1. Define Wireless Communication. Explain its evolution in brief.

- Wireless refers to the method of transferring information between computing devices, such as a personal data assistant (PDA) and a data source such as an agency database server, without a physical connection or wires.
- The distances involved may be short or long.
- Wireless communication is simply data communication without the use of a physical connection or wires but propagates the signal through space.
- Space only allows for signal transmission without any guidance, the medium used in Wireless Communication is called Unguided Medium.
- This may involve cellular telephone, two-way radio, fixed wireless, laser, or satellites communication

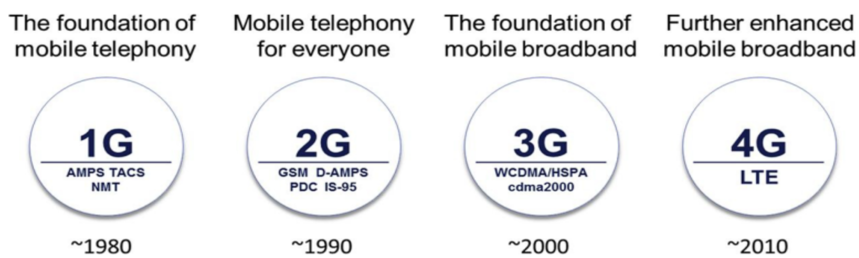


Figure: Generations of mobile communication (E. Dahlman et al, 5G NR: The Next Generation Wireless Access Technology)

1. 1G: Foundation of mobile telephony
   - Developed: late 1970s and early 1980s
   - Used analog signal for voice services
   - Based on technology called as Advanced Mobile Phone System (AMPS)
   - Frequency modulated and Frequency division multiple access (FDMA) with a channel capacity of 30KHz
   - circuit switching
   - Frequency band of 450MHz − 1GHz
   - Allows voice calls in 1 country

2. 2G: Mobile Telephony for everyone
   - Developed: early 1990s
   - Used digital signal for voice services and SMS possible
   - Technology: Digital cellular, GSM, CDMA
   - Digital modulated (Binary, QPSK, GMSK)
   - TDMA/FDD, FDMA/FDD
   - Circuit switching
   - Frequency band of 900MHz − 1.9GHz
   - Data rate upto 64 kbps

3. 2.5G
   - 2G cellular technology with General Packet Radio Service (GPRS),
   - Data rate upto 114 kbps
   - Enhanced Data Rates for GSM Evolution (EDGE), providing 384 kbps rate by using improved modulation (8-PSK instead of GMSK in GSM)
   - CDMA: high speed data access multiple orthogonal user channels providing 115.2kbps rate
   - Support email, web browsing
   - Enabling location - based mobile service

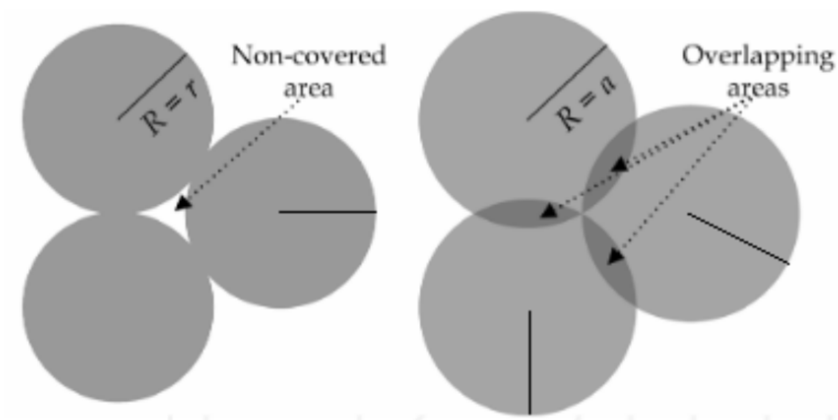
4. 3G: Foundation of mobile broadband
   - Developed: 2000 based on GSM
   - Support Voice, SMS, Data
   - Technology: UMTS, WCDMA and FDD/TDD
   - Data rate 144 kbps to 2 Mbps enable MMS
   - Digital modulated (QPSK, QAM)
   - Circuit switching for voice and packet for data
   - Frequency band of 1.6GHz − 2GHz

5. 4G: Further enhanced mobile broadband
   - Developed: 2010
   - Support Voice, SMS, Data (High Speed)
   - Technology: long term evolution (LTE), OFDMA and FDD/TDD
   - Data rate 100 Mbps to 1 Gbps enable MMS
   - Digital modulated (QAM)
   - Packet switching
   - Frequency band of 2GHz − 8GHz
   - Good QoS and high security
   - Bigger battery usage

6. 5G:
   - Developed: 2020
   - main focus :world-Wireless World Wide Web (WWWW)
   - Technology: NOMA, mmWave, small cell, MIMO
   - Data rate > 1Gbps High speed, high capacity
   - Internet switching

2. Why hexagonal cell geometry is used in the design of cellular systems. Prove that the co-channel reuse ratio is given by Q = $\sqrt{3N}$, where N = $i^2 + ij + j^2$ is the cluster size.

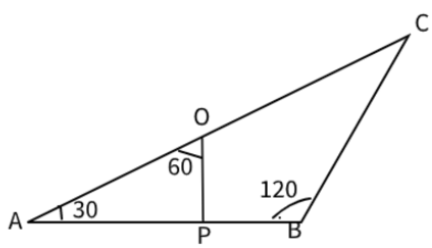
- Circular is natural selection for geometric shape of Cell due to omni-directional base station antenna and free space propagation but adjacent circles can not be overlaid upon a map without leaving gaps or creating overlapping regions.
- Three sensible choices to cover entire region without overlapping and with equal area
  - a square;
  - an equilateral triangle; and
  - a hexagon
- For a given distance between the center of a polygon and its farthest perimeter points, the hexagon has the largest area of the three.
- By using the hexagon geometric the fewest number of cells can cover a geographic region, and the hexagon closely approximates a circular radiation pattern which would occur for an omni-directional base station antenna and free space propagation.



Circle	Triangle	Square	Hexagon
Overlap	No overlap	No overlap	No overlap
Criteria no fulfilled	Area to circle 17.7%	Area to circle 63.7%	Area to circle 83%

- Mathematically easy for calculation in compare to higher degree of polygon

1. The size of each cell is approximately the same
2. Radius of the cell (R)
3. Distance between centers of the nearest co-channel cells (D)
4. Hexagonal geometry has exactly six equidistant neighbors and each of its neighbors are separated by multiples of 60 degrees
5. Let R_p be perpendicular distance from center of a cell to its one of the side



In right-angled $\triangle OPA$

$$\sin 60^\circ = \frac{AP}{AO}$$

$$R_p = \frac{\sqrt{3}}{2} R \tag{11}$$

In $\triangle$ ABC, applying cosine law of triangle

$$AC^2 = AB^2 + BC^2 - 2AB \times BC \times \cos 120^\circ$$

$$D^2 = (i \cdot 2R_p)^2 + (j \cdot 2R_p)^2 - 2ij \cdot 4R_p^2 \left(-\frac{1}{2}\right)$$

$$= (2R_p)^2 (i^2 + j^2 + ij)$$

Substituting the value of R_p from eq. 11, we get

$$D^2 = 4\left(\frac{\sqrt{3}}{2} R\right)^2 N \quad [\because N = i^2 + j^2 + ij]$$

$$= 3R^2 N$$

$$D = \sqrt{3N} R$$

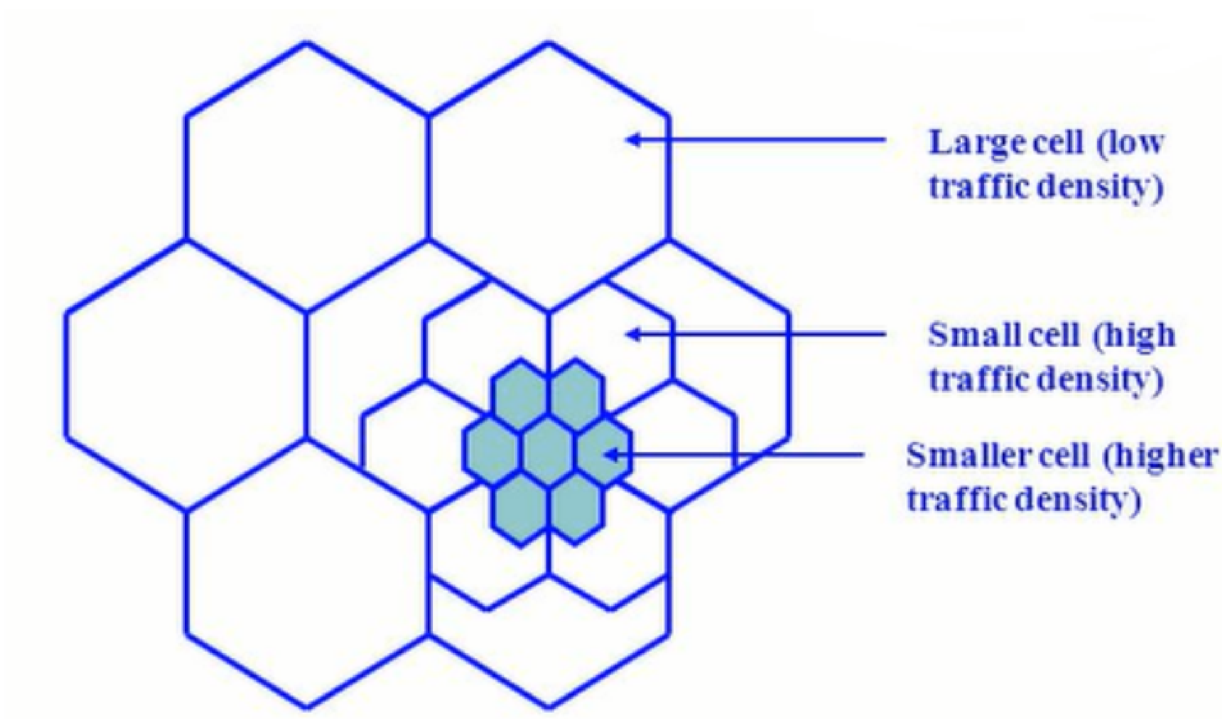
$$Q = \frac{D}{R} = \sqrt{3N} \tag{12}$$

3. Explain how cell splitting and sectoring improves the coverage and capacity in Cellular System

- When the number of user increases, the number of channels assigned to cell eventually becomes insufficient to support the required number of users
- Cellular design techniques needs to provide more channels per unit coverage area
- Cellular systems can improve the capacity using techniques such as
    - cell splitting
    - cell sectoring

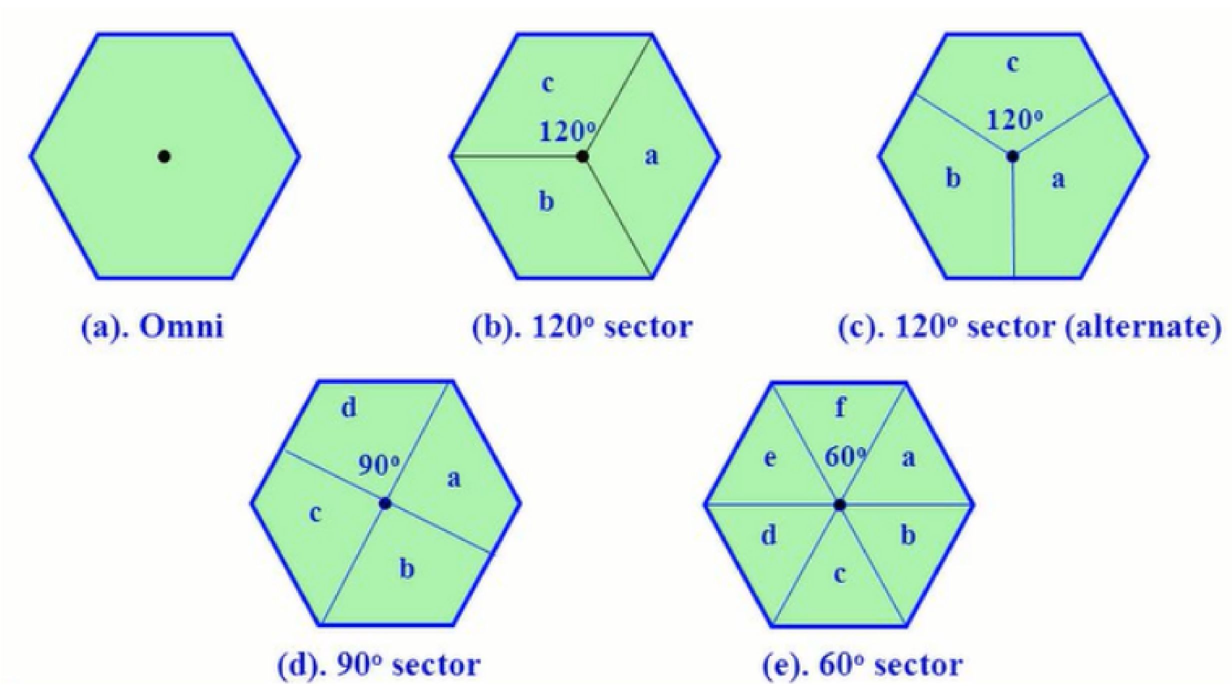
Cell Splitting

- Process of subdividing a congested cell into smaller cells
- Each smaller cell consists of own base station and a corresponding reduction in antenna height and transmitter power
- new cells (called microcells) have a smaller radius than the original cells
- leads to increase frequency reuse factor
- Cell splitting increases the capacity of a cellular system since it increases the number of times that channels are reused
- Allows a system to replace large cells with smaller cells, while not upsetting the channel allocation scheme required to maintain the minimum co-channel reuse ratio Q between co-channel cells
- Handoff issues must be addressed so that high speed and low speed traffic can be simultaneously accommodated (umbrella cell approach: commonly used)
- Increase cell capacity by decreasing the cell radius R and keeping the co-channel reuse ratio Q = D/R unchanged



Cell Sectoring

- Technique for decreasing co-channel interference and increasing system capacity by using directional antennas
- Decrease the co-channel interference and keep the cell radius R unchanged
- Replacing single Omni-directional antenna by several directional antennas
- Radiating within a specified sector
- Co-channel interference in a cellular system may be decreased by replacing with several directional antennas
- interference will received from particular direction only
- Factor by which the co-channel interference is reduced depends on the amount of sectoring used.
- A cell is partitioned into three 120◦ sectors, four 90◦ sectors and six 60◦ sectors
- SIR is improved using directional antennas, then capacity improvement is achieved by reducing the number of cells in a cluster
- With increasing number of directional antenna in sectoring, breaks up the available trunked channel pool into several smaller pools, and decreases trunking efficiency

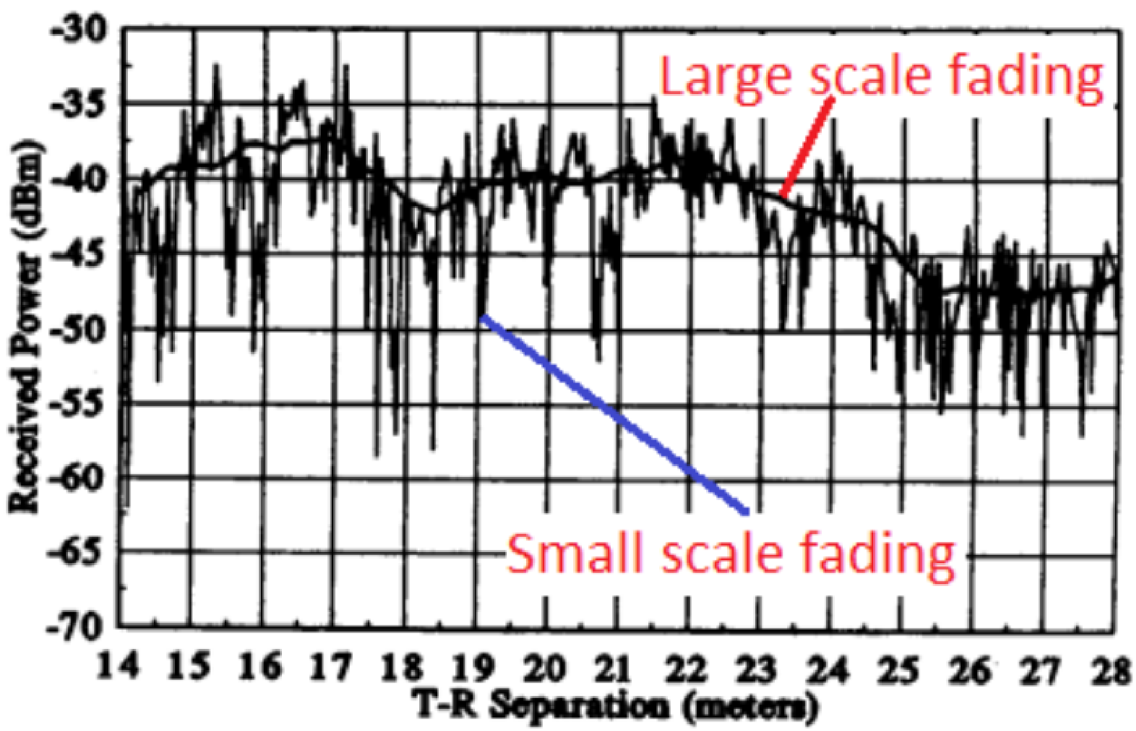


4. What is the role of the large scale and small scale propagation model in support of the Okumura model?

- Propagation models: focused on predicting the average received signal strength at a given distance from the transmitter
- Large-scale propagation models
    - Characterize signal strength for large transmitter-receiver (T-R) separation (several hundreds or thousands of meters)
    - Received signal decrease gradually
    - Useful for estimating the coverage area of transmitters

Small-scale propagation models

- Characterize rapid fluctuations in the received signal strength over very short travel distances (a few wavelengths)
- Signal is the sum of many contributors coming from different directions.
- Thus phases of received signals are random and the sum behave like a noise



Okumura Model

- Models for signal prediction in large urban and suburban
- macrocells model is applicable over distances of 1 − 100 km and frequency ranges of 150 − 1500 MHz with omni-directional antenna at both the base and mobile station
- Okumura based on measurements of **base station-to-mobile signal** attenuation throughout Tokyo, i.e, empirical model

- to develop a set of curves giving median attenuation A_{mu} relative to free space of signal propagation in irregular terrain
- with a base station effective antenna height (h_t) of 200 m and a mobile antenna height (h_r) of 3 m.
- The empirical path-loss formula of Okumura at distance d parameterized by the carrier frequency fc is given by:

$$PL_{50}(d)dB = L(f_c, d) + A_{\mathrm{mu}}(f_c, d) - G(h_t) - G(h_r) - G_{\mathrm{AREA}}$$

PL_{50}: 50^{th} percentile (i.e., median) value of propagation path loss,

$L(f_c, d)$: free space propagation loss

A_{mu}: median attenuation relative to free space

$G(h_t)$: base station antenna height gain factor

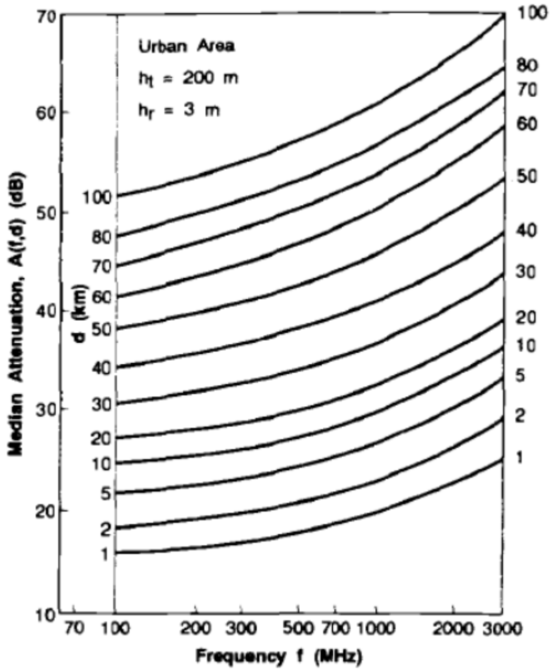
$G(h_r)$: mobile antenna height gain factor

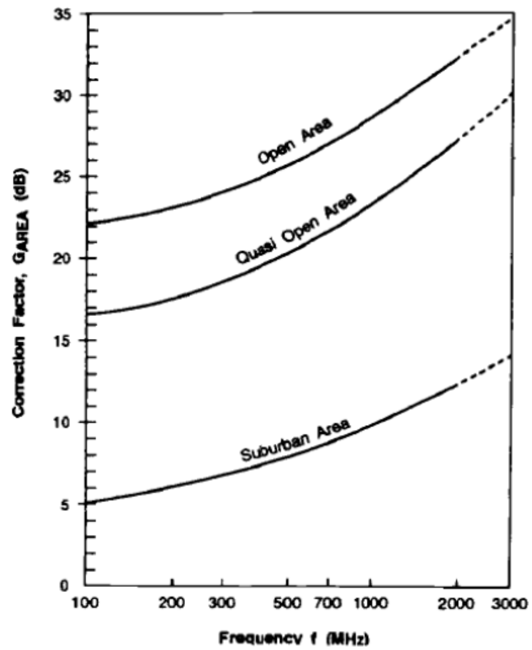
G_{AREA}: gain due to the type of environment.

$$G(h_t) = 20\log_{10}\left(\frac{h_t}{200}\right) \qquad 30m < h_t < 1000m \qquad ($$

$$G(h_r) = 20\log_{10}\left(\frac{h_r}{3}\right) \qquad 3m < h_r < 10m \qquad ($$

$$G(h_r) = 10\log_{10}\left(\frac{h_r}{3}\right) \qquad h_r \leq 3m \qquad ($$





Advantage

- Okumuras' model is considered to be among the simplest and best in terms of accuracy in path-loss prediction for mature cellular and land mobile system in a cluttered environment

Disadvantage

- Low response to rapid changes in terrain

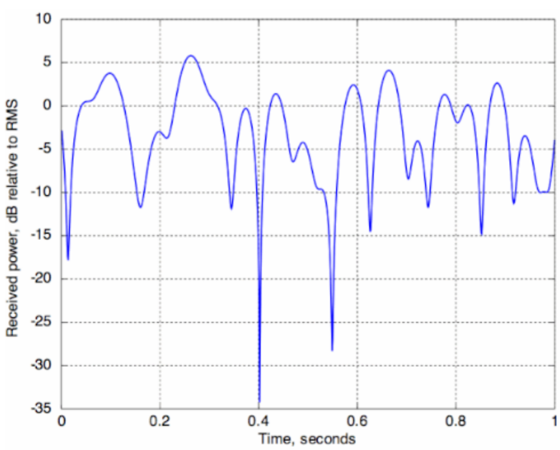
4. Briefly explain the Rayleigh and Ricean fading distribution.

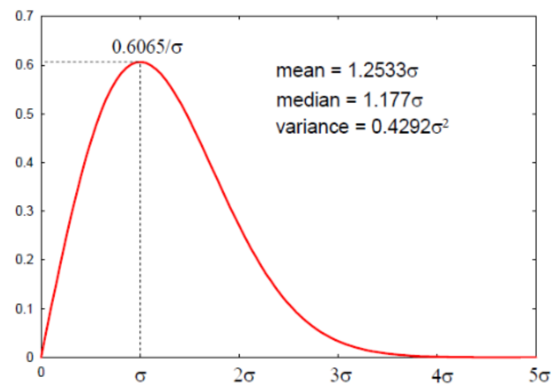
Rayleigh Fading

- Describes the received signal envelope distribution for channels, where all the components are non-LOS:
    - i.e. there is no line-of–sight (LOS) component.
- Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of flat fading signal, or the envelope of an individual multipath component
- Rayleigh distribution has the probability density function (PDF) given by:

$$p(r) = \begin{cases} \frac{r}{\sigma^2} e^{\left(-\frac{r^2}{2\sigma^2}\right)} & (0 \leq r \leq \infty) \\ 0 & (r < 0) \end{cases}$$

- σ^2 is the time average power of the received signal before envelope detection.
- σ is the rms value of the received voltage signal before envelope detection





CDF of Rayleigh fading is given by:

$$P(r \leq R) = \int_0^R p(r)dr = 1 - e^{\left(-\frac{R^2}{2\sigma^2}\right)}$$

$$r_{mean} = \mathbb{E}[r] = \int_0^\infty rp(r)dr = \sigma\sqrt{\frac{\pi}{2}}$$

$$r_{median} = 1.177\sigma$$

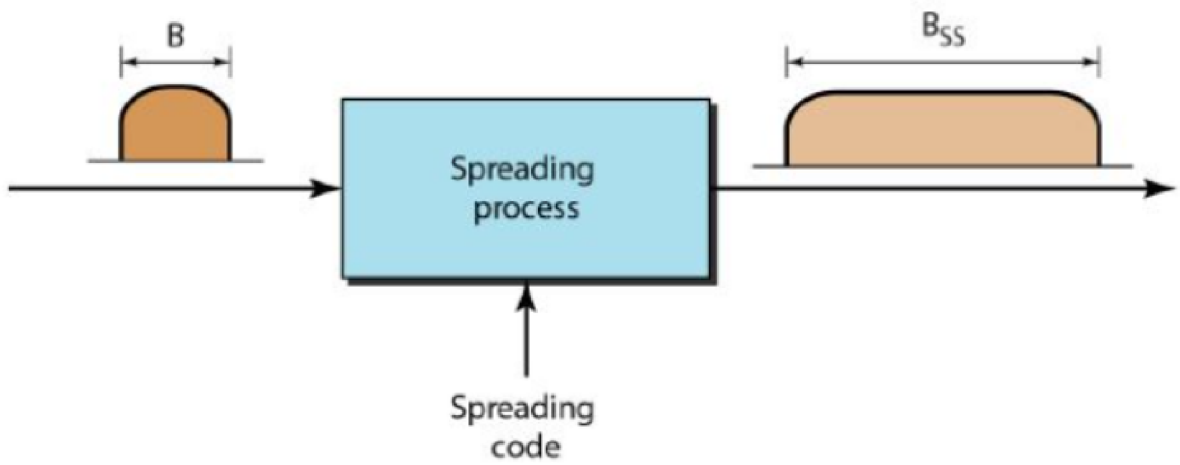
$$r_{rms} = \sqrt{2}\sigma$$

Ricean Fading
- When there is a stationary (non-fading) LOS signal present, then the envelope distribution is Ricean
- The Ricean distribution degenerates to Rayleigh when the dominant component fades away
- Rayleigh distribution has the probability density function (PDF) given by:

$$p(r) = \begin{cases} \frac{r}{\sigma^2} e^{\left(-\frac{r^2+A^2}{2\sigma^2}\right)} I_0\left(\frac{Ar}{\sigma^2}\right) & for(A \geq 0, r \geq 0) \\ 0 & for(r < 0) \end{cases}$$

- parameter $K = \frac{A^2}{2\sigma^2} \Rightarrow K, dB = 10 \log \frac{A^2}{2\sigma^2}$
  - √ When $K = 0$: Rayleigh fading
  - √ When $K = \infty$: No fading, channel has no multipath, only LOS component

5. Briefly explain different types of spread spectrum modulation technique. Discuss the principle of OFDM modulation scheme.
- Spread Spectrum Modulation Techniques
  - Due to limited bandwidth, it requires highly spectral efficiency
    - Narrow band spectrum is observed in TDMA, FDMA
  - Spread spectrum modulation technique uses transmission bandwidth (B_{SS}) that is several times greater than the information signal bandwidth (B)
    - $B_{SS} >> B$
    - Many users can simultaneously use the same bandwidth without significantly interfering with one another
  - In a multiple-user, multiple access interference environment, spread spectrum systems become very bandwidth efficient
  - Spread spectrum signals are pseudorandom and have noise-like properties
  - The spreading waveform is controlled by a pseudo-noise (PN) sequence or pseudo-noise code, which is a binary sequence that appears random but can be reproduced in a deterministic manner by intended receivers
  - PN sequence is independent of the data in the signal
  - PN sequence have
    - nearly equal number of zeros and ones
    - very low correlation between shifted versions of the sequence
    - very low cross-correlation between any two sequences

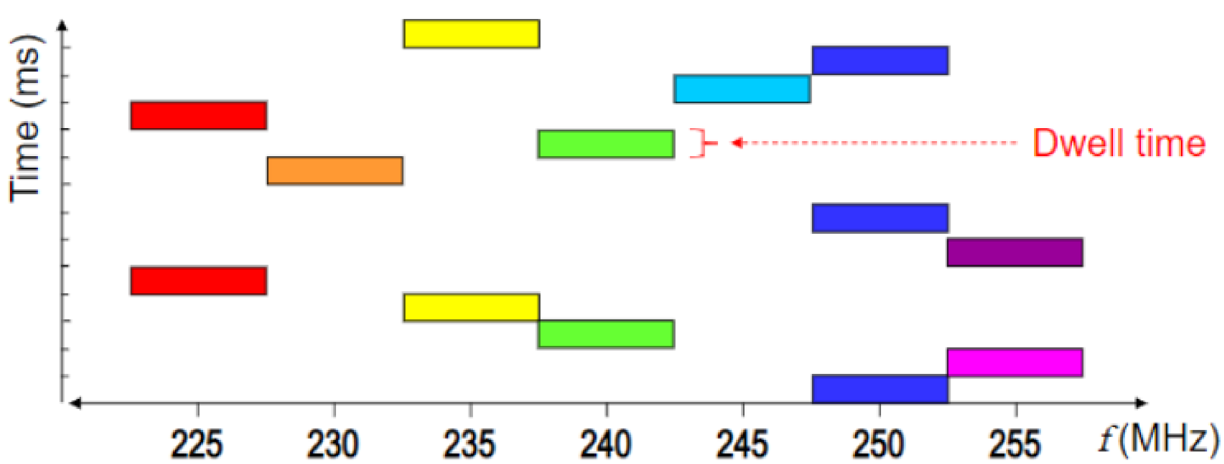


Types of spread spectrum techniques:

- Frequency Hopped Spread Spectrum (FH-SS): for Analog system
- Direct Sequence Spread Spectrum (DS-SS): for Digital system

Frequency Hopped Spread Spectrum (FH-SS)

- Frequency hopping involves a periodic change of carrier frequency in pseudorandom fashion
- transmitter and receiver know the pattern and are synchronized
- A frequency hopping signal may be regarded as a sequence of modulated data bursts with time-varying, pseudorandom carrier frequencies
- The set of possible carrier frequencies is called the hopset



- Hopping occurs over a frequency band that includes a number of channels
- Each channel is defined as a spectral region with a central frequency in the hopset and a bandwidth large enough to include narrowband modulation burst (usually FSK) having the corresponding carrier frequency

- Dwell Time: The amount of time spent on a specific frequency in an FHSS hopping sequence (typically < 10 ms)
- Hop duration or Hopping period (Th): time duration between hops

Direct Sequence Spread Spectrum (DS-SS)

- Technique in which the data (message) signal is multiplied with a pseudo-random spreading sequence that has a much higher chip rate R_c than the original data rate R_b
  - $R_c >> R_b$
- The spread spectrum signal is PSK modulated.
- Each bit is assigned a code of n bits, called chips, where the chip rate is n times that of the data bit.

Orthogonal Frequency Division Multiplexing (OFDM)

- Modulation scheme that is especially suited for high-data-rate transmission in delay-dispersive (frequency selective) environments
- Converts a high-rate data stream into a number of low-rate streams that are transmitted over parallel, narrowband channels that can be easily equalized
- It is a digital multi-carrier modulation scheme that extends the concept of single subcarrier modulation by using multiple subcarriers within the same single channel
- OFDM makes use of a large number of closely spaced orthogonal subcarriers that are transmitted in parallel
- Each subcarrier is modulated with a conventional digital modulation scheme (such as QPSK, 16QAM, etc.) at low symbol rate
- The combination of many subcarriers enables data rates similar to conventional single-carrier modulation schemes within equivalent bandwidths.

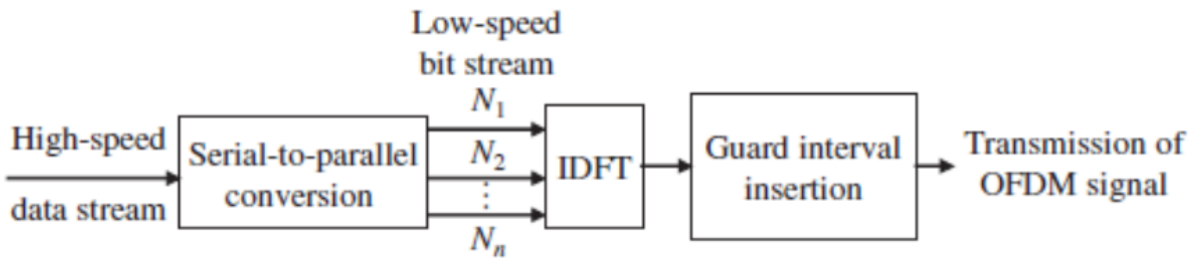
OFDM Transmitter

- The orthogonality condition of the two signals in OFDM can be given by

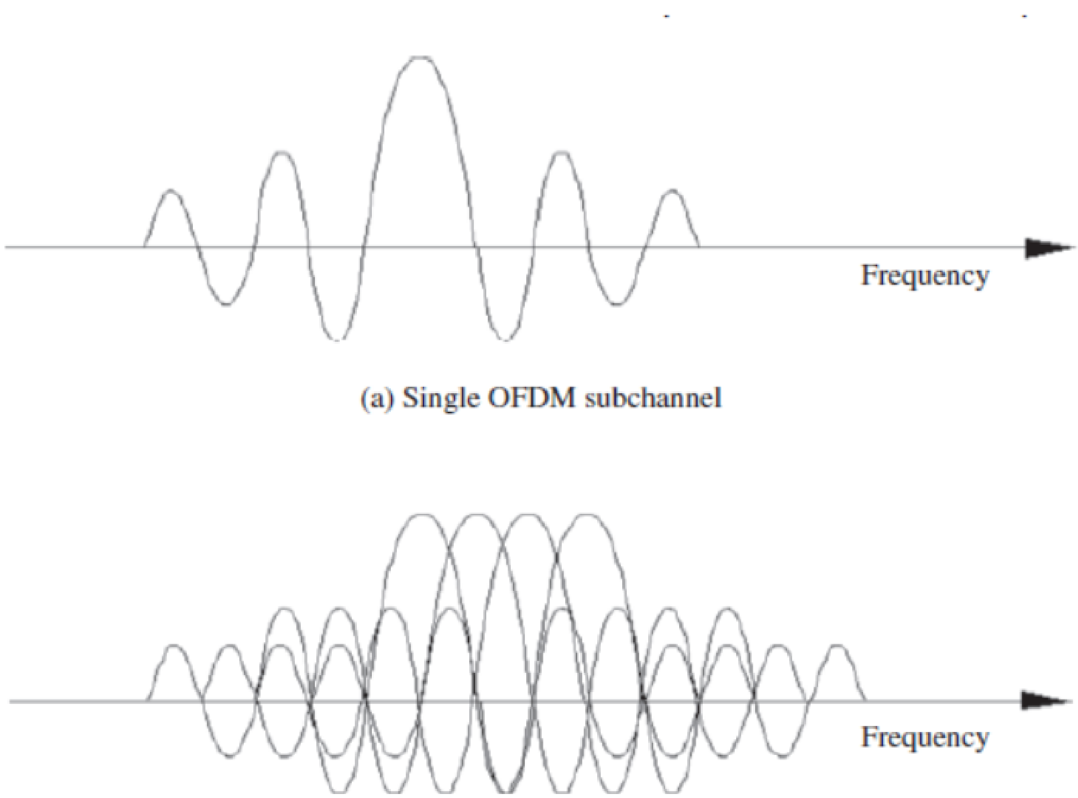
$$\int_F s_i(f,t)s_j^*(f,t)dt = \begin{cases} 1 & i = j \\ 0 & i \neq j \end{cases}$$

- OFDM is based on the well-known technique of Frequency Division Multiplexing (FDM)
- In FDM different streams of information are mapped onto separate parallel frequency channels

- Each FDM channel is separated from the others by a frequency guard band to reduce interference between adjacent channels



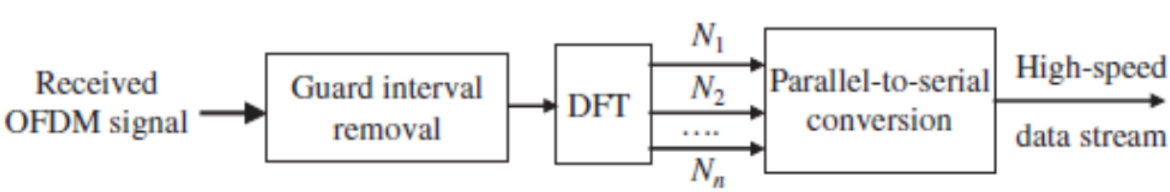
OFDM Waveform



(a) Single OFDM subchannel

(b) An OFDM signal with multiple subchannels

OFDM Receiver



6. Why do you need a speech coding technique? Explain the basic concept of VOCODERS.

- In mobile communication systems, bandwidth is a precious commodity, and service providers are continuously met with the challenge of accommodating more users within a limited allocated bandwidth
- The lower the bit rate at which the coder can deliver toll quality speech, the more speech channels can be compressed within a given bandwidth
- The performance of speech coders determines the quality of the recovered speech and the capacity of the system
- The goal of all speech coding systems:
    - to transmit speech with the highest possible quality using the least possible channel capacity
    - process to convert speech signal with higher bit rate to lower bit rate, i.e., speech compression process
- It is a procedure to represent a digitized speech signal using as few bits as possible while maintaining the speech quality

Speech waveforms have a number of useful properties that can be exploited when designing efficient coders

- Non uniform probability distribution of speech amplitude
- Non zero autocorrelation between successive speech samples
- Non flat nature of the speech spectra
- Existence of voiced and unvoiced segments in speech
- Quasi-periodicity of voiced speech signals

VOCODERS

- Coding systems that analyze the voice signal at the transmitter
- transmit parameters derived from the analysis, and then synthesize the voice at the receiver using those parameters
- Much more complex than the waveform coders
- Achieve a very high economy in transmission bit rate.
- Less robust
- Types:
    - Linear predictive coder (LPC)
    - Channel vocoder
    - Formant vocoder
    - Cepstrum vocoder
    - Voice excited vocoder

Linear predictive coder (LPC)

- Belong to the time domain class of vocoders.
- Attempts to extract the significant features of speech from the time waveform.

- Computationally intensive, but most popular among the class of low bit rate vocoders
- Transmit good quality voice at 4.8 kbps and poorer quality voice at even lower rates
- The prediction principles are similar to those in ADPCM, but LPC transmits only selected characteristics of the error signal, includes:
  - Gain factor
  - Pitch information
  - Voiced/unvoiced decision information.
- Models the vocal tract as an all pole linear filter

Multi-pulse Excited LPC
- No matter how well the pulse is positioned, excitation by a single pulse per pitch period produces audible distortion.
- Using more than one pulse, typically eight per period, and adjusting the individual pulse positions and amplitudes sequentially to minimize a spectrally weighted mean square error.
- Can results in better speech quality, because the prediction residual is better approximated by several pulses per pitch period
- The multi-pulse algorithm does not require pitch detection.

Code-Excited LPC
- The coder and decoder have a predetermined code book of stochastic (zero-mean white Gaussian) excitation signals.
- For each speech signal the transmitter searches through its code book of stochastic signals for the one that gives the best perceptual match to the sound when used as an excitation to the LPC filter.
- The index of the code book where the best match was found is then transmitted.
- The receiver uses this index to pick the correct excitation signal for its synthesizer filter.
- Extremely complex, but can provide high quality even when the excitation is coded at only 0.25 bits per sample.
- CDMA digital cellular standard (IS-95): variable rate CELP codec at 1.2 to 14.4 kbps, and QCELP13 at 13.4 kbps

Residual Excited LPC
- In this class of LPC coders, after estimating the model parameters (LP coefficients or related parameters) and excitation parameters (voiced/unvoiced decision, pitch, gain) from a speech frame, the speech is synthesized at the transmitter and subtracted from the original speech signal to from a residual signal.
- The residual signal is quantized, coded, and transmitted to the receiver along with the LPC model parameters.

- At the receiver the residual error signal is added to the signal generated using the model parameters to synthesize an approximation of the original speech signal.
- The quality of the synthesized speech is improved due to the addition of the residual error

7. Why Equalization and Diversity is needed in Wireless communication. Explain the training and tracking modes of operation for Adaptive Equalizer in detail.
- Mobile radio channel is particularly dynamic due to multipath propagation and doppler's effect
- these effect have a strong negative impact on bit error rate of any modulation techniques
- mobile radio channel impairment cause negative signal at receiver to distort or fade significantly

Equalization:
- equalization, diversity and channel coding are three technique which can be used independently or intandem to improve received signal quality and link performance over small scale times and distances
- equalization compensate for intersymbol interference(ISI) created by multipath within time dispersive channel
- use to counter the effect of time dispersion (ISI)
    - If modulation bandwidth exceed coherence bandwidth ISI occurs and modulation pulse are spread in time into adjacent symbol
    - Equalizer in receiver compensate for the average range of expected channel amplitude and delay characterization
    - Equalizer must be adaptive since positive channel is unknown at time varying

Diversity:
- technique used to compensate for fading channel impairment and is usually implemented using two or more receiving antennas
- improves the quality of wireless communication link without altering common air interface and without increasing the transmitted power and bandwidth
- usually employed to reduce depth and duration of fades experienced by a receiver in local area which are due to motion
- common diversity technique is spatial diversity, whereby multiple antenna strategically spaced and connected common receiving system
- when one antenna see the null signal other can see signal peas so receiver select the antenna with best signal

The training and tracking modes of operation for Adaptive Equalizer:
Adaptive equalizer works on two operating modes, that are training
and tracking

Training Mode
Initially a known, fixed length training sequence is sent by the transmitter so that the receiver equalizer may average to a proper setting. Training sequence is typically a pseudo-random binary signal or a fixed, or prescribed bit pattern.

The training sequence is designed to permit an equalizer at the receiver to acquire the proper filter coefficient in the worst possible channel condition. An adaptive filter at the receiver thus uses a recursive algorithm to evaluate the channel and estimate filter coefficients to compensate for the channel.

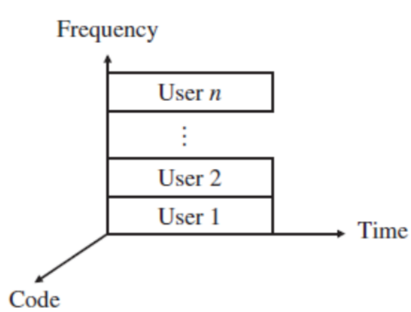
Tracking Mode
When the training sequence is finished the filter coefficients are near optimal. Immediately following the training sequence, user data is sent.

When the data of the users are received, the adaptive algorithms of the equalizer track the changing channel. As a result, the adaptive equalizer continuously changes the filter characteristics over time.

8. What is Multiple Access Technique? Compare TDMA, FDMA and CDMA.
- Enable many mobile users to simultaneously share radio spectrum to achieve high capacity
- Aim to share a channel between two or more signals in such way that each signal can be received without interference from another

Frequency Division Multiple Access (FDMA)

- FDMA assigns individual channels to individual users
- Each user is allocated a unique frequency band or channel
- During the period of the call, no other user can share the same channel
    - If an FDMA channel is not in use, then it is a wasted resource
- FDMA is a continuous transmission scheme
- FDMA uses duplexers since both the transmitter and receiver operate at the same time
- FDMA: 1G

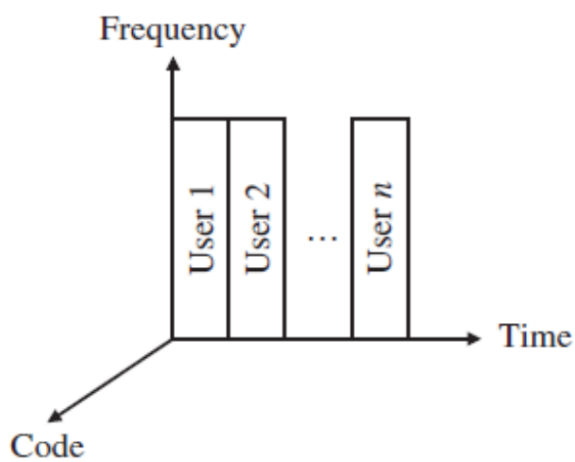


The orthogonality condition of the two signals in FDMA is given by

$$\int_F s_i(f,t)s_j(f,t)df = \begin{cases} 1, & i = j \\ 0, & i \neq j \end{cases} i, j = 1, \cdots k$$

Time Division Multiple Access (TDMA)

- TDMA splits a single carrier wave into several time slots and distributes the slots among multiple users
- The communication channels essentially consist of many units, i.e., time slots, over a time cycle, which makes it possible for one frequency to be efficiently utilized by multiple users, given that each utilizes a different time slot
- Data transmission for users of a TDMA system is not continuous, but occurs in bursts
  - discontinuous transmissions in TDMA, the handoff process is much simpler for a subscriber unit
  - it is able to listen for other base stations during idle time slots
- TDMA uses different time slots for transmission and reception, thus duplexers are not required
- TDMA: 2G

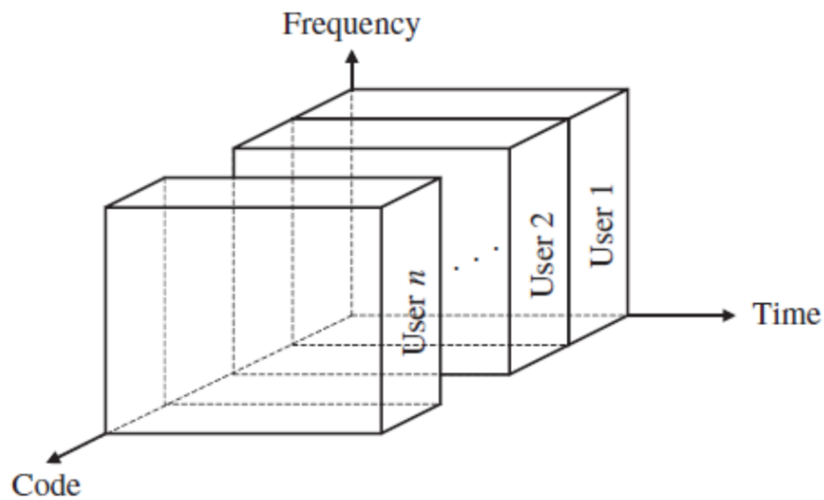


The orthogonality condition of the two signals in TDMA is given by

$$\int_T s_i(f,t)s_j(f,t)dt = \begin{cases} 1, & i=j \\ 0, & i \neq j \end{cases} \quad i,j = 1,\cdots k$$

Code Division Multiple Access (CDMA)

- The spreading signal has a pseudo-noise code sequence that has a chip rate which is orders of magnitudes greater than the data rates of the message
- All users use the same carrier frequency and can transmit simultaneously
- Each user has its own pseudorandom codeword that is orthogonal to the others
- The receivers need to know the codeword of the corresponding sender



The orthogonality condition of the two signals in CDMA is given by

$$\int_C s_i(f,t)s_j(f,t)dt = \begin{cases} 1, & i = j \\ 0, & i \neq j \end{cases} i,j = 1,\cdots k$$

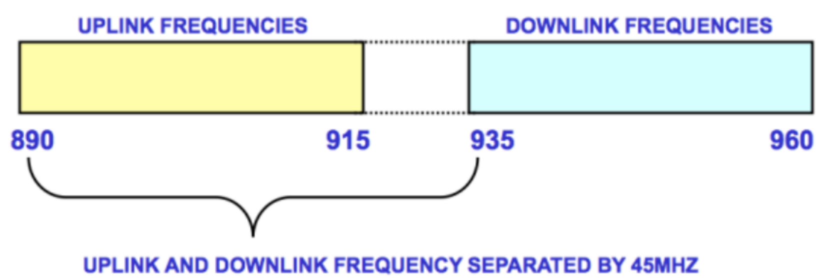
Technique	FDMA	TDMA	CDMA	SDMA
Concept	Divide the frequency band into disjoint sub-bands	Divide the time into non-overlapping time slots	Spread the signal with orthogonal codes	Divide the space in to sectors
Active terminals	All terminals active on their specified frequencies	Terminals are active in their specified slot on same frequency	All terminals active on same frequency	Number of terminals per beam depends on FDMA/ TDMA/ CDMA
Signal separation	Filtering in frequency	Synchronization in time	Code separation	Spatial separation using smart antennas
Handoff	Hard handoff	Hard handoff	Soft handoff	Hard and soft handoffs
Advantages	Simple and robust	Flexible	Flexible	Very simple, increases system capacity
Disadvantages	Inflexible, available frequencies are fixed, requires guard bands	Requires guard space, synchronization problem	Complex receivers, requires power control to avoid near-far problem	Inflexible, requires network monitoring to avoid intra cell handoffs
Current applications	Radio, TV and analog cellular	GSM and PDC	2.5G and 3G	Satellite systems, LTE

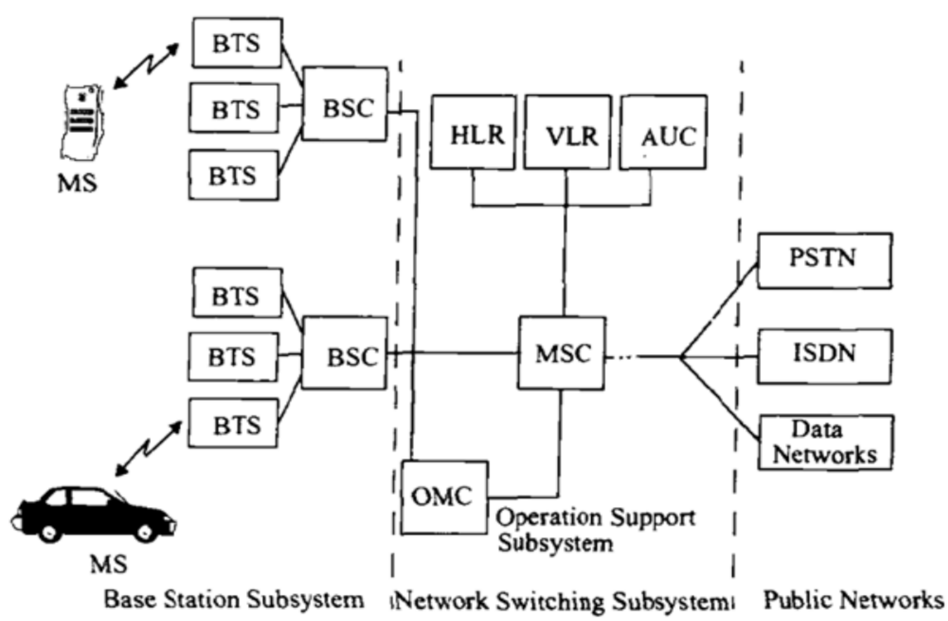
9. Briefly explain the architecture of GSM system and the role played by HLR, VLR, EIR, OMC and AUC in GSM

- GSM is a second generation digital cellular system standard.
- It is the world's most popular 2G technology.

Features and Services:

- Frequency reuse
- Use of standardized open interface
- Support for international roaming
- Distinction between user and device identification
- Excellent speech quality
- Cleaner Handovers i.e., Mobile Assisted HandOver (MAHO)
- Enhanced range of services
    - Voice, SMS, Data (max 9.6 kbps)
    - Call waiting, Call forward
    - Caller line identification
- Interworking (e.g., with ISDN, DECT)





GSM system architecture.

GSM system architecture consists of
- Mobile Station (MS)
- Base Station Subsystem (BSS)
- Network and Switching Subsystem (NSS)
- Operation and Support Subsystem (OSS)

Mobile Station (MS)
- The mobile station (MS) consists of
    - Mobile equipment (ME)
    - Subscriber Identity Module (SIM)
- By inserting the SIM card into another GSM terminal, the user is able to:
    - receive calls at that terminal
    - make calls from the terminal
    - receive other subscribed services
- The mobile equipment is uniquely identified by the International Mobile Equipment Identity (IMEI).
- The SIM card contains the International Mobile Subscriber Identity (IMSI) used to identify the subscriber to the system, a secret key for authentication, and other information.
- The IMEI and the IMSI are independent, thereby allowing personal mobility.
- The SIM card may be protected against unauthorized use by a password or personal identity number (PIN).

Base Station Subsystem (BSS):
- The fixed end of the radio interface that provides control and radio coverage functions for one or more cells and their associated MSs
- The interface between MS and MSC
- BSS comprises
    - one or more Base Transceiver Stations (BTSs)
    - one Base Site Controller (BSC)
- Digital radio techniques are used for the radio communications link, known as Air Interface, between the BSS and the MS

Base Station Controller (BSC):
- Provides the control for BSS
- The purpose of BSC is to perform a variety of functions
    - controls the BTS components
    - controls the BTS components MSs
    - provides A Interface between BSS and MSC
    - handles the radio channels, frequency hopping, and handovers

Base Transceiver Station (BTS):
- Consists of the hardware components, such as radios, interface modules and antenna systems that provide the Air Interface between BSS and MSs

- Provides radio channels (RF carriers) between MSs and BSS for a specific RF coverage area
- BTS also has a limited amount of control functionality which reduces the amount of traffic between BTS and BSC

Network and Switching Subsystem (NSS)

- The central component of the NSS or Network Subsystem (NS) is the Mobile services Switching Center (MSC)
- It acts like a normal switching node of the PSTN or ISDN, and additionally provides all the functionality needed to handle a mobile subscriber, such as
  - registration, authentication, location updating, handovers, and call routing to a roaming subscriber
- These services are provided in conjunction with several functional entities, which together form the Network Subsystem.

Mobile Switching Center (MSC):

- MSC co-ordinates the setting up of calls to and from GSM users
- MSC provides the interface between PSTN and BSS in the GSM network it is called the Gateway MSC

Home Location Register (HLR):

- Contains all the administrative information of each subscriber registered in the corresponding GSM network
- The parameters stored in HLR
  - subscribers ID (IMSI and MSISDN)
  - current vistor location register (VLR) address
  - supplementary subscribed services
- HLR data is remotely accessed by the MSCs and VLRs in the network

Authentication Centre (AUC):

- A processor system that performs authentication function
- The authentication process usually takes place each time the subscriber initializes on the system
- Each subscriber is assigned an authentication key (K_i) which is stored in the SIM and at the AUC

Visitor Location Register (VLR):

- A local subscriber database, holding details on those subscribers who enter the area of the network that it covers
- The details are held in the VLR until the subscriber moves into the area serviced by another VLR

- The data includes most of the information stored at the HLR, as well as more precise location and status information

Operation and Maintenance Centre:
- Monitors the quality of service being provided by the network
- OMC is used to support NMC (Network Management Center)
- OMC main functions:
    - allows network devices to be manually removed for or restored to service
    - the alarms generated by the network elements are reported and logged at the OMC
    - keeps on collecting and accumulating traffic statistics from network elements for analysis

10. Explain the term Spread Spectrum. What are the main features of CDMA technology?

\- Spread spectrum signals are pseudorandom and have noise-like properties
\- The spreading waveform is controlled by a pseudo-noise (PN) sequence or pseudo-noise code, which is a binary sequence that appears random but can be reproduced in a deterministic manner by intended receivers
- PN sequence is independent of the data in the signal
- PN sequence have
    - nearly equal number of zeros and ones
    - very low correlation between shifted versions of the sequence

\- Spread spectrum modulation technique uses transmission bandwidth (B_{SS}) that is several times greater than the information signal bandwidth (B): $B_{SS} >> B$
\- In a multiple-user, multiple access interference environment, spread spectrum systems become very bandwidth efficient

CDMA:
- CDMA stands for Code Division Multiple Access.
- It is basically a channel access method and is also an example of multiple access.
- Multiple access basically means that information by several transmitters can be sent simultaneously onto a single communication channel.

Characteristics of CDMA

- It allows more users to connect at a given time and thus provides improved data and voice communication capacity.
- A full spectrum is used by all the channels in CDMA.
- CDMA systems make the use of power control to eliminate the interference and noise and to thus improve the network quality.
- CDMA encodes the user transmissions into distinct and unique codes in order to secure its signals.
- In CDMA systems all the cells can thus use the same frequency.
- CDMA systems have a soft capacity.Thus there is no particular limit to the number of users in a CDMA system but with increase in the number of users the performance degrades.

Advantages

- Increased user capacity is an advantage of the CDMA as it supports a lot more users in comparison to TDMA or FDMA.
- CDMA is more secure as the information transmitted is below the noise floor making the intrusion of the spectrum difficult.
- CDMA systems have comparatively fewer dropouts than GSM. Thus, it can also be used in rural areas.
- The cost of the calls in CDMA is lower in comparison to the cost in GSM.
- CDMA provides a high quality of voice with almost no noise during the calls.
- Using CDMA problems like multipath and fading do not occur.
- CDMA has a very low power requirement.

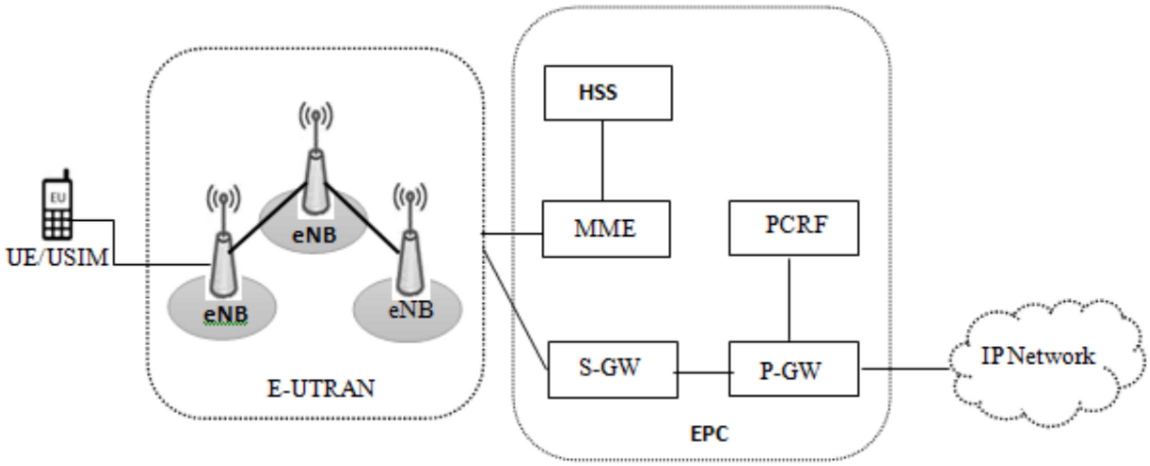
Disadvantages

- CDMA lacks the facility of international roaming which is provided by GSM.
- Since there is no limit to the number of users the system performance degrades with an increase in the number of users.
- Self-jamming problems occur in CDMA systems because of loss of orthogonality.
- The problem of channel pollution occurs in CDMA systems which thus degrades the quality of audio.
- Since most of the mobile companies use GSM thus there is a lack of handsets for CDMA technology.
- near-far problem.

11. Define WiMaX and LTE. Explain the architecture of LTE.

Difference between WiMAX and LTE :

S.No.	WIMAX	LTE
01.	Worldwide Interoperability for Microwave Access, in short, is referred to as WiMAX.	Long Term Evolution in short is referred to as LTE.
02.	WiMAX is a wireless communication standard based on IEEE 802.16 and it is a newer technology for point to multipoint wireless networking means it specifies how wireless devices communicate over the air in a wide area.	LTE is not a technology rather it is a path followed to achieve 4G speed and a standard for wireless data transmission means it is behind 4G which is used worldwide for transferring data over cellular networks.
03.	Its network architecture is Flat and IP-based, Access Service Network Gateway (ASN-GW).	Its network architecture is Very flat and IP-based, Evolved Node B (ENode B).
04.	The subscriber is identified using EAP (Extensible Authentication Protocol) protocol.	The subscriber is identified using the SIM (Subscriber Identity Module) card.
05.	The range of frequency bands: 700 MHz – 2.2 GHz.	The range of frequency bands: 2-11 GHz
06.	It provides mobility with a target of up to 120km/h.	It provides mobility with a target of up to 350km/h.
07.	Modulation Schemes: Downlink: BPSK (optional for OFDMA-PHY) QPSK 16QAM 64QAM Uplink: BPSK QPSK 16QAM 64QAM(optional)	Modulation Schemes: Downlink: QPSK 16QAM 64QAM Uplink: QPSK 16QAM 64QAM (optional)
08.	The subcarrier spacing can be variable due to which capacity can be varied.	Subcarrier spacing constant at 15Khz.
09.	In this due to high channel utilization, processing that much information requires 1000 point Fast Fourier Transform (FFT).	In this due to organization of data into smaller chunks makes it process the information by lower point Fast Fourier Transform (FFT) like 16 point FFT.
10.	Duplex mode mostly focus on Time Division Duplex (TDD).	Duplex mode mostly focus on Frequency Division Duplex (FDD).
11.	It mostly provides fixed bandwidth.	It mostly provides flexible bandwidth.
12.	The technology used to access is OFDMA (Orthogonal Frequency-division Multiple Access) for both downlink and uplink.	The technology used to access for downlink is OFDMA and for uplink is SC-FDMA (Single Carrier Frequency Division Multiple Access).
13.	Multiple Antenna Techniques- DL: 2X2 MIMO UL: 2X2 MIMO	Multiple Antenna Techniques- DL: 2X2 MIMO 4X4 MIMO UL: 2X2 MIMO DL: Downlink, UL: Uplink
14.	WiMAX does not provide backward compatibility.	LTE provides full backward compatibility with full 3GPP interoperability.



- User Equipment (UE)
- E-UTRAN
- Evolved Packet Core (EPC): core network

User Equipment (UE)

- The user equipment comprised of the following important modules:
    - Mobile Termination (MT) : This handles all the communication functions
    - Universal Integrated Circuit Card (UICC) : This is also known as the SIM card for LTE equipments. It runs an application known as the Universal Subscriber Identity Module (USIM)
    - A USIM stores user-specific data very similar to 3G SIM card. This keeps information about the user’s phone number, home network identity and security keys etc

evolved UMTS Terrestrial Radio Access Network
(E-UTRAN): access network

- The E-UTRAN handles the radio communications between the mobile and the evolved packet core (EPC)
- Mainly consist of evolved base stations (eNodeB)
- eNodeB: based on OFDMA instead of CDMA
- Main functions
    - Radio resource management: radio bearer control, radio mobility control, scheduling and dynamic allocation of radio resource at uplink and downlink

    - Connectivity to EPC via S1 interface
- An interface X2 interconnects between eNodeB

Evolved Packet Core (EPC): core network:

- Operator or carrier core network
- Traditionally circuit switched but now entirely packet switched
    - Based on IP
    - Voice supported using voice over IP (VoIP)

EPC COMPONENTS:

Packet Data Network Gateway (PGW):

- Connects the EPC with external networks
- A router that performs UE IP assignment, per user packet filtering
- Anchor point for mobility with non 3GPP access network
- Policy Control and Charging Rules Function (PCRF)Responsible for policy control decision-making
- Determines the allowed traffic types in real-time
- Operators use this information for billing purpose

12. Explain the transmitter and receiver of QPSK modulation.

- Variation of BPSK
    - Multilevel Modulation Technique: 2 bits per symbol
- Two bits per symbol with a minimum phase separation of π/2
- Modulating signals onto carrier signal using four phase 0, π/2 , π, 3π/2 states to code two digital bits

The modulated signal is $S_i(t) = A_c \cos(2\pi f_c t + \phi_i(t))$, $1 \leq i \leq 4$

Dibit	Phase $\phi(t)$
00	0
01	$\frac{\pi}{2}$
10	π
11	$\frac{3\pi}{2}$

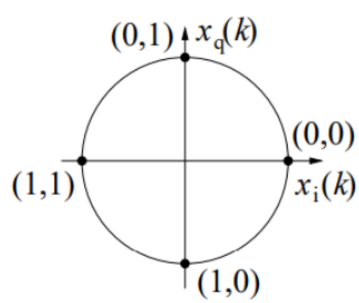
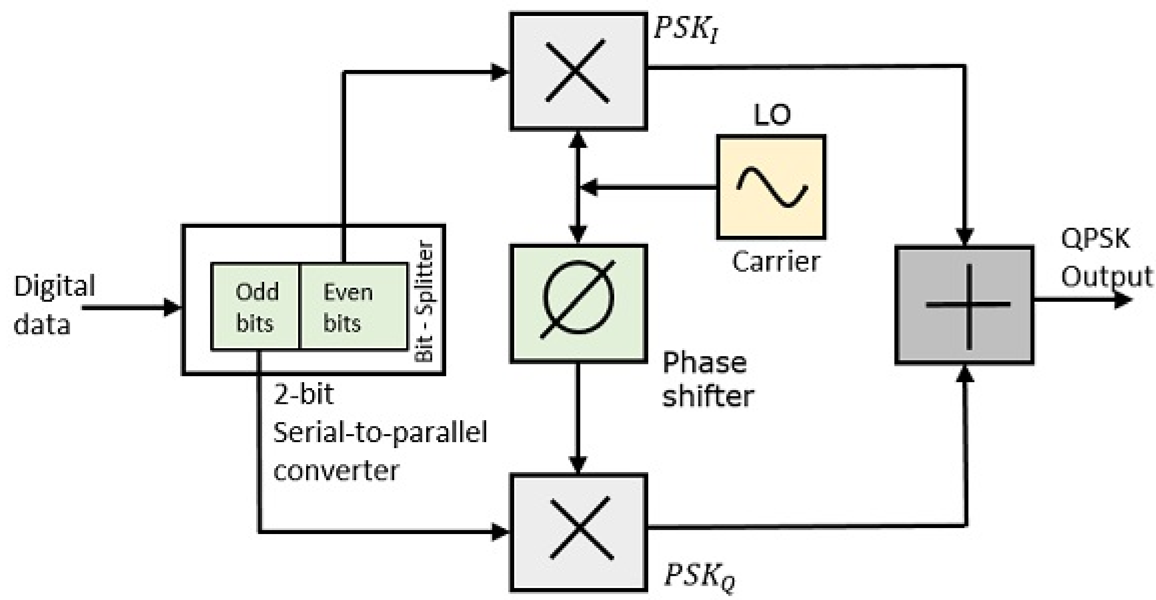


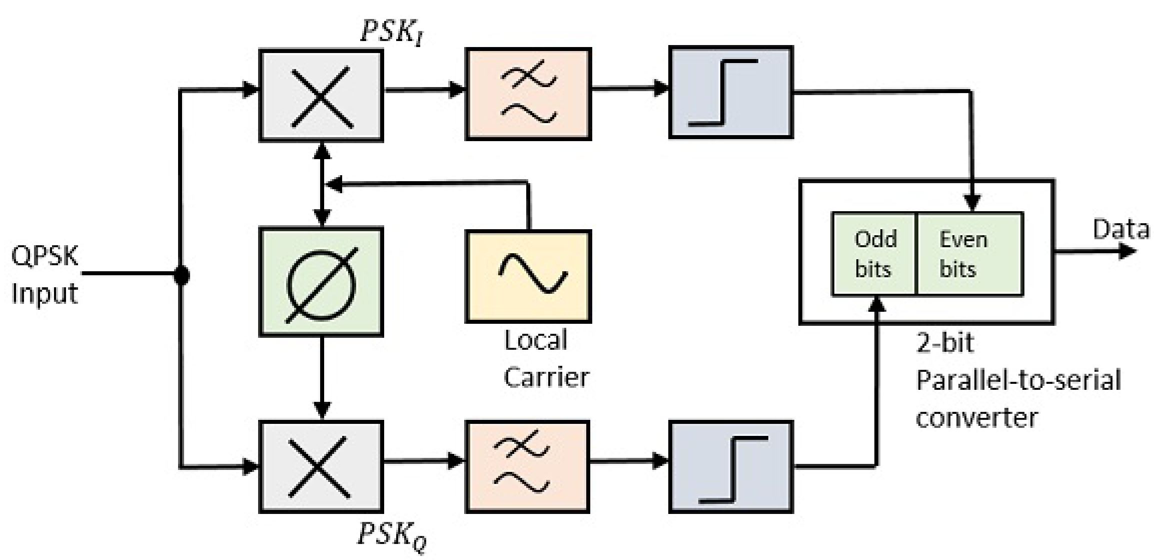
Figure: Constellation

Transmitter:

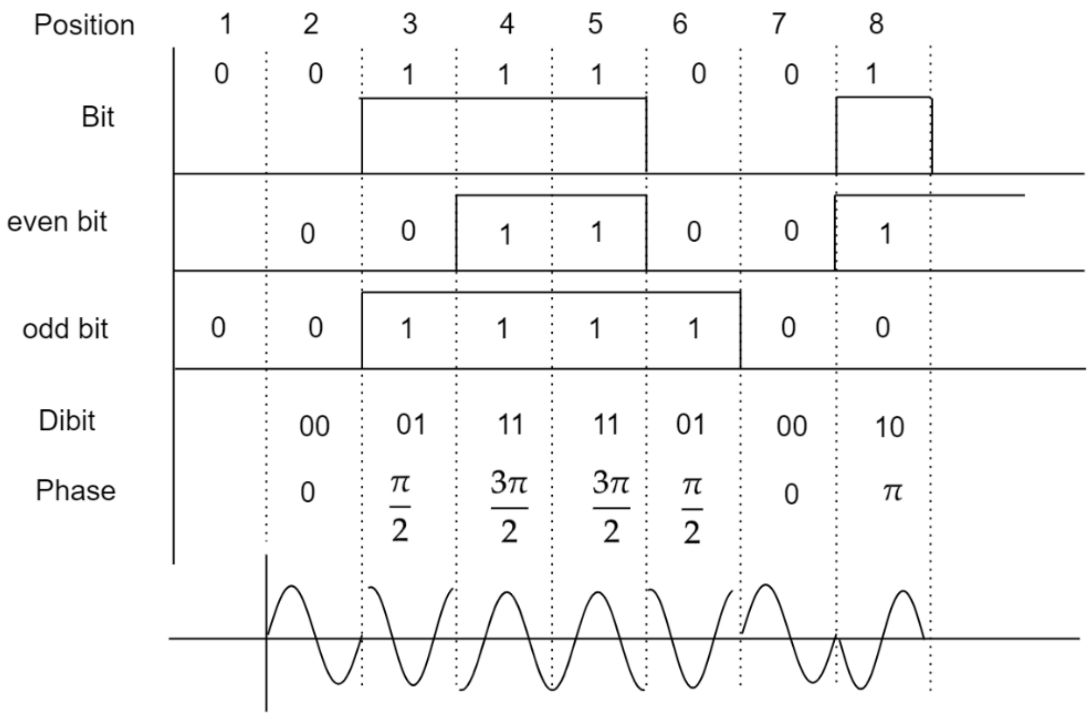


- The QPSK Modulator uses a bit-splitter, two multipliers with local oscillator, a 2-bit serial to parallel converter, and a summer circuit
- At the modulator's input, the message signal's even bits (i.e., 2nd bit, 4th bit, 6th bit, etc.) and odd bits (i.e., 1st bit, 3rd bit, 5th bit, etc.) are separated by the bits splitter are multiplied with the same carrier to generate odd BPSK (called as PSKI) and even BPSK (called as PSKQ)
- The PSKQ signal is any how phase shifted by 90° before being modulated.

Receiver:



Example



Position
1
2
3
4
5
6
7
8
Bit
0 0 1 1 1 0 0 1
even bit
0 0 1 1 0 0 1
odd bit
0 0 1 1 1 1 0 0
Dibit
00 01 11 11 01 00 10
Phase
0 $\frac{\pi}{2}$ $\frac{3\pi}{2}$ $\frac{3\pi}{2}$ $\frac{\pi}{2}$ 0 π

13. Short Note:
1. Difference between Android and IOS

S.No.	IOS	ANDROID
1.	It was developed and is owned by **Apple Incorporation**.	It was developed by Google and Open Handset Alliance and is owned by **Google LLC**.
2.	IOS was initially released on July 29, 2007	Google was initially released on 23 September 2008.
3.	when IOS was released its first version is iPhone OS 1 before named IOS.	When Google released its first version of Android 1.0, Alpha.
4.	It was launched in 2007.	It was launched in 2008.
5.	Its target system types are smartphones, music players, and tablet computers.	Its target system types are smartphones and tablets.
6.	It is specially designed for Apple iphones and ipads.	It is designed for smartphones of all companies.
7.	Its kernel type is Hybrid.	Its kernel type is Linux-based.
8.	It has preferred license is Proprietary, APSL, and GNU GPL.	It has the preferred license of Apache 2.0 and GNU GPLv2.
9.	It is mainly written in C, C++, Objective-C, assembly language, and Swift.	It is written using C, C++, Java, and other languages.
10.	Its update management is Software Update.	Its update management is Systems Software Update.
11.	Swift is majorly used for iOS application development.	Java and Kotlin are majorly used for Android application development.
12.	IOS has a Commercial Based Source model with open source components.	Android is an Open Source based Source model.
13.	IOS-based Devices have Safari as the default Internet Browser.	Android devices have google chrome but one can install any Internet Browser.
14.	IOS has Siri as Voice Assistant.	Google has Google Assistance.

2. Reverse CDMA Channel:
CDMA channels can be broadly categorized as Forward channel and Reverse channel.

Forward Channel
The Forward channel is the direction of the communication or mobile-to-cell downlink path. It includes the following channels −

- Pilot Channel − Pilot channel is a reference channel. It uses the mobile station to acquire the time and as a phase reference for coherent demodulation. It is continuously transmitted by each base station on each active CDMA frequency. And, each mobile station tracks this signal continuously.

- Sync Channel − Synchronization channel carries a single, repeating message, which gives the information about the time and system configuration to the mobile station. Likewise, the mobile station can have the exact system time by the means of synchronizing to the short code.

- Paging Channel − Paging Channel's main objective is to send out pages, that is, notifications of incoming calls, to the mobile stations. The base station uses these pages to transmit system overhead information and mobile station specific messages.

- Forward Traffic Channel − Forward Traffic Channels are code channels. It is used to assign calls, usually voice and signaling traffic to the individual users.

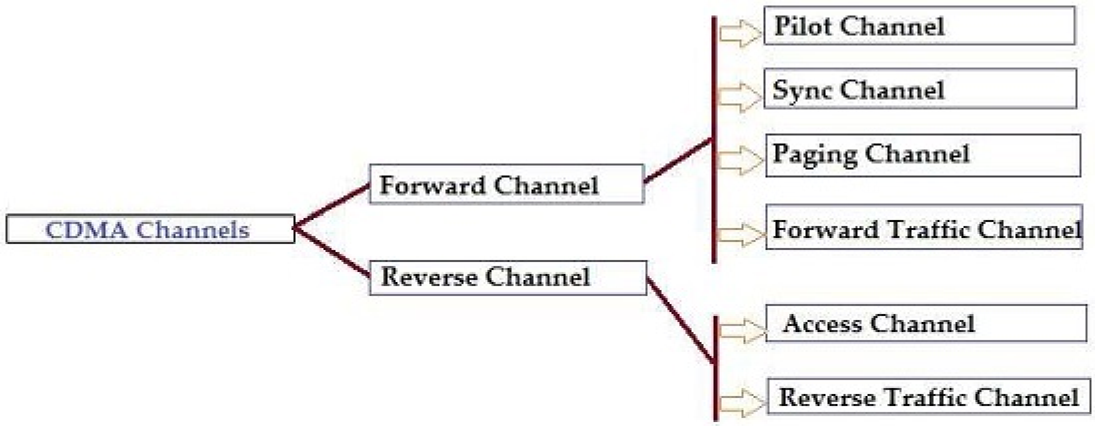
Reverse Channel

The Reverse channel is the mobile-to-cell direction of communication or the uplink path. It consists of the following channels −

- Access Channel − Access channel is used by mobile stations to establish a communication with the base station or to answer Paging Channel messages. The access channel is used for short signaling message exchanges such as call-ups, responses to pages and registrations.

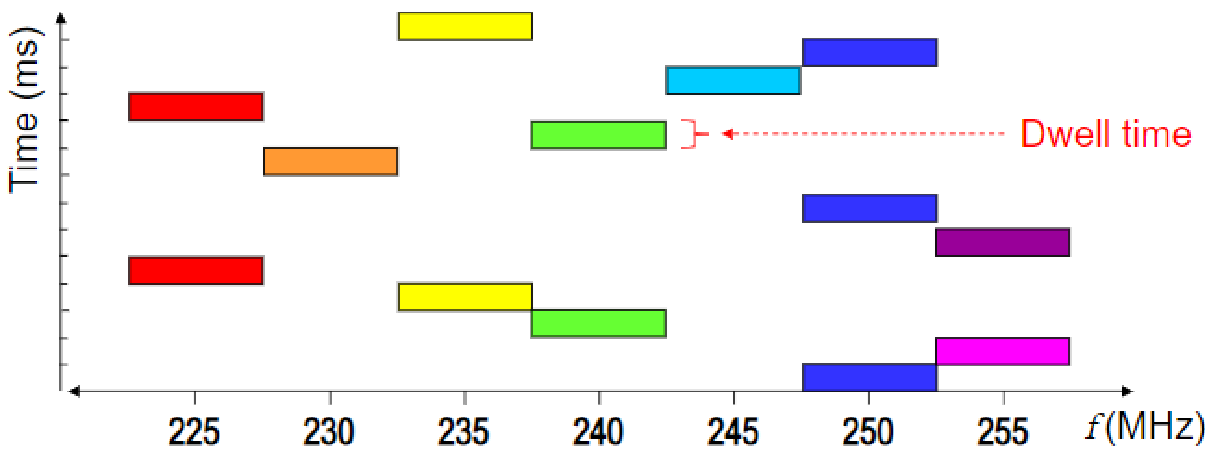
- Reverse Traffic Channel − Reverse traffic channel is used by the individual users in their actual calls to transmit traffic from a single mobile station to one or more base stations.

CDMA Channels

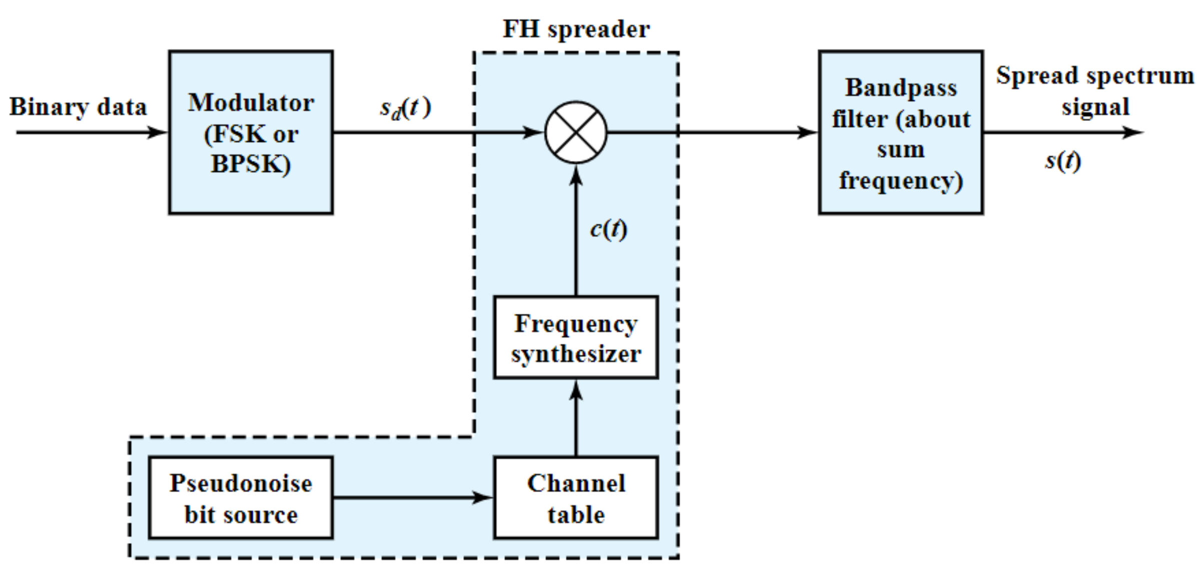


3. Frequency Hopping

- Frequency hopping involves a periodic change of carrier frequency in pseudorandom fashion
- transmitter and receiver know the pattern and are synchronized
- A frequency hopping signal may be regarded as a sequence of modulated data bursts with time-varying, pseudorandom carrier frequencies
- The set of possible carrier frequencies is called the hopset

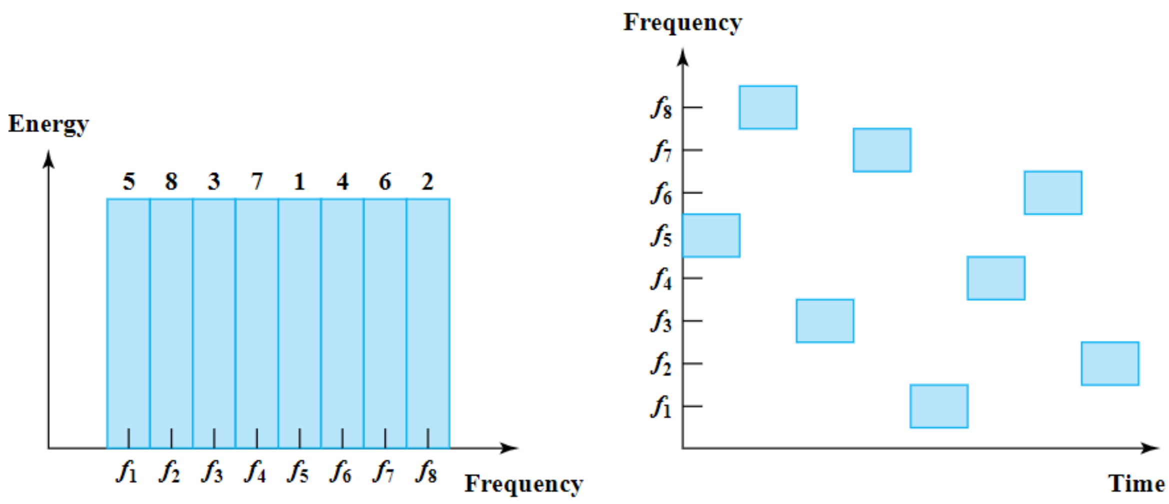


- Hopping occurs over a frequency band that includes a number of channels
- Each channel is defined as a spectral region with a central frequency in the hopset and a bandwidth large enough to include narrowband modulation burst (usually FSK) having the corresponding carrier frequency
- Dwell Time: The amount of time spent on a specific frequency in an FHSS hopping sequence (typically < 10 ms)
- Hop duration or Hopping period (Th): time duration between hops

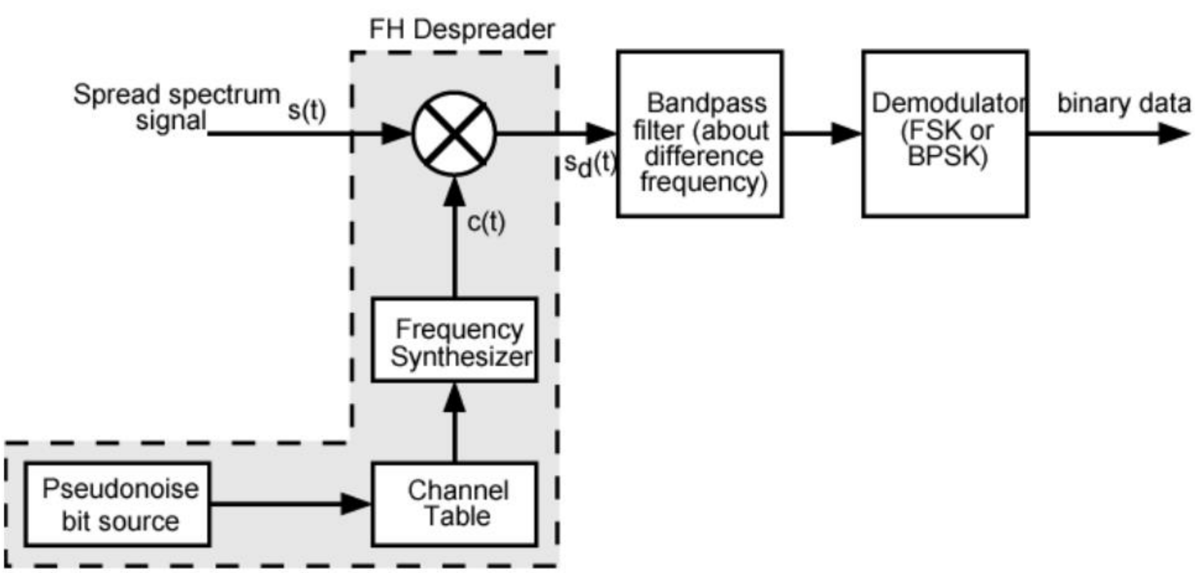


4. Frequency synthesizer

- A pseudo-random code generator (PN): creates a k-bit pattern for every hopping period T_h
- The frequency/ channel table uses the pattern to find the frequency to be used for hopping period and passes it to the frequency synthesizer
- The frequency synthesizer creates a carrier signal of that frequency and the source signal modulates the carrier signal



(a) Channel assignment (b) Channel use



5. DECT

- Also known as Digital Enhanced Cordless Telecommunications
- Digital wireless technology for telephony: used for home and business
- Created by European Telecommunication Standards Institute (ETSI): 1980
    - to communicate with in small or short range upto 300m

  - aprox. 50 m in buildings, 300 m open space
  - Transmit average power 10mW (max. 250mW)
- uses time division multiple access (TDMA)
- TDD with 10 ms frame length
  - UL:DL = 1:1
- Modulation: GMSK (Gaussian Minimum Shift Keying)
- Frequency band: 1880 MHz - 1900 MHz
- Consist of two components:
  - Mobile handset
  - Base station: connected to fixed telephone network
- Fixed network: Public switched telephone network (PSTN) or Private automatic branch exchange (PABX)