Name	: Shaurya Verma	SAP	: 70362019068
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Assignment 1

Signals

Ques 1. What are the main problems of signal propagation? Why do radio waves not always follow a straight line? Why is reflection both useful and harmful?

Ans 1. Signal propagation is the movement of radio waves to and from cell sites and devices. Cell sites are structures that send wireless communication signals to devices via electromagnetic waves.

The main problems of signal propagation are:

Attenuation: The signal strength signal falls with distance over transmission medium. This also occur in vacuum and is known as free space loss. The received power *P* is proportional to $1/d^2$ with *d* being the distance between sender and receiver. This is called *inverse square law*. The extent of attenuation is a function of distance, transmission medium, as well as the frequency of the underlying transmission.

Shadowing: Extreme form of attenuation is called blocking or shadowing of radio signals due to large objects. The higher the frequency of a signal, the more it behaves light and the easier it is to block the signal.

Reflection: If an object is large compared to the wavelength of the signal, the signal is reflected. The reflected signal is not as strong as the original signal. It helps in signal transmission as soon as no LOS exists.

Refraction: Itis change in the direction of signal propagation due to change in velocity of signal caused by a change in density of transmission medium.

Scattering: When the size of an object is of the order of the wavelength of the signal, the incoming signal scatters into several weaker outgoing signals. This is caused due to the wave nature of signal.

Diffraction: It is the deflection of the radio waves from the edge of a large object which causes multiple weaker outgoing signals travelling in different directions.

Multi-path propagation: Due to finite speed of light, signals travelling along different paths with different lengths arrive at the receiver at different times. This effect is called delay spread.
due to signal propagation issues, the original signal reaches the receiver via different paths of different lengths at different times. This is called delay spread. Delay spread gives rise to intersymbol interference (ISI) which is distortion of signal by due to interference with

other signals. In addition, the power of the received signal changes considerably and is called fading.

Radio waves are electromagnetic waves just like light waves. Therefore, radio waves are also prone to different effects of electromagnetic waves such as reflection, refraction, diffraction and spreading. These effects change the direction of radio waves and thus, radio waves do not always travel in straight line.

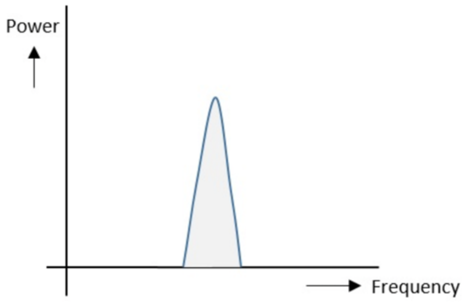
Reflection is useful as it helps in signal transmission when there is no LOS between sender and receiver. Sky waves use reflection to send and receive radio waves over very long distances using ionosphere as a reflecting medium.

Reflection is harmful as the signal becomes weaker every time it reflects. Thus, reducing the chances of good connection between sender and receiver.

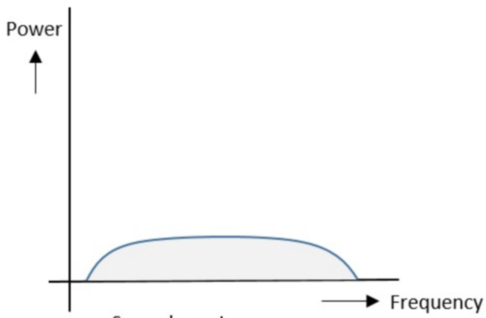
Ques 2. What are the means to mitigate narrowband interference? What is the complexity of the different solutions?

Ans 2. Narrowband interference can be mitigated by spread spectrum. In spread spectrum, the signal is spread from a narrowband to a broadband for transmission. The signal occupies a wider bandwidth (band of signals is spread over a wide range of frequencies). The energy spreads over the bandwidth and power density drops. This makes the spread spectrum signal highly resistant to interference and jamming.

In addition, it allows multiple users to share the spectrum without interference with each other.



Narrow-band Signal



Spread spectrum signal

Spread spectrum can be implemented in the following ways:

1. FHSS (Frequency Hopping Spread Spectrum)

   In FHSS, users are made to change the frequency after a fixed period of time. For example, user 1 uses frequency f_1 for a time period. After that user one switched to frequency f_2 and user 2 uses f_1 frequency. This is called **frequency reuse**.

   The frequencies of the data are hopped from one to another in order to provide a secure transmission. The amount of time spent on each frequency hop is called as **Dwell time**.
2. DSSS (Direct Sequence Spread Spectrum)

   In DSSS, when the user wants to send some data, the data is multiplied (XOR) by a secret code called **chipping sequence**, which is spreading code. The information is then send over a single frequency and the same chipping sequence is used by the receiver to reconstruct the original message.

FHSS requires error detection and requires complex and costly digital frequency synthesizers are required to be used. DSSS requires fast code generators and has longer acquisition time.

Ques 3. Name several methods for ISI mitigation. How does ISI depend on the carrier frequency, symbol rate, and movement of sender/receiver? What are the influences of ISI on TDM schemes?

Ans 3. ISI can be mitigated by using large enough guard spaces between symbols, channel estimation/calculate the n strongest paths and adapt the receiver accordingly. Using. Higher frequencies reduce the effects of multipath and thus ISI. The higher the symbol rate the stronger the ISI. If senders and/or receivers move fast the chances for ISI are higher because the location of obstacles changes, hence the number, magnitude, and timing of the secondary pulses – it is difficult to follow the signals and adjust the delays for recombination. ISI lowers the bandwidth of a TDM scheme as the guard spaces require some time.

Ques 4. What are the main benefits of a spread spectrum system? How can spreading be achieved?

Ans 4. Main benefits of spread spectrum system are as follows:

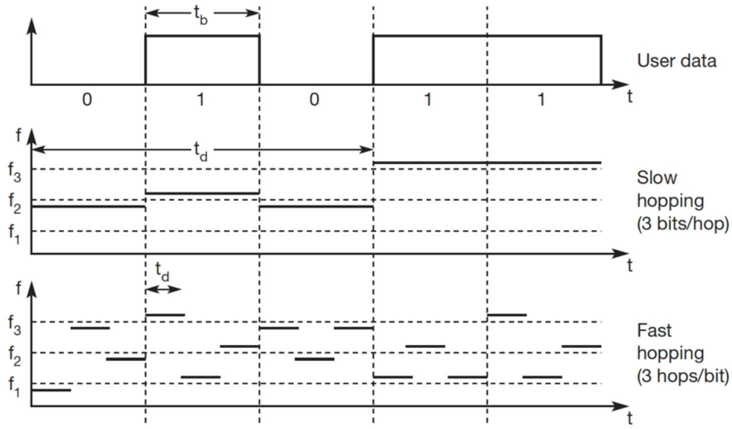
- High resistance to interference
- Cross-talk elimination
- Better output with data integrity
- Reduced effect of multipath fading
- Better security
- Reduction in noise
- Co-existence with other systems
- Longer operative distances
- Hard to detect
- Not easy to demodulate/decode
- Difficult to jam the signals

Spread spectrum can be achieved in the following ways:

1. FHSS (Frequency Hopping Spread Spectrum)

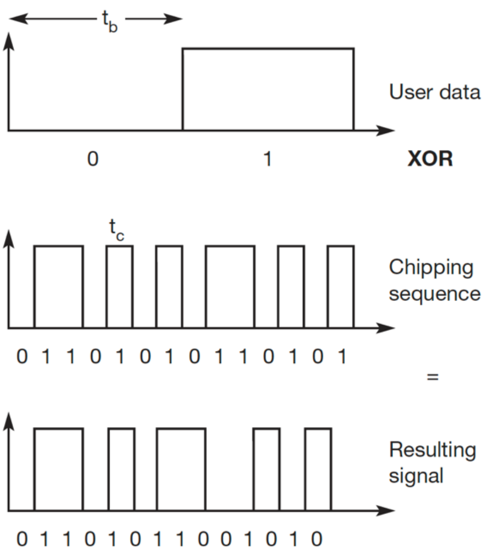
   In FHSS, the spectrum is divided into multiple channels of smaller bandwidth with guard spaces between them. The users (transmitters and receivers) stay on one of the channels for a certain period of time (called **dwell time**) and then are made to switch to another channel. This changing of channels is called **frequency hopping** and the pattern is called **hopping sequence**.

   FHSS is of two types, slow hopping and fast hopping. In slow hopping, the transmitter uses one frequency for transmitting several bits while in fast hopping, the transmitter switches frequency with every bit transmitted.



2. DSSS (Direct Sequence Spread Spectrum)

   DSSS takes the information stream and XOR it with a chipping sequence. This process is called **digital modulation**. The spread signal is then modulated on a radio carrier (**radio modulation**) and transmitted. The receives the signal and has to perform the inverse functions. However, noise and multi-path propagation requires additional mechanisms to reconstruct the original data. This makes the demodulation more complex than modulation.



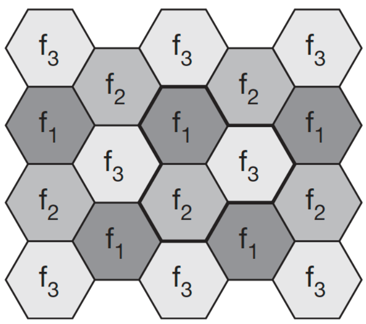
Ques 5. What are the main reasons for using cellular systems? How is SDM typically realized and combined with FDM?

Ans 5. Main reasons for using cellular systems are as follows:

1. **Higher capacity**: Cellular systems are implemented using SDM which allows frequency reuse. If one transmitter is out of interference range of another transmitter, both of them can use the same frequency without interference. Frequencies available for use are limited and so is the number of users that can be supported per cell at a time. Using smaller cells allows more users to connect per km^2 compared to larger cells and thus, smaller cells are preferred in dense areas.
2. **Less transmission power**: As small cells have to cover small areas, less transmission power is required by mobile stations to connect to base stations.
3. **Local interference**: Interference increased in longer transmission due to noise and other signals. Using small cellular structures reduces this problem and base stations have to deal with only 'local' interference.
4. **Robustness**: As small areas are covered by cellular systems, failure of a single component will affect a smaller area.

A large area is divided into smaller areas or cells to implement cellular systems. These cells are adjacent to each other and thus can cause interference when using same frequencies. To avoid this, cells using same frequencies have space between them (SDM). This space is in the form of another cell which work on another frequency, thus allowing connections to users while avoiding interference due to same frequency usage. The cells using same frequencies are outside each other's interference range.

The neighbouring cells form a cluster where each cell uses a different frequency to avoid interference (FDM). This cluster forms a repeating pattern such that cells using same frequencies are outside each other's interference range.



Repeating pattern of cell cluster to avoid overlapping of frequencies in adjacent cells

In the above diagram, a group of adjacent cells f_1, f_2 and f_3 forms a cell cluster.

Open Ended Problem (Based on FHSS)

1. The school has a novel dress protocol. Each standard student can use colored dress on different days but should still be identifiable. How can the protocol follow hopping sequence for using the colors for the dress code: blue (B), Green (G), yellow (y) and orange (O).

Ans. For a particular day, following can be the solution:

	Colour			
	Red	Green	Yellow	Orange
Classes	1	2	3	4
	5	6	7	8
	9	10	11	12

From the above solution, 4 different sets can be derived. These are as follows:

Set 1 – Classes {1, 5, 9}

Set 2 – Classes {2, 6, 10}

Set 3 – Classes {3, 7, 11}

Set 4 – Classes {4, 8, 12}

Now, for each day their colour can be changed and due to the difference in height, they can be identified to be from a particular standard on any given day.

For example, if the above solution is for Monday, then a student wearing red is certain to be from either 1st, 5th or 9th standard. There is usually good height difference due to age in the students of the said standards. Thus, a toddler wearing a red uniform on a Monday is certain to be from 1st standard.