5G Presentation Instructor Guide

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Slide Notes

Slide 3 - 5G Overview

5G is being designed to handle the increasing demand for connectivity, the volume of which prior network infrastructures were not built to support. To do this, wireless carriers will need to build entirely new network infrastructures, including new routers, as well as new devices – however, many carriers are beginning this evolution by attaching 5G components to LTE networks to improve functionality while the true 5G networks are developed.

Slide 17 – Frequency

To calculate, count the number of sine wave cycles completed in one second and take reciprocal to calculate frequency in Hertz.

Slide 23 – MODEMS

Computing devices (computers, PDA's, laptops, etc) use digital signals (1's and 0's) to process, store and manipulate information. Sending this information over long distances though typically involves a conversion or modulation of digital signals to analog signals on the sending device and a conversion or demodulation of analog signals to digital signals on the receiving device.

Slide 24 - 5G Modulation - Orthogonal Frequency Division Multiplexing (OFDM)

In general, any modulation scheme can be used across a wide variety of frequencies. Modulation type is usually driven by the application, the available bandwidth, and regulatory requirements.

5G spectrum is divided into Frequency Range 1 and 2 (FR1 and FR2). FR1 is below 6 GHz and FR2 is ~24 to 52 GHz. So the 5G modulation methods may be used in those frequency ranges. Also, Wi-Fi 4, 5, and 6 use the 5 GHz band with OFDM and a variety of modulation types. See https://www.eeworldonline.com/ofdma-improves-spectrum-use-in-wi-fi-6/

The FCC frequency allocations between 5 GHz and 10 GHz include radiolocation (RADAR) and satellite communications. Satellite comms are usually wideband digital signals and may use OFDM.

See https://blogs.keysight.com/blogs/tech/rfmw.entry.html/2020/08/24/modulation_schemes f-6MpZ.html

Slide 25 - Modulation and Quadature Amplitude Modulation (QAM)

QAM has been the method of choice for transmitting signals for years. Let's try to get a basic understanding of how QAM works - without any math!

QAM is categorized by the number of bits that can be transmitted in one sine wave cycle. To get a simple understanding let's take a look at 16-QAM. 16-QAM is considered rectangular QAM - the square root of 16 is 4 and this indicates that each cycle of a 16-QAM waveform can represent a 4 bit binary (1 and 0) pattern. Using the same method we can calculate 64-QAM represents an 8 bit binary (1 and 0) pattern because the square root of 64 is 8. 256-QAM can represent a 16 bit binary (1 and 0) pattern because the square root of 256 is 16, etc.

Slide 30 - 5G: new Antennas, new network Architecture

Two leading technologies: active phased arrays (APAs) and Holographic Beam Forming® (HBF). Digital beamforming, i.e., Massive MIMO, will not be discussed here because exorbitant power requirements and component costs associated with high sampling rates preclude it from practical usability at mmWave frequencies.

The defense industry has been using APAs for decades at very high cost, size, weight and power consumption, although recent advancements in highly integrated semiconductors have brought APAs closer to commercially viability. By contrast, HBF constitutes a breakthrough in electromagnetic physics with much lower C-SWaP (cost, size, weight and power consumption) than APA.

Slide 32 - Antennas … directional, more efficient

Beamforming essentially "points" an antenna to actively or passively "listen" to a specific area or device and, as a technology, has been around since of the early days of mobile broadband. Beginning with 3G, Multiple Input Multiple Output (MIMO) technology allows for data signals to be sent or received over several antennas using the same channel. Imagine how good your car radio would sound if you had an array of multiple antennas!

Fast forward to June 2019 and 3GPP's Release 15. Improvements in beamforming and beam management (beam switching, recovery and refinement) techniques can now increase coverage and capacity across more control and broadcast channels compared to LTE, with radios of up to 64 or more transceiver and antenna elements. Massive MIMO adds even more capacity without adding more antenna elements, due to the increasing degrees of freedom that is available to an antenna array to modify a transmitted signal – even for multiple users and antennas.

The new antenna technologies are now capable of taking advantage of spectrum that has never been used before in commercial cellular wireless communications – millimeter wave (mmWave) bands. Fully integrated radio arrays can now include more than 100 transceiver and antenna elements.

With these improvements, new 5G spectrum below 6 GHz and in the millimeter wave range will allow for significant improvements in coverage and capacity, which were not possible using 4G spectrum alone. Usage of these large wide swaths of new spectrum bands for 5G are part of the reason 5G trials are showing vast increases in peak throughput - for instance, up to 8 concurrent streams at 20 Gbits/sec downloads and 4 concurrent streams of 10 Gbits/sec uploads.

Slide 33 – Antenna evolution

In general, high band spectrum coverage can be more challenging than low or mid-band, requiring more advanced antenna systems to achieve high performance in large areas. Here are a few basic scenarios:

In dense city centers with few macro cell locations, increased small cell density takes advantage of both vertical and horizontal beamforming

Dense urban high-rise environments with tall buildings, high traffic density, and rooftop site deployments often use macro cells complemented by dedicated indoor small cell sites using primarily low-power horizontal beamforming

In urban low-rise, vertical beamforming can be lower due to even building heights of about four to six floors

In suburban and rural areas, capacity and coverage is primarily provided with existing macro cells primarily using horizontal beamforming

With rural and fixed wireless, cost effective coverage means sparse deployment of tall sites using low band spectrum with selective densification at population centers. Fixed wireless deployments use large antenna apertures and new mid or high band spectrum

Slide 34 – Small Cell

To avoid data transmission dead spots in the millimeter range, many small transmitting stations are located at close proximity to subscribers. They form a small cell network, which extends the existing cellular network. Expanding the network in this way allows closer proximity to users, yet at a low transmitting power level. Due to the smaller spacing of the stations, the cellular or IoT device can always find a good connection to the next station. Infineon supplies the maximum frequency components necessary to make this happen. Monolithic Microwave Integrated Circuits (MMIC) allow transmission of data at frequencies of up to 90 GHz – the market is currently focusing on frequencies of up to 40 GHz.

Slide 38 - What about airports and 5G?

The spurious emissions actually fall within the normal receive bandwidth of the radar altimeter, and may produce undesirable effects such as desensitization due to reduced signal-to-interference-plus-noise ratio (SINR), or false altitude determination due to the erroneous detection of the interference signal as a radar return.

July 5, 2022 was originally picked as the date to turn on around airports.

Two Videos Appropriate for Lab Sessions

5G uses a lot of specialized equipment. These videos give a nice demonstration of 5G using this equipment.

> *Live from the 5G Lab in Australia – the behind the scenes cut*
> (10 minutes 49 seconds)
> https://youtu.be/nN5pRPtcz8c
>
> *'Live from the Lab' - Young Professionals working in 5G & IoT*
> (1 hour 1 minute 15 seconds)
> https://iec.zoom.us/rec/play/70nlwZStbj3rTS5kR1qXpS0-WABYE_tpuw9WIKKvRmfTwaytGpLZMsu1OzAt5tqiDN7S7GxbRhOKXDOB.NyKXTxJXFAX7xHV5?startTime=1615963902000&_x_zm_rtaid=-S5LyddbT3CIjh8RbGRJyQ.1641891869103.9473d7a0eb92bb1c71c7714f1c5c19e4&_x_zm_rhtaid=200

Answers to Class Exercises

Slide 20 Exercises

Question 1: Verizon's 5G Ultra Wideband network uses 28 GHz and 39 GHz mmWave spectrum bands. Calculate the wavelength for each of these frequencies.

Answers:

For 28 GHz

$$\lambda = \frac{c}{f} = (3 \times 10^8 \frac{m}{s})/(28 \times 10^9\ Hz) = 10.7\ cm$$

For 39 GHz

$$\lambda = \frac{c}{f} = (3 \times 10^8 \frac{m}{s})/(39 \times 10^9\ Hz) = 7.7\ cm$$

Notes: Notice the higher frequency has a much shorter wavelength. Higher frequencies can carry more information but do not travel as far or penetrate as well as lower frequencies.

Also notice there is an inverse relationship between wavelength and frequency – as wavelength increases, frequency decreases and vice versa.

Question 2: Verizon's 4G network uses about 700 MHz-2500 MHz frequency to transfer information. What is the wavelength for a 2500 MHz 4G signal?

Answer:

$$\lambda = \frac{c}{f} = (3 \times 10^8 \frac{m}{s})/(700 \times 10^6\ Hz) = 42.9\ cm$$

Notes: Notice 4G frequencies have longer wavelengths and lower frequencies when compared to 5G. This means 4G signals can travel further and penetrate better than 5G signals. The tradeoff is throughput – the higher 5G frequencies can carry a lot more information.

Question 3: Compare your answers from 1 and 2.

- Which has the longer wavelength, 4G or 5G?
- Which signal will travel farther? Why?

Answer:

4G signals have longer wavelengths and will travel further than 5G signals because there is less energy is transferred to the transmission medium (air in our example) at lower frequencies.

Slide 39 Exercises

These questions require students do some research. Answers will vary depending on region and timing. Have your students complete the questions as a homework assignment.