Answers for Session Session 2a - Frequency Allocation and Modulation Basics

1. Do windows operating systems support the 6GHz band?

Yes, Windows 11 supports 6GHz WiFi. However, Windows 10 does not support 6GHz WiFi, even if you have a 6GHz-capable network adapter.

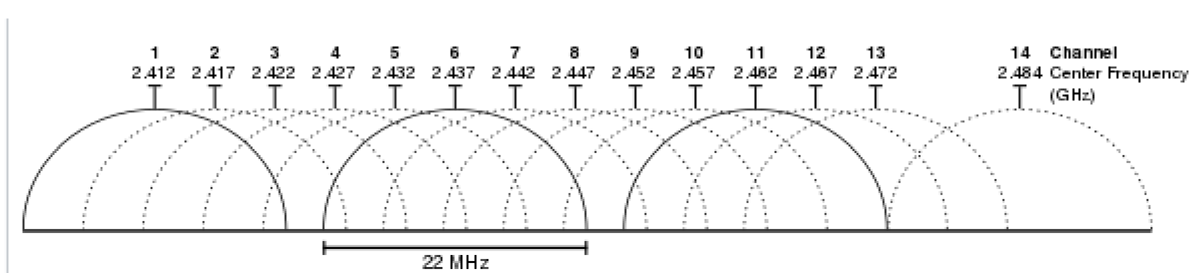
To use 6GHz WiFi on Windows 11, you must have:

- A 6GHz-capable network adapter
- The latest Windows 11 updates installed
- The latest drivers for your network adapter installed
- A 6GHz-compatible router

To check if your network adapter supports 6GHz, you can look at the specifications of your adapter or contact the manufacturer.

2. What does overlapping channels mean? Will the energy interfere with each other?

An overlapping channel is a wireless channel that shares the same frequency band as another channel. This means that the signals from the two channels can interfere with each other.
For example, in the 2.4 GHz Wi-Fi band, there are 11 channels. However, only three of these channels (1, 6, and 11) are non-overlapping. This means that if two Wi-Fi networks use channels 1 and 3, their signals will overlap.



3.Why Bandwidth is related to capacity sometimes ? higher bandwidth means higher amount of data

Bandwidth refers to the range of frequencies that a medium can transmit and is usually measured in Hertz (Hz). Now, let's establish a definition for modulation. Modulation involves taking a high-frequency wave and altering it according to a message signal. Essentially, a group of frequencies is collectively known as a bandwidth. During modulation, each frequency within this bandwidth is utilized to convey the message signal.

Different modulation techniques use different logics to use these different frequencies. A broader bandwidth provides the opportunity to use more frequencies simultaneously, which in turn enhances data transmission rates."

Considering below formula for data rate:

Number of Data Subcarriers — *Number of Coded Bits per Subcarrier per Stream* — *Coding* — *Number of Spatial Streams*

$$\text{Data Rate} = \frac{N_{SD} * N_{BPSCS} * R * N_{SS}}{T_{DFT} + T_{GI}}$$

OFDM Symbol Duration — *Guard Interval Duration*

Data rate is directly proportional to the number of subcarriers (Bandwidth is divided into smaller equal parts called Subcarriers.(OFDM used subcarriers)

Bandwidth ⬆️ -> subcarriers ⬆️ -> data rate ⬆️

4. Why does higher frequencies always relate to higher data rate or modulation schemes only decide data rate ?

The frequency bands that Wi-Fi is currently being used are 2.4GHz band,5GHz band,6GHz band .These are nothing but the carrier wave frequencies.

Higher frequencies can relate to higher data rates because more data that can be transmitted per second

As we grow from generation to generation, modulation techniques have improved a lot in making more efficient and faster communication.

Both bands of operation and modulation schemes decide data rate. There are many factors affecting data rates like spatial streams, guard interval, the signal strength of the client, Tx power of Access points.

5. when we say 22 MHz bandwidth, it will consist of only one wave?

No, When we say 22 MHz bandwidth.It means that the signal can occupy any frequency within a range of 22 MHz.

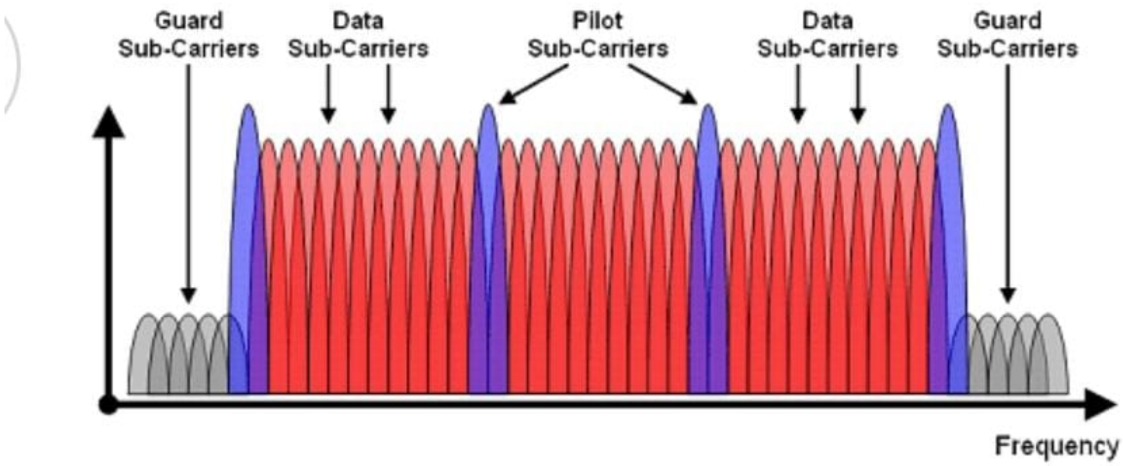
Answer for question 3 can help in understanding what is bandwidth and how modulation uses different frequencies in the bandwidth

6. How are non overlapping channels identified in the field ?
Use a WiFi analyzer app.
There are many WiFi analyzer apps available for both smartphones and computers. These apps can show you the signal strength and channel usage of all the WiFi networks in your area. You can use this information to identify non-overlapping channels.

conducting site survey is good option using the above tool, will give a good insight in the field
Examples: WiFi monitor, InSSIDer.

7. What is the guard band for OFDM?
Guard intervals are used to ensure that distinct transmissions do not interfere with one another, or otherwise cause overlapping transmissions. These transmissions may belong to different users (as in TDMA) or to the same user (as in OFDM).

In OFDM, the beginning of each symbol is preceded by a guard interval. As long as the echoes fall within this interval, they will not affect the receiver's ability to safely decode the actual data, as data is only interpreted outside the guard interval.



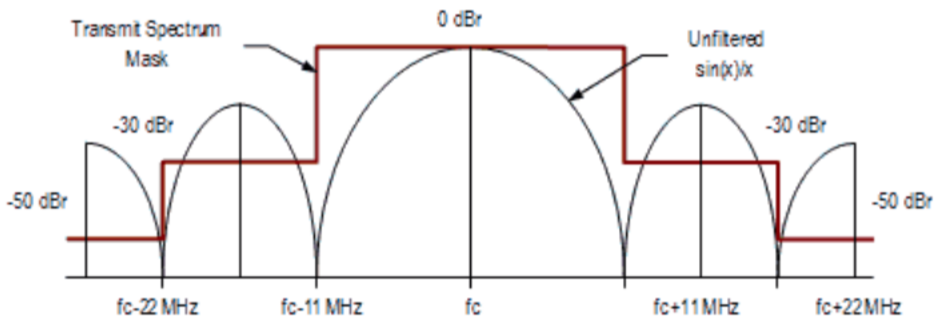
The standard symbol guard interval used in IEEE 802.11 OFDM is 0.8 μs. To increase data rate, 802.11n added optional support for a 0.4 μs guard interval. This provides an 11% increase in data rate. To increase coverage area, IEEE 802.11ax provides optional support for 0.8 μs, 1.6 μs, and 3.2 μs guard intervals.

The shorter guard interval results in a higher packet error rate when the delay spread of the channel exceed the guard interval and/or if timing synchronization between the transmitter and receiver is not precise.

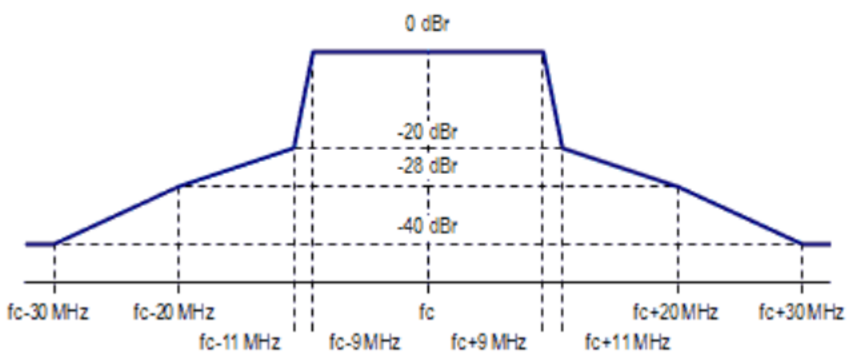
8. Why are the 20 MHZ channels shown as peculiar shapes in the last slide?

A Spectral Mask makes sure a transmission stays within its band and, therefore, reduces interference by limiting excessive radiation at frequencies beyond the necessary bandwidth

The shape helps to provides less interference



IEEE 802.11b WLAN Spectral Masks



IEEE 802.11a WLAN Spectral Masks

9. Bandwidth of 20MHz can carry signals from fc-BW/2 and fc+BW/2. Is there a minimal frequency separation between two transmitted signals when transmitted with in the Bandwidth

Yes, there is a minimal frequency separation between two transmitted signals when transmitted within the same bandwidth. This is to prevent inter-signal interference (ISI).

ISI occurs when the signals overlap in the frequency domain, causing them to interfere with each other.

The minimum frequency separation required depends on the modulation scheme used and the desired bit error rate (BER). For example, for binary frequency shift keying (BFSK), the minimum frequency separation is equal to the symbol rate. For quadrature amplitude modulation (QAM), the minimum frequency separation is equal to the symbol rate divided by the number of constellation points.

As a general rule of thumb, the minimum frequency separation between two transmitted signals should be at least 20% of the bandwidth. This will provide sufficient separation to prevent ISI and ensure reliable communication.

For example, if one signal is centered at 10MHz, the other signal must be centered at 12MHz or higher. If the two signals are centered too close together, they will overlap in the frequency domain and cause ISI.

It is important to note that the minimum frequency separation required may also be affected by other factors, such as the noise level in the channel and the desired BER. In some cases, it may be necessary to use a larger frequency separation to achieve the desired performance.

10. How the modulations are done or created? Ie how dsss/fhss are invented or created

Both direct-sequence spread spectrum (DSSS) and frequency-hopping spread spectrum (FHSS) were invented in the early 1940s during World War II. They were developed to make communication systems more resistant to interference and jamming.

FHSS: The thought that made it possible was to spread the signal over a wider frequency range or hop it from one frequency to another at a very fast rate. This makes it more difficult for an enemy to jam the signal because they would need to jam a wider range of frequencies or track the signal as it hops from one frequency to another

DSSS: previously narrow band signals are used for communication, DSSS works by spreading the original narrowband signal across a broader frequency range. This safeguards it against interference from other narrowband signals. The use of a pseudorandom PN sequence makes it unpredictable, making it challenging for potential disruptors to jam the signal without knowledge of the PN sequence

11. What are the factors that cause the RF signal phase/frequency shift?

The following factors can cause the RF signal phase/frequency shift in Wi-Fi:

- **Doppler effect:** The Doppler effect is a change in the frequency of a wave due to the relative motion of the source and observer. This can cause a shift in the phase and frequency of an RF signal if the transmitter or receiver is moving.
  example:
  A person walking around with a laptop will experience a Doppler effect, which will cause a shift in the frequency of the Wi-Fi signals it receives.

- **Multipath propagation**: Multipath propagation is the phenomenon of a radio signal reaching the receiver by multiple paths. This can cause phase and frequency shifts in the signal, as the different paths have different lengths and delays. This is a major challenge for Wi-Fi networks, as it can cause interference and reduce performance.
  example:
  A Wi-Fi signal propagating through a crowded office will experience multipath propagation, which can cause phase and frequency shifts in the signal.

- **Atmospheric effects:** Atmospheric effects, such as refraction and reflection, can also cause phase and frequency shifts in RF signals. This is especially pronounced in outdoor Wi-Fi networks, where the signal must travel through the atmosphere.
  example:
  A Wi-Fi signal propagating outdoors will experience refraction and reflection from buildings and other objects, which can cause phase and frequency shifts in the signal
  .

- **Component imperfections**: Imperfections in electronic components, such as filters and amplifiers, can also cause phase and frequency shifts in RF signals. This can be a problem for Wi-Fi routers and access points, as they need to be able to generate and receive high-quality RF signals.

  example:
  A Wi-Fi router or access point with a faulty filter may not be able to generate or receive high-quality RF signals, which can cause phase and frequency shifts.

- Interference: Interference from other RF signals, such as microwaves, cordless phones, and other Wi-Fi networks, can also cause phase and frequency shifts. This can be a major problem for Wi-Fi networks, as it can reduce performance and reliability.

  example:
  A Wi-Fi network operating near a microwave oven or cordless phone may experience interference that causes phase and frequency shifts in the Wi-Fi signal.

12. Any updates on use of 6GHz in India?

Currently it is not available in India.
In July 2023, the Department of Telecommunications (DoT) released a draft notification proposing to delicence the 6GHz band for unlicensed use, including Wi-Fi. This is a significant step towards making 6GHz Wi-Fi available in India.

Once the notification is released, it is expected that 6GHz Wi-Fi will be available in India