M1:Fundamentals of Wireless Communication

1. Define the following terms : Channel, Multipath propagation, Fading, Simplex channel, Duplex channel, FDD, TDD, Multiple Access, Processing gain in Spread spectrum system, subcarrier and subchannel.

Channel:

- In communication systems, a channel refers to the medium through which signals are transmitted from the sender to the receiver. It can be a physical medium, such as a wire or fiber optic cable, or it can be a wireless medium, like radio waves or microwaves.

Multipath Propagation:

- Multipath propagation occurs when signals travel from the transmitter to the receiver via multiple paths. This can result in signal reflections, refractions, and diffractions, leading to the reception of multiple copies of the same signal at the receiver with different delays.

Fading:

- Fading is the variation in the received signal strength over time and space due to factors such as multipath propagation, atmospheric conditions, and obstacles in the signal path. Fading can be classified as slow fading (changes occur gradually) or fast fading (changes occur rapidly).

Simplex Channel:

- A simplex channel is a communication channel that allows communication to occur in only one direction. Communication is unidirectional, and it is typically used for applications where information needs to flow from one point to another without the need for a two-way exchange.

Duplex Channel:

- A duplex channel is a communication channel that allows communication in both directions. It enables two-way communication, where information can be transmitted and received simultaneously.

FDD (Frequency Division Duplex):

- FDD is a duplex communication method where the uplink (transmit) and downlink (receive) communication occur at different frequencies simultaneously. It is commonly used in cellular communication systems.

TDD (Time Division Duplex):

- TDD is a duplex communication method where the uplink and downlink communication share the same frequency but occur at different time intervals. Time is divided into alternating time slots for transmission and reception.

Multiple Access:

- Multiple Access refers to the ability of multiple users or communication devices to share the same communication channel simultaneously. Common multiple access techniques include Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA).

Processing Gain in Spread Spectrum System:

- Processing gain is the increase in signal-to-noise ratio achieved by spreading a signal over a wider bandwidth using spread spectrum techniques. It provides a measure of the system's ability to resist interference and improve signal quality.

Subcarrier and Subchannel:

- A subcarrier is a carrier wave that is modulated by another carrier wave. In communication systems, subcarriers are often used to convey additional information within the main carrier signal.
- A subchannel refers to a portion of the total available bandwidth in a communication system. It may contain one or multiple subcarriers, each serving a specific purpose, such as carrying data or signaling. Subchannels are often used in multiplexing to accommodate multiple communication streams within the same frequency band.

2. Compare FDMA & TDMA on following points: Definition, Sharing Resource, Guard band requirement, Synchronization requirement, Filtering, ISI, Capacity, and Channel BW.

Definition:

- FDMA (Frequency Division Multiple Access): In FDMA, different users are assigned different frequency bands within the overall bandwidth, allowing them to communicate simultaneously without interference.
- TDMA (Time Division Multiple Access): In TDMA, multiple users share the same frequency band, but each user is assigned a specific time slot during which they can transmit or receive data.

Sharing Resource:

- FDMA: Users share the resource (total available bandwidth) by being allocated separate frequency bands.
- TDMA: Users share the resource by being allocated specific time slots within the same frequency band.

Guard Band Requirement:

- FDMA: Requires guard bands between frequency allocations to prevent interference between adjacent channels.
- TDMA: Guard bands are not required since users share the same frequency band but at different time slots.

Synchronization Requirement:

- FDMA: Users do not require tight synchronization since they operate in different frequency bands.
- TDMA: Tight synchronization is essential to ensure that users transmit and receive within their assigned time slots.

Filtering:

- FDMA: Requires frequency domain filters to **separate different channels.**
- TDMA: Requires time domain filters to **isolate signals during specific time slots.**

ISI (Intersymbol Interference):

- FDMA: Typically not affected by ISI since each user occupies a different frequency band.
- TDMA: May experience ISI if there is insufficient guard time between time slots.

Capacity:

- FDMA: Capacity is determined by the number of available frequency bands, limiting the number of users that can operate simultaneously.
- TDMA: Capacity is determined by the number of time slots within the overall time frame, allowing for a flexible allocation of users.

Channel Bandwidth:

- FDMA: Each user is allocated a dedicated frequency band, which determines the channel bandwidth.
- TDMA: The channel bandwidth is shared among users, and each user's transmission occurs within a specific time slot.

3. Explain CDMA has infinite theoretical capacity but is limited by the number of users.

Code Division Multiple Access (CDMA) is a multiple access technique used in communication systems, particularly in wireless networks. CDMA has a unique characteristic that allows it to theoretically support an infinite number of users, but in practical terms, its capacity is limited by various factors, including available resources and system design considerations. Here's an explanation of why CDMA is often said to have infinite theoretical capacity but is limited by the number of users:

Spread Spectrum Technique:

- CDMA employs a spread spectrum technique where each user's signal is spread over a wide frequency band using a **unique code**. This spreading allows multiple users to share the same frequency band simultaneously.

Orthogonal Codes:

- CDMA uses orthogonal codes (codes that are orthogonal to each other) to distinguish between different users. Each user is assigned a unique code, and the codes are designed to be orthogonal, meaning they do not interfere with each other.

Interference Mitigation:

- The use of orthogonal codes allows CDMA systems to mitigate interference between users. Even when multiple users transmit simultaneously on the same frequency, their signals can be separated at the receiver using the unique codes, reducing interference.

Soft Capacity Limits:

- Theoretically, CDMA can support an unlimited number of users because each user's signal is spread across a wide bandwidth, and the orthogonal codes provide a means of separating them. However, in practice, there are limits imposed by factors such as **available spectrum, signal-to-noise ratio, and the complexity of managing a large number of users.**

Noise and Interference:

- As the number of users increases, the potential for noise and interference also increases. In a real-world scenario, the system will reach a point where the noise and interference levels become significant, affecting the overall performance and limiting the number of users that can be effectively supported.

System Design and Resource Allocation:

- The practical capacity of a CDMA system is influenced by the overall system design, including the **allocation of resources such as bandwidth, power, and codes.** Efficient resource management is crucial for maximizing the number of users that can be accommodated.

4. List the main characteristics of CDMA.

Spread Spectrum Technique:

- CDMA utilizes a spread spectrum technique, where the transmitted **signal is spread over a wide frequency band using a unique code.** This spreading enables multiple users to share the **same frequency band simultaneously.**

Unique Codes for Each User:

- Each user in a CDMA system is assigned a unique code, often called a **spreading code** or Walsh code. These codes are **orthogonal** to each other, meaning they **do not interfere with one another.**

Simultaneous Transmission:

- Multiple users can transmit simultaneously on the same frequency band without causing interference. The unique codes assigned to each user allow their signals to be distinguished at the receiver.

Interference Mitigation:

- CDMA systems are designed to mitigate interference by using the unique codes. Even if multiple users transmit on the same frequency at the same time, their signals can be separated at the receiver.

Soft Capacity Limits:

- CDMA is theoretically capable of supporting a large number of users simultaneously. However, practical limitations arise due to factors such as available spectrum, signal quality, and the complexity of managing a large number of users.

Improved Spectral Efficiency:

- CDMA offers improved spectral efficiency compared to some other multiple access techniques. It allows for more efficient use of available bandwidth by accommodating multiple users in the same frequency band.

Robustness to Fading:

- CDMA exhibits robustness to multipath fading and other channel impairments. The spread spectrum nature of the signal **helps in recovering the transmitted information even in the presence of fading and interference.**

Soft Handoff:

- CDMA systems support soft handoff, allowing a mobile device to be in communication with multiple base stations simultaneously. This enhances reliability and ensures seamless transitions between cells.

Adaptive Power Control:

- CDMA systems often employ adaptive power control to manage the transmit power of mobile devices. This helps in maintaining a balance between signal quality and power consumption.

Wide Applications:

- **CDMA is widely used in various wireless communication systems, including 3G and 4G cellular networks**. It has been employed in technologies such as CDMA2000 and WCDMA (UMTS), **contributing to the evolution of mobile communication standards.**

5. What are the main features of Spread Spectrum?

Spread Spectrum is a communication technique that spreads the signal over a wide frequency band, providing benefits such as **increased resistance to interference, improved security, and the ability to share the spectrum with other users.** There are **two main types of Spread Spectrum:** Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS). Here are the main features and characteristics of Spread Spectrum:

Wideband Transmission:

- Spread Spectrum systems transmit signals over a bandwidth that is much wider than the minimum required for the information signal. This wideband transmission provides several advantages, including increased resistance to interference and improved signal quality.

Resistance to Interference:

- Spread Spectrum signals are resistant to narrowband interference, as the energy is spread across a wide frequency band. This makes Spread Spectrum systems robust in the presence of various types of interference, including narrowband jammers.

Security:

- Spread Spectrum offers a level of security because the spread signal appears as noise to a receiver without knowledge of the spreading code or hopping sequence. This makes it challenging for unauthorized users to intercept or interfere with the communication.

Multiple Access Capability:

- Spread Spectrum allows multiple users to share the **same frequency band simultaneously.** Each user is assigned a unique spreading code or hopping sequence, enabling the receiver to differentiate between different users.

Resistance to Fading:

- Spread Spectrum is robust against multipath fading and other channel impairments. The spread nature of the signal helps in recovering the transmitted information even in challenging channel conditions.

Direct Sequence Spread Spectrum (DSSS):

- In DSSS, each bit of the **original signal is represented by multiple chips, and a spreading code is used to modulate the signal.** This results in a spread signal that **appears as noise to unauthorized receivers.**

Frequency Hopping Spread Spectrum (FHSS):

- In FHSS, the **signal rapidly changes its frequency within a predefined sequence.** The receiver is synchronized with the transmitter to follow the hopping pattern, allowing secure and interference-resistant communication.

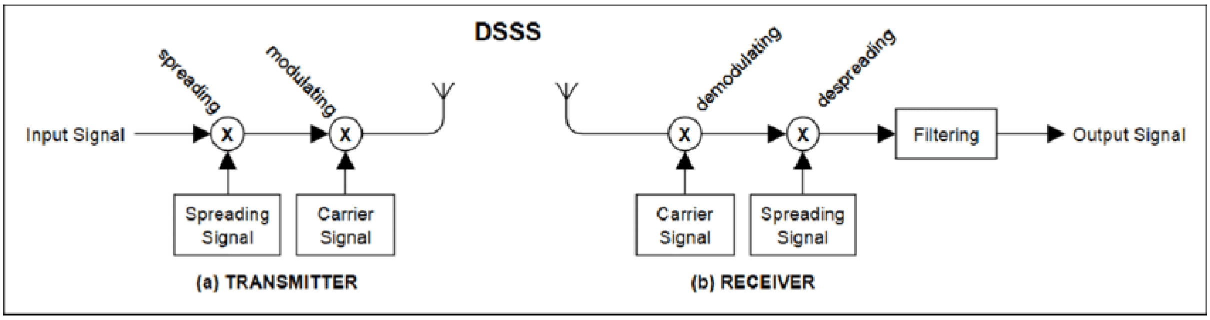
Low Probability of Intercept (LPI):

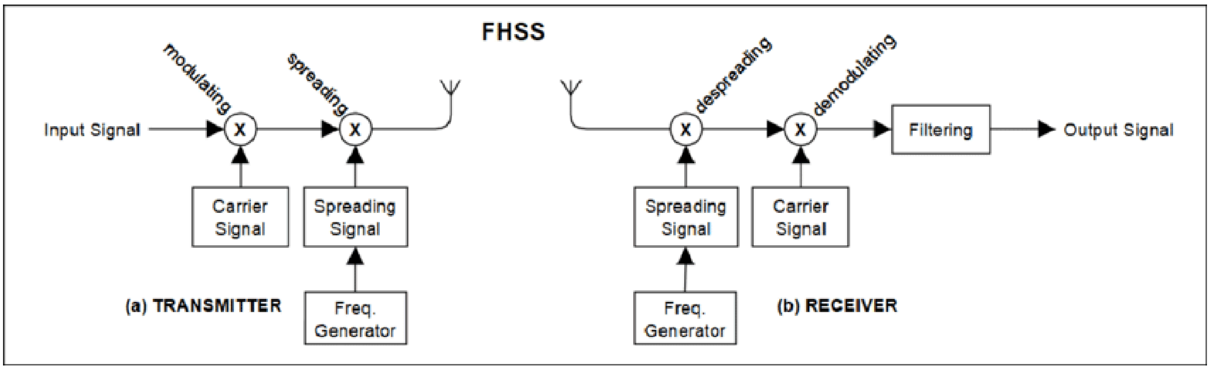
- Spread Spectrum signals, especially those with random hopping patterns, exhibit a low probability of intercept. This means that the **signal is less likely to be detected by unintended receivers.**

Applications:

- **Spread Spectrum is widely used in various applications, including wireless communication systems (Wi-Fi, Bluetooth), satellite communication, GPS, military communication, and secure data transmission.**

6. Draw the block diagram of DSSS and FHSS transmitter and receiver.





7. List the properties of PN code.

Pseudorandom Noise (PN) codes, also known as spreading codes or sequences, are essential in Spread Spectrum communication systems, including technologies like Code Division Multiple Access (CDMA). These codes possess several properties that make them suitable for their intended purposes. Here are the key properties of PN codes:

Pseudorandomness:

- **PN codes are designed to appear random**, even though they are **deterministically generated**. This pseudorandom nature enhances **security** and makes it **difficult for unauthorized users to predict or reproduce the code.**

Periodicity:

- PN codes have a **finite period after which the code sequence repeats.** The period is determined by the length of the code. For example, an N-length PN code will repeat after N chips or bits.

Orthogonality:

- In systems using multiple PN codes, the codes are often designed to be orthogonal to each other. This orthogonality property helps in **distinguishing between different users or channels in a multiple access environment.**

Balanced Distribution of Ones and Zeros:

- A well-designed PN code has a balanced distribution of ones and zeros within each period. This balance is crucial for maintaining a consistent power spectrum and ensuring desirable properties in Spread Spectrum systems.

Code Length:

- **PN codes have a specific length, denoted by the number of chips or bits in a single period**. The length of the code determines the spreading effect and the ability to differentiate between users.

Chip Rate:

- The **rate at which individual chips are generated or transmitted is known as the chip rate.** This parameter is important in determining the bandwidth occupied by the spread signal.

Ease of Generation:

- PN codes should be **generated easily and efficiently** to facilitate implementation in practical systems.

Avalanche Effect:

- A **small change in the input** to the PN code generation process should result in a **significant change in the output.** This avalanche effect enhances the security of the code.

8. Explain SDMA in brief with suitable illustrations.

Space Division Multiple Access (SDMA) is a multiple access technique used in wireless communication systems to enhance the capacity and performance of the network by exploiting the spatial dimension. Unlike traditional multiple access methods that focus on dividing the frequency or time resources, SDMA separates users in the spatial domain, allowing multiple users to share the same frequency band simultaneously. SDMA can be implemented using various antenna technologies, such as smart antennas or multiple-input-multiple-output (MIMO) systems.

Illustration of SDMA:

Consider a cellular communication scenario where a base station serves multiple mobile users. In a traditional system without SDMA, all users in the coverage area share the same frequency band, and the base station communicates with each user in a time-division or frequency-division manner.

In the illustration above, each user is represented by a different color, and the **base station communicates with them sequentially.** This approach limits the system capacity and may lead to congestion, especially in areas with a high density of users.

Now, let's introduce SDMA to the scenario:

With SDMA, the base station uses multiple antennas or antenna elements to communicate with different users simultaneously. Each antenna can form a spatial beam that is directed towards a specific user. As a result, **multiple users in different spatial directions can be served simultaneously using the same frequency band.**

Key Points about SDMA:

Spatial Separation:

- SDMA relies on the spatial separation of users, allowing them to share the same frequency band without causing interference. Each user is associated with a unique spatial direction.

Smart Antennas or MIMO Systems:

- SDMA can be implemented using smart antennas or MIMO systems. **Smart antennas can dynamically adjust their radiation patterns to focus on specific users,** while MIMO systems utilize multiple antennas for spatial multiplexing.

Increased System Capacity:

- By exploiting the spatial dimension, SDMA increases the overall system capacity, enabling the simultaneous transmission and reception of multiple independent data streams.

Improved Quality of Service (QoS):

- SDMA can enhance the quality of service by providing better spatial reuse of the available spectrum, reducing interference, and improving the overall efficiency of the communication system

.

Adaptive Beamforming:

- Adaptive beamforming techniques are often used in SDMA to **dynamically adjust the direction of the beams, optimizing the communication link for each user** and adapting to changing channel conditions.

9. List the data rate, frequency band, services offered and technology used in 1G to 5G mobile systems.

1G (First Generation):

- Data Rate: Analog voice only, no data services.
- Frequency Band: Primarily in the 800 MHz range.
- Services Offered: Voice calls only.
- Technology Used: Analog modulation (AMPS - Advanced Mobile Phone System).

2G (Second Generation):

- Data Rate: Digital voice, limited data services (up to **64 kbps**).
- Frequency Band: Various frequency bands, including 900 MHz and 1800 MHz.
- Services Offered: Voice calls, short messaging service (SMS).
- Technology Used: Digital modulation (GSM - Global System for Mobile Communications, CDMA - Code Division Multiple Access).

2.5G (2.5 Generation):

- Data Rate: Enhanced data services (up to **144 kbps**).
- Frequency Band: Similar to 2G, various bands.
- Services Offered: Improved data services, GPRS (General Packet Radio Service).
- Technology Used: Enhanced versions of 2G technologies.

3G (Third Generation):

- Data Rate: High-speed data services (up to several **Mbps**).
- Frequency Band: Various bands, including 850 MHz, 1900 MHz, and 2100 MHz.
- Services Offered: High-speed data, video calling, mobile internet.
- Technology Used: WCDMA (Wideband Code Division Multiple Access), CDMA2000.

4G (Fourth Generation):

- Data Rate: Very high-speed data services (up to 100 Mbps to 1 Gbps).
- Frequency Band: Multiple bands, including 700 MHz, 1700 MHz, 2300 MHz, and 2600 MHz.

- Services Offered: Mobile broadband, multimedia streaming, VoIP.
- Technology Used: LTE (Long-Term Evolution), WiMAX (Worldwide Interoperability for Microwave Access).

5G (Fifth Generation):

- Data Rate: Extremely high-speed data services (up to 10 Gbps).
- Frequency Band: Millimeter wave bands (24 GHz and above), sub-6 GHz bands.
- Services Offered: Ultra-fast internet, low-latency communication, massive device connectivity.
- Technology Used: NR (New Radio), Massive MIMO (Multiple-Input Multiple-Output), Network Slicing.

10. If 20 MHz of total spectrum is allocated for a duplex wireless cellular system and each simplex channel has 25 KHz RF bandwidth, find: The number of duplex channels

To find the number of duplex channels, you can use the formula:

$$\text{Number of Duplex Channels} = \frac{\text{Total Spectrum}}{\text{Bandwidth per Duplex Channel}}$$

In this case:

$$\text{Total Spectrum} = 20\,\text{MHz}$$

$$\text{Bandwidth per Duplex Channel} = 2 \times \text{Bandwidth per Simplex Channel}$$

Since each simplex channel has 25 KHz RF bandwidth, the bandwidth per duplex channel is $2 \times 25\,\text{KHz} = 50\,\text{KHz}$.

Now, plug in these values into the formula:

$$\text{Number of Duplex Channels} = \frac{20\,\text{MHz}}{50\,\text{KHz}}$$

Make sure the units are consistent. You may need to convert the total spectrum to KHz:

$$\text{Number of Duplex Channels} = \frac{20{,}000\,\text{KHz}}{50\,\text{KHz}}$$

$$\text{Number of Duplex Channels} = 400$$

Therefore, there are 400 duplex channels in the given duplex wireless cellular system.

****