Subject Name: Mobile Computing and Wireless Communication
Subject Code: 3170710

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CHAPTER NO – 2: Cellular Wireless Networks:

TOPIC 1. Cellular Wireless Networks

DESCRIPTIVE QUESTIONS

1. Explain the differences between 1G, 2G, 2.5G and 3G mobile communications.**(June-2012)[L.J.I.E.T]** 7,
what are the essential functional differences between 1st generation, 2nd generation and 3rd generation of networks?**(Dec-2012)[L.J.I.E.T]** 4,
What are the essential functional differences between 1st generation, 2nd generation and 3rd generation of networks? **[New] (May-2015)[L.J.I.E.T]** 7,
Explain: 2G v/s 3G.**[New] (Dec-2015)[L.J.I.E.T]** 4

2. Write short note on: 1G, 2G, 2.5G and 3G mobile communications. **[New] (Dec-2013)[L.J.I.E.T]** 7,
Explain the 1G, 2G, 2.5G and 3G Mobile Communications. **(May-2018)[L.J.I.E.T]** 7

3. Explain 3G networks. How is a 3G network different from a 2G CDMA network? **[New] (Dec-2016)[L.J.I.E.T]** 7

	1G	**2G**	**2.5G**	**3G**	**4G**
Year of introduction	1980	1993	1997	2001	2009
Location of First Commerce	USA	Finland	Finland	Japan	South Korea
Technology	AMPS (Advance Mobile Phone System) , NMT (Nordiac Mobile Telephone) , NIT (Nippen Telegraph and Telelphone) , ETACS (Enhanced Total Access Communication System)	IS-95 (Interim Standard – 95), GSM (Global System Mobile), IS-136 (Interim Standard – 136), PDC (Pacific Digital Cellular)	GPRS (General Packet Radio Service), EDGE (Enhanced Data rate for GSM Evolution), HSCSD (High Speed Circuit Switched Data)	IMT-2000 (International Mobile Telephone), WCDMA (Wideband Code Division Multiple Access), TD-SCDMA (Time Division Synchronous Code Division Multiple Access), UMTS (Universal Mobile Telecommunication Service)	WIMAX, LTE (Long Term Evolution) , WIFI
Type of Switching	Circuit Switching	Circuit switching for voice and	Packet	Packet	Packet

		packet switching for data			
Multiple Access	FDMA	TDMA, CDMA	TDMA, CDMA	CDMA	CDMA
Data Rates	2.4-14.4 kbps	14.4 kbps	20-40 kbps 171.2 kbps for gprs	3.1 mbps	100 mbps
Supports	Voice only	Data, voice and SMS	Data, Voice, SMS, MMS	Data and Voice	Data and Voice
Internet	No internet	Narrowband	Narrowband	Broadband	Ultra-broadband
Operating frequency	800 MHz	GSM 900-1800 MHz CDMA 800 MHZ	GPRS 850-1900 MHz	2100 MHz	850-1800 MHz
Carrier Frequency	30 KHz	200 KHz	200 KHz	5MHz	15 MHz
Bandwidth	Analog	25 MHz	25 MHz	25 MHz	100 MHz
Handoff	Horizontal	Horizontal	Horizontal	Horizontal and Vertical	Horizontal and Vertical
Advantages	Network Elements are simple and easy to use	SIM and Internet Starts	Supports SMS and MMS, High speed internet	High security International Roaming	High Speed
Disadvantage	1) Limited capacity 2) Susceptible to noise 3) Frequent call drop 4) Poor battery life 5) Poor handoff	1) Slow Data rate 2) Low Network range	Low Network range	1) High Power Consumption 2) High cost of spectrum licenses	1) Difficult Implementation 2) Needs complex hardware
Application	Voice calls	Voice calls , SMS,FAX	Voice call, SMS, MMS, VPN	Voice call, SMS, MMS, VPN, Mobile TV, GPS, Video conferencing, VoIP	Voice call, SMS, MMS, VPN, Mobile TV, GPS, High speed Applications, Mobile Web access

TOPIC 2. Antennas and Propagation

DESCRIPTIVE QUESTIONS

1. What is antennas? Explain types of antennas. **[L.J.I.E.T]** 7

- In radio, an **antenna** is the interface between radio waves propagating through space and electric currents moving in metal conductors, used with a transmitter or receiver.
- Antenna radiate and receive electromagnetic waves.
- So, it must be capable of radiating or receiving the electromagnetic waves.

- It converts high frequency current into electromagnetic waves at transmitter and converts electromagnetic waves received by the receiving antenna to a high frequency electric current.

Application:

- Wireless Communication
- Mobile Communication
- Broadcast system
- Microwave Linking
- Satellite communication

Radiation pattern:

There are two radiation pattern for antenna:

1. **Directional antenna:** It radiates in single straight direction. Real antennas all exhibit directive effects, i.e., the intensity of radiation is not the same in all directions from the antenna. The simplest real antenna is a thin, center-fed dipole, also called Hertzian dipole. A dipole has a uniform or omni-directional radiation pattern in one plane and a figure eight pattern in the other two planes as shown in Figure 2.7

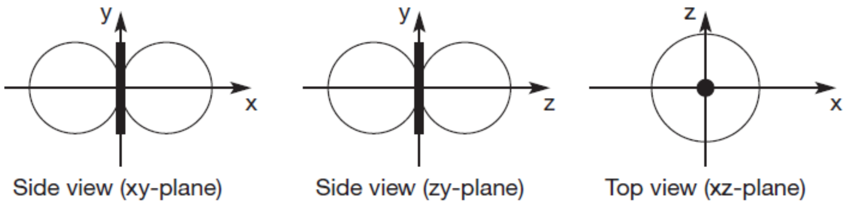
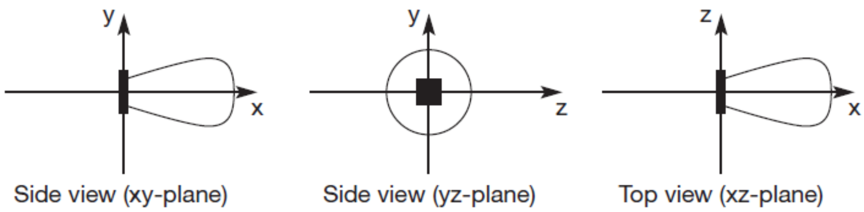


Figure 2.7
Radiation pattern of a simple dipole

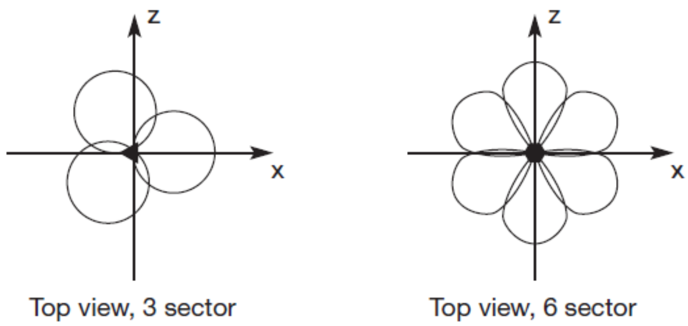
Figure 2.8 shows the radiation pattern of a directional antenna with the main lobe in the direction of the x-axis. A special example of directional antennas is constituted by satellite dishes.

Figure 2.8
Radiation pattern of a directed antenna



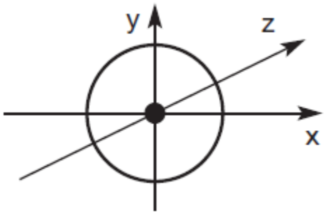
Directed antennas are typically applied in cellular systems. Several directed antennas can be combined on a single pole to construct a sectorized antenna. A cell can be sectorized into, for example, three or six sectors, thus enabling frequency reuse. Figure 2.9 shows the radiation patterns of these sectorized antennas.

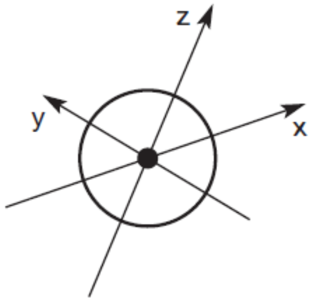
Figure 2.9
Radiation patterns of sectorized antennas



2. **Isotropic or Omnidirectional:** It radiates in all directions. A point in space radiating equal

power in all directions, i.e., all points with equal power are located on a sphere with the antenna as its center. The radiation pattern is symmetric in all directions





Types of Antenna:

1. **Linear wire antennas:** They are used at VHF (very high frequency) and UHF (ultra-high frequency) .

- They are observed at the top of the buildings, automobiles etc.
- It is difficult to mount on vehicle.

2. **Horn Antenna:** It is used at microwave frequency.

- They may have a horn whose aperture is square, circle, rectangle etc.
- Used for super craft applications. They can be mounted on the surface of spacecraft or aircraft.
- Used as feeds for reflectors either singly or in cluster
- They are example of aperture antenna.
- Antenna gain is up to 23 db.
- For high gain value, high gain reflectors and array must be used.

3. **Corner Reflectors:** Antenna shape depends on the frequency band for which it is designed.

- Used for all frequency band
- At microwave frequency, Physical size of antenna becomes small to practically construct metallic curved reflectors to produce desired gain and directivities.
- Example: Parabolic reflectors, parabolic microwave dish, Corner reflector antenna.

4. **Array Antenna:**

- Requires High gain to meet the receiver of long distance communication.
- It can be obtained by increasing the electrical size of antenna.
- But enlarging the dimensions of single element leads to more directive characteristics.
- To avoid this an assembly of radiating elements is formed in an electrical and geometrical configuration.
- The new antenna comprising multi element is called as an array.
- It is used to increase the directivity.
- Any power pattern can be obtained.

5. **Yagi Antenna:**

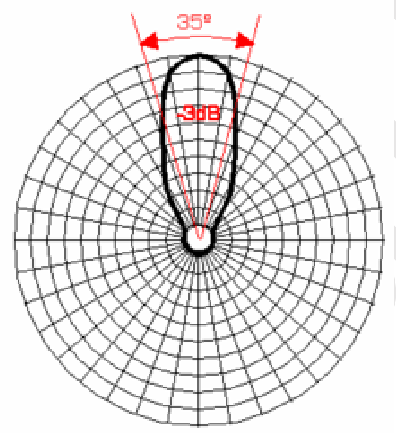
- It is Inexpensive and effective
- It can be constructed with one or more reflector element and one or more director element.

2. What is Antenna Gain? Explain with its formula **(Nov-2017)[L.J.I.E.T]** 3

Some definition:

Radiation Intensity: It is defined as the power per unit solid angle.

Directive gain: The ratio of the power density radiated in that direction by an isotropic antenna to that

	by a directional antenna. Directive gain =Power density in Isotropic / Power density in directional **Directivity:** It is maximum directive gain which is obtained in only one direction in which the radiation is maximum. **Power Gain (Ap):** Power gain of an antenna is defined as ration of power fed to an isotropic antenna to the power fed to a directional antenna, to develop the same field strength at the same distance, in the direction of maximum radiation. Power gain = Power fed to isotropic antenna / Power fed to directional antenna Ap = ŋ D where D= directivity and ŋ = Antenna Efficiency **Bandwidth of antenna**: It is defined as the frequency range over which the operation is satisfactory. **Beamwidth of antenna:** It is defined as the angular separation between the two half power points (-3db) on the power density radiation pattern. Or it can be defined as the angular separation between two 3 db down points on the field strength of radiation pattern of antenna. BeamWidth is expressed in degrees.  	

3.	Explain different types of Propagation Mode. **[New] (Winter-2012) [L.J.I.E.T]**
	
	➢ In connection with signal propagation, these two networks exhibit considerable differences.
	➢ In wireless networks, the signal has no wire to determine the direction of propagation, whereas signals in wired networks only travel along the wire (which can be twisted pair copper wires, a coax cable, but also a fiber etc.).
	➢ As long as the wire is not interrupted or damaged, it typically exhibits the same characteristics at each point. One can precisely determine the behaviour of a signal travelling along this wire, e.g., received power depending on the length.
	➢ For wireless transmission, this predictable behaviour is only valid in a vacuum, i.e., without matter between the sender and the receiver. The situation would be as follows (Figure 2.11):
	  o **Transmission range**: Within a certain radius of the sender transmission is possible, i.e., a receiver receives the signals with an error rate low enough to be able to communicate and can also act as sender.
	  o **Detection range**: Within a second radius, detection of the transmission is possible, i.e., the transmitted power is large enough to differ from background noise. However, the error rate is too high to establish communication.
	  o **Interference range**: Within a third even larger radius, the sender may interfere with other transmission by adding to the background noise. A receiver will not be able to detect the signals, but the signals may disturb other signals.
		7

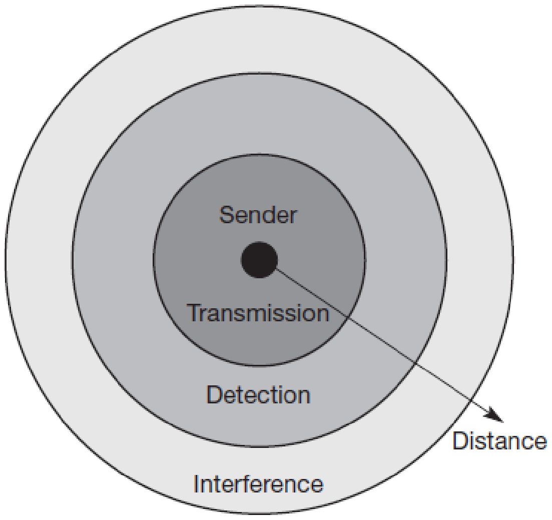


Figure 2.11
Ranges for transmission, detection, and interference of signals

Type of propagation:

1. Ground wave of surface wave (< 2MHz):

- It is guided along the surface of earth. Radio waves in the VLF band propagate in a ground, or surface wave. The wave is connected at one end to the surface of the earth and to the ionosphere at the other.
- The ionosphere is the region above the troposphere (where the air is), from about 50 to 250 miles above the earth.
- It is a collection of ions, which are atoms that have some of their electrons stripped off leaving two or more electrically charged objects. The sun's rays cause the ions to form which slowly modified.
- The propagation of radio waves in the presence of ions is drastically different than in air, which is why the ionosphere plays an important role in most modes of propagation.
- Ground waves travel between two limits, the earth and the ionosphere, which acts like a channel. Since the channel curves with the earth, the ground wave will follow. Therefore very long range propagation is possible using ground waves.
- This propagation exist when the Transmitter and receiver antenna are close to the surface of the earth and is supposed at the lower edge by the presence of ground.
- The Ground wave is produced by vertical antenna (Vertical polarized).
- The wave energy can be lost by absorption.
- It suffers from varying amount of attenuation because of curvature of earth,
  - Frequency surface irregularities
  - Permittivity
  - Conductivity
- As frequency increases attenuation also increases, so suitable for low and medium frequency up to 2 MHz.

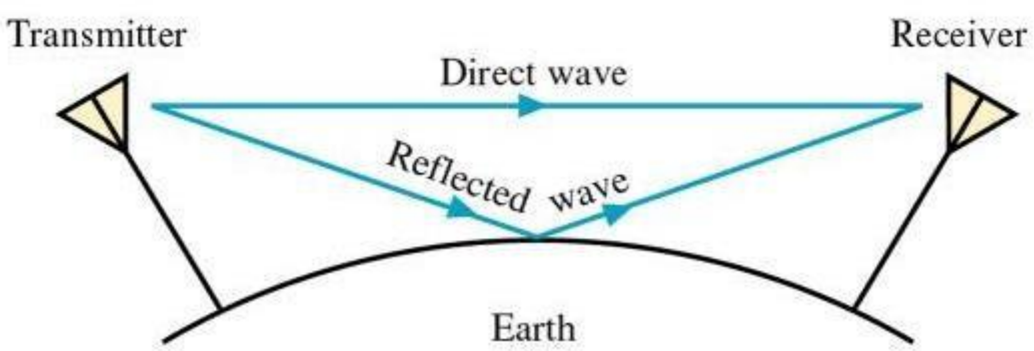
Advantages:

- Transmitted power is large enough, then ground wave propagation can be used to communication between any two points.
- Atmospheric condition do not affect too much.

Disadvantages:

- Limited range for higher operating frequency
- Tall antenna should be used for low operating frequency. Height of antenna should be (λ/4)

- High transmission power is necessary to cover the adequate range

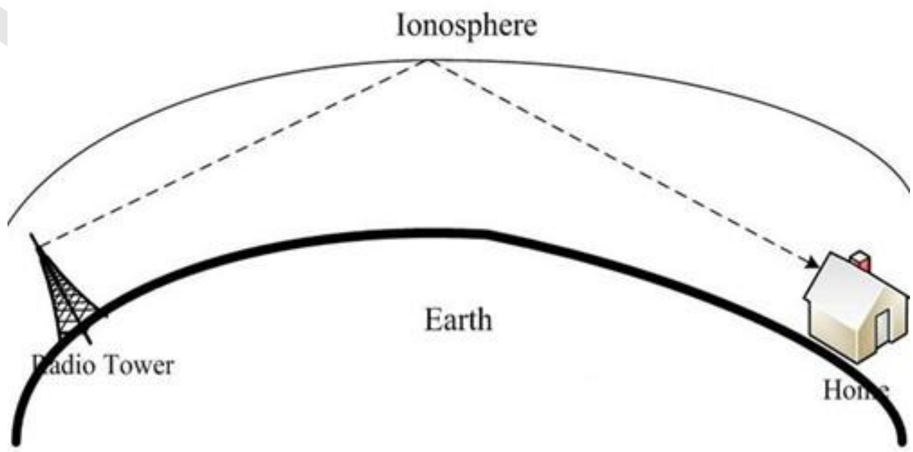


Application:

- AM Radio Broadcasting operating in Microwave band
- Radio navigation and marine mobile communication
- VLF is also used for time and frequency transmission.

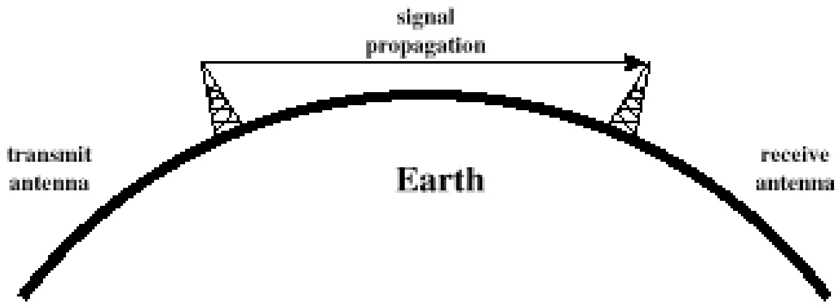
2. Sky wave or Ionospheric Propagation (2- 30 MHz):

- Radio waves in the LF and MF ranges may also propagate as ground waves, but suffer significant losses, or are attenuated, particularly at higher frequencies. But as the ground wave mode fades out, a new mode develops: the sky wave.
- Radio wave is reflected back to earth from ionised region in the upper atmosphere called ionosphere. While the wave is in the ionosphere, it is strongly bent, or refracted, ultimately back to the ground.
- Many international broadcasts and amateur radio use these short waves that are reflected2 at the ionosphere. This way the waves can bounce back and forth between the ionosphere and the earth's surface, travelling around the world.
- Sky waves in this frequency band are usually only possible at night, when the concentration of ions is not too great since the ionosphere also tends to attenuate the signal.
- However, at night, there are just enough ions to reflect the wave but not reduce its power too much.
- Waves above 30 MHz frequency does not reflect back they penetrate the ionosphere, so it is suitable for 2 MHz to 30 MHz short wave propagation.
- Long distance point to point communication is possible.
- Signals are subjected to fading



3. Space wave Propagation or Line- of sight Propagation (> 30 MHz):

- It is also known as line of sight propagation.
- Mobile phone systems, satellite systems, cordless telephones etc. use even higher frequencies. The emitted waves follow a (more or less) straight line of sight. This enables direct communication with satellites (no reflection at the ionosphere) or microwave links on the ground. However, an additional consideration for ground-based communication is that the waves are bent by the atmosphere due to refraction.
- The distant covered by this waves is slightly larger than line of sight due to refraction in earth atmosphere.
- For this waves frequency above 30 MHz is used.
- This waves travels in a straight line directly from the transmitting antenna to the receiving antenna.
- Due to straight line nature waves can be blocked because of curvature of earth.
- Antenna must be tall enough for this kind of propagation.



Applications:

- Transmitting and receiving antennas must be within line of sight
  - Satellite communication – signal above 30 MHz not reflected by ionosphere
  - Ground communication – antennas within effective line of site due to refraction
- Microwaves and appliances like TV, Radar, Frequency modulation

1. What are propagation modes? Explain free Space loss propagation modes in details? **(May-2017) [L.J.I.E.T]** 7

2. Explain in brief LOS wireless transmission and its significant impairments. **[L.J.I.E.T]** 7

- Free space radio signals propagate light does (Independently of their frequency) they follow as straight line.
- Even if no matter exists between sender and receiver the signal still experiences the free space loss.
- The received power Pr is directly proportional to d^2, where d= distance between sender and receiver.
- Receiver power also depends on the wavelength and the gain of receiver and transmitters antennas.
- This is only in vacuum condition but in real situation becomes more complex due to signal travel through air, rain, snow, fog, dust particles.
- Path loss or attenuation does not cause too much trouble for short distance.
- Reasons for significant impairments of LOS:

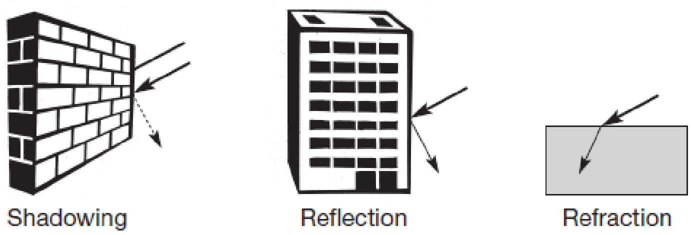
1. When Obstacle present:

1. **Blocking or shadowing:** An extreme form of attenuation is blocking or shadowing of radio signals due to large obstacles. The higher the frequency of a signal, the more it behaves like light. Even small obstacles like a simple wall, a truck on the street, or trees in an alley may block the signal.
2. **Reflection:** If an object is large compared to the wavelength of the signal, e.g., huge buildings, mountains, or the surface of the earth, the signal is reflected. The reflected

signal is not as strong as the original, as objects can absorb some of the signal's power. Reflection helps transmitting signals as soon as no LOS exists. This is the standard case for radio transmission in cities or mountain areas. Signals transmitted from a sender may bounce off the walls of buildings several times before they reach the receiver. The more often the signal is reflected, the weaker it becomes

3. **Refraction:** This effect occurs because the velocity of the electromagnetic waves depends on the density of the medium through which it travels. Only in vacuum does it equal c. As the figure shows, waves that travel into a denser medium are bent towards the medium. This is the reason for LOS radio waves being bent towards the earth the density of the atmosphere is higher closer to the ground.

Figure 2.12
Blocking (shadowing), reflection and refraction of waves



4. **Scattering:** If the size of an obstacle is in the order of the wavelength or less, then waves can be scattered. An incoming signal is scattered into several weaker outgoing signals.
5. **Diffraction:** this effect is very similar to scattering. Radio waves will be deflected at an edge and propagate in different directions. The result of scattering and diffraction are patterns with varying signal strengths depending on the location of the receiver.

Figure 2.13
Scattering and diffraction of waves

6. **Multipath Propagation:** Radio waves emitted by the sender can either travel along a straight line, or they may be reflected at a large building, or scattered at smaller obstacles.

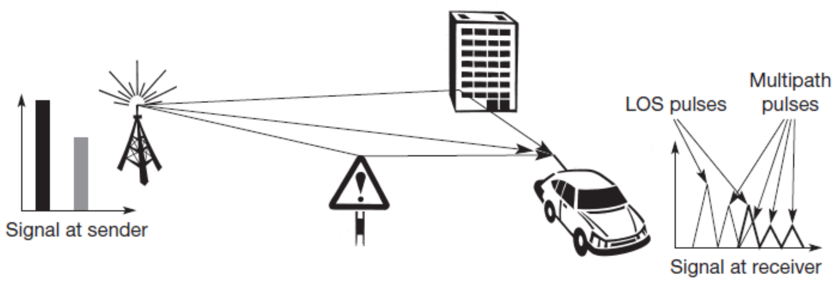


Figure 2.14
Multi-path propagation and intersymbol interference

- This simplified figure only shows three possible paths for the signal. In reality, many more paths are possible.
- As there is no direct LOS (line of sight), multiple reflections from different objects causes the radio waves to travel along different paths of varying lengths resulting in fading. The interaction between these waves causes multipath propagation at a particular location.
- As distance between transmitter and receiver increases the strength of the waves decreases.

- Due to the finite speed of light, signals travelling along different paths with different lengths arrive at the receiver at different times. This effect (caused by multi-path propagation) is called delay spread: the original signal is spread due to different delays of parts of the signal.
- This delay spread is a typical effect of radio transmission, because no wire guides the waves along a single path as in the case of wired networks.
- Notice that this effect has nothing to do with possible movements of the sender or receiver.
- Typical values for delay spread are approximately 3 μs in cities, up to 12 μs can be observed.
- For a real situation with hundreds of different paths, this implies that a single impulse will result in many weaker impulses at the receiver. Each path has a different attenuation and, the received pulses have different power.
- Some of the received pulses will be too weak even to be detected.
- At the receiver, both impulses interfere, i.e., they overlap in time. Now consider that each impulse should represent a symbol, and that one or several symbols could represent a bit. The energy intended for one symbol now spills over to the adjacent symbol, an effect which is called inter symbol interference (ISI).
- The higher the symbol rate to be transmitted, the worse the effects of ISI will be, as the original symbols are moved closer and closer to each other. ISI limits the bandwidth of a radio channel with multi-path propagation (which is the standard case).

7. **Noise:** Noise are the unwanted signals that are transmitted in addition to the distortions in the transmitted signal.

- It greatly impact the system performance.
- Different types of noise are:

1. Thermal Noise: It is the noise generated by active and passive devices because thermal agitation process of electrons.

→ Also known as white noise or Johnson-Nyquist noise.
→ It is a function of system temperature
→ It is significant in satellite communication receivers.
→ It can not be eliminated. This restricts the system performance.
→ Thermal noise is expressed as,

$$N_0 = KTB$$

Where , N_0 = Noise Power density
K = Boltsman Constant = $1.39 * 10^{-23}$ J/K
T= Temperature in K

2. Intermodulation Noise: when there is some non-linearity in the transmitting system or receiving system intermodulation noise is produced.

→ It results in signals that are at a frequency that is the sum or difference of the two given frequencies or their multiples.
→ Non linearity in the elements is because of malfunctioning of the different components.

3. Cross talk: cross talk is the unwanted coupling between the signal paths that is observed when different users are talking on the telephone line and some user can listen to that conversation.

→ It can also be a result of unwanted signals picked up by the microwave antennas.
→ Magnitude of crosstalk is almost sum or less than that of thermal noise.

→ Cross talk is a dominating factor in unlicensed ISM bands.

4. Impulse Noise: It comprises of short duration noise spikes or irregular pulses having high amplitudes.

→ The sources of impulse noise are electromagnetic disturbance like thunderstorms, lighting, errors and faults in the communication system.
→ It introduces errors in digital data transmission.
→ For evaluating digital data rates and error rates in digital communication (Eb/N0) is a parameter related to SNR.
→ (E_b/N_0) parameter is ratio of signal energy per bit to noise power density.
→ Let R be bit rate then energy per bit is given by

$$E_b = S\,T_b$$

→ Where, E_b = energy per bit, S= signal power, T_b = time required for transmitting a bit.
→ The data rate is,

$$R = 1 / T_b$$
$$(E_b/N_0) = S/R/N_0$$
$$(E_b/N_0) = S / KTBR$$

2. No obstacle:

Free Space Loss:

1. Attenuation & attenuation distortion:

→ When a signal is transmitted its signal strength decreases as the distance increases. This Phenomenon is called attenuation.
→ At higher frequencies, the attenuation is greater. This causes distortion called as attenuation distortion.
→ The signal strength of the received signal should be sufficient enough for electric circuit at the receiver end to detect and indicated the signal.

2. Atmospheric Attenuation:

→ In the atmosphere at microwave frequencies the electromagnetic waves interact with the molecules to cause signal attenuation.
→ However at some frequencies atmospheric absorption can occur and as a result there can be atmospheric attenuation.
→ Losses that are related to weather are termed as atmospheric attenuation.
→ Losses that are related absorption are termed as atmospheric absorption.

3. Free space loss: The free space loss propagation model is used for measurement of received signal strength when the transmitter and receiver of the communication system have clear line of sight between the transmitter and receiver.
There is no obstacle between transmitter and receiver.
FSP model predicts the received power delay level as a function of the transmitter and receiver separation distance.
The Friss free space euation,

→ The friss free space equation,

Power received at receiver antenna is given by,

$$\boxed{P_R(d) = \frac{P_T G_T G_R \lambda^2}{(4\pi)^2 d^2 L}} \quad \text{----- (1)}$$

where, $P_R(d)$ = free space received power

P_T = Transmitted power

G_T = Transmitter antenna gain

G_R = Receiver antenna gain

d = distance between Transmitter and Receiver in meters

L = system loss factor ($L \geq 1$)

λ = wavelength in meters

→ If effective aperture of antenna is A_e then gain of antenna is,

$$G_e = \frac{4\pi A_e}{\lambda^2}$$

$$\Rightarrow \boxed{A_e = \frac{G_e \lambda^2}{4\pi}} \quad \text{----- (2)}$$

→ Relation between λ and f will be given by,

$$\lambda \propto \frac{1}{f} \Rightarrow \boxed{\lambda = \frac{c}{f}} \quad \text{----- (3)}$$

where f = frequency
c = speed of light in mps

→ $L = 1$ indicates that no Loss in the system.

→ The free space loss is given as ratio of the radiated power P_t to the received power P_R (P_t / P_R)

→ Unit of free space loss is desible (db). So,

$$\boxed{\left(\frac{P_t}{P_R}\right)_{db} = 10 \log_{10} \left(\frac{P_t}{P_R}\right)}$$

→ By equation (1),

$$\boxed{\frac{P_t}{P_R} = \frac{(4\pi)^2 d^2}{G_T G_R \lambda^2}} \quad (\because L = 1)$$

→ We can find free space loss considering gain of antenna and without considering gain of antenna,

Case 1 Consider antenna gain

$$\frac{P_t}{P_R} = \frac{(4\pi)^2 d^2}{G_T G_R \lambda^2}$$

$$= \frac{4\pi}{G_T \lambda^2} \times \frac{4\pi}{G_R \lambda^2} \times \lambda^2 d^2$$

$$= \frac{1}{A_T} \times \frac{1}{A_R} \times \lambda^2 d^2 \quad (\because eq (2))$$

$$\boxed{\left(\frac{P_t}{P_R}\right)_\lambda = \frac{\lambda^2 d^2}{A_T A_R}}$$

$$\boxed{\left(\frac{P_t}{P_r}\right)_f = \frac{c^2 d^2}{f^2 A_t A_r}} \quad (\because eq (3))$$

Case - 2 without considering gain

$$\boxed{\left(\frac{P_t}{P_r}\right)_\lambda = \frac{(4\pi)^2 d^2}{\lambda^2}} \quad (\because G_t = G_R = 1)$$

in decible,

$$\left(\frac{P_t}{P_r}\right)_{\lambda\, db} = 10 \log_{10} \frac{P_t}{P_r}$$

$$= 10 \log_{10} \left(\frac{4\pi d}{\lambda}\right)^2$$

$$= 20 \log_{10} \left(\frac{4\pi d}{\lambda}\right)$$

$$\boxed{\therefore \left(\frac{P_t}{P_r}\right)_{\lambda\, db} = -20 \log \lambda + 20 \log d + 21.98 \text{ db}}$$

$$\Rightarrow \boxed{\left(\frac{P_t}{P_r}\right)_f = \frac{(4\pi)^2 f^2 d^2}{c^2}} \quad (\because eq (3))$$

in decible

$$\left(\frac{P_t}{P_r}\right)_{f\, db} = 10 \log_{10} \frac{P_t}{P_r}$$

$$= 10 \log_{10} \left(\frac{4\pi f d}{c}\right)^2$$

$$= 20 \log_{10} \left(\frac{4\pi f d}{c}\right)$$

$$= 20 \log_{10} (4\pi/c) + 20 \log_{10} f + 20 \log_{10} d$$

$$\boxed{\therefore \left(\frac{P_t}{P_r}\right)_{f\, db} = 20 \log_{10}(f) + 20 \log_{10}(d) - 147.56 \text{ db}}$$

3. What is fading? Differentiate [**New**]**(Nov-2016) [L.J.I.E.T]** — 7

i. Fast and slow fading

ii. Flat and selective fading.

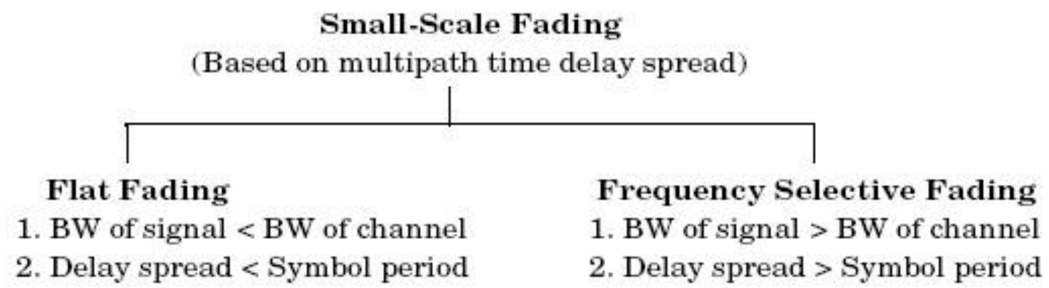
4. Explain the term Fading and its types in the Mobile Environment in detail.**(May-2018)[L.J.I.E.T]** — 7

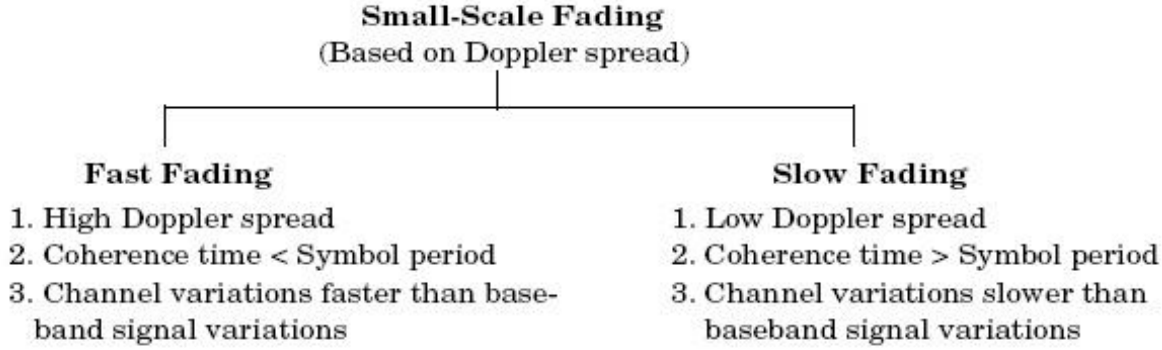
Note:

- **Coherence bandwidth:** It is a statistical measurement of the range of frequencies over which two frequencies over which the channel can be considered approximate maximum bandwidth or frequency interval over which two frequencies of a signal are likely to experience comparable or correlated amplitude fading.
- **Delay Spread:** It is a measure of the multipath richness of a communication channel difference in received and transmitted signal in multipath channel.
- **Doppler shift**: frequency shift at receiver in multipath channel is referred to as Doppler shift.
- **RMS delay spread**: It is a root mean square value of delay spread.

ANSWER:

- Fading is used to explain the quick changes or fluctuations in the amplitude, frequency or phase of the signal over a short period of time.
- Due to effect of multipath signal the multipath signal combines at receiver will vary in amplitude and phase depending upon the distributions of intensity, relative propagation time of waves and bandwidth of transmitted signal.
- Fading: In wireless communication, It is variation of the attenuation of a signal with various variables like time, geographical position and radio frequency.
- Fading is of two types:
  1. Small scale fading: Short distance
  2. Large scale fading: Long distance





- **Flat Fading:**

  → Such types of fading occur when the bandwidth of the transmitted signal is less than the coherence bandwidth of the channel. Equivalently if the symbol period of the signal is more than the rms delay spread of the channel, then the fading is Flat fading.

→ So we can say that at fading occurs when $B_S << B_C$

→ Where B_S is the signal bandwidth and B_C is the coherence bandwidth. Also,

$$T_S >> \sigma_r$$

→ Where T_S is the symbol period and σ_r is the rms delay spread. And in such a case, mobile channel has a constant gain and linear phase response over its bandwidth.

→ In flat fading the amplitude of the received signal varies in gain, but all frequency components of the signal experience the same magnitude of fading and the spectrum of transmitted signal is not distorted.

- **Frequency Selective Fading:**

→ Frequency selective fading occurs when the signal bandwidth is more than the coherence bandwidth of the mobile radio channel or equivalently the symbols duration of the signal is less than the rms delay spread.

$B_S >> B_C$ and $T_S << \sigma_r$

→ At the receiver, we obtain multiple copies of the transmitted signal, all attenuated and delayed in time. The channel introduces inter symbol interference.

→ In frequency domain, different component of the signal may be affected differently by the channel and the spectrum of the transmitted signal will be distorted at the receiver.

- **Fast Fading:**

→ In a fast fading channel, the channel impulse response changes rapidly within the symbol duration of the signal. Due to Doppler spreading, signal undergoes frequency dispersion leading to distortion.

→ Therefore a signal undergoes fast fading if

$T_S >> T_C$

→ Where T_C is the coherence time and $B_S >> B_D$

→ Where B_D is the Doppler spread. Transmission involving very low data rates suffers from fast fading.

- **Slow Fading:**

→ In such a channel, the rate of the change of the channel impulse response is much less than the transmitted signal.

→ We can consider a slow faded channel a channel in which channel is almost constant over at least one symbol duration. Hence

$$T_S << T_C \text{ and } B_S >> B_D$$

→ We observe that the velocity of the user plays an important role in deciding whether the signal experiences fast or slow fading.

TOPIC 3. Modulation Techniques

DESCRIPTIVE QUESTIONS

1.	Explain ASK, FSK , PSK, QPSK in Detail. **[L.J.I.E.T]**	7
2.	Explain Delta Modulation with their Transmission and Reception block diagram? **(May-2017) (Nov-2017) [L.J.I.E.T]**	7,

	Enlist and Expain the different Modulation Techniques in the signal theory. **(May-2018) [L.J.I.E.T]**	
3.	What is the bandwidth efficiency for FSK, ASK, PSK and QPSK for a bit error rate of 10^{-7} on a channel with an SNR of 12 dB? **[New] (Nov-2016)[L.J.I.E.T]**	7
	TOPIC 4. Spread Spectrum	
	DESCRIPTIVE QUESTIONS	
1.	What is spread spectrum technology? Compare it with narrow band. **[New](June-2014) [L.J.I.E.T]**	7

Answer:

- **There are several problems in communication system:**
  1. Utilization of channel bandwidth effectively.
  2. Minimizing of amount of transmitted power.
  3. security
  4. Channel should immune to any kind of external interference.

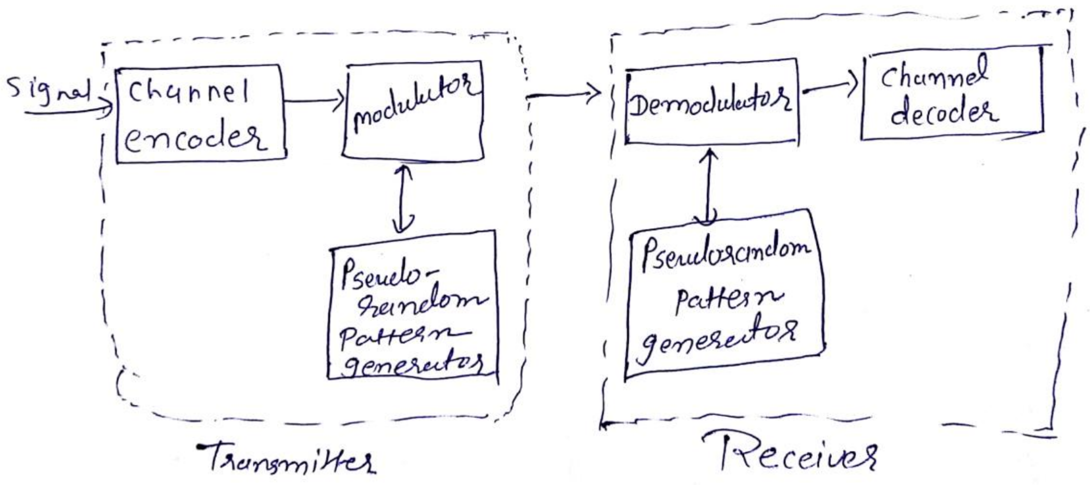
→ This all problems can be solved by " Spread Spectrum Modulation"

- **Characteristics of spread spectrum signal:**
  1. Spread spectrum signal is "Pseudorandom" signal. So it appears like random noise.
  2. It occupies a large bandwidth than original signal so transmitting power is less.
  3. It uses some kind of coding by this coding the signal information is independent of spread spectrum signal.
  4. Separation of noise and original signal is possible.

→ Mobile phone technology had a reincarnation from first generation analogue (using FDMA) to second generation digital (using TDMA)
→ The next incarnation is from second generation digital TDMA to third generation packet (using CDMA)
→ CDMA is a specific modulation technique of Spread-Spectrum technology.
→ In a conventional transmission system, the information is modulated with a carrier signal and then transmitted through a medium.
→ When that transmitted, all the power of the signal is transmitted centered around a particular frequency. This frequency represents a specific channel and generally has a very narrow band.
→ In spread-spectrum we spread the transmission power over the complete band as shown in figure.
→ In spread-spectrum the transmission signal bandwidth is much higher than the information bandwidth.

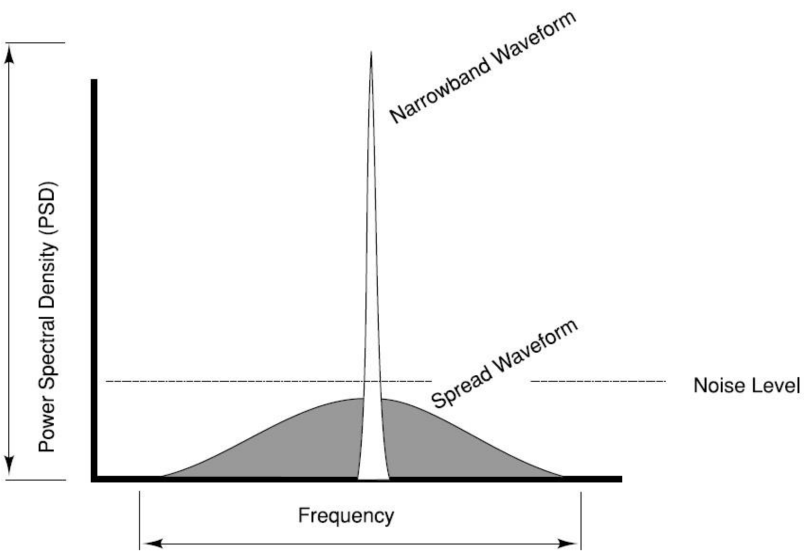
Block Diagram:

→ There are numerous ways to cause a carrier to spread; however, all spread-spectrum systems can be viewed as two steps modulation processes.
→ First, the data to be transmitted is modulated.
→ Second, the carrier is modulated by the spreading code, causing it to spread out over a large bandwidth



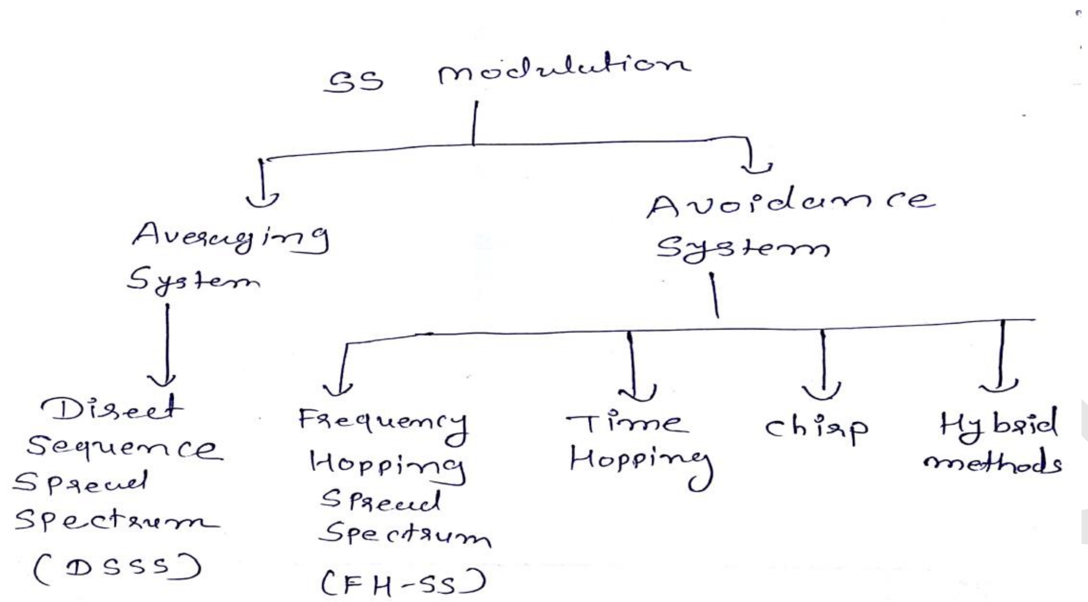
Disadvantages:

1. Complexity of receiver that have to dispread a signal.
2. Large frequency band that is needed due to the spreading of the signal.
3. Spread signal appear more like noise, they still raise the background noise level and may interfere with other transmissions if no special precautions are taken.



2. Explain various spreading techniques used in spread spectrum. **[New](May-2017)[L.J.I.E.T]** 7

- SS modulation technique is classified depending upon their operating concept. The spread spectrum may be averaging type or avoidance type.
- **Averaging System:** In this system the interference is reduced by averaging it over the log period.
- **Avoidance system**: In those systems the interference is reduced by making the signal to avoid the interference at large fraction of time.



➢ **Different Spreading Techniques**

→ **Direct Sequence (DS):** DS spread spectrum is typically used to transmit digital information. A common practice in DS systems is to mix the digital information stream with a pseudo random code

→ **Frequency Hopping (FH):** Frequency hopping is a form of spreading in which the center frequency of a conventional carrier is altered many times within a fixed time period (like one second) in accordance with a pseudo-random list of channels.

→ **Chirp**: The third spreading method employs a carrier that is swept over a range of frequencies. This method is called chirp spread spectrum and finds its primary application in ranging and radar systems.

→ **Time Hopping**: The last spreading method is called time hopping. In a time-hopped signal, the carrier is on-off keyed by the pseudo-noise (PN) sequence resulting in a very low duty cycle. The speed of keying determines the amount of signal spreading.

→ **Hybrid System:** A hybrid system combines the best points of two or more spread-spectrum systems. The performance of a hybrid system is usually better than can be obtained with a single spread-spectrum technique for the same cost.

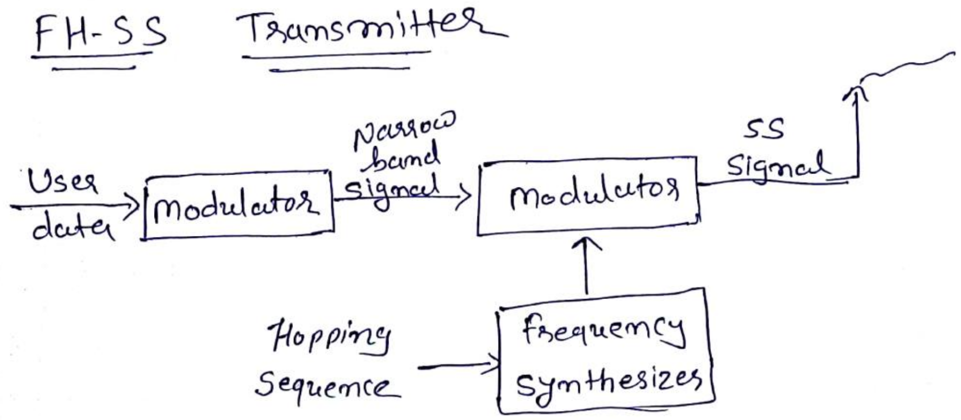
→ The most common hybrids combine both frequency-hopping and direct-sequence techniques.

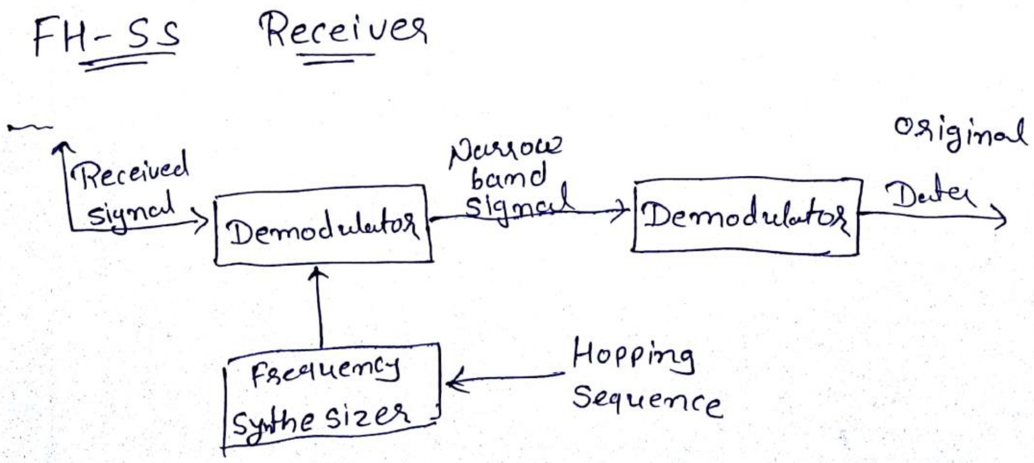
→ Amateurs and business community are currently authorized to use only two spreading techniques. These are frequency hopping and direct sequence techniques.

→ Rest of the Spread-Spectrum technologies are classified and used by military and space sciences.

3.	Define spreading sequence. List different categories of spreading sequences. Explain Walsh code with example. **[New] (Nov-2016) [L.J.I.E.T]**	7
4.	What is Walsh function? Explain it for CDMA orthogonal codes **(Winter-2013)(Summer-2015) [L.J.I.E.T]**	7, 7
5.	What is frequency hopping in spread spectrum? Explain TDMA in detail. **[New](Dec-2015) [L.J.I.E.T]**	7

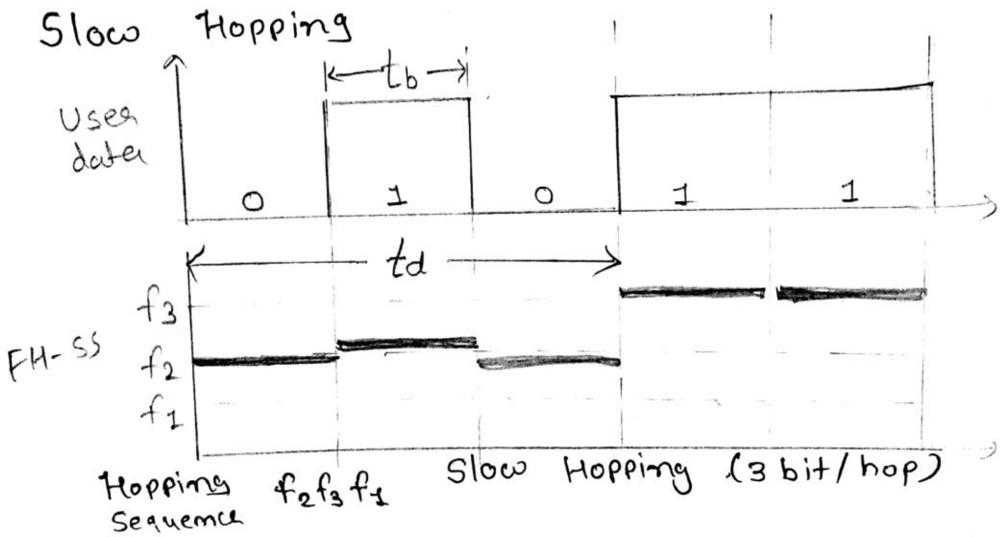
- **Block Diagram of FH-SS:**



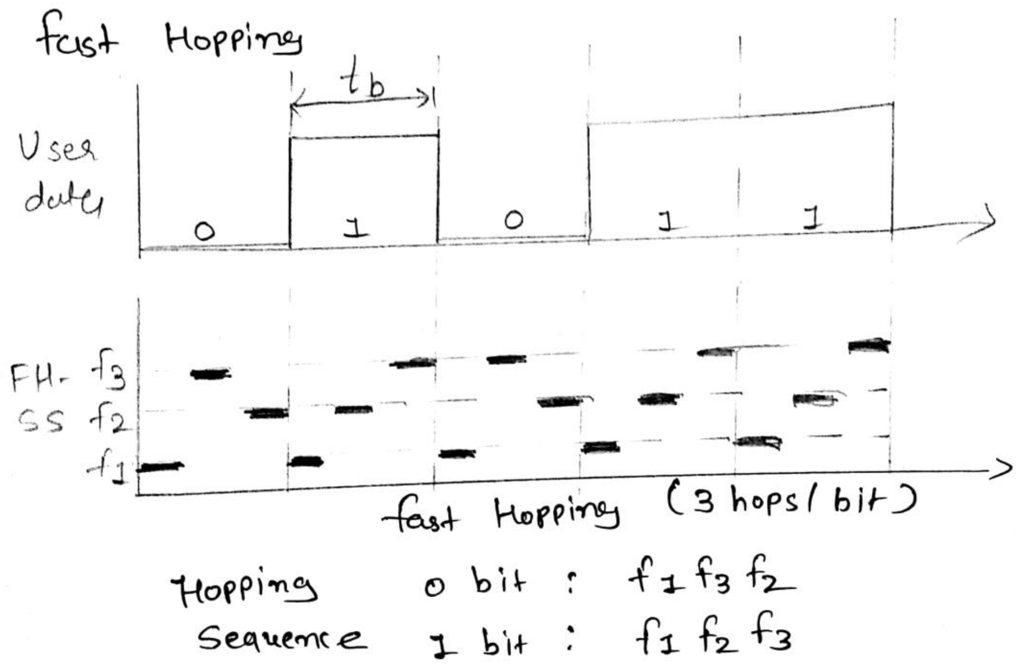


- In FH-SS system, the total available bandwidth is split into many channels of smaller bandwidth plus guard spaces between the channels.
- Transmitter and receiver stays on one of these channels for a certain time and then hop to another channel.
- The pattern of channel usage is called as the hopping sequence and the time spend on a channel with a certain frequency is called the Dwell time.
- FH-SS comes in two variants depending on the rate of frequency hopping.
  1. Slow frequency hopping
  2. Fast frequency hopping

- **Slow Frequency hopping:**
  - → In slow FH the symbol rate R_S of the MFSK signal is an integer multiple of the hop rate R_h
  - → That means several symbols are transmitted corresponding to each frequency hop
  - → Each frequency hope Implies several symbols
  - → Frequency hopping takes place slowly.
  - → In figure shows five user bits with a bit period T_b. performing slow hopping the transmitted uses the frequency f2 for transmitting the first three bits during the dwell time T_d.
  - → Then, the transmitter hops to the next frequency f3
  - → It is typically cheaper and have relaxed tolerances, but they are not as immune to narrowband interference as fast hopping system.
  - → Slow FH is an option for GSM.



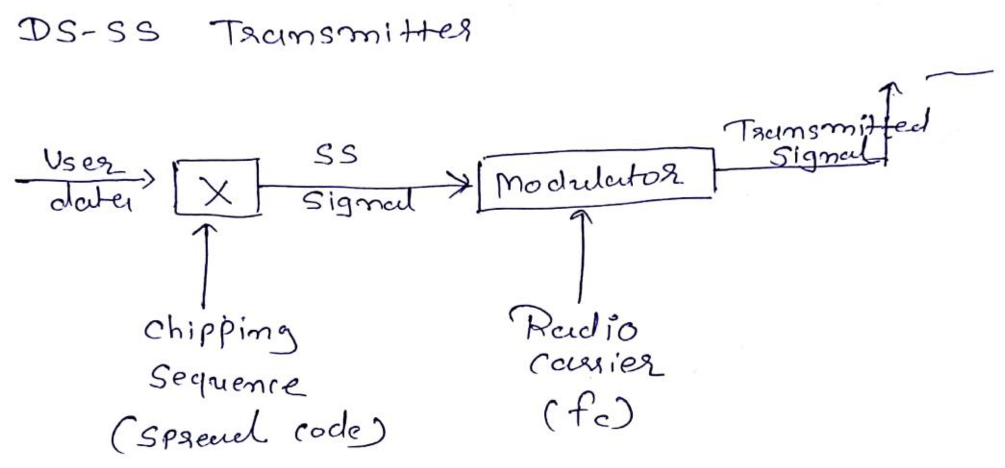
- **Fast Frequency hopping:**
  - → Fast FH is used for defeating a smart jammer who tries to interfere the transmission.
  - → The transmitter changes the frequency several times during the transmission of a single bit.
  - → In fast FH-SS system, there are multiple hops for each M-ary symbol.
  - → Hence, each hop is a "chip"
  - → In figure the transmitter hops three times during a bit period.
  - → Fast hopping systems are more complex to implement Transmitter and receiver have to stay synchronized within smaller tolerance to perform hopping at more or less the same points in time.
  - → Much better at overcoming the effects of narrow band interference and frequency selective fading.
  - → Much better at overcoming the effects of narrowband interference and frequency selective fading.
  - → Frequency synthesizer is used to synchronize transmitter and receiver with same hopping sequence applied.

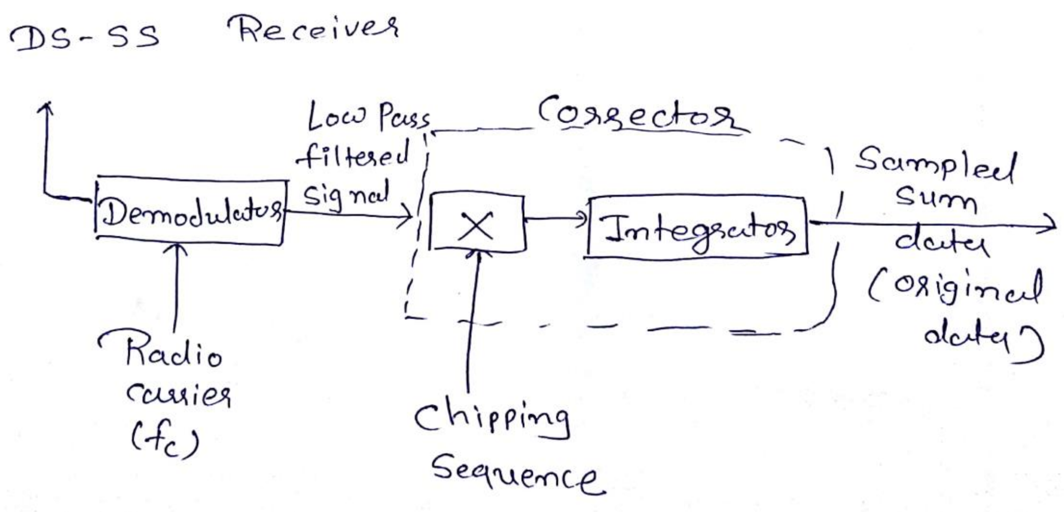


6.	Define frequency hopping in spread spectrum. Write Note on TDMA,FDMA,CDMA. **(Nov-2011) (May-2018)[L.J.I.E.T]**	7
7.	Explain the Direct Sequence Spread Spectrum Techniques.**[New] (May-2013)[L.J.I.E.T]** Explain in detail Direct Sequence Spread Spectrum Techniques (DSSS). **(Winter-2014)[New] (Dec-2013)(Summer-2015) (Nov-2017) (May-2018) [New] (May-2018)[L.J.I.E.T]** Explain Direct sequence spread spectrum with example. **[New] (May-2015)[L.J.I.E.T]** What is direct sequence spread spectrum technology? Explain how it works in the CDMA technology? **(Dec-2012) (Summer-2013) (May-2017)[L.J.I.E.T]** What is CDMA technology? Explain the Direct Sequence Spread Spectrum Techniques.**[New] (Dec-2014) [New] (May-2016) [L.J.I.E.T]**	6,7,7,7,7,7,7,7,7,7,7,7,7

ANS:

- The most important advantage of spread spectrum modulation is that it provides protection against externally generated interfering signals. Such signals are called as a jamming signal.
- The information bearing signal is made to occupy a bandwidth which is much larger than the minimum bandwidth required for its transmission.
- This will make the signal to appear like a noise and blends into the background.
- Every user assigned a special code that code is used to encode signal
- XOR technique is used to combine data stream with chip-sequence code (Spread Code)
- These chip sequence codes produced by transmitter are already known to receiver. And receiver dispread the signal.





- The receiver will use the same chip-sequence to reconstruct the information signal.
- To get the original signal we need to XOR the signal.
- The DSSS receiver is more complex than the transmitter.
- The pseudorandom sequence at the sender and receiver have to be precisely synchronized because the receiver calculates the product of a chip with the incoming signals.
- During a bit period, which also has to be derived via synchronization, an integrator adds all the products.
- Calculating the products of chips and signal and adding the products in an integrator is also called correlation and the device is called corrector.
- Finally, in each bit period a decision unit samples the sums generated by the integrator and decides if this sum represents a binary 1 or a 0.

Features of DSSS:

1. It provides good security against potential jamming or interpretation
2. Extremely effective against narrowband signal.
3. Very effective against broadband interference.

Application:

1. Jamming signal
2. Military communication
3. Cordless phone
4. Digital cellular telephony
5. Satellite navigation
6. WLAN
7. Bluetooth

Disadvantages:

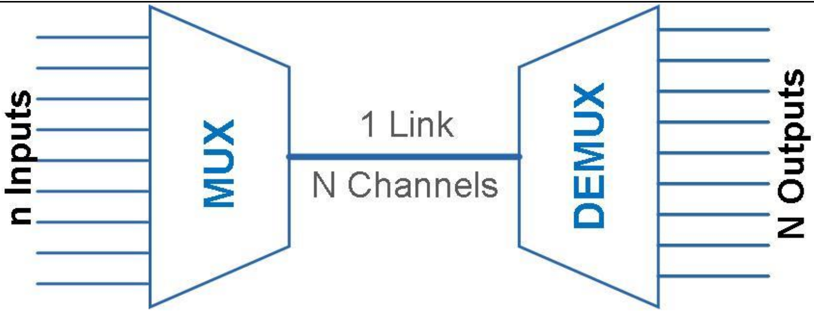
1. Increased bandwidth
2. Need for broad PN sequence.
3. Synchronization is affected by the variable distance between the transmitter and receiver.

8. What is DSSS? Explain CDMA chip sequence with example. **(Winter-2013) [L.J.I.E.T]** 7

9. What is multiplexing? Explain FDM and TDM in details with one example.**(May-2017) [L.J.I.E.T]** 7, 4
Define the term Multiplexing. Explain the FDM and TDM with one example each. **(May-2018) [L.J.I.E.T]**

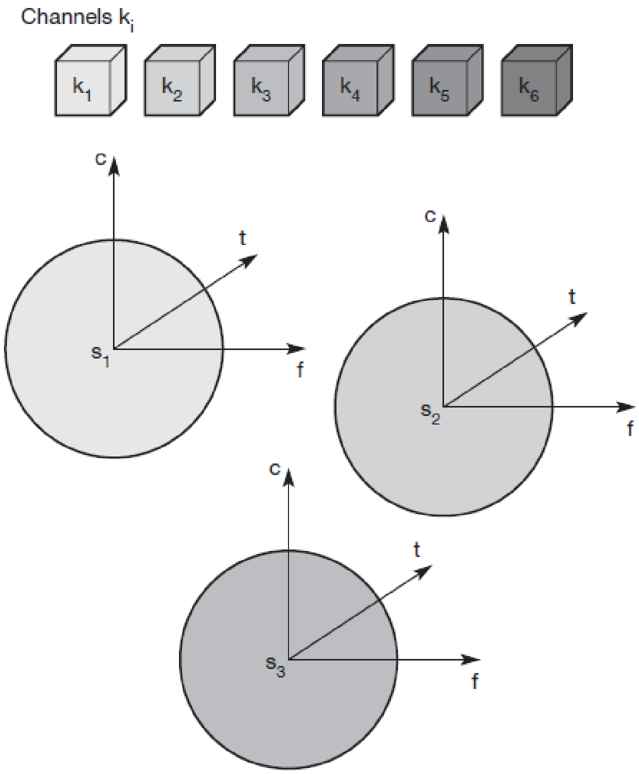
- In both local and wide area communications, it is almost always the case that the capacity of the transmission medium exceeds the capacity required for the transmission of a single signal. To make efficient use of the transmission system, it is desirable to carry multiple signals on a single medium. This is referred to as *multiplexing.*

- Figure depicts the multiplexing function in its simplest form. There are *n* inputs to a multiplexer.
- The multiplexer is connected by a single data link to a demultiplexer.
- The link is able to carry *n* separate channels of data. The multiplexer combines (multiplexes) data from the *n* input lines and transmits over a higher capacity data link.
- The demultiplexer accepts the multiplexed data stream, separates (demultiplexes) the data according to channel, and delivers them to the appropriate output lines.
- In short, Multiplexing is combining the all input signal into a single composite signal and transmit it over the communication medium.



- This can be carried out in four dimension:
  1. **Space Division Multiplexing (SDM):** In SDM the space is divided into different carrier signal for transmission. For example, the figure shows 3 channels Ki and introduces a three dimensional coordinate system.

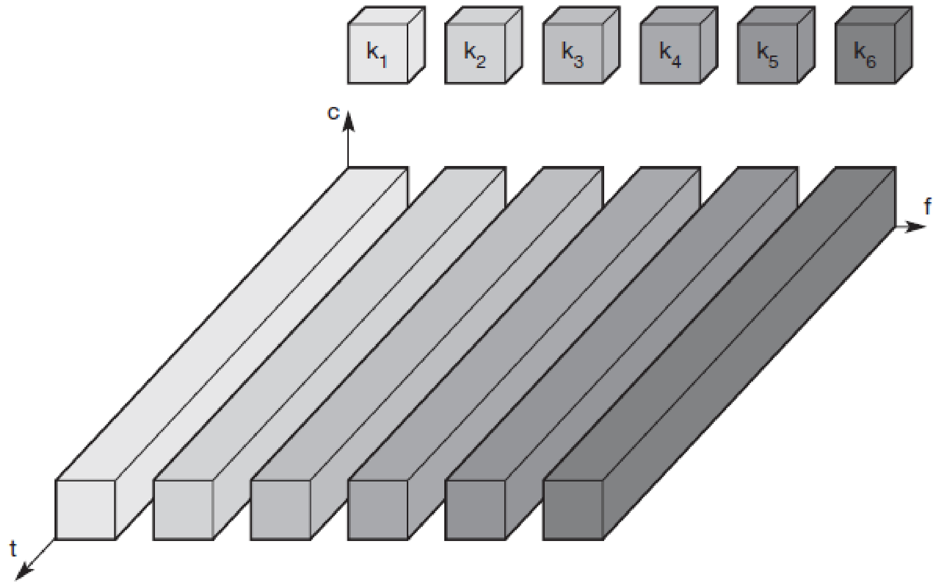
→ 3 dimensions are code (C), time (T), frequency (F)
→ Space dimensions are represented via circles.
→ Channel K1 and K3, can be mapped onto the three spaces S1 to S3, which clearly separates the channels and prevent the interference ranges from overlapping.
→ The space between the interference ranges is called guard spaces.
→ Example, on Highway, driver has own lane



2. **Frequency Division Multiplexing (FDM):** In FDM, it subdivide the frequency dimensions into several non-overlapping frequency bands

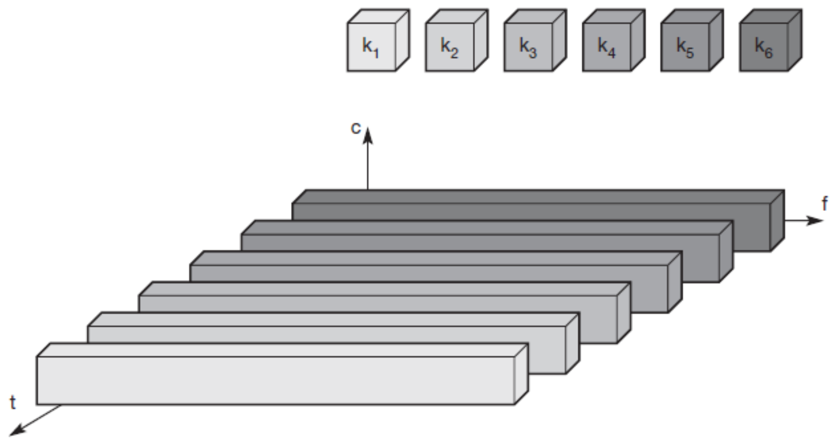
→ Each channel Ki allocated its own frequency band as indicated.
→ Sender using a certain frequency band can use this band continuously.
→ Guard space (adjacent channel interference, avoid frequency band over lapping)
→ Example, Radio station within the same region, where each radio station has its own frequency.
→ No need complex co-ordination between sender and receiver. Receiver only has to tune

into the specific sender.



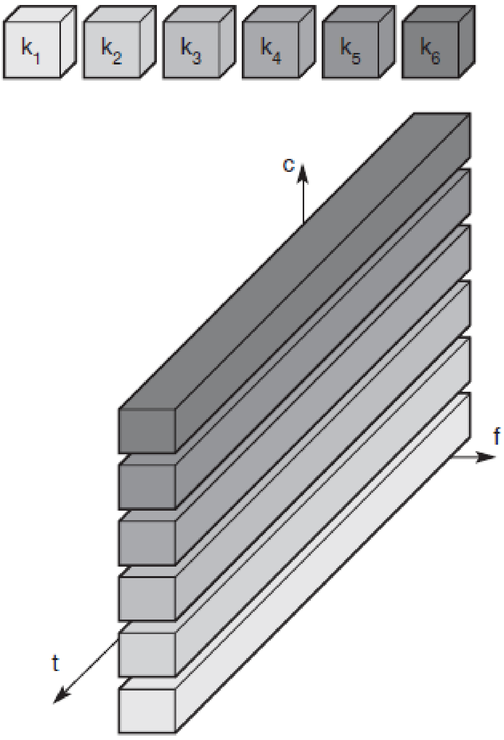
3. **Time Division Multiplexing (TDM):** In TDM, Channel Ki is given the whole bandwidth for a certain amount of time.

→ All senders are at the same frequency but at different point in time.
→ Guard space is represented by time gaps.
→ Synchronization between sender and receiver is necessary. So all needs precise clock.
→ In receiver tunning needs adjusting frequency at exactly the right point in time.



4. **Code Division Multiplexing (CDM):** In CDM, each user is assigned separate code for transmission.

→ It is more secure
→ Guard space is represented by orthogonal code.
→ Communication is done over separate language.



NUMERICALS

1. In a CDMA network, assume there are four stations A, B, C, and D with their chip sequences, shown in Fig. 1. Fig. 2 shows four cases of four stations transmitting at the same time. Show the transmitted sequences S1 to S4 and how DSSS does the recovery at receiver. [**New**]**(Dec-2013) [L.J.I.E.T]** 7

A: 00011011
B: 00101110
C: 01011100
D: 01000010

Fig 1: bit sequence

A	B	C	D	
-	-	1	-	C sent 1
-	1	1	-	B & C sent 1
1	0	-	-	A sent 1 & B sent 0
1	1	0	1	A sent 1, B sent 1, C sent 0 & D sent 1

Fig. 2 transmition details

Transmitter Side :

station-1 only C Transmits '1'

$C = (01011100)$

$S_1 = C = (-1, +1, -1, +1, +1, +1, -1, -1)$

station-2 B sent 1 and C sent 1

$B = (-1, -1, +, -1, +1, +1, +1, -1)$

$C = (-1, +1, -1, +1, +1, +1, -1, -1)$

$S_2 = B + C$

$= C$

station-3 A sent 1, B sent 0

$A = (-1, -1, -1, +1, +1, -1, +1, +1)$

$\overline{B} = (+1, +1, -1, +1, -1, -1, -1, +1)$

$S_3 = A + \overline{B}$

$S_3 = (0, 0, -2, +2, 0, -2, 0, +2)$

station-4 A sent 1, B sent 1, C sent 0 and D sent 1

$A = (-1, -1, -1, +1, +1, -1, +1, +1)$

$B = (-1, -1, +1, -1, +1, +1, +1, -1)$

$\overline{C} = (+1, -1, +1, -1, -1, -1, +1, +1)$

$D = (-1, +1, -1, -1, -1, -1, +1, -1)$

$S_4 = A + B + \overline{C} + D$

$S_4 = (-2, -2, 0, -2, 0, -2, +4, 0)$

Receiver Side :

station -1

$S1 = C = (-1, +1, -1, +1, +1, +1, -1, -1)$

$S1 \cdot C = (-1, +1, -1, +1, +1, +1, -1, -1)$
$\cdot (-1, +1, -1, +1, +1, +1, -1, -1)$

$= (+1, +1, +1, +1, +1, +1, +1, +1)$

$= 8/8 = 1 \rightarrow$ '1' bit.

station -2

$S_2 - (-2, 0, 0, 0, +2, +2, 0, -2)$

for B $S_2 \cdot B = (-2, 0, 0, 0, +2, +2, 0, -2)$
$\cdot (-1, -1, +1, -1, +1, +1, +1, -1)$

$= (+2, +0, +0, +0, +0, +2, +2, +0, +2)$

$= (+2 + 0 + 0 + 0 + 0 + 2 + 2 + 0 + 2)$

$= 8/8 = +1$

$\Rightarrow$ '1' bit sent.

station -3 $S_3 = (0, 0, -2, +2, 0, -2, 0, +2)$

for A $S_3 \cdot A = (0, 0, -2, +2, 0, -2, 0, +2)$
$\cdot (-1, -1, -1, +1, +1, -1, +1, +1)$

$= (0, 0, +2, +2, 0, +2, 0, +2)$

$= (0 + 0 + 2 + 2 + 0 + 2 + 0 + 2)$

$= 8/8 \Rightarrow$ bit '1' sent

for B $S_3 \cdot B = (0, 0, -2, +2, 0, -2, 0, +2)$
$\cdot (-1, -1, +1, -1, +1, +1, +1, -1)$

$= (+0, +0, -2, -2, +0, -2, +0, -2)$

$= (0 + 0 - 2 - 2 + 0 - 2 + 0 - 2)$

$= -8/8 = -1 \Rightarrow$ bit '0' sent.

Station - 4

$S_4 = (-2, -2, 0, -2, 0, -2, +4, 0)$

for A $S_4 \cdot A = (-2, -2, 0, -2, 0, -2, +4, 0) \cdot (-1, -1, -1, +1, +1, -1, +1, +1)$

$= +2 + 2 + 0 - 2 + 0 + 2 + 4 + 0$

$= 8/8 \Rightarrow$ bit '1' sent

$S_4 \cdot B = (-2, -2, 0, -2, 0, -2, +4, 0) \cdot (-1, -1, +1, -1, +1, +1, +1, -1)$

$= +2 + 2 + 0 + 2 + 0 - 2 + 4 + 0$

$= 8/8 \Rightarrow$ bit '1' sent

$S_4 \cdot C = (-2, -2, 0, -2, 0, -2, +4, 0) \cdot (-1, +1, -1, +1, +1, +1, -1, -1)$

$= +2 - 2 + 0 - 2 + 0 - 2 - 4 + 0$

$= -8/8 = -1 \Rightarrow$ bit '0' sent

$S_4 \cdot D = (-2, -2, 0, -2, 0, -2, +4, 0) \cdot (-1, +1, -1, -1, -1, -1, +1, -1)$

$= +2 - 2 + 0 + 2 + 0 + 2 + 4 + 0$

$= 8/8 = 1 \Rightarrow$ bit '1' sent

2.	In a CDMA network, assume there are two stations A (chip sequence: 00011011) and E (chip sequence: 00101110). Figure-1 shows two cases of both stations transmitting at the same time. Show the transmitted sequences S1 and S2 and how DSSS does the recovery at receiver. **A E** 1 0 A sent 1 and B sent 0 0 - only A sent 0 (Figure-1) **[New] (Nov-2016) [L.J.I.E.T]**	7

Transmitter

A = 0 0 0 1 1 0 1 1

A = (−1 , −1 , −1 , +1 , +1 , −1 , +1 , +1)

B = 0 0 1 0 1 1 1 0

B = (−1 , −1 , +1 , −1 , +1 , +1 , +1 , −1)

for, $S1 = A + \overline{B}$

$= (-1, -1, -1, +1, +1, -1, +1, +1) +$
$(+1, +1, -1, +1, -1, -1, -1, +1)$

$\boxed{S1 = (0, 0, -2, +2, 0, -2, 0, +2)}$

for, $S2 = \overline{A}$

$\boxed{S2 = (+1, +1, -1, +1, -1, -1, -1, +1)}$

Receiver

@ Station A & Signal S1 :

$S1 \cdot A = (0, 0, -2, +2, 0, -2, 0, +2) \cdot$
$(-1, -1, -1, +1, +1, -1, +1, +1)$

$= (0, 0, +2, +2, 0, +2, 0, +2)$

$= 0 + 0 + 2 + 2 + 0 + 2 + 0 + 2$

$= 8 / 8$

$= \boxed{+1} \Rightarrow \boxed{\text{1 bit was send}}$

@ station B and signal S1 :

$$S1 \cdot B = (0,0,-2,+2,0,-2,0,+2) \cdot (-1,-1,+1,-1,+1,+1,+1,-1)$$

$$= (0,0,-2,-2,0,-2,0,-2)$$

$$= 0+0-2-2+0-2+0-2$$

$$= -8/8$$

$$= \boxed{-1} \Rightarrow \boxed{\text{0 bit was send}}$$

@ station A and signal S2 :

$$S2 \cdot A = (+1,+1,-1,+1,-1,-1,-1,+1) \cdot (-1,-1,+1,-1,+1,+1,+1,-1)$$

$$= (-1,-1,-1,-1,-1,-1,-1,-1)$$

$$= -1-1-1-1-1-1-1-1$$

$$= -8/8$$

$$= \boxed{-1} \Rightarrow \boxed{\text{0 bit was send}}$$

TOPIC 5. Coding and Error Control

DESCRIPTIVE QUESTIONS

1. What is Error? And Explain Type of Error. **[L.J.I.E.T]** 7

- When signal transmitted from sender to receiver the signal can distorted due to noise.
- The noise can introduce an error in the binary bits travelling from one system to the other.
- That means 0 may change to 1 or 1 may changes to 0.
- This reduces the accuracy of the digital system. So, it is necessary to detect and correct the error.

Types of Error:

→ Error can be of content error (0 changes to 1 and vice versa) and flow integrity error (missing blocks of data).

→ Depending on the number of bits in error we can classify the error into two types as

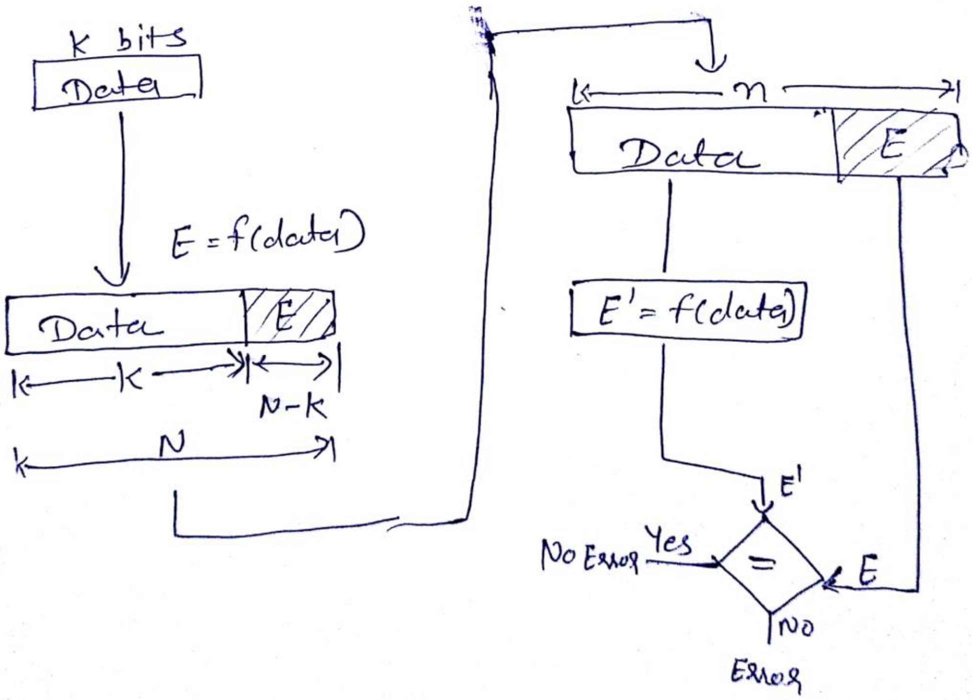
1. **Single bit:** Only one bit is affected by error
2. **Burst error:** If two or more bits from data unit is affected.

2. Describe the Error Control Coding in detail. **(May-2018)[L.J.I.E.T]** 4

The most important two techniques for error are as follow:

1. **Error Detection:** In this receiver can request for the retransmission of the complete or a part of message if it finds some error in the received signal message.

→ This required additional feedback channel to send request for retransmission.
→ Error detection technique operates on the following principle.
→ For a given frame of bits, the transmitter adds additional bits that constitute error-detection code.
→ This code is calculated as a function of the other transmitted bits.
→ For a data block of K bits, the error detection algorithm yields. Error detection code of N-K bits where (N-K) < K.
→ This error detection code also referred to as the check bits, and this is appended to the data block to produce a frame of n bits, which is then transmitted.
→ At receiver side it separates the incoming frame into the K bit of data and N-K bits of error detection code.
→ Now, receiver will performs the error detection calculation on the data bits and compare this value with the value of incoming error detection code.
→ A detected error occurs if and only if there is a mismatch.
→ Some techniques are CRC and ARQ.



2. **Error Correction:** In this at receiver side the error is corrected. So there is no such feedback path and request for retransmission. Error is corrected. Some of the technique is known as hamming code and convolutional code.

3. Explain Error Detection. **[L.J.I.E.T]** 7

4. Explain Hamming Code. **[L.J.I.E.T]** 7

ANS:

Hamming codes can detect up to two- bit error or correct one bit error.

The key of the hamming code is the use of extra parity bit to allow the identification of a single error.

To create parity bit: All parity bit position that is power of 2 is our parity bits.

Example

↳ Each parity bit calculates the parity for some of bits in the codeword.

→ The position of the parity bit determines, the sequence of bits that it alternatively checks & skips.

→ ex, for P_1 check 1 bit and skip 1 bit
for P_2 check 2 bit and skip 2 bit
for P_4 check 4 bit and skip 4 bit
for P_8 check 8 bit and skip 8 bit

Ex Suppose
Original bit = 1001000
Received bad bit = 1001010

0	0	1	1	0	0	1	0	0	0	0
P_1	P_2	d_3	P_4	d_5	d_6	d_7	P_8	d_9	d_{10}	d_{11}

Assume, bits are in Even Parity

$P_1 \Rightarrow$ 1, 3, 5, 7, 9, 11
? 1 0 1 0 0

$\boxed{P_1 = 0}$

$P_2 \Rightarrow$ 2, 3, 6, 7, 10, 11

? 1 0 1 0 0

$\boxed{P_2 = 0}$

$P_4 \Rightarrow$ 4, 5, 6, 7

? 0 0 1

$\boxed{P_4 = 1}$

$P_8 \Rightarrow$ 8, 9, 10, 11

? 0 0 0

$\boxed{P_8 = 0}$

0	0	1	1	0	0	1	0	0	0	0

↳ This signal is sent to receiver

⇒ but the Receiver Receives

P_1	P_2	d_3	P_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}
0	0	1	1	0	0	1	0	0	1	0

@ Receiver

for $P_1 \Rightarrow$ 1, 3, 5, 7, 9, 11

0 1 0 1 0 0

⇒ Even parity ⇒ No Error ⇒ $\boxed{P_1 = 0}$

for $P_2 \Rightarrow$ 2, 3, 6, 7, 10, 11

0 1 0 1 1 0

⇒ odd parity ⇒ Error ⇒ $\boxed{P_2 = 1}$

for $P_4 \Rightarrow 4, 5, 6, 7$

1 0 0 1

$\Rightarrow$ Even Parity $\Rightarrow$ No Error $\boxed{P_4 = 0}$

for $P_8 \Rightarrow 8, 9, 10, 11$

0 0 1 0

$\Rightarrow$ Odd Parity $\Rightarrow$ Error $\boxed{P_8 = 1}$

$\Rightarrow$ now, Error code

$P_8 \; P_4 \; P_2 \; P_1 = (1\;0\;1\;0)_2$

· Error code is in Binary convert it into decimal

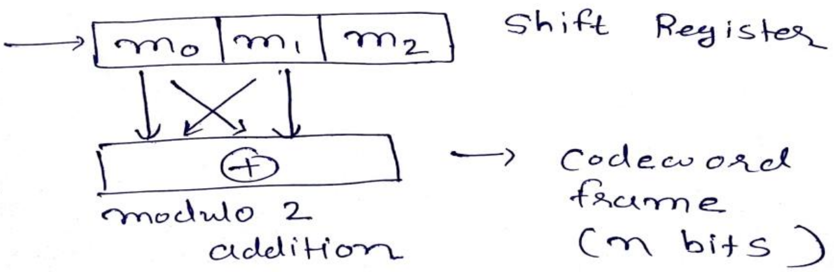
$(1010)_{10} \Rightarrow \boxed{10} \rightarrow$ So 10^{th} no bit is erroneous

So flip that bit

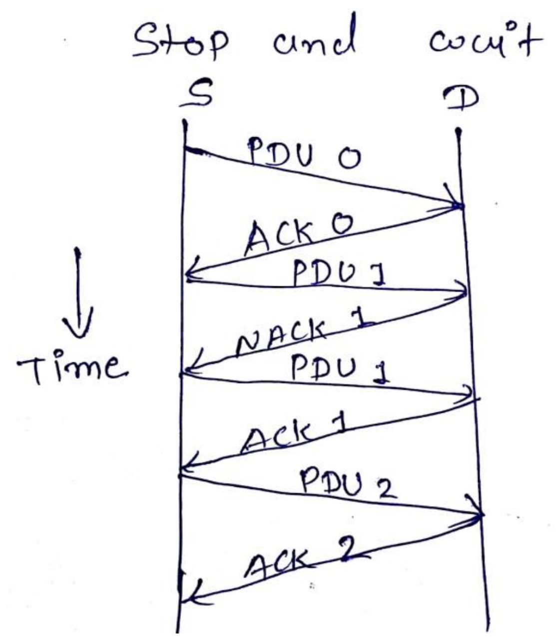
5. Explain Convolutional Codes. **[L.J.I.E.T]** 4

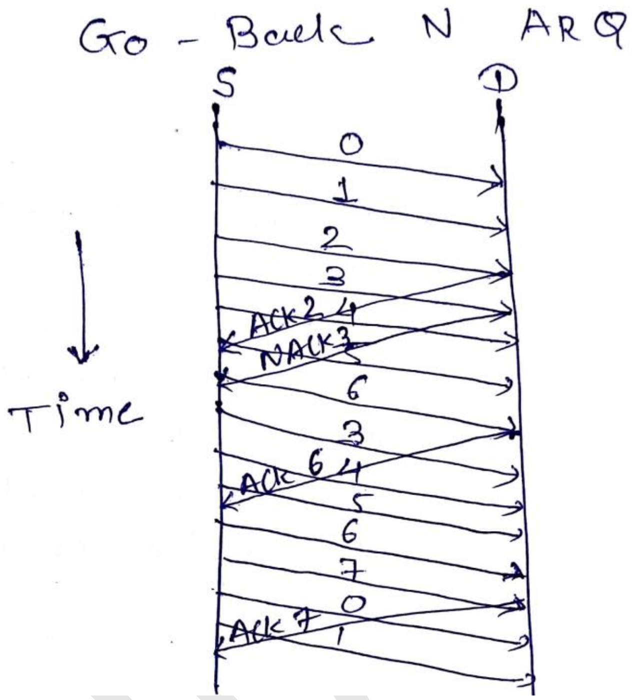
- Hamming code is larger length of block code. This length actually reduce overhead and works better in error control but if this length is too large the receiver has to wait for a long time.
- To overcome this type of code is created which is called convolution code or Tree code.
- In this method full information is divided into smaller blocks of message. There are known as information frames.
- This information frame is encoded in code word.
- In decoding is done depends on previous code word and which requires some memory.

Convolution encoder



	➢ There are two parts 1. **Shift register:** Shift register act as memory. L bit shift register is capable of storing L information frames (bits) As new bit arrives the shift register shift one position and flushed out oldest frame. At the end L no of most recent frames remains. 2. **Logic circuit:** Computes the code word frame and shift it out.	
6.	Explain Automatic repeat request. **[L.J.I.E.T]**	7
7.	What is the need of ARQ? Explain Automatic Repeat Request (ARQ) in details? **(May-2017) [L.J.I.E.T]** → ARQ is mechanism used in data link control and transport protocol. → It relies on the use of an error detection code, such as CRC → ARQ error control mechanism is closely related to flow control. → ARQ data are send in sequence o PDUs. → **PDU (Packet Data Unit):** The Block of data that is transmitted from one protocol entity to another is referred as protocol data unit. → PDUs arrive in same order in which they are sent and each PDU suffers an arbitrary and variable amount of delay before reception. → There are 3 types of errors: 1. **Lost PDU:** PDU fails to arrive at receiver side. 2. **Damaged PDU:** PDU arrives with damaged bit. 3. **Lost ACK:** ACK is lost from receiver to sender. → The most common techniques for error control: 1. **Error detection:** receiver detects error and discards PDU. 2. **Positive ACK:** the destination returns positive ACK to successfully received, error free PDU. 3. **Retransmission after timeout:** PDU not acknowledged by receiver then sender retransmit the PDU after time out. 4. **Negative ACK and Retransmission**: The destination sends negative ACK. if it receive error in PDU. The source is retransmitted. → Collectively this all mechanism is known as ARQ. → There are basically 3 types of ARQ 1. **Stop and Wait:** In this flow control mechanism the sender after transmitting a data frame to stop and wait until the acknowledgment of data- frames sent is receiver. And after some specific time out period the sender retransmits the latest PDU 2. **Go back and ARQ:** Stop and wait ARQ mechanism does not utilize the resources at their best when the acknowledgement is received, the sender sits idle and does nothing. In go back and ARQ method, both sender and receiver maintain a window. → It also based on Sliding window protocol. → The no of unacknowledged PDUs outstanding is determined by window size, using sliding window flow control techniques. → If the destination is detects the error. The destination station will discard that PDU and all future incoming PDUs until the PDU in error is correctly received. → So, the source station when receives negative acknowledgement, It must retransmit the PDU in error plus all succeeding PDU.	7

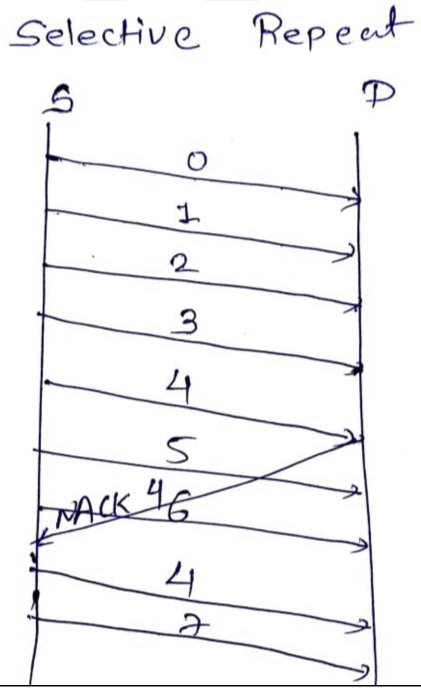




3. **Selective Repeat ARQ:** In go back and ARQ, it is assumed that the receiver does not have any buffer space for its window size and has to process each frame as it comes.

→ This enforces the sender to retransmit all the frames which are not acknowledged.

→ In selective repeat ARQ the receiver while keeping track of sequence number, buffers the frames in memory and sends NACK for only frame which is missing or damaged.



8. What is the need for ARQ? Explain Sliding Window Protocol with example. **(Nov-2017) [L.J.I.E.T]** 7

→ ARQ is mechanism used in data link control and transport protocol.

→ It relies on the use of an error detection code, such as CRC

→ ARQ error control mechanism is closely related to flow control.

→ **Flow Control:** Flow control is a technique for assuring that a transmitting entity does not overwhelm a receiving entity with data.

→ **PDU (Packet Data Unit):** The Block of data that is transmitted from one protocol entity to another is referred as protocol data unit.
→ Mechanism of how control in absent of even is shown using vertical time sequence diagram.
→ Typically. When a source has a block of stream of data to transmit the source will break up the block of data into smaller blocks and transmit the data into smaller blocks and transmit the data in many PDUs.
→ Each error represents single PDU traversing a data link between two stations.
→ This is done for the following reasons:
1. The buffer size of the receiver may be limited.
2. The longer the transmission, the more likely that there will be an error.
3. On a shared medium, such as LAN, it is usually desirable not to permit one station to occupy the medium for an extended period, thus causing long delays at the other sending stations.

→ Solution to this is sliding window protocol.
→ SWP is features of packet based data transmission protocol.
→ SWP used where reliable in order delivery of packet is required such as in datalink layer (OSI model) as well as in the TCP.
→ Basically the protocol for sending ACKs in all ARQ protocols is based on sliding window flow control scheme.
→ Sequence no to be used occupies a field in the PDU.
→ For K- bit field, so the sequence no can be range from 0 to 2^{K-1}, for 3 bit field sequence of PDU will be 0 to 7.
→ In our example, the window size is 7 bits,
→ The window expands from leading edge as acknowledgements are received.
→ And window will shrinks from trailing edge as PDU are received.

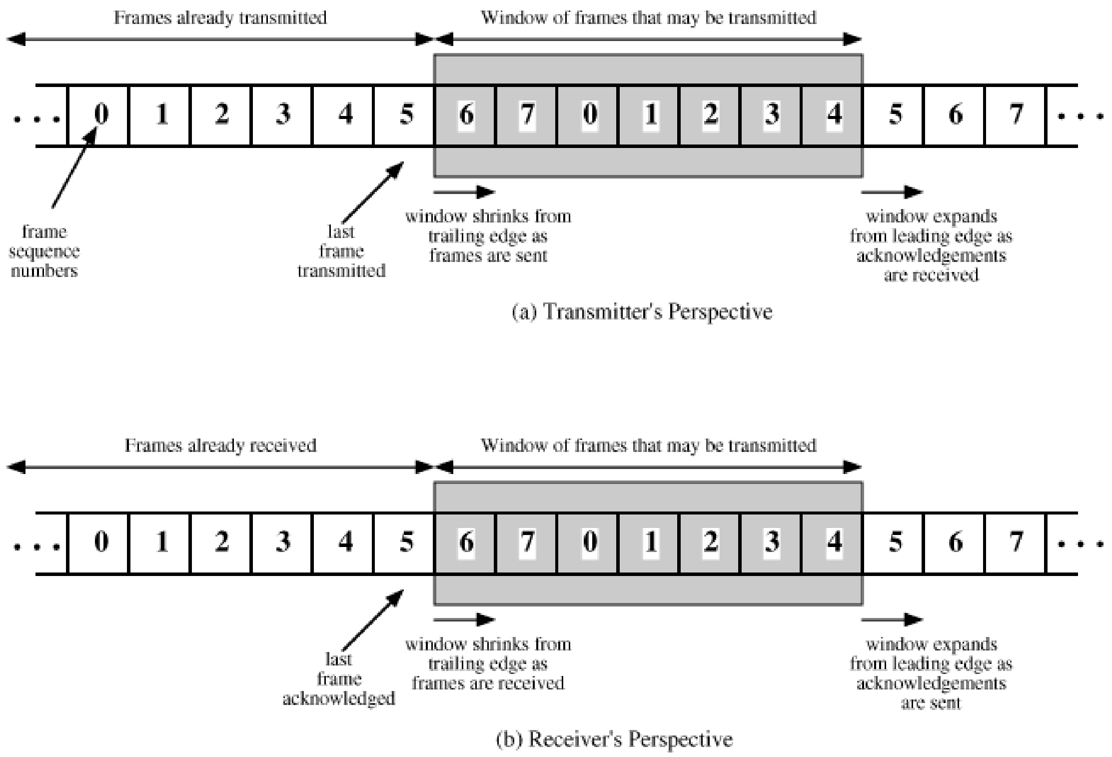


Figure 6.3 Sliding-Window Depiction

NUMERICALS

1. For Message M = 1010001101 and Pattern P = 110101, find CRC. **(Nov-2017)[L.J.I.E.T]** 4

bit sequence ⇒ 1010001101

Pattern P = 110101

Transmitter

```
                 110101011
110101 | 101000110100000
         110101
         0111011
          110101
          00111010
            110101
            00111110
              110101
              00101100
                110101
                0110010
                 110101
                 0001110
```

Code word

101000110101110

Receiver

```
                 110101011
110101 | 101000110101110
         110101
         0111011
          110101
          00111010
            110101
            00111110
              110101
              00101111
                110101
                0110101
                 110101
                 0000000
```

All bits are zero