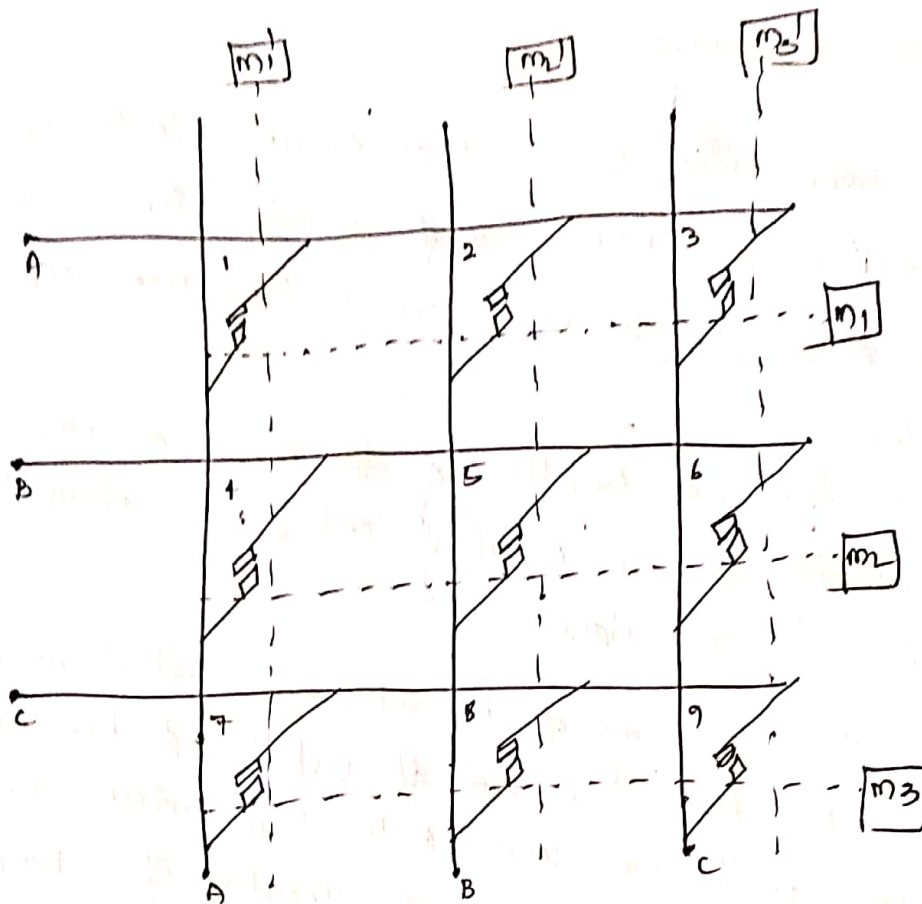
→ The basic idea of crossbar switching is to provide a matrix of $n \times m$ sets of contacts with $n+m$ activations or lines to select one of the $n \times m$ sets of contacts.

→ This form of switching is also known as coordinate switching as the switching contacts are arranged in a xy plane.

→ There is an array of horizontal and vertical wires shown on figure. A set of vertical and horizontal contact points are connected to these wires. The points form pairs, each pair consisting of a bank of three or four horizontal and corresponding bank of vertical contact points.

→ A contact point pair acts as a crosspoint switch and remains separated or open when not in use.

→ The contact points are mechanically mounted (electrically isolated) on a set of horizontal and vertical bars shown as dotted lines. Bars are attached to set of electromagnets.



→ working of crossbar switch:

when an electromagnet, say the horizontal direction is energised the bar attached to it slightly rotates in such a way that the contact points attached to the bar and moving along to its contacts, now if an electromagnet in the vertical direction is energised the corresponding bar move towards contact for intersection, this happens due to contact points move towards each other.

ex. If magnets m_2 and m_3 are energised a contact is established at the cross point 6.

→ The following 6x6 crossbar switch will fully explained how a switch is connected.

Inlets:

A	AA	AB	AC	AD	AE	AF
B	BA	BB	BC	BD	BE	BF
C	CA	CB	CC	CD	CE	CF
D	DA	DB	DC	DD	DE	DF
E	EA	EB	EC	ED	EE	EF
F	FA	FB	FC	FD	FE	FF
	A	B	C	D	E	F

Outlets

→ connection Sequence

A to C and B to E

- 1) First the horizontal bar A is energised, then the vertical bar C is energised.
- 2) Then crosspoint AC latched and the connection between A and C can now proceed.
- 3) If we now energise the horizontal bar B to establish the connection BE, the crosspoint BC may latch and B will be brought into the circuit of AC. This is prevented by introducing an energising sequence for latching cross points.

→ If we want to establish the connection, definitely one of the bar is de-energised after connection made.

Energize the H BAR (or) Energize the V-BAR
 Energize the V BAR (or) Energize the H-BAR
 De-energize H BAR De-energize V BAR.

⇒ Crossbar Switch configurations:

In a nonblocking crossbar configuration, there are N^2 switching elements for 'N' subscribers. When all subscribers are engaged, only $N/2$ switches are actually used to connections.

→ providing N^2 crosspoints even for moderate number of users lead to impractical complex circuitry. A 1000-subscriber exchange would require 1m cross points.

→ Non-Blocking crosspoint switch : Design parameters

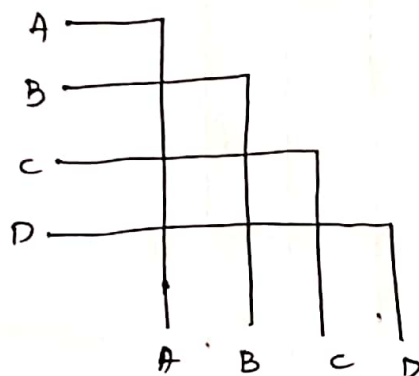
N	S	SC	EOF	C	CC1
4	16	2	12.50	16	0.5
16	256	8	3.13	256	0.5
64	4096	32	0.78	4096	0.5
128	16384	64	0.39	16384	0.5

N = no. of subscribers S = no. of switching elements
 SC = switching capacity C = total cost EOF = equipment with

(11)

→ In a non blocking configurations switch the that are connected to establish a call and very large to handle $N(N-1)/2$ crosspoint switches.

→ The number of crosspoint switches can be reduced significantly by designing blocking configurations.



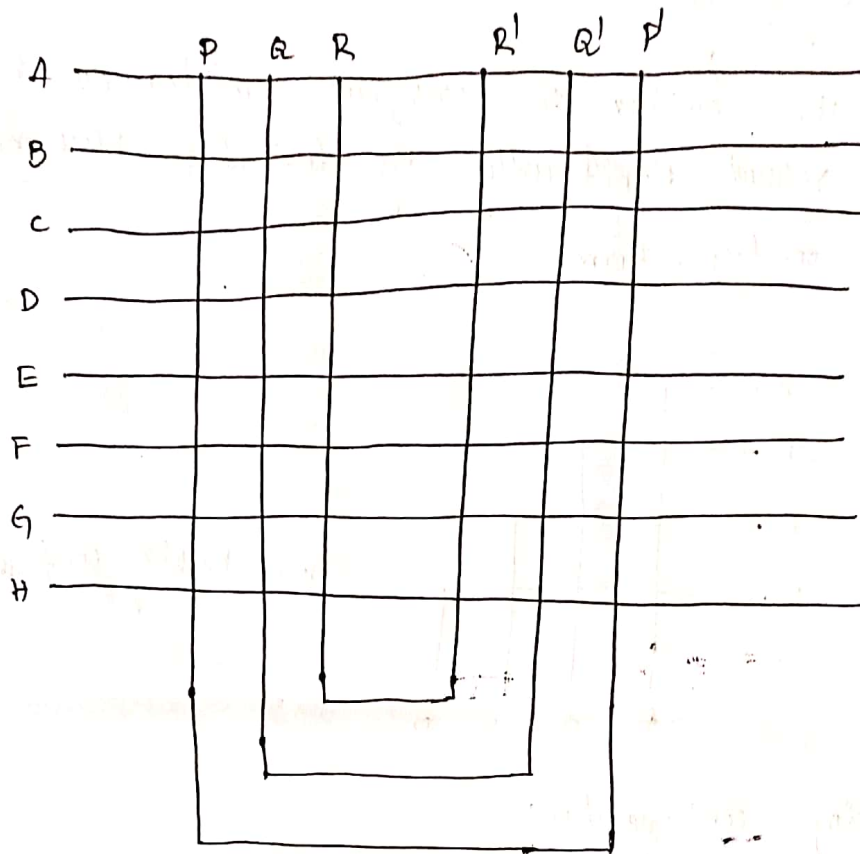
Non blocking configurations.

Blocking configurations:

The crossbar hardware may be reduced by connecting two subscribers to a single bar and letting the bar turn both in the clockwise and anticlockwise directions, and thus closing two different crosspoint contacts. With this arrangement the no. of crossbar reduces, but no. of crosspoints switches remains same.

→ In blocking crossbar switches, the no. of vertical bar is less than the no. of subscribers and determines the simultaneous calls that can be put through the switch.

Blocking configuration



→ The crosspoint connection in above 8x8 blocking configuration like this, to establish AB circuit is like follow

Energize horizontal A

Energize free vertical P

De-energize the horizontal A

Energize the horizontal B — AB

Energize the vertical — P1

De-energize the horizontal B.

⇒ Cross point Technology:

- The hardware of the crossbar system predominantly consists of crosspoint switches.
- The cost of the system increases in direct proportion to the number of crosspoint in system.
- The reduction of crosspoints has been the major thrust of crosspoint technology development.
- At present two technologies for crosspoint design are prevalent. Electro mechanical & Electronic.
- Electro mechanical crosspoint are extensively used even today. They are capable of switching in 1-10 ms time duration and several million times without adjustments.

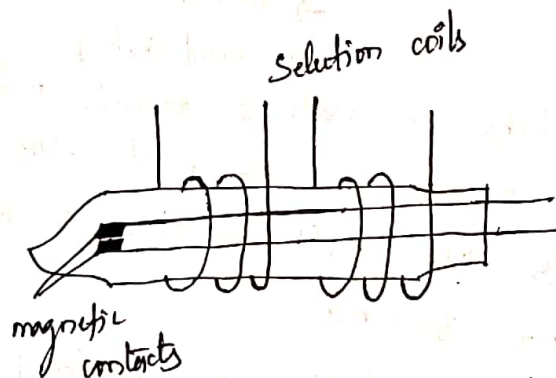
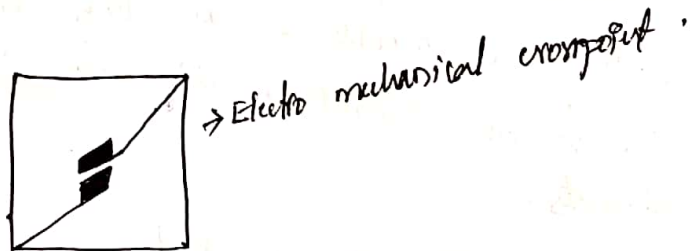
two principle types are used

- miniswitches
- Reed Relays
- miniswitches are made of precious metal like palladium which permits the design of electrically quieter contacts. The switching time of miniswitches is about 8-10 ms.
- Reed relay switches were developed to eliminate the mechanical motion of bars in a crossbar system, thus increasing the operating life of the system.

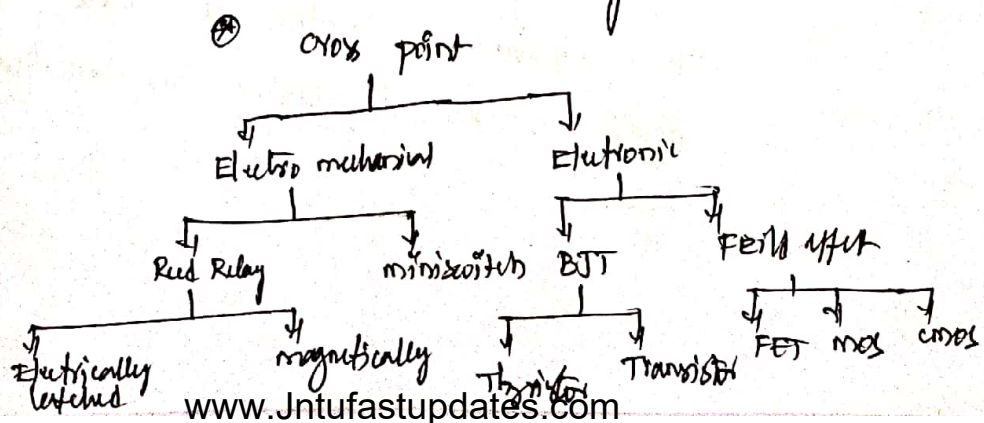
→ The reed relay comprises a pair of contacts made of a magnetic material sealed in a glass tube from preventing external contamination.

→ The glass tube is surrounded by a pair of coils and when current is passed through both the coils simultaneously, a field is created which causes the reed contact to move together.

→ A crosspoint matrix is constructed by placing one reed relay at each crosspoint, the two windings are connected to vertical and horizontal neighbour rods.



→ Reed Relay cross point

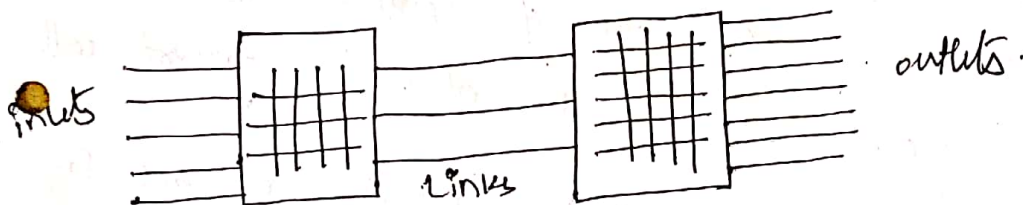


⇒ Crossbar Exchange Organisation:

The basic building blocks of a crossbar exchange are link frames, control markers and registers.

→ Link frames consist of number of crossbar switches arranged in two stages called primary and secondary with links between them.

→ The two stage arrangement with links has the effect of increasing the number of outlets for a given no. of inlets, thereby providing greater selectivity. markers control the connection between the inlets and the outlets via primary and secondary section.

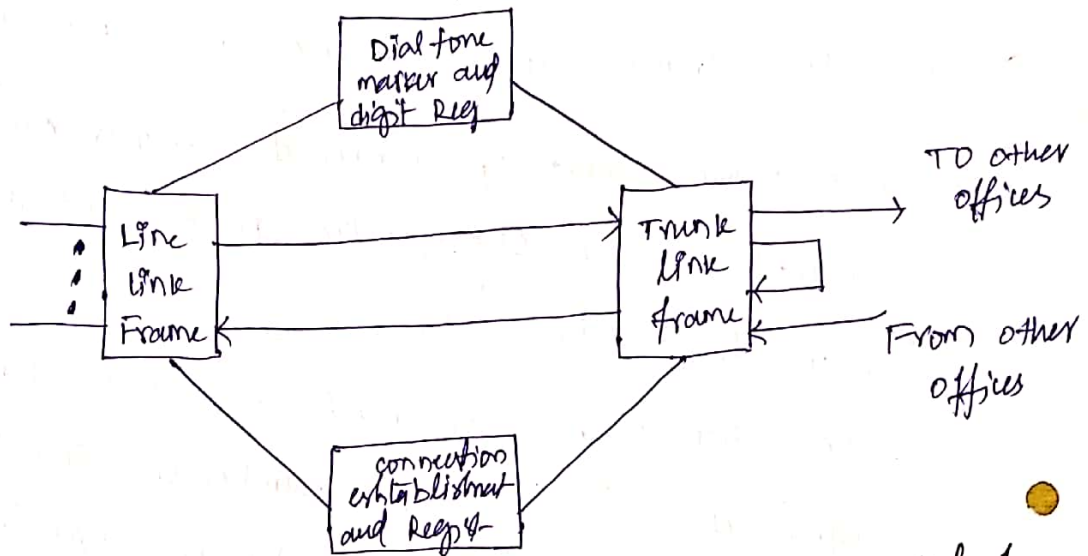


Link frame

→ In a crossbar exchange organisation, the line link frames along with the associated markers and registers are known as line unit. and the trunk link frame with its associated H/W are a group unit.

→ The trunk link frame may be subdivided into two or three link frames like local office link frame. etc.

organisation of a crossbar Exchange.



- Line units are two way units, they can be used for originating as well as terminating calls.
- The group unit is a unidirectional device, it receives the calls from the line units and reroute the calls. It is capable of handling calls of local, outgoing, incoming, terminating and transit calls.
- In crossbar exchange, the call processing progresses in three stages: preselection, group selection and line selection.
 - 1) which is performed by the originating marker, starts from the moment the subscriber lifts the handset.
 - 2) In group selection stage the call is switched through the desired direction. The direction is decided in accordance with code given by translator.
 - 3) In the line selection the calling subscriber is connected to called subscriber by terminating marker.

Red box