Department of Electrical Engineering
Final-Assignment
Date: 22/06/2020

Course Details

Course Title: Advance Computer Networks **Module:** 3rd
Instructor: DR Naeem Ahmed Jan **Total Marks:** 50

Student Details

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Q1.	(a)	The Advanced Mobile Phone System (AMPS) uses two bands. The first band, 800 to 850 MHz, is used for sending; and 860 to 910 MHz is used for receiving. Each user has a bandwidth of 60 KHz in each direction. The 3-KHz voice is modulated using FM, creating 60 KHz of modulated signal. How many people can use their cellular phones simultaneously?	Marks 6
	(b)	Express a period of 1 ms in microseconds, and express the corresponding frequency in kilohertz and A sine wave is offset one-fourth of a cycle with respect to time zero. What is its phase in degrees and radians?	Marks 4
Q2.	(a)	Explain wave division multiplexing and it's applications?	Marks 5
	(b)	Nine channels, each with a 99-KHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 13 KHz between the channels to prevent interference?	Marks 5
Q3.	(a)	A constellation diagram consists of sixteen equally spaced points on a circle. If the bit rate is 4800 bps, what is the baud rate?	Marks 5
	(b)	Given a bandwidth of 7000 Hz for a 128-PSK signal, what are the baud rate and bit rate?	Marks 5
Q4.		Explain wireless propagation methods & wireless transmission waves? We need to send 265kbps over a noiseless channel with a bandwidth of 20KHz. How many signal levels do we need?	Marks 10
Q5.		What is the difference between Shannon & Nyquist Capacity? Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with 4 signal levels, the maximum bit rate can be ?	Marks 10

Q = 1 (part a) The Advanced Mobile Phone System (AMPS) uses two bands. The first band, 800 to 850 MHz, is used for sending; and 860 to 910 MHz is used for receiving. Each user has a bandwidth of 60 KHz in each direction. The 3-KHz voice is modulated using FM, creating 60 KHz of modulated signal. How many people can use their cellular phones simultaneously?

Answer

The first band is 50 MHz

If we divided 50 MHz into 60 KHz, (Each user has a bandwidth of 60 KHz)

Mega is equal to 10^6 or 1000000 and kilo is equal to 10^3 or 1000

Solution

50 x 10^6 / 60 x 10^ 3

8333.33

The band is divided into 832 channels.

42 channels of these are used for control which means only **790 channels** are available for cellular phones users

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Q 1 (part b) Express a period of 1 ms in microseconds, and express the corresponding frequency in kilohertz and A sine wave is offset one-fourth of a cycle with respect to time zero. What is its phase in degrees and radians?

Solution

1 ms = 1 x10^{-3} S

Mille second = 10^{-3} S

Micro second = 10^{-6} S

Kilo = 10^{3}

We can also write

= 10^{-3} x 10^{3} x 10^{-3} S

= 10^{3} x 10^{-6} S

= 10^{3} μs

1 ms = 10^{3} μs

As 1 ms = 10^{-3} S

As $f = 1 / t$

so

$f = 1 / 10^{-3}$ Hz

$f = 10^{3}$ Hz

f= 1000 Hz

f = 1 KHz

a sin wave is offset one forth of a cycle with respect to time zero its phase in degree is :

As Complete cycle is 360°

Therefore ¼ cycle is

¼ x 360 = **90°**

a sin wave is offset one forth of a cycle with respect to time zero its phase in radian is :

$90° \times \frac{2\pi}{360} = \frac{\pi}{2} =$ **1.5708 radian**

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Q2 (a) Explain wave division multiplexing and its applications?

Explanation

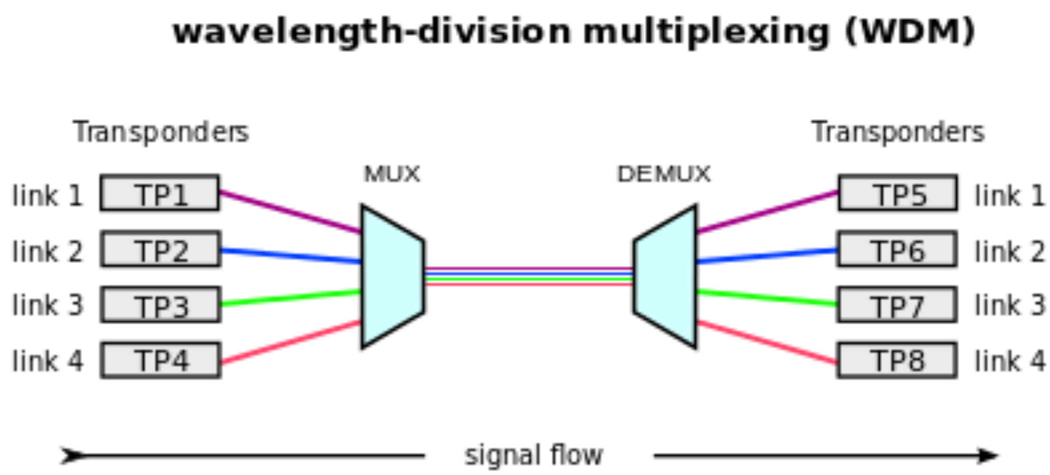
Wavelength division multiplexing (WDM) is a technique modulating various data streams, i.e. optical carrier signals of varying wavelengths in terms of colors of laser light onto a single optical fiber. Wavelength division multiplexing WDM is similar to frequency-division multiplexing (FDM) but referencing the wavelength of light to the frequency of light. WDM is done in the IR portion of the electromagnetic spectrum instead of taking place at radio frequencies (RF). Each IR channel carries several RF signals combined with frequency-division multiplexing (FDM) or time-division multiplexing (TDM). Each multiplexed infrared channel is separated or DE multiplexed into the original signals at final point. Data in different formats and at different speeds can be transmitted simultaneously on a single fiber by using FDM or TDM in each IR channel in combination with WDM. It allows network capacity to be gradually and cost effectively increased.

Application of Wavelength Division Multiplexing:

- WDM multiply the effective bandwidth of a fiber optic communications system

- A fiber optic repeater device called the erbium amplifier can make WDM a cost-effective and it is the long-term solution.
- This reduces the cost and increases the capacity of the cable to carry data.
- Wavelength Division Multiplexing (WDM) uses multiple wavelengths (colors of light) to transport signals over a single fiber.
- It uses light of different colours to create a number of signal paths.
- It uses Optical prisms to separate the different colours at the receiving end and optical prisms does not require power source.
- These systems used temperature stabilized lasers to provide the needed channels count.

WDM systems are divided according to wavelengths – WDM (CWDM) and dense WDM (DWDM). CWDM operates with 8 channels (i.e., 8 fiber optic cables) which is called as the "C-Band" or "erbium window" with wavelengths about 1550 nm (nanometers or billionths of a meter, i.e. 1550 x 10-9 meters). DWDM also operates in the C-Band but with 40 channels at 100 GHz spacing or 80 channels at 50 GHz spacing. Mostly WDM systems are operated on single-mode fiber optical cables having a core diameter of 9 µm. Wavelength division multiplexing are a technique where optical signals with different wavelengths are combined, transmitted and separated.



WDM is a technique in fiber optic transmission that enables the use of multiple light wavelengths (or colors) to send data over the same medium. Two or more colors of light can travel on one fiber and several signals can be transmitted in an optical waveguide at differing wavelengths.

Early fiber optic transmission systems put information onto strands of glass through simple pulses of light. A light was flashed on and off to represent digital ones and zeros. The actual light could be of almost any wavelength—from roughly 670 nanometers to 1550 nanometers.

There are two types of WDM:

Coarse WDM (CWDM): WDM systems with fewer than eight active wavelengths per fiber. CWDM is defined by wavelengths. DWDM (see below) is defined in terms of frequencies. DWDM's tighter wavelength spacing fits more channels onto a single fiber, but cost more to implement and operate.

CWDM is for short-range communications, so it employs wide-range frequencies with wavelengths spread far apart. Standardized channel spacing permits room for wavelength drift as lasers heat up and cool down during operation. CWDM is a compact and cost-effective option when spectral efficiency is not an important requirement.

Dense WDM (DWDM): DWDM is for systems with more than eight active wavelengths per fiber. DWDM dices spectrum finely, fitting 40-plus channels into the same frequency range used for two CWDM channels.

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Q 2 (part b) Nine channels, each with a 99-KHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 13 KHz between the channels to prevent interference?

Solution

9 Number of Channels we have

Each has 99Khz Bandwidth

Guard band =13Khz

So,

For the 9 channels, we need at eight guard bands. This means that the required bandwidth is at least

$9 \times 99 + 8 \times 13 = 995$kHz

So the require bandwidth of each channel is **99KHz**

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Q 3 (part a) A constellation diagram consists of sixteen equally spaced points on a circle. If the bit rate is 4800 bps, what is the baud rate?

Solution

Finding baud rate? **Bit rate/bits per signal**

4 bits are transmitted with each signal i-e 16 = 2^4 and bit rate is 4800 bps as per question

As Baud rate = bit rate/bits per signal

Therefore,

Baud rate = 4800/4 = **1200 Baud**

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Q 3 (Part b) Given a bandwidth of 7000 Hz for a 128-PSK signals, what are the baud rate and bit rate?

Solution

For PSK the baud rate is the same as the bandwidth, which means the baud rate is 7000,

but in 128 – PSK the bit rate is 7 times the baud rate

Note: 2^7 = 128

Bit rate = 7 x 7000

=49000 bps

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Q 4 (Part a) Explain wireless propagation methods & wireless transmission waves? We need to send 265kbps over a noiseless channel with a bandwidth of 20KHz. How many signal levels do we need?

Wireless propagation

The wireless channel causes the transmitted signal to lose power as it propagates from the transmitter to the receiver. Reflections, diffraction, and scattering create multiple propagation paths between the transmitter and the receiver, each with a different delay. The net result is that wireless propagation leads to a loss of received signal power as well as the presence of multipath, which creates frequency selectivity in the channel. In this section, we provide an introduction to the key mechanisms of propagation. Then we rationalize the need for developing models and explain the distinction between large-scale models (discussed further in Section 5.6) and small-scale models (discussed further in Section 5.7 and Section 5.8). In this section, we briefly describe important factors affecting propagation in wireless channels to explain the need for several different channel models. The interested reader is referred to [270] or [165] for more extensive treatment of wireless propagation

In a wireless communication system, a transmitted signal can reach the receiver via a number of propagation mechanisms. In this section, we review at a high level these key mechanisms, each potentially associated with a different propagation path. These mechanisms are illustratedWhen a signal reaches the receiver from the transmitter in a single path, without suffering any reflections, diffractions, or scattering, this is known as propagation along the *line-of-sight* (LOS) path. An LOS component has the shortest time delay among all the received signals and is usually the strongest signal received. The exact classification of a path being LOS requires that any obstructions be sufficiently far away from the path, which is quantified by the idea of the Fresnel zone.

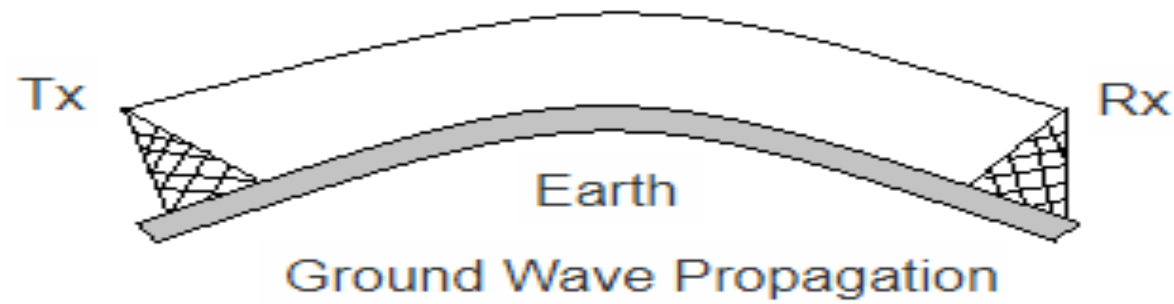
Wireless propagation methods are

- **Ground wave**
- **Sky wave**

- **Space wave**

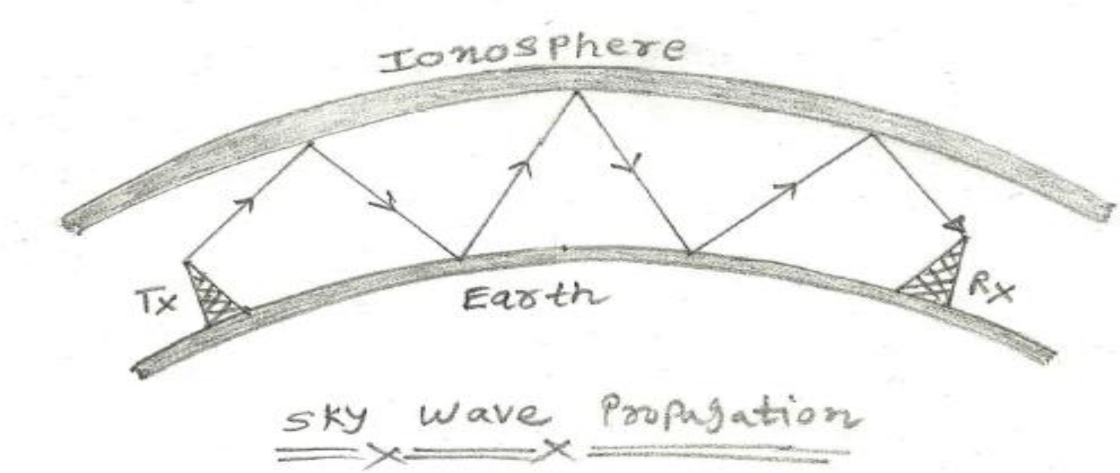
Ground wave

Used for a low-frequency range transmission, mostly less than 1 MHz. This type of propagation employs the use of large antennas order of which is equivalent to the wavelength of the waves and uses the ground or Troposphere for its propagation. Signals over large distances are not sent using this method. It causes severe attenuation, which increases with increased frequency of the waves.



SKY Wave

Used for the propagation of EM waves with a frequency range of 3 – 30 MHz. Make use of the ionosphere so called due to the presence of charged ions in the region of about 60 to 300 km from the earth surface. These ions provide a reflecting medium to the radio or communication waves within a particular frequency range. We use this property of the ionosphere for long-distance transmission of the waves without much attenuation and loss of signal strength.



Another important point to note is the consideration of the angle of the emission of these waves from the ground. The transmitter emits the EM Waves at a critical angle to ensure total reflection to the ground just like the total internal reflection of optic waves otherwise the waves may escape into space. Skip Distance is the distance between the 2 points between which the wave transmission happens.

Space wave / Line of sight propagation

Used for a line of Sight communication also known as LoS. Space satellite communication and very high-frequency waves use this propagation method. It basically involves sending a signal in a straight line from the transmitter to the receiver. We must ensure that for very large distances, the height of the tower used for transmission is high enough to prevent waves from touching the earth curvature thus preventing attenuation and loss of signal strength.

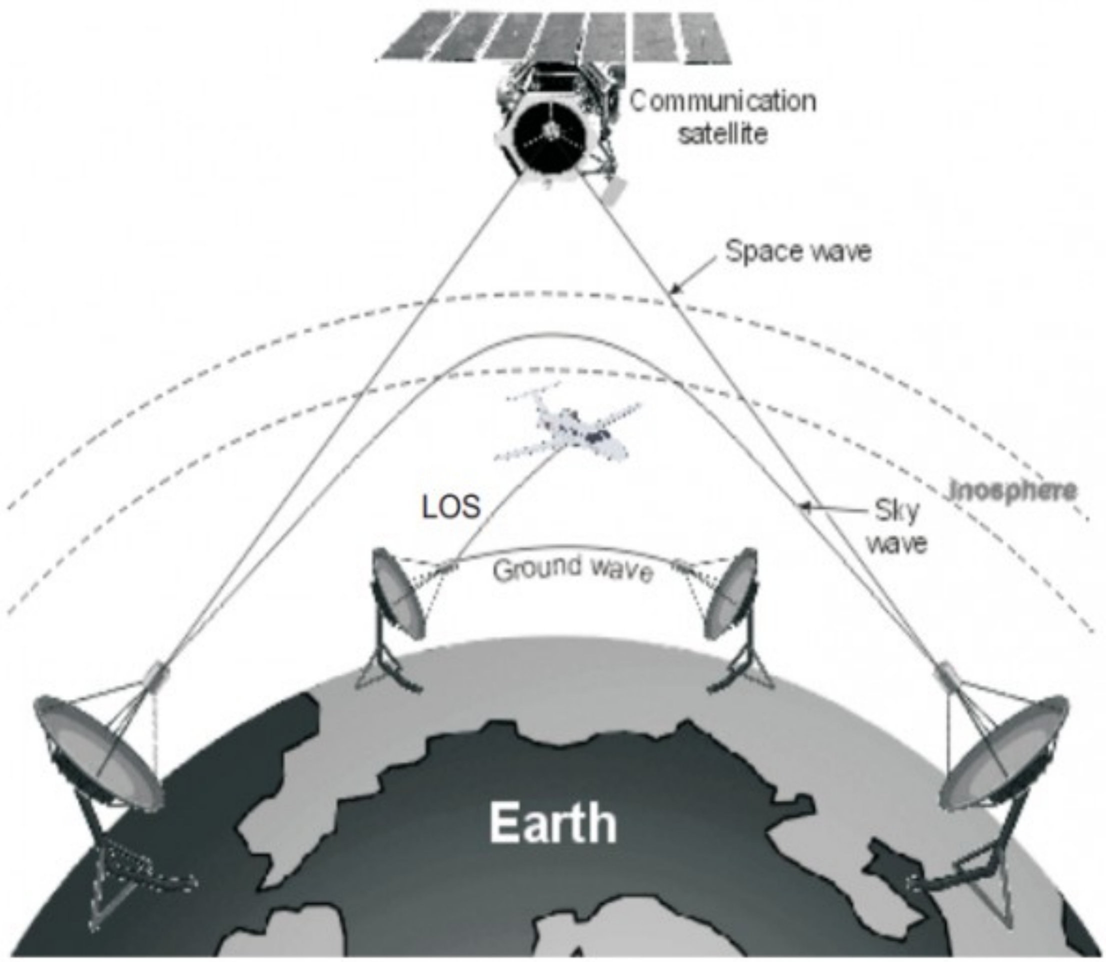
There is a very important relationship for determining the height of the antennas and their corresponding distance of transmission given by:

$Dm=(2RH_t)^{-1/2} +(2RH_r)^{-1/2}$

where Dm=distancbetweenen 2 antennas; R=Radius of earth=6400 km H_t=Height of transmission antenna; H_r=Height of receiver antenna. Also, very important to note is another important relation to determining the range of transmission(Dt) for a given antenna of height H_t is:

$D_t=(2RH_t)^{-1/2}$

Thus we have reached the end of this discussion. Wherein we have seen and studied about electromagnetic waves, understood the concept of their production and studied their properties. We also looked at various types of EM waves available, their utilization and studied the method of their propagation.



Three propagation modes of em waves

Wireless transmission wave

Wireless signals are spread over in the air and are received and interpreted by appropriate antennas. When an antenna is attached to electrical circuit of a computer or wireless device, it converts the digital data into wireless signals and spread all over within its frequency range. The receptor on the other end receives these signals and converts them back to digital data.

Wireless transmission wave are four types

- **Radio transmission**
- **Microwave transmission**
- **Infrared transmission**

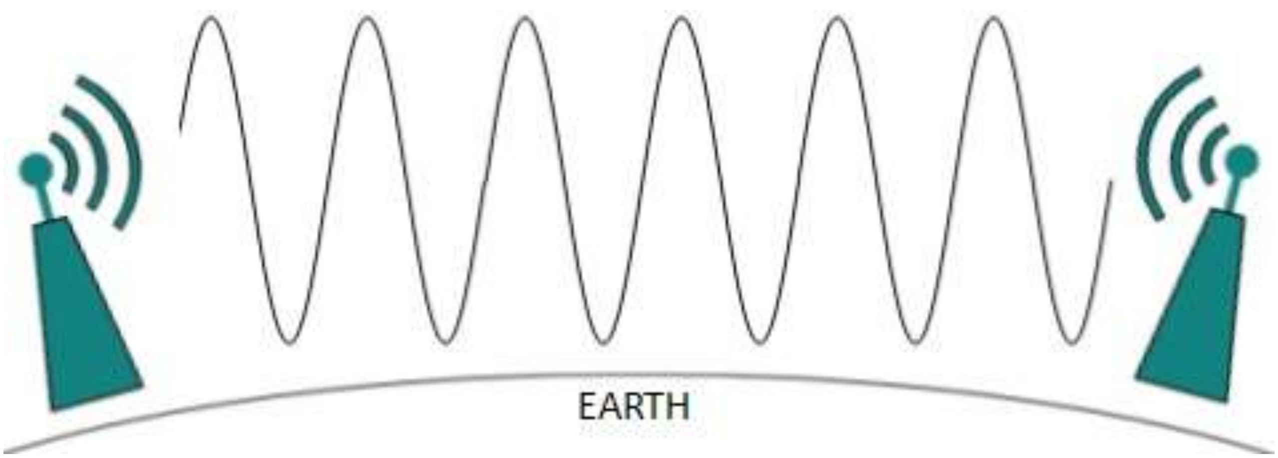
- **Light transmission**

Radio Transmission

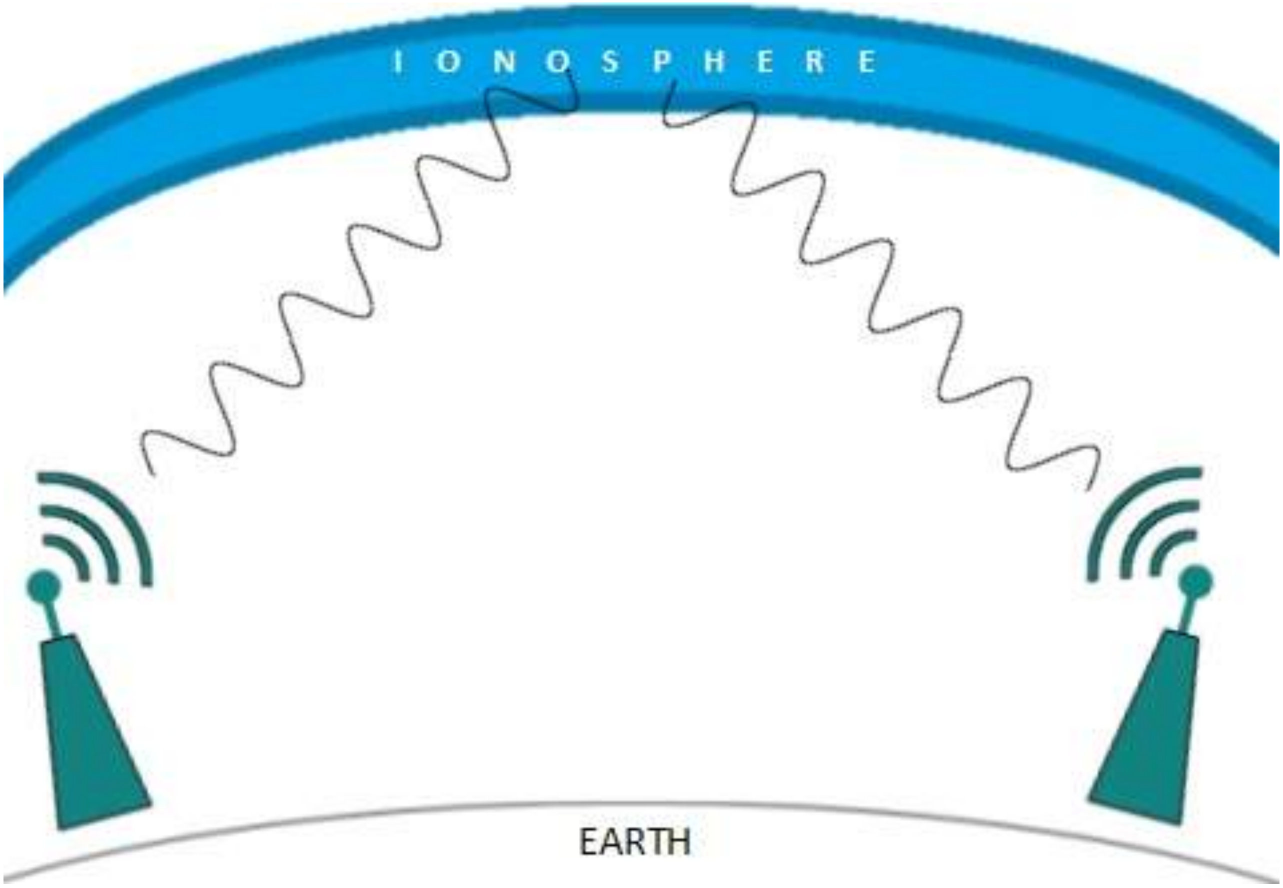
Radio frequency is easier to generate and because of its large wavelength it can penetrate through walls and structures alike.Radio waves can have wavelength from 1 mm – 100,000 km and have frequency ranging from 3 Hz (Extremely Low Frequency) to 300 GHz (Extremely High Frequency). Radio frequencies are sub-divided into six bands.

Radio waves at lower frequencies can travel through walls whereas higher RF can travel in straight line and bounce back.The power of low frequency waves decreases sharply as they cover long distance. High frequency radio waves have more power.

Lower frequencies such as VLF, LF, MF bands can travel on the ground up to 1000 kilometers, over the earth's surface.



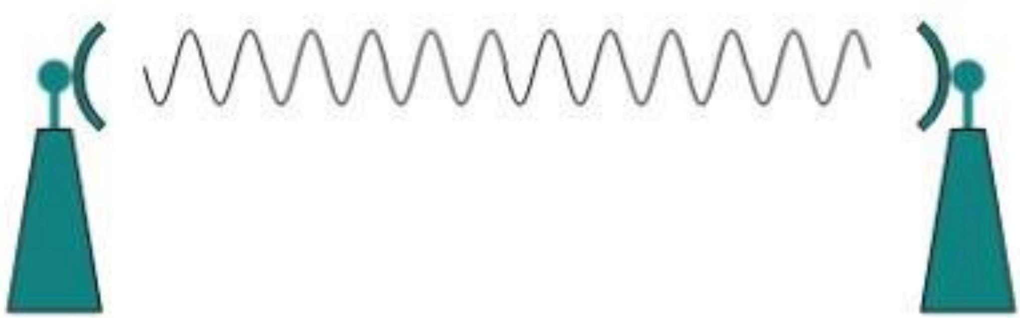
Radio waves of high frequencies are prone to be absorbed by rain and other obstacles. They use Ionosphere of earth atmosphere. High frequency radio waves such as HF and VHF bands are spread upwards. When they reach Ionosphere, they are refracted back to the earth.



Microwave Transmission

Electromagnetic waves above 100 MHz tend to travel in a straight line and beaming those waves towards one particular station can send signals over them. Because Microwaves travels in straight lines, both sender and receiver must be aligned to be strictly in line-of-sight.

Microwaves can have wavelength ranging from 1 mm – 1 meter and frequency ranging from 300 MHz to 300 GHz.



Microwave antennas concentrate the waves making a beam of it. As shown in picture above, multiple antennas can be aligned to reach farther. Microwaves have higher frequencies and do not penetrate wall like obstacles.

Microwave transmission depends highly upon the weather conditions and the frequency it is using.

Infrared Transmission

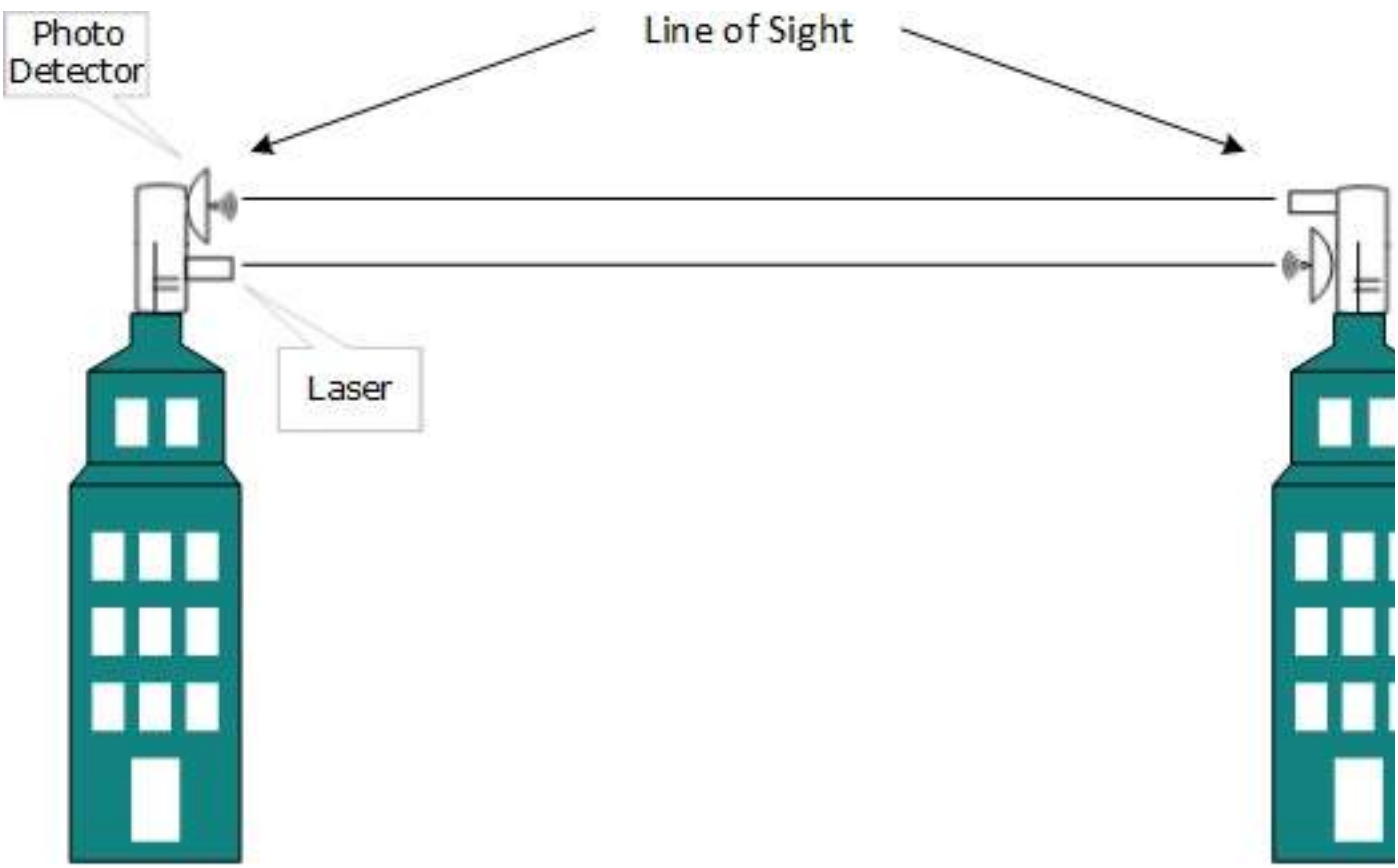
Infrared wave lies in between visible light spectrum and microwaves. It has wavelength of 700-nm to 1-mm and frequency ranges from 300-GHz to 430-THz.

Infrared wave is used for very short range communication purposes such as television and it's remote. Infrared travels in a straight line hence it is directional by nature. Because of high frequency range, Infrared cannot cross wall-like obstacles.

Light Transmission

Highest most electromagnetic spectrum, which can be used for data transmission, is light or optical signaling. This is achieved by means of LASER.

Because of frequency light uses, it tends to travel strictly in straight line. Hence the sender and receiver must be in the line-of-sight. Because laser transmission is unidirectional, at both ends of communication the laser and the photo-detector needs to be installed. Laser beam is generally 1mm wide hence it is a work of precision to align two far receptors each pointing to lasers source.



Laser works as Tx (transmitter) and photo-detectors works as Rx (receiver).

Lasers cannot penetrate obstacles such as walls, rain, and thick fog. Additionally, laser beam is distorted by wind, atmosphere temperature, or variation in temperature in the path.

Laser is safe for data transmission as it is very difficult to tap 1mm wide laser without interrupting the communication channel.

We need to send 265kbps over a noiseless channel with a bandwidth of 20KHz. How many signal levels do we need?

Solution

We can use nyquist formula

Nmax = 2 x B x Log2L

265000 = 2 x 20000 x Log2L **Note: (265000 = 265Kbps), (20000 = 20KHz)**

Log2L = 6.625 L = 26.625 = 98.7 levels

So,

We need 98.7 signals levels

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Q 4 What is the difference between Shannon & Nyquist Capacity? Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with 4 signal levels, the maximum bit rate can be?

Shannon & Nyquist Capacity

Nyquist rate tells you in order to reconstruct a baseband signal with bandwidth W from sampling; you need to sample the signal at 2W rate. A good intuition is to think about a sine wave. This theory is applying to a signal without noise.

On the contrary, Shannon's Capacity theorem needs to specify noise distribution, Under Gaussian noise, For a noiseless channel, the Nyquist bit rate formula defines the theoretical maximum bit rate

r = 2 X B X log2 L

In this formula, B is the bandwidth of the channel, L is the number of signal levels used to represent data, and r is the bit rate in bits per second.

According to the formula, we might think that, given a specific bandwidth, we can have any bit rate we want by increasing the number of signal levels.

Although the idea is theoretically correct, practically there is a limit. When we increase the number of signal levels, we impose a burden on the receiver. If the number of levels in a signal is just 2, the receiver can easily distinguish between a 0 and a 1. If the level of a signal is 64, the receiver must be very sophisticated to distinguish between 64 different levels. In other words, increasing the levels of a signal reduces the reliability of the system.

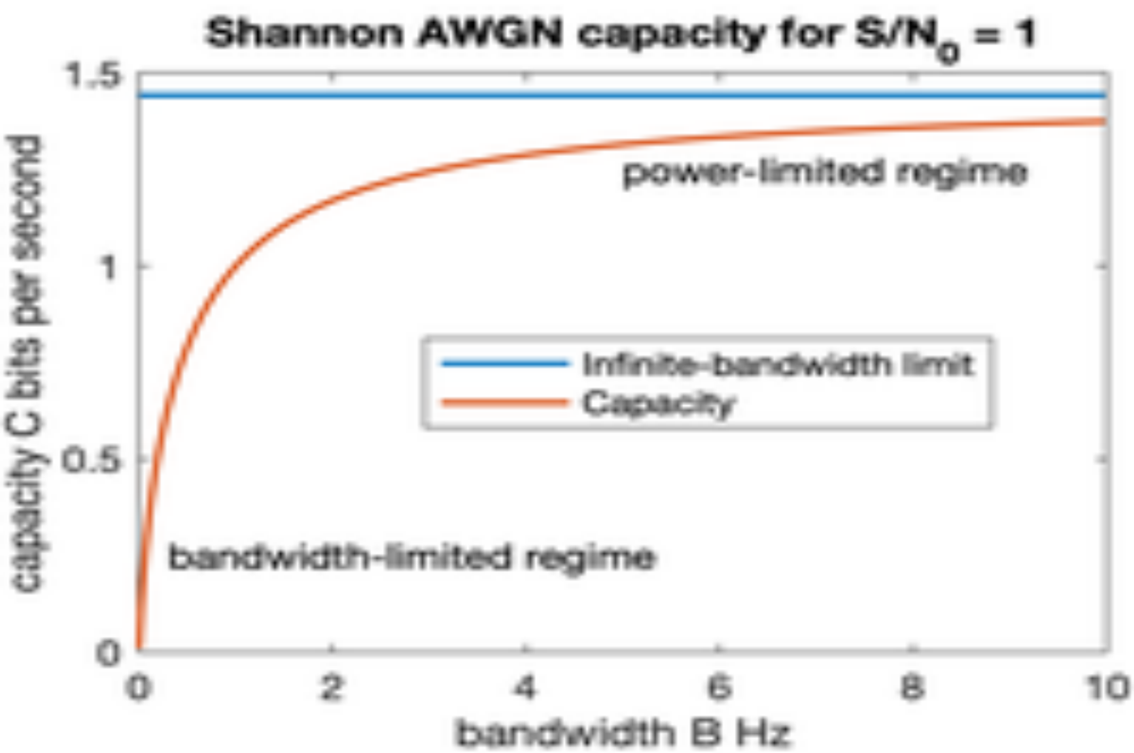
Noisy Channel: Shannon Capacity

In reality, we cannot have a noiseless channel; the channel is always noisy. In 1944, Cloude-shannon introduced a formula called the Shannon capacity, to determine the theoretical

highest data rate for a noisy Channel.

C = B x Iog2(1 + SNR)

In this formula B is the bandwidth of the channel, SNR is the signal-to noise ratio, and C is the capacity of the channel in bits per second. Note that the Shannon formula there is no indication of the signal level, which means that no matter how many levels we have. We cannot achieve a data rate higher than the capacity of the channel. in other words, the formula defines a characteristic of the channel, not the method of transmission.



In conclusion, we can say for channel capacity that the Shannon capacity gives us the' upper limit while the Nyquist formula tells us how many signal levels we need.

For a noiseless channel, the Nyquist bit rate formula defines the theoretical maximum bit rate

BitRate = 2 * Bandwidth * $\log_2$(L)

In the above equation, bandwidth is the bandwidth of the channel, L is the number of signal levels used to represent data, and BitRate is the bit rate in bits per second.
Bandwidth is a fixed quantity, so it cannot be changed. Hence, the data rate is directly proportional to the number of signal levels.
Note –Increasing the levels of a signal may reduce the reliability of the system.

Nyquist's theorem specifies the maximum data rate for noiseless condition, whereas the Shannon theorem specifies the maximum data rate under a noise condition. The Nyquist theorem states that a signal with the bandwidth B can be completely reconstructed if 2B samples per second are used.

Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with 4 signal levels, the maximum bit rate can be?

Solution

As Bit Rate = 2 x Bandwidth x log2 L

Bit rate = 2 3000 log2 4

Bit rate = 12000 bps

So,

The maximum bit rate is 12000bps