Wireless Networks

Prof. Dr. Hassan Al-Mahdi

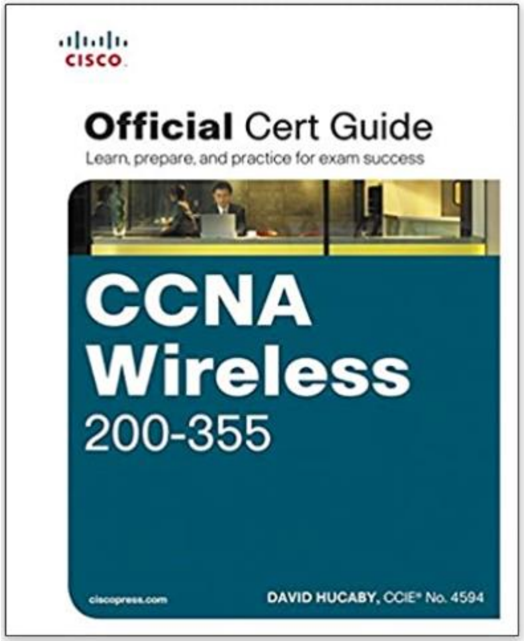
2022-2023-2

CS453 Wireless Networks

Agenda

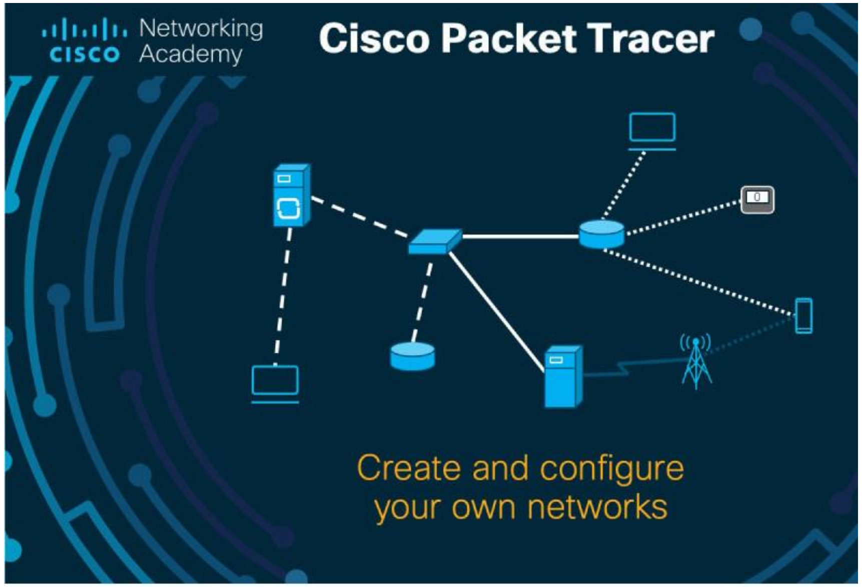
- Course Books
- Course Content
- Course Evaluation

Course Book



[CCNA Wireless 200-355 Official Cert Guide (Certification Guide)](#)
by David Hucaby

Practical



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Course Contents

- **Chapter 1, “RF Signals and Modulation”:** the basic theory behind radio frequency (RF) signals and the methods used to carry data wirelessly.
- **Chapter 2, “RF Standards”:** the agencies that regulate, standardize, and validate the correct use of wireless LAN devices.
- **Chapter 3, “RF Signals in the Real World”:** explores many of the conditions that can affect wireless signal propagation.
- **Chapter 4, “Understanding Antennas”:** explains some basic antenna theory, in addition to various types of antennas and their application.

Course Contents

- **Chapter 5, “Wireless LAN Topologies”:** explains the topologies that can be used to control access to the wireless medium and provide data exchange between devices.
- **Chapter 6, “Understanding 802.11 Frame Types”:** covers the frame format and frame types that APs and clients must use to communicate successfully. It also discusses the choreography that occurs between an AP and its clients.
- **Chapter 7, “Planning Coverage with Wireless APs”:** explains how wireless coverage can be adjusted to meet a need and how it can be grown to scale over a greater area and a greater number of clients. It also explains how coverage can be measured, surveyed, and validated.

Course Contents

- **Chapter 14, “Wireless Security Fundamentals”:** This chapter covers many of the methods you can use to secure a wireless network.
- **Chapter 15, “Configuring a WLAN”:** This chapter explains how to define and tune a wireless LAN to support wireless clients and connectivity with a wired infrastructure.

Course Evaluation

الكود	اسم المقرر	الساعات		النهايات العظمى للدرجات			
		نظري	عملي	تحريري	شفوى وعملى	اعمال الفصل	المجموع
ع ح ٤١٧	تعريب الحاسبات	٢	٢	٧٠	١٥	١٥	١٠٠
ع ح ٤٦٠	الذكاء الاصطناعي	٣	٣	٨٠	٢٠	٢٠	١٢٠
ع ح ٤٤٥	نظم الرؤية بالحاسب	٢	٢	٥٠	١٥	١٥	٨٠
ع ح ٤٣٢	الأنظمة الموزعة	٣	٣	٨٠	٢٠	٢٠	١٢٠
	منهج اختياري (٤)	٣	٣	٨٠	٢٠	٢٠	١٢٠
ع ح ٤٩٩	مشروع التخرج	٢	٣		١٠٠	٥٠	١٥٠
	المجموع	١٥	١٦				٦٩٠

Lecture 1

RF Signals and Modulation

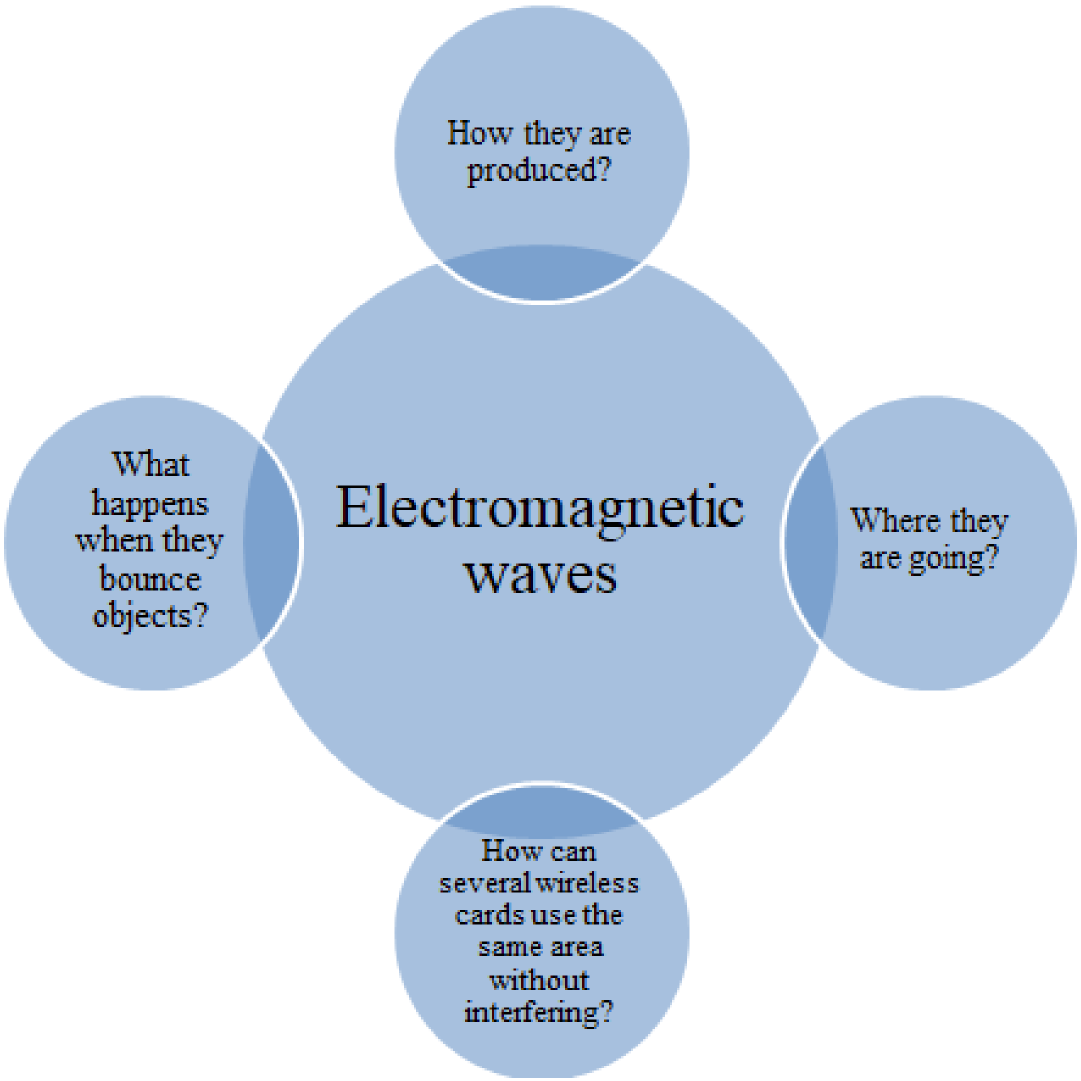
This chapter covers the following topics

- 1.1—Describe the propagation of radio waves
  - 1.1a—Frequency, amplitude, phase, wavelength (characteristics)
- 1.2—Interpret RF signal measurements
  - 1.2a—Signal strength (RSSI, transmit power, receive sensitivity)
  - 1.2b—Differentiate interference vs. noise
  - 1.2d—Define SNR
- 1.3—Explain the principles of RF mathematics
  - 1.3a—Compute dBm, mW, Law of 3s and 10s
- 1.4—Describe Wi-Fi antenna characteristics
  - 1.4c—dBi, dBd, EIRP
- 2.3—Describe 802.11 fundamentals
  - 2.3a—Modulation techniques

Radio Physics: What is a wave?

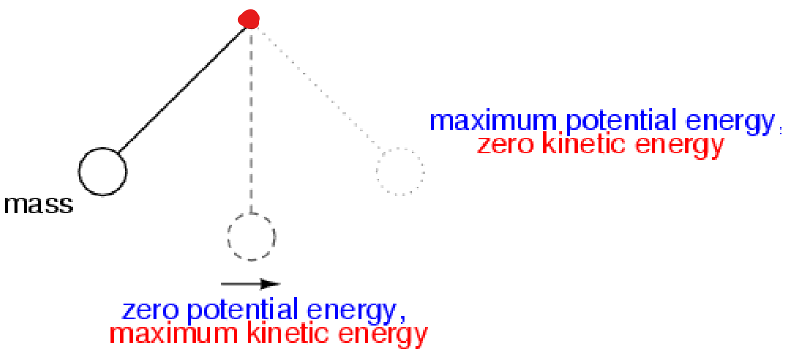
Wireless communications make use of electromagnetic waves to send signals across long distances.

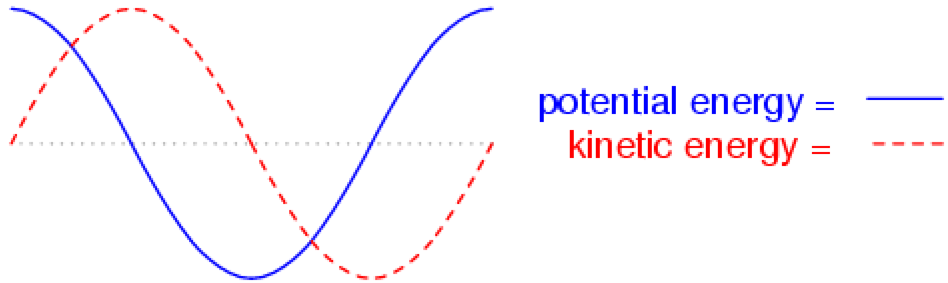
The following questions arise:



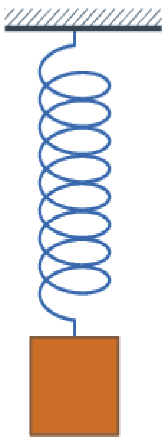
Radio Physics: What is a wave?

Oscillations: Periodic motion and restoring force due to weight of the body. Even rigid body can oscillate. For example: simple pendulum is oscillate or anything tie at the end of the thread and hang it. It oscillate.





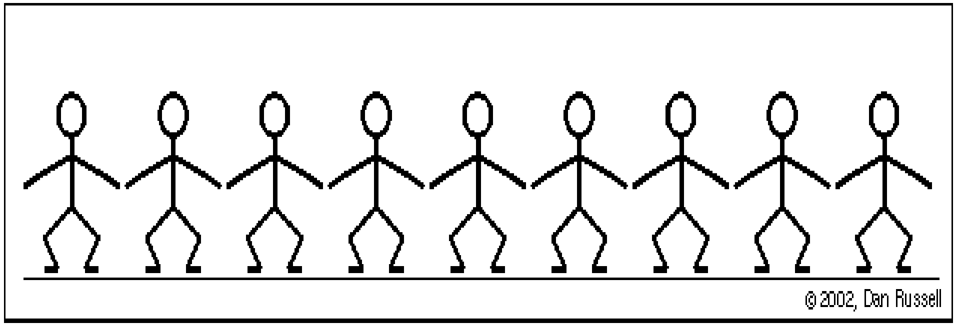
Vibrations: The force due to elastic property of body. Rigid body can not vibrate. Anything has mass and elasticity can **vibrate**.



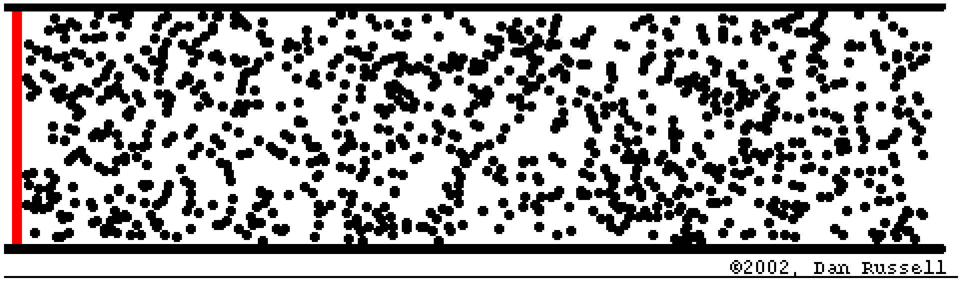
A classic example is provided by a weight suspended from a spring. In equilibrium, the system has minimum energy and the weight is at rest. If the weight is pulled down and released, the system will respond by vibrating vertically.

Radio Physics: What is a wave?

A wave can be described as a disturbance that travels and transfers energy through a matter or space from one location to another.

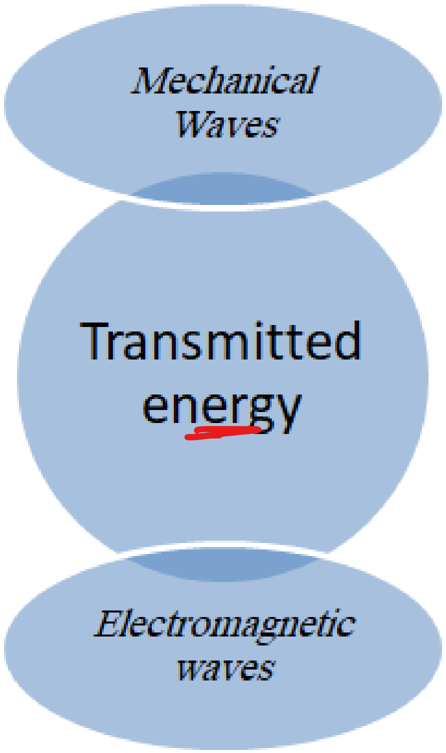


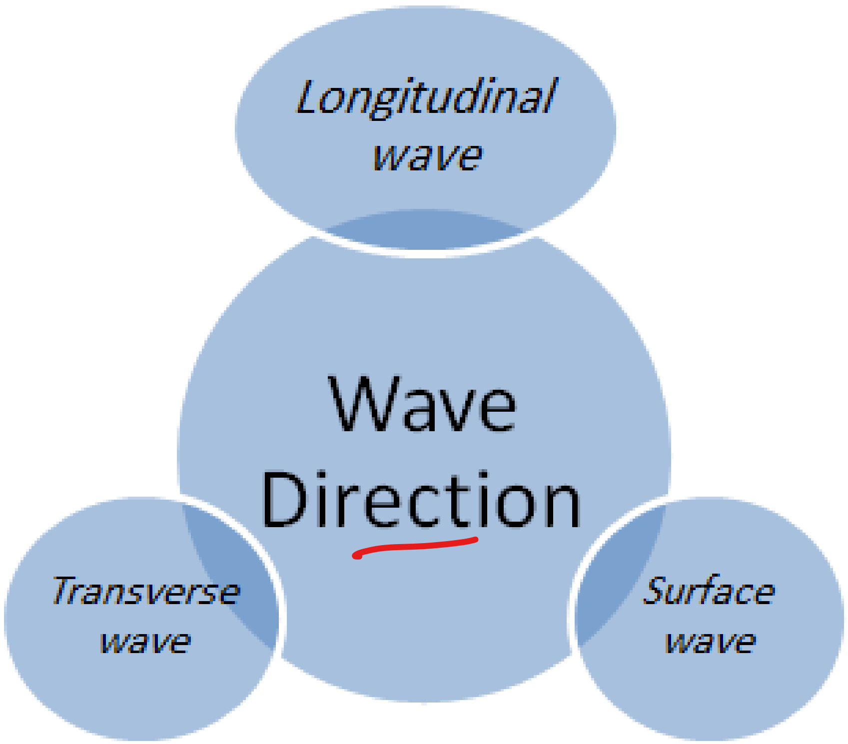
A group of people at a football stadium jumps up and sits back down. They seem like a wave travelling around the stadium. However, all individual people remain at their seats.



Sound wave pulse passes through, the particles in the air oscillate back and forth about their equilibrium positions but it is the disturbance which travels, not the individual particles in the medium.

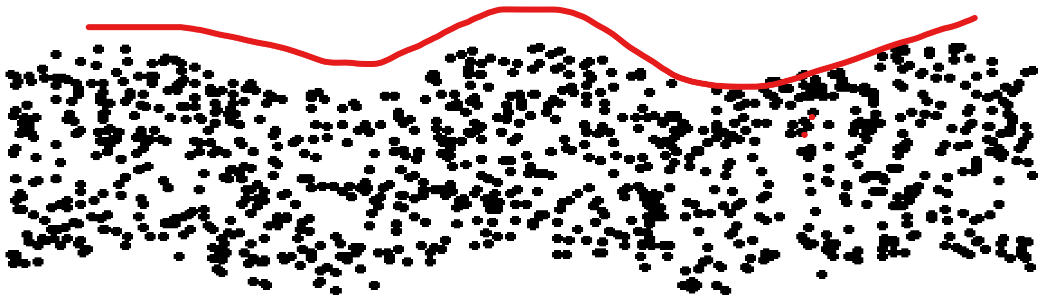
Types of waves: Waves share some basic characteristic properties and behaviors, some waves can be distinguished from others based on some observable characteristics. It is common to categorize waves based on these distinguishing characteristics.



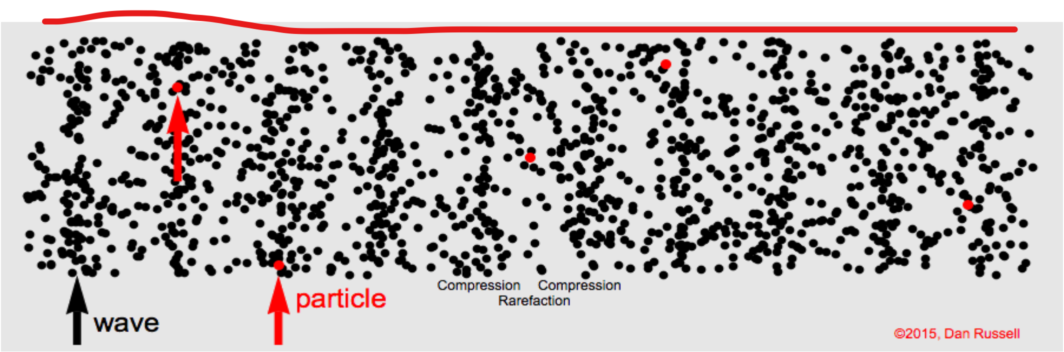


Radio Physics: What is a wave?

One way to categorize waves is on the basis of the **direction of movement** of the individual particles of the medium relative to the direction that the waves travel. Categorizing waves on this basis leads to three notable categories: transverse waves, longitudinal waves, and surface waves.



A transverse wave is a wave in which particles of the medium move in a direction perpendicular to the direction that the wave moves.



A longitudinal wave is a wave in which particles of the medium move in a direction parallel to the direction that the wave moves.

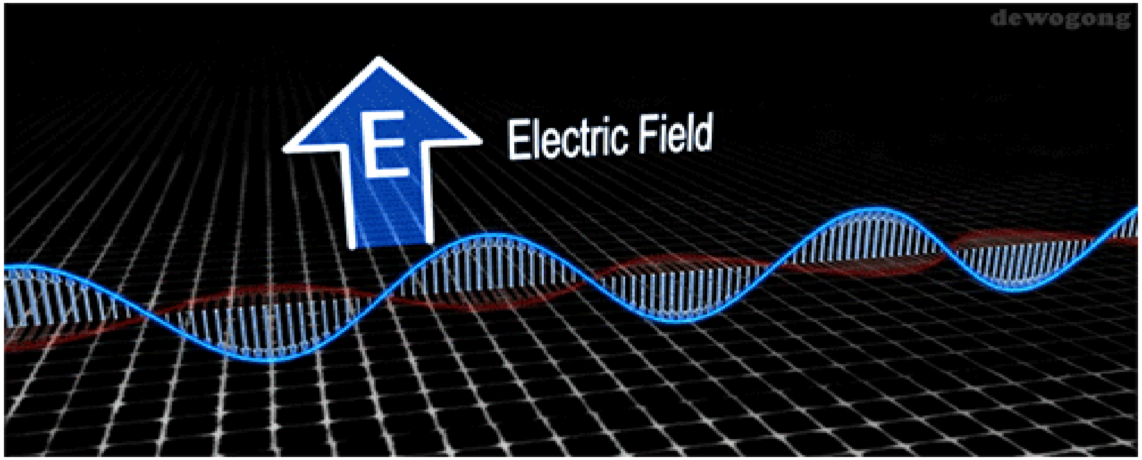
Radio Physics: What is a wave?

Another way to categorize waves is on the basis of their ability or inability to transmit energy through a vacuum (i.e., empty space).

Electromagnetic wave

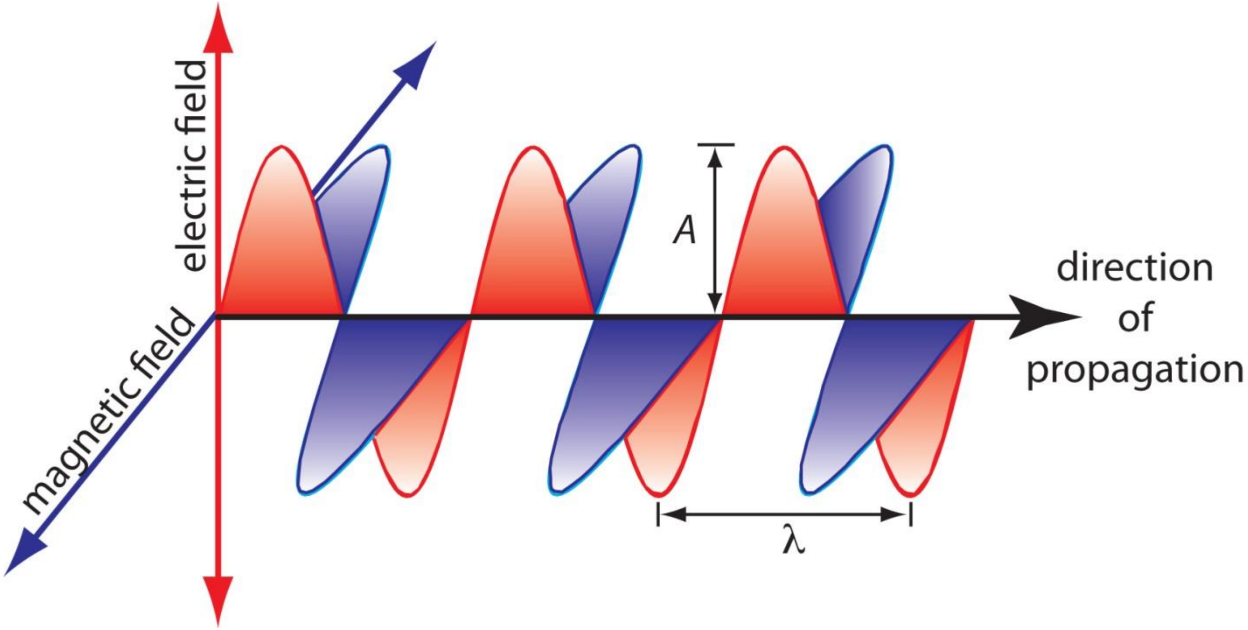
- No medium for propagation,
- Transmitting energy through an empty space or vacuum.
- Caused because of the varying magnetic and electric fields.
- Produced by the vibration of charged particles.
- Consist of periodic variations of electric and magnetic fields at right angles to each other and also at right angles to the direction of propagation.
- They are all the same kind of wavy disturbance that repeats itself over a distance called the wavelength.

Electromagnetic wave



As the wave moves through space,

- the E (electric) field increases and decreases.
- the B (magnetic) field increases and decreases



- ❖ The waves (each representing one up and down cycle of the sender's arm) actually travel from the sender to the receiver.

Figure 1-1 Failed Attempt to Pass a Message Down a Rope

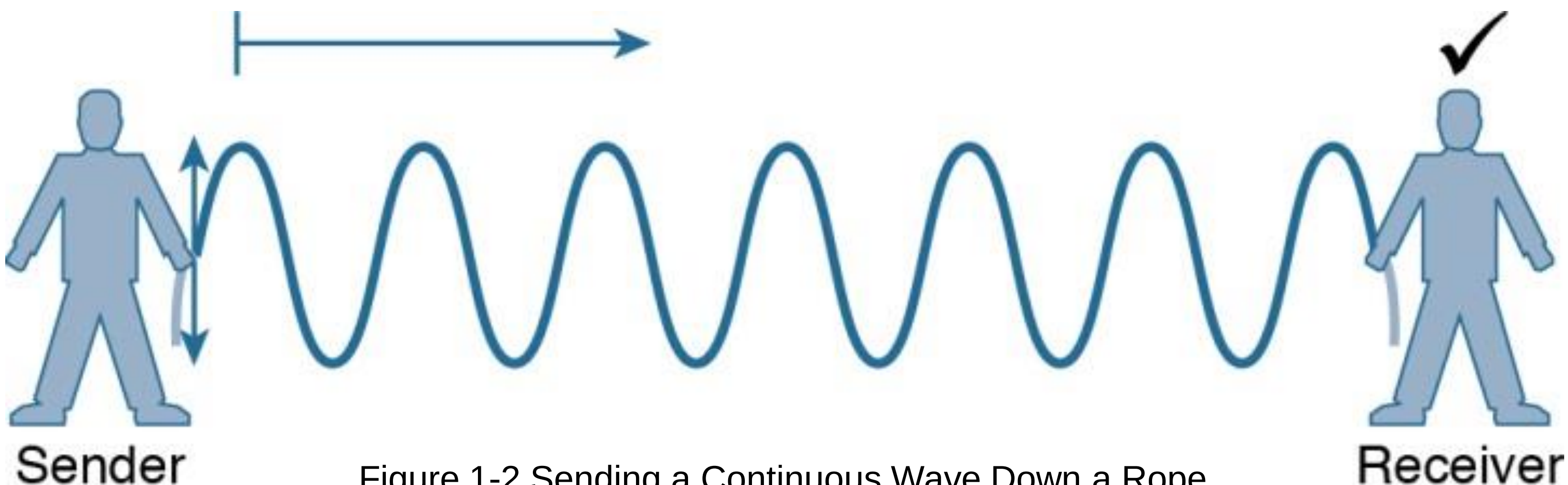


Figure 1-2 Sending a Continuous Wave Down a Rope

- The waves produced expand outward in a spherical shape. The waves will eventually reach the receiver, in addition to many other locations in other directions.

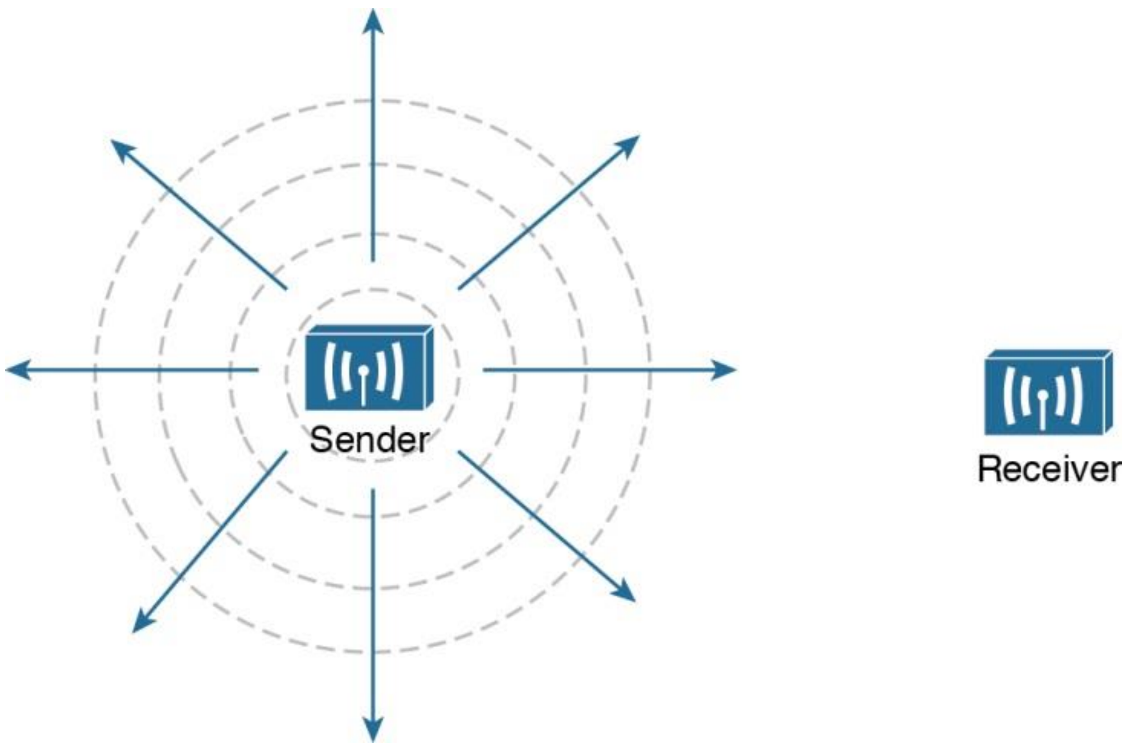
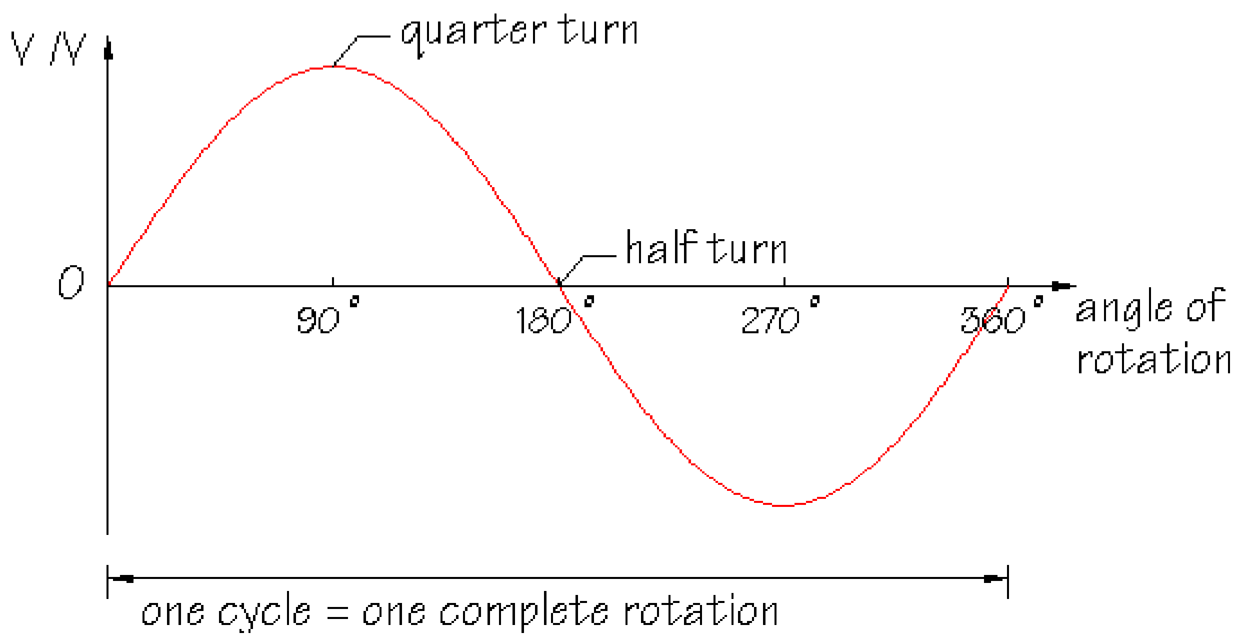


Figure 1-4 Wave Propagation with an Idealistic Ante

- At the receiving end of a wireless link, the process is reversed.
- As the electromagnetic waves reach the receiver's antenna, they induce an electrical signal.
- If everything works right, the received signal will be a reasonable copy of the original transmitted signal.

❖ Properties of Waves

❖ **Wave frequency (*f*)** is defined as the total number of cycles that are made per second and measured in **Hertz** (abbreviated Hz) where 1 Hz is equivalent to 1 cycle/second.



frequency

distance

$$\text{Hertz} = \frac{\text{cycle}}{\text{second}}$$

time

$$\text{frequency} = \frac{\text{cycle}}{\text{time}}$$

❖ Properties of Waves

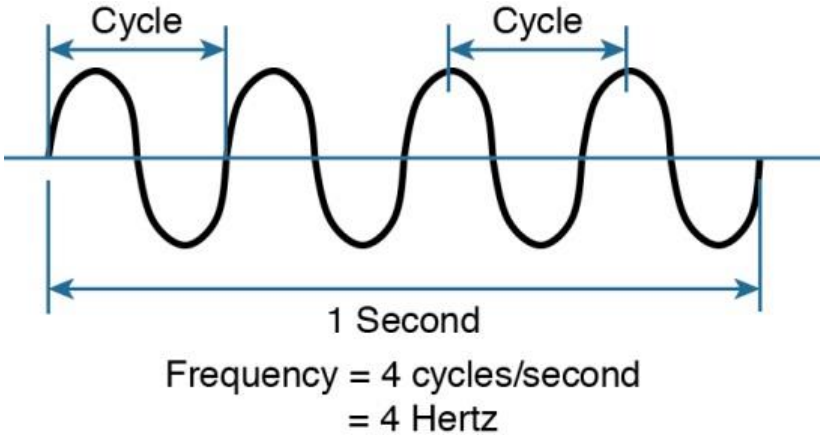


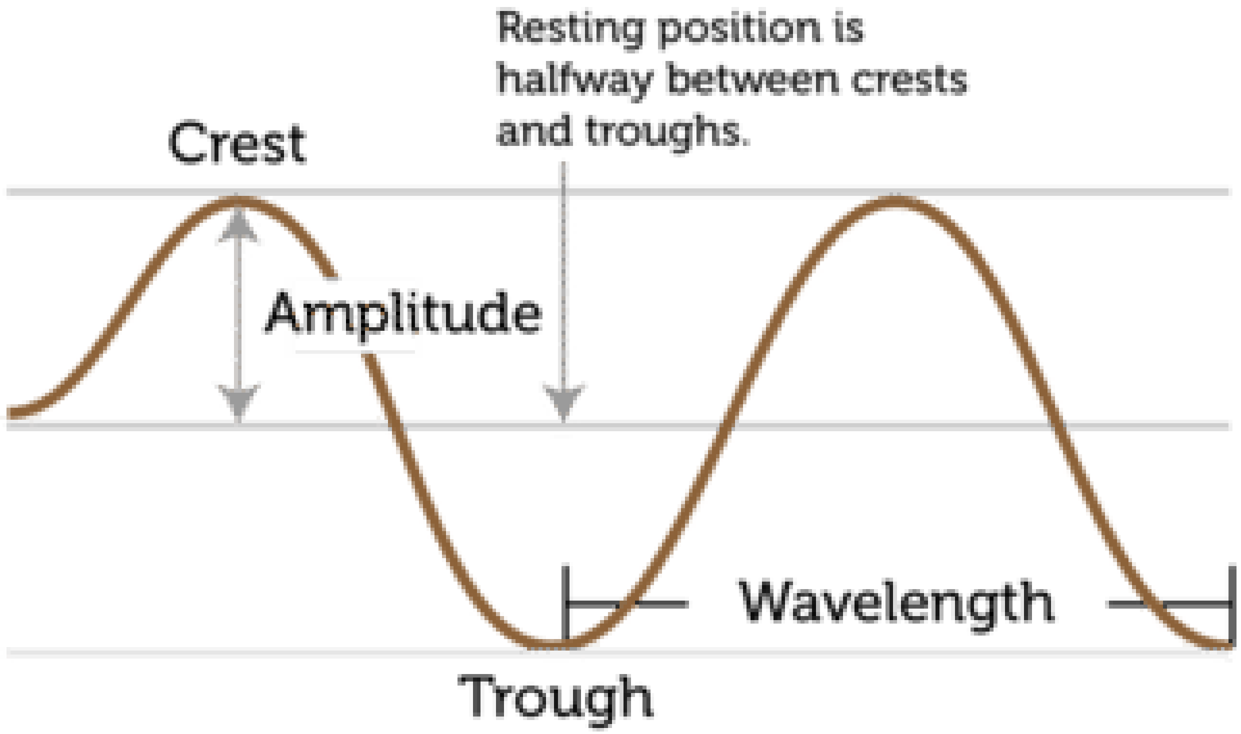
Figure 1-5 Cycles Within a Wave

- **A cycle :** is measured from the center of one peak to the center of the next peak.
- ***A hertz (Hz) :*** is the most commonly used frequency unit and is nothing other than one cycle per second.

Unit	Abbreviation	Meaning
Hertz	Hz	Cycles per second
Kilohertz	kHz	1000 Hz
Megahertz	MHz	1,000,000 Hz
Gigahertz	GHz	1,000,000,000 Hz

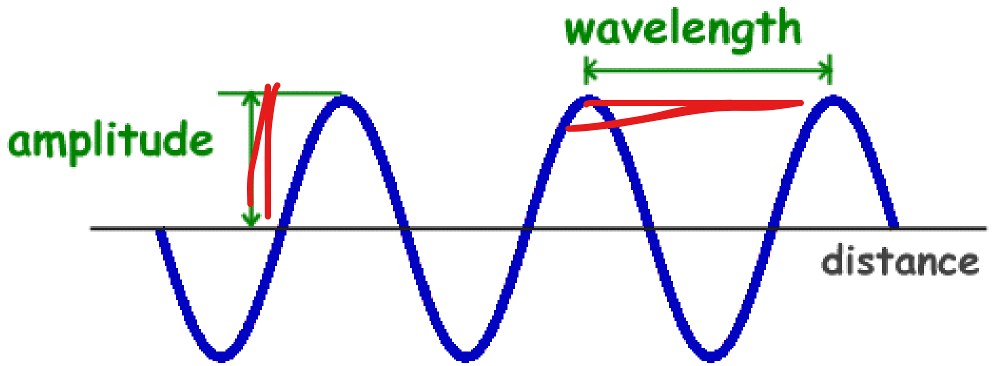
❖ Properties of Waves

Wave amplitude (A) is the maximum distance from the resting positions . The resting position of a particle of the medium is where the particle would be in the absence of a wave.

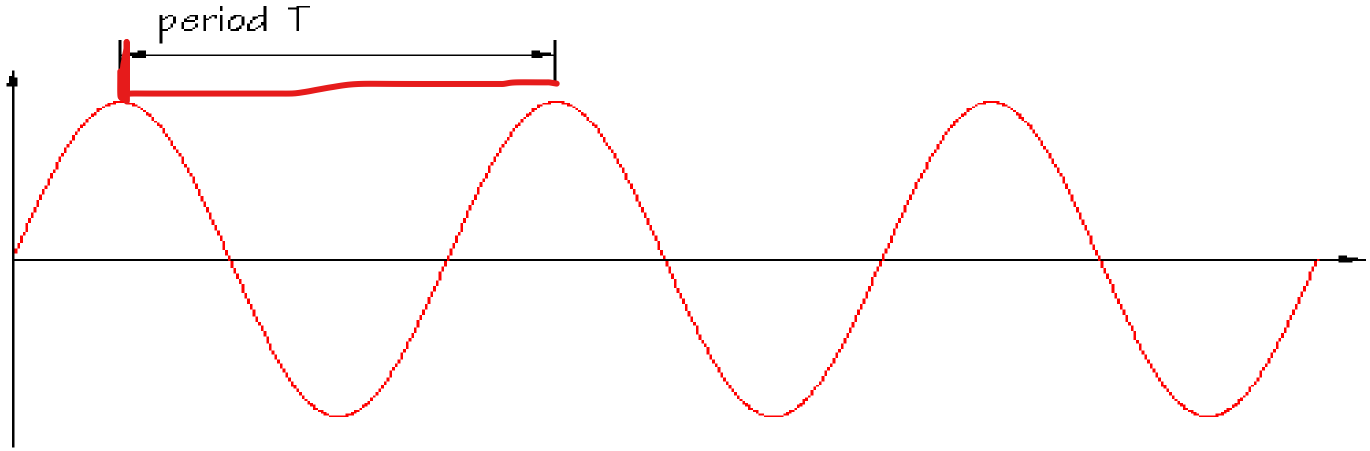


❖ Properties of Waves

Wavelength (λ) is the distance between identical points in adjacent cycles of a waveform signal propagated in space or along a wire, usually peak-to-peak or trough-to-trough.



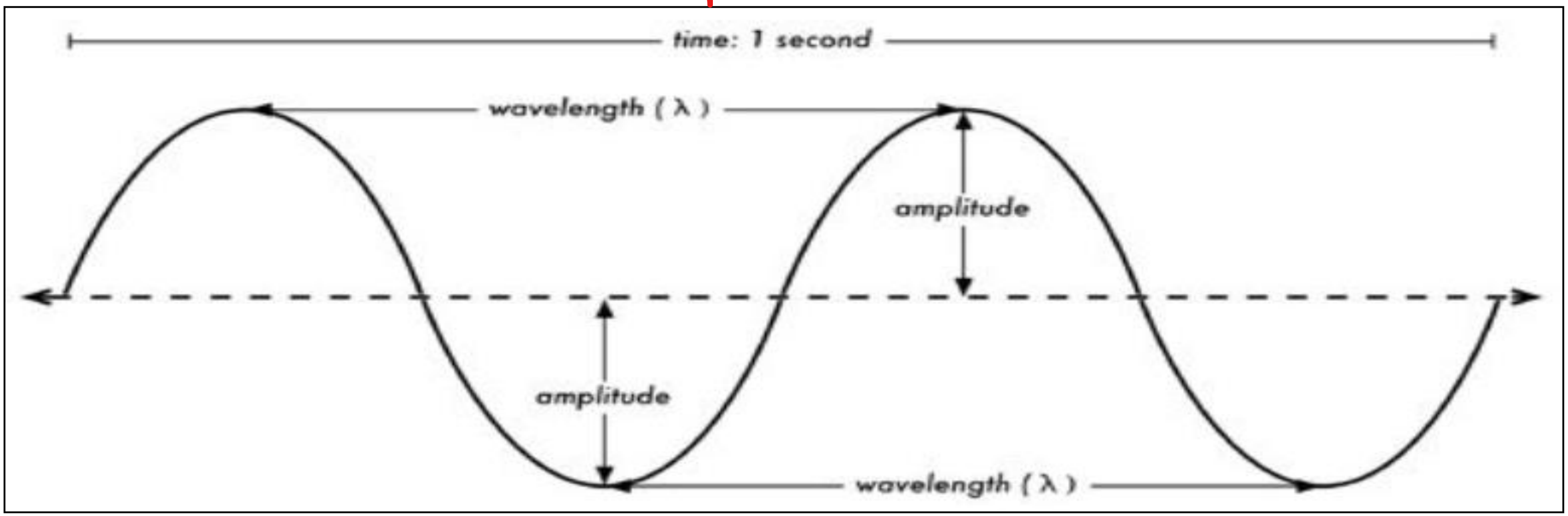
Wave period (*T*) is just how much time wave takes for one cycle to pass and the units are always in terms of time. The faster a wave moves, its wave period becomes smaller.



❖ Properties of Waves

Wave Speed

*Speed = Frequency * Wavelength.* $= \frac{1}{T}$



The frequency is 2 cycles per second, or 2 Hz, while the speed is 1 m/s.

Example

If a wave on water travels at one metre per second, and it oscillates five times per second, then each wave will be twenty centimetres long:

1 metre/second = 5 cycles/second * λ

λ = 1 / 5 metres

λ = 0.2 metres = 20 cm

❖ Properties of Waves

❖ Knowing the speed of light, we can calculate the wavelength for a given frequency. Let us take the example of the frequency of 802.11b wireless networking, which is:

$$f = 2.4\ GHz = 2{,}400{,}000{,}000\ cycles\ /\ second$$

$$wavelength\ (\lambda) = c\ /\ f = 3*10^{8}\ /\ 2.4*10^{9} = 1.25*10^{-1}\ m = 12.5\ cm$$

❖ Wireless standards, for example, 802.11b, 802.11g, 802.11n and 802.16 can all work at 2.4 GHz

❖ Continuous Frequency Spectrum

- At the low end of the spectrum are frequencies that are too low to be heard by the human ear.
- 3 kHz to 300 GHz: radio frequency (RF).
- 2.4 and 5 GHz : WLAN communication.
- **Band** is a range of frequencies might be used for the same purpose.
- 530 kHz to 1710 kHz is AM band.
- WLAN 5-GHz band actually contains the following four separate and distinct bands:
    - **5.150 to 5.250 GHz**
    - **5.250 to 5.350 GHz**
    - **5.470 to 5.725 GHz**
    - **5.725 to 5.825 GHz**

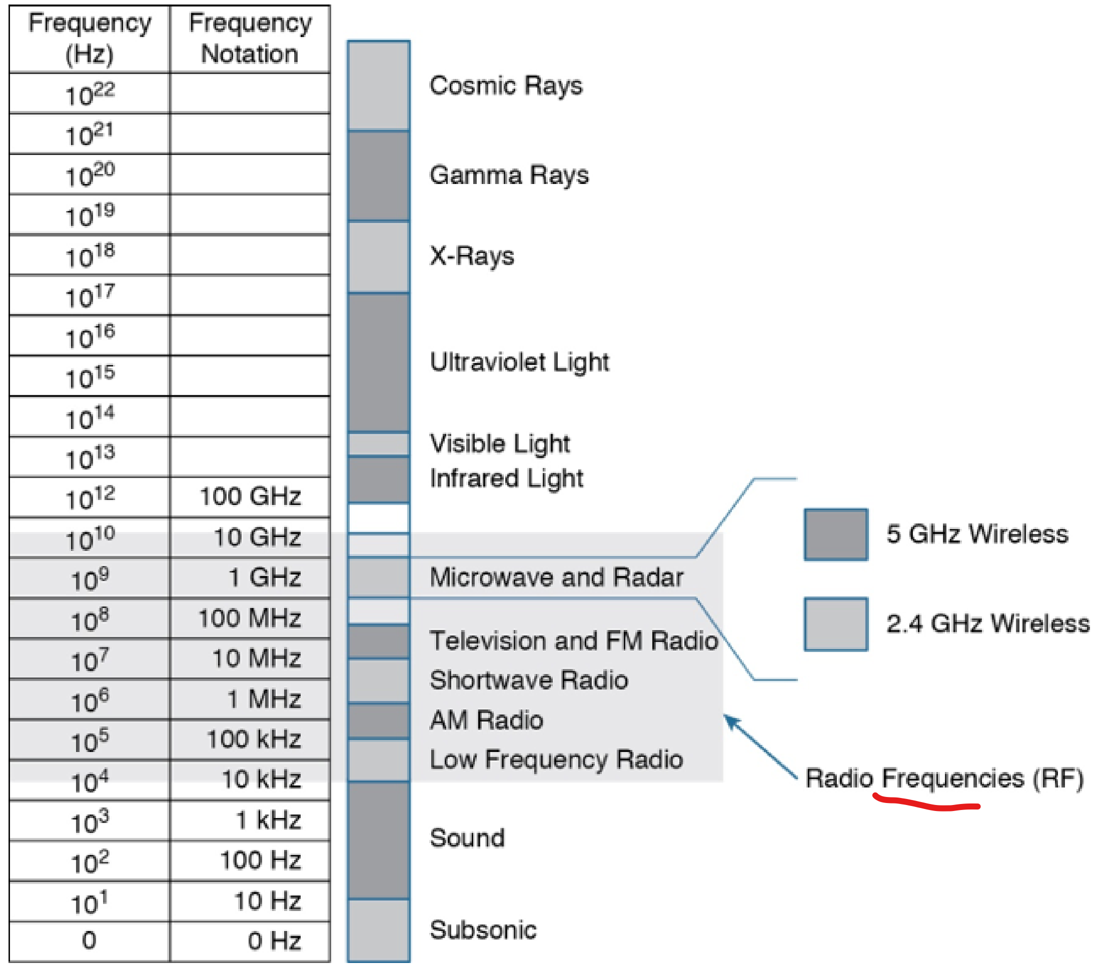
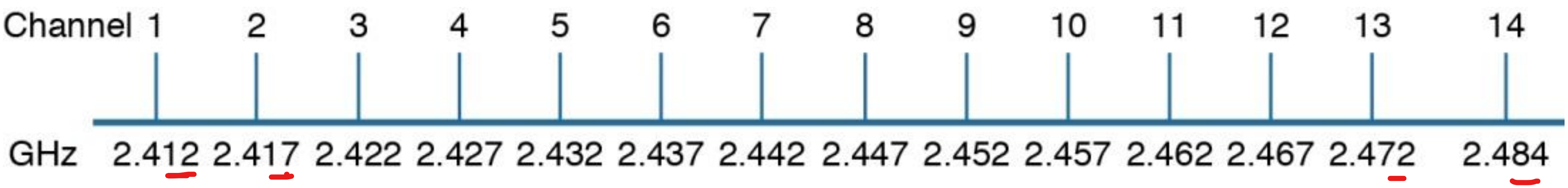


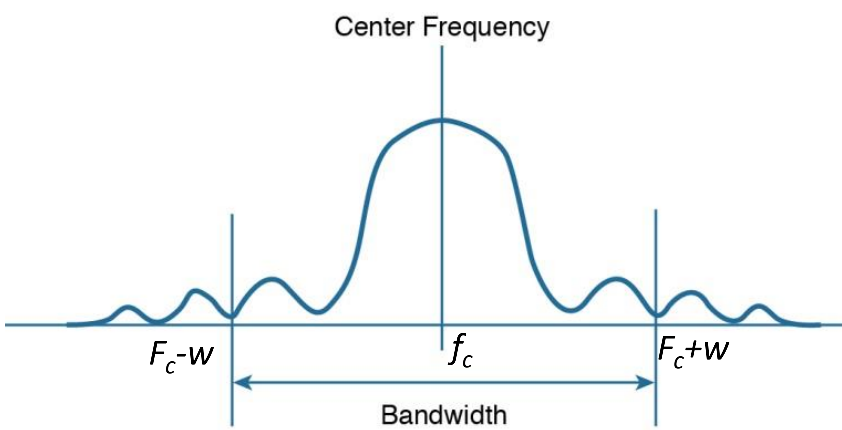
Figure 1-6 Continuous Frequency Spectrum

❖ Continuous Frequency Spectrum

- Bands are usually divided up into distinct channels with a specific frequency for each.
- For example, the WLAN 2.4-GHz band contains 14 channels numbered 1 through 14.
- The channels are spaced at regular intervals that are 0.005 GHz (or 5 MHz) apart, except for channel 14.

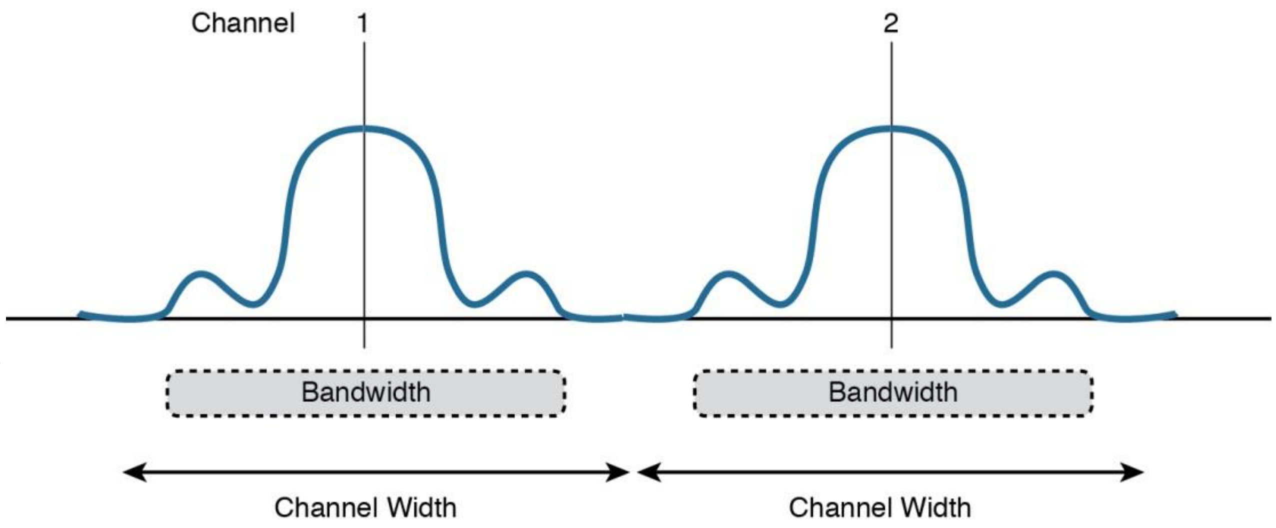


- In practice, an RF signal is not infinitely narrow.
- Instead, it spills above and below a center frequency.
- It is the center frequency that defines the channel location within the band.
- The actual frequency range needed for the transmitted signal is known as the signal bandwidth.
- For example, a signal with a 22-MHz bandwidth is bounded at 11 MHz above and below the center frequency.

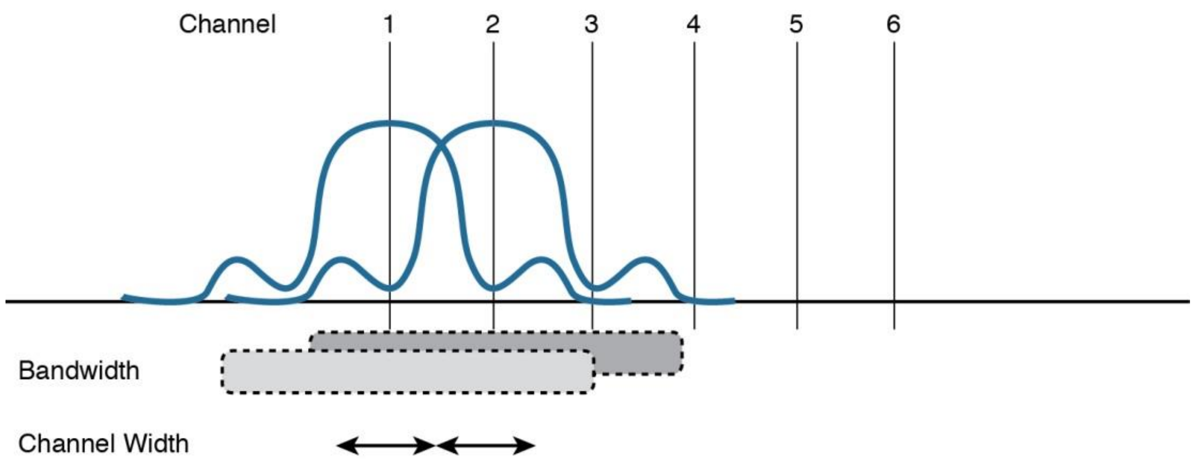


❖ Continuous Frequency Spectrum

Non-overlapping Channel Spacing

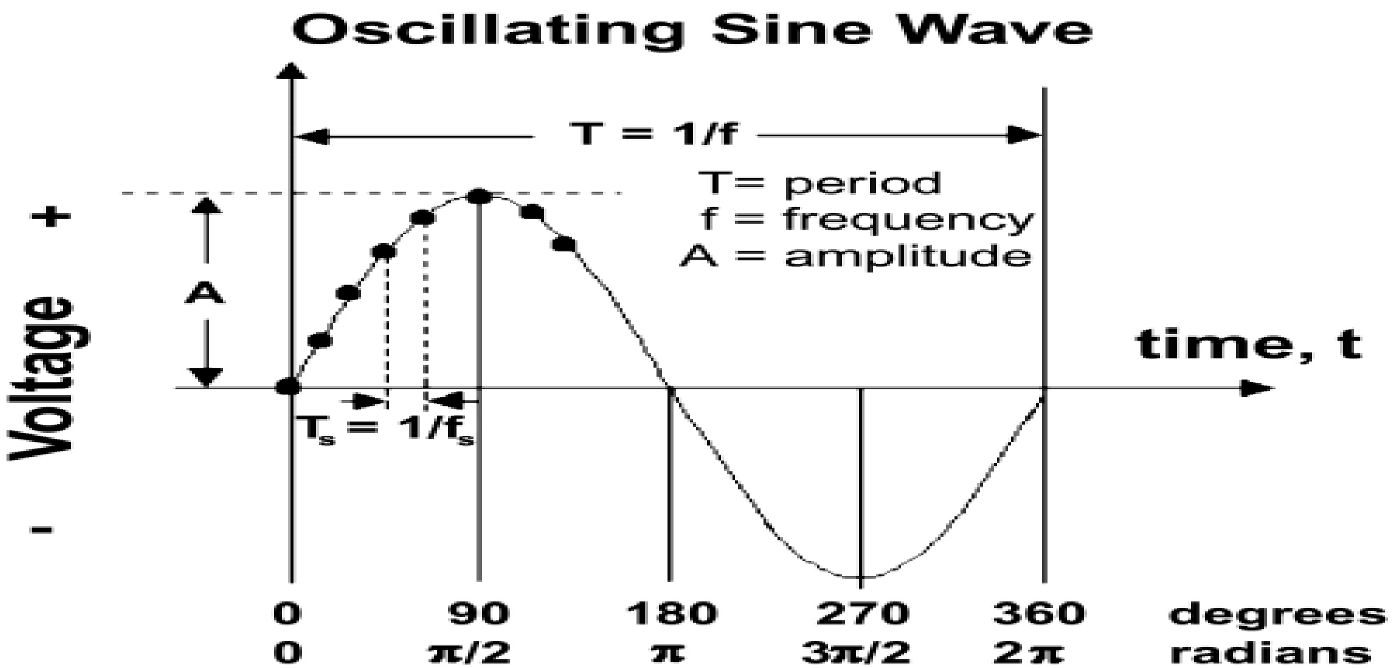


Overlapping Channel Spacing



Phase of a wave

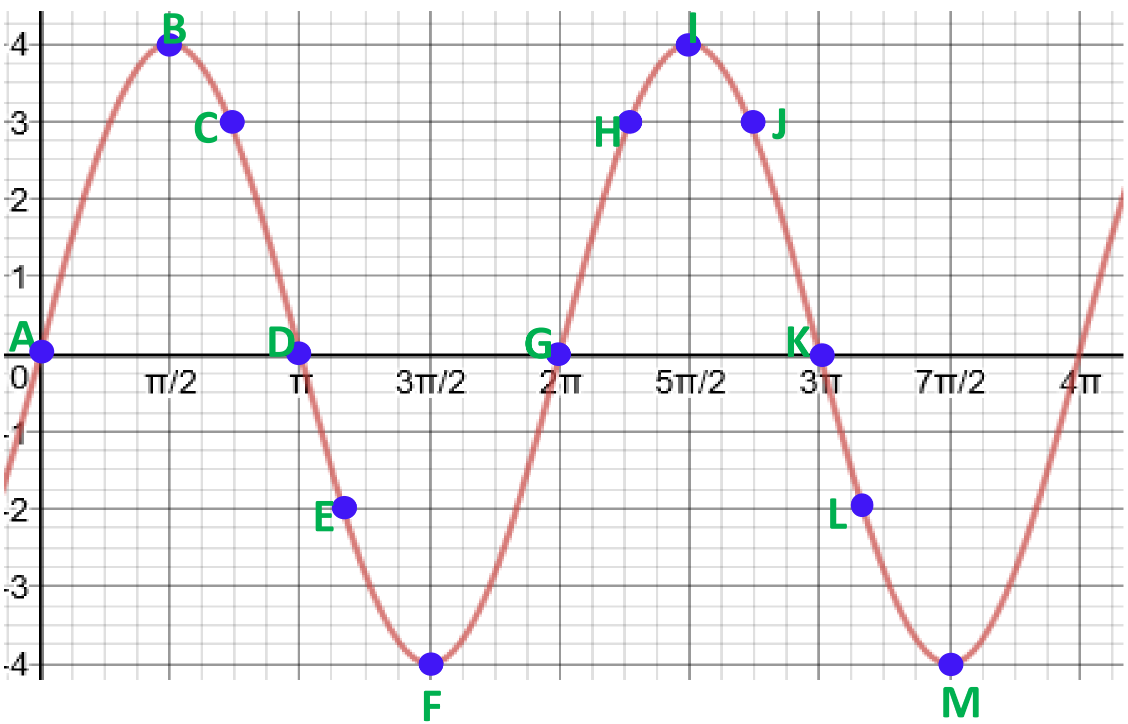
Phase is used to describe a location of a point on a single periodic waveform cycle.



Phase of a wave

Phase describes the state of motion as the wave sweeps through an element at particular position.

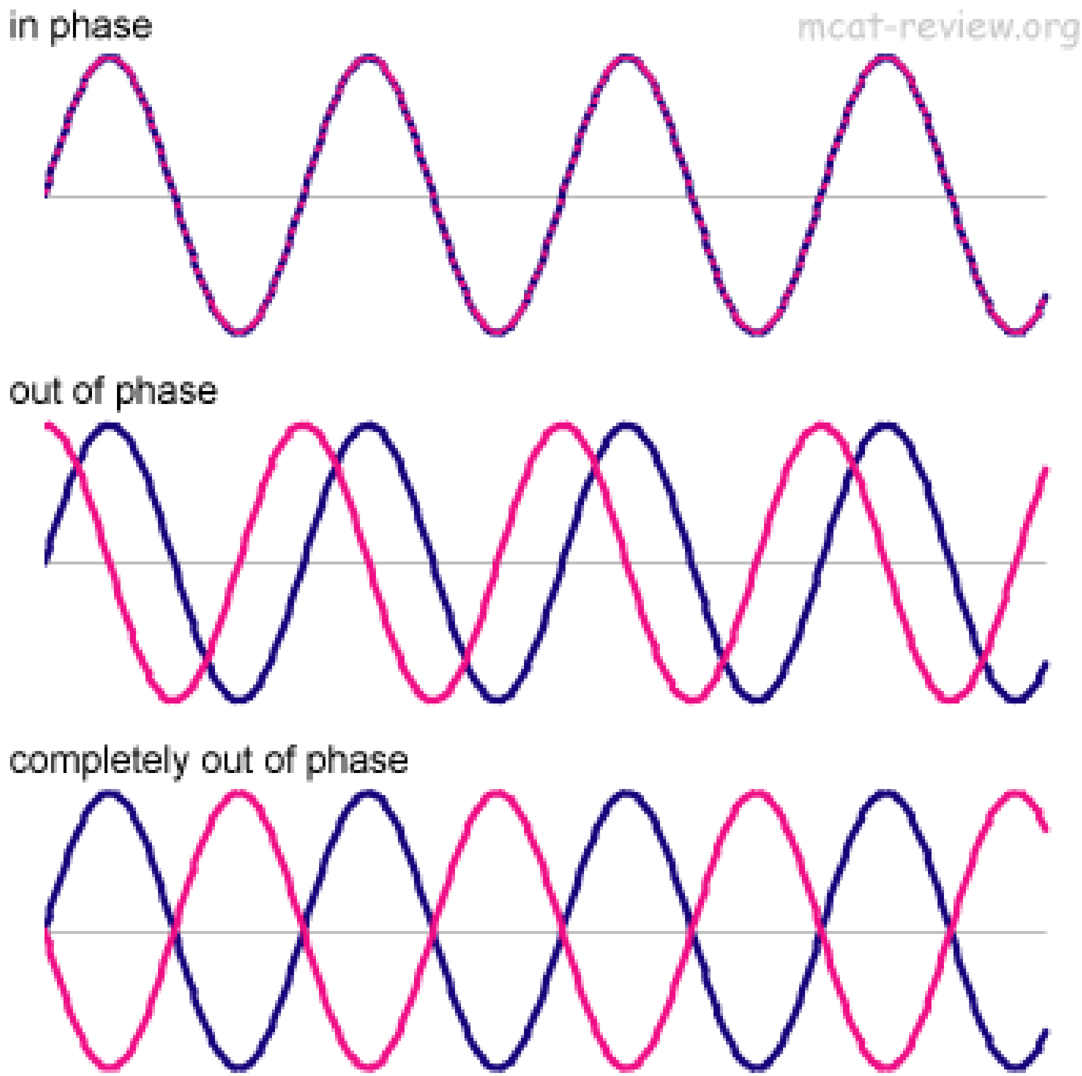
- Two points are said to be **in-phase** if they are in the same place and do the same thing, i.e. the direction of the wave are the same.
- Two points are said to be **out-phase** if even they are in the same place, they not doing the same thing, i.e. the direction of the wave are not the same.



- A and G are in-phase
- B and I are in-phase
- C and J are in-phase
- D and K are in-phase
- E and L are in-phase
- F and M are in-phase

- A and D are out-phase
- C and H are out-phase
- G and K are out-phase

Phase of a wave

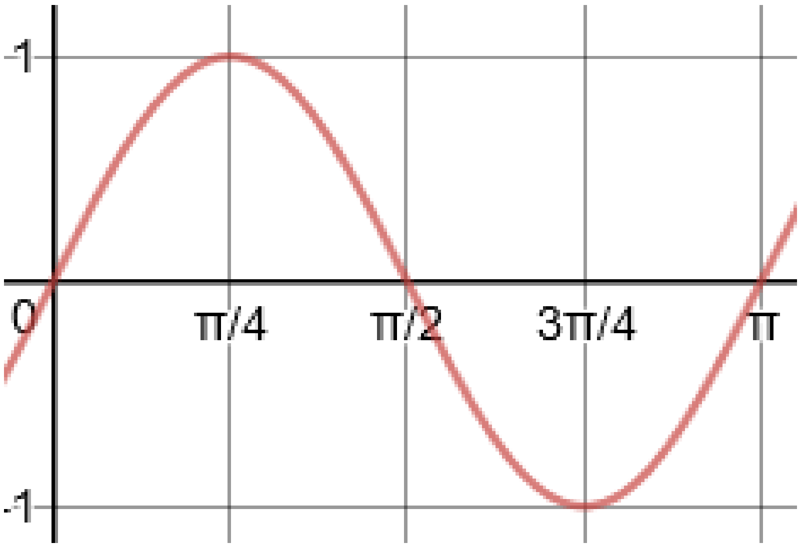


Phase shift

The fundamental equation of a sine wave is given as

$$y = A \sin(Bx + C) + D$$

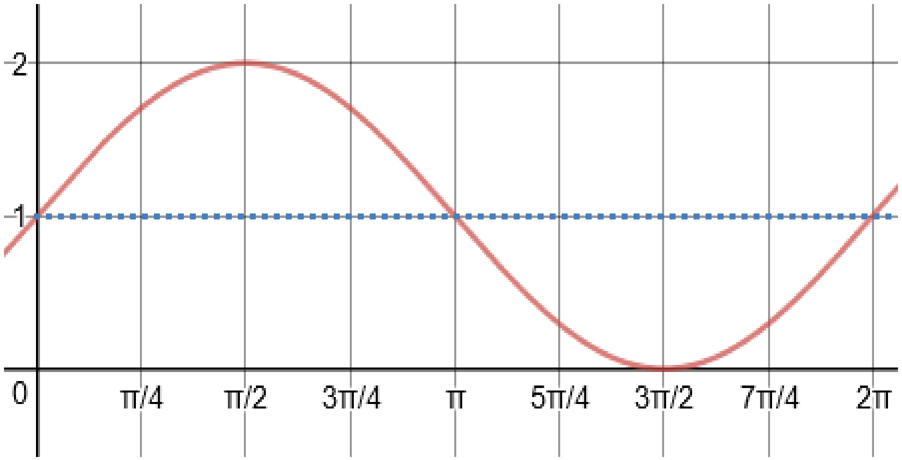
- amplitude is **A**
- period **P** is **2π/B**
- phase shift is $\boxed{Bx + C = 0}$ That is x= **−C/B**
- vertical shift is **D**



Y=+sin(2x)

- amplitude is **A=1**
- period **P=2π/2=π**
- phase shift is Bx+C=0 → 2x+0=0 →x=0
- vertical shift is **D =0**
- Range [D+A, D-A]=[0+1,0-1]=[1,-1]

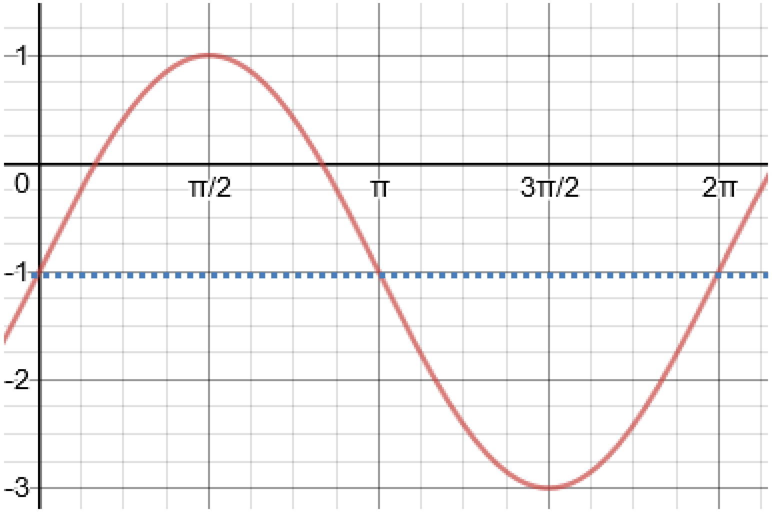
Phase shift



A

Y=+sin(x)+1

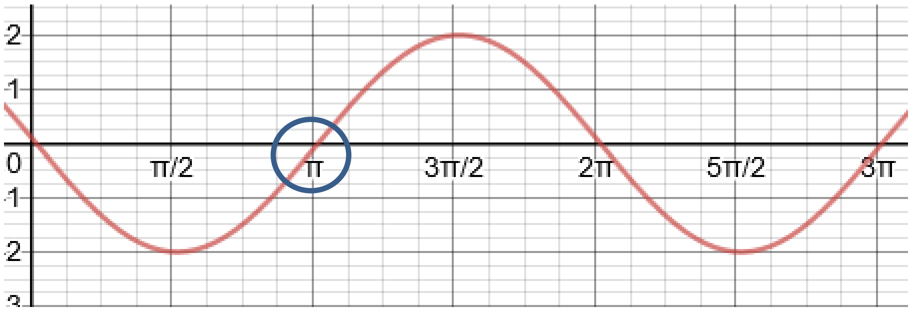
- amplitude is **A=1**
- period **P=2π/1=2π**
- phase shift is Bx+C=0 → x+0=0 →x=0
- vertical shift is **D =1**.
- Range [D+A, D-A]=[1+1,1-1]=[2,0]



Y=2sin(x)-1

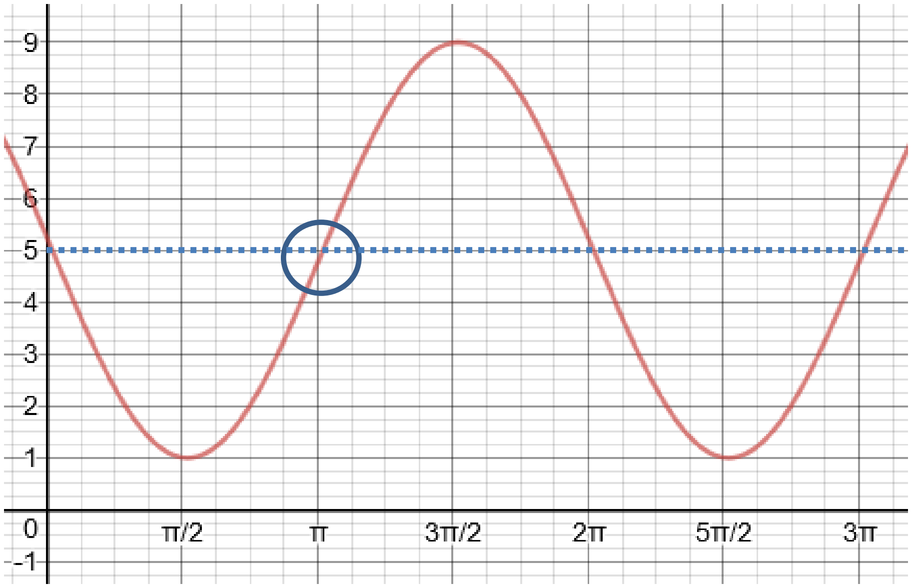
- amplitude is **A=2**
- period **P=2π/1=2π**
- phase shift is Bx+C=0 → x+0=0 →x=0
- vertical shift is **D = -1**.
- Range [D+A, D-A]=[-1+2,-1-2]=[1,-3]

Phase shift



$Y=2\sin(x-\pi)$

- amplitude is **A=2**
- period $\mathbf{P=2\pi/1=2\pi}$
- Horizontal phase shift is Bx+C=0 → $x-\pi=0$ → $\mathbf{x=\pi}$
- vertical shift is **D =0**.
- Range [D+A, D-A]=[0+2,0-2]=[2,-2]



$Y=-4\sin(1/2x-1/2\pi)+5$

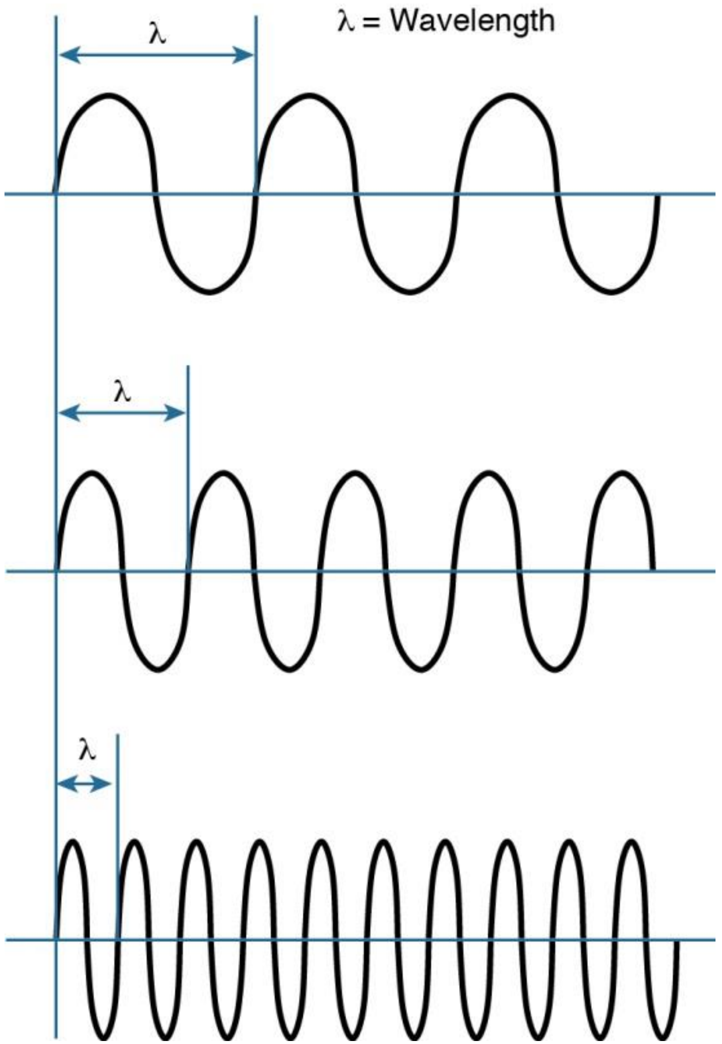
- amplitude is **A=4**
- period $\mathbf{P=2\pi/1/2=4\pi}$
- Horizontal phase shift is Bx+C=0 → $1/2x-1/2\pi=0$ → $x=\pi$
- vertical shift is **D = 5**.
- Range [D+A, D-A]=[5+4,5-4]=[9,1]

Measuring Wavelength

- The **wavelength** (λ) is a measure of the physical distance that a wave travels over one complete cycle.
- Increasing Frequency and Decreasing Wavelength.

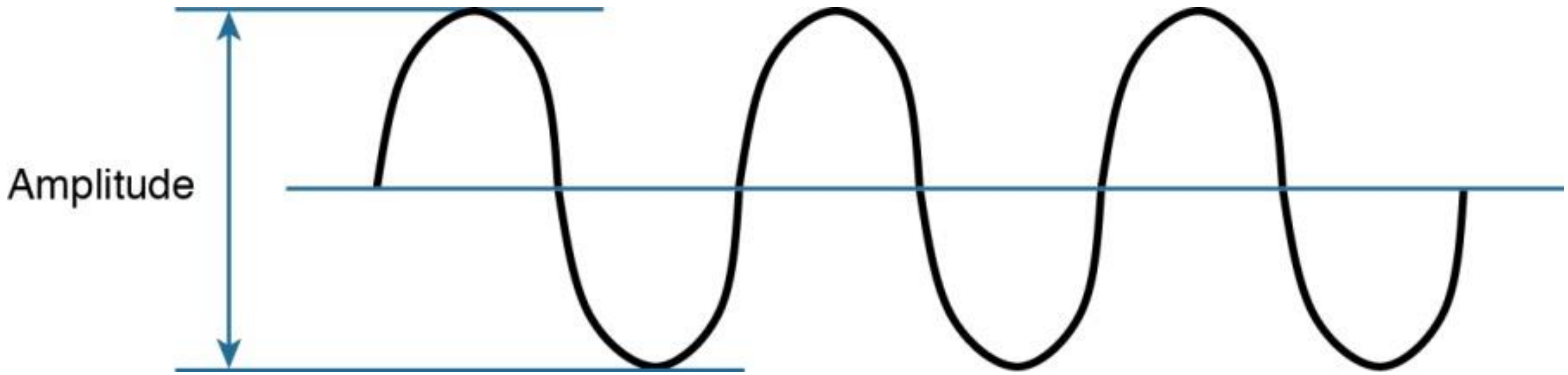
$$f = \frac{c}{\lambda}$$

where: f = frequency
c = speed of wave
λ = wavelength of wave



Understanding RF Power and dB

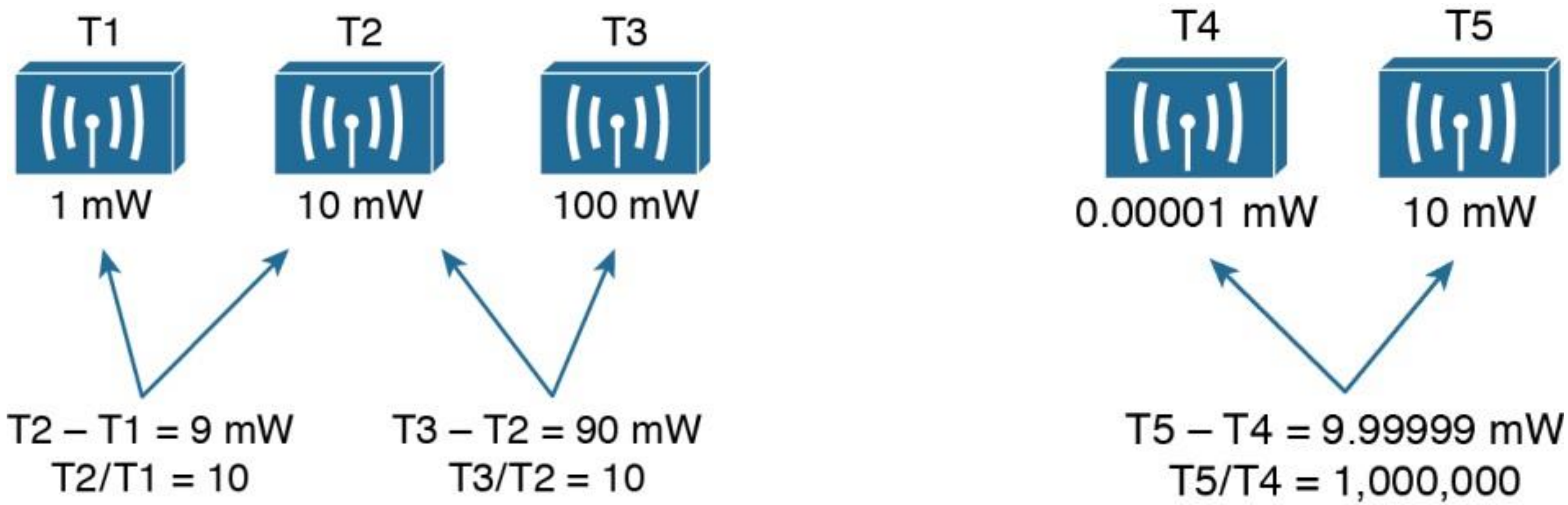
- This **strength** or **power** of signal can be measured as the amplitude, or the height from the top peak to the bottom peak of the signal's waveform.



- The strength of an RF signal is usually measured by its power, in watts (W).
- For example, a typical AM radio station broadcasts at a power of 50,000 W
- FM radio station might use 16,000 W.
- In comparison, a wireless LAN transmitter usually has a signal strength between 0.1 W (100 mW) and 0.001 W (1 mW).

Understanding RF Power and dB

❖ Comparing Power Levels Between Transmitters



- ❖ Because absolute power values can fall anywhere within a huge range, from a tiny decimal number to hundreds, thousands, or greater values,.
- ❖ We need a way to transform the exponential range into a linear one.
- ❖ **Logarithm** takes values that are orders of magnitude apart (0.001, 0.01, 0.1, 1, 10, 100, and 1000, for example) and spaces them evenly within a reasonable range

Understanding RF Power and dB

- The **deciBel**, dB utilizes a logarithmic scale based to compare two quantities. It is a convenient way of comparing two physical quantities like electrical power, intensity, or even current, or voltage.
- In communication it is used to measures Power gain or loss.

$$\text{dB} = 10 \log_{10} \frac{P_2}{P_1}$$

- **P2** represents the source of interest, and **P1** is usually called the reference value or the source of comparison.

- **Law of Zero**— 0 dB when P2=P1.
- **Law of 3s**— 3 dB when P2=2P1 , –3 dB when P2=0.5P1.
- **Law of 10s**— 10 dB when P2=10P1, -10 dB when P2= 1/10 P1.

Comparing Power Against a Reference: dBm

dBm indicates that the specified dB level is relative to a 1 milliwatt reference.

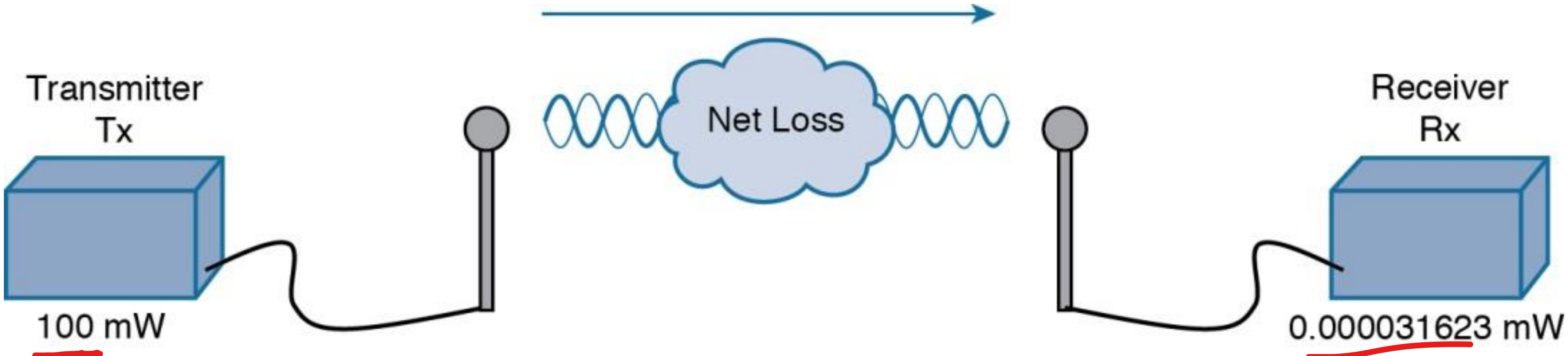
$$\mathrm{dBm} = 10\log_{10}\frac{P_2}{0.001\mathrm{W}}$$

If Power is expressed in watts instead of milliwatts.

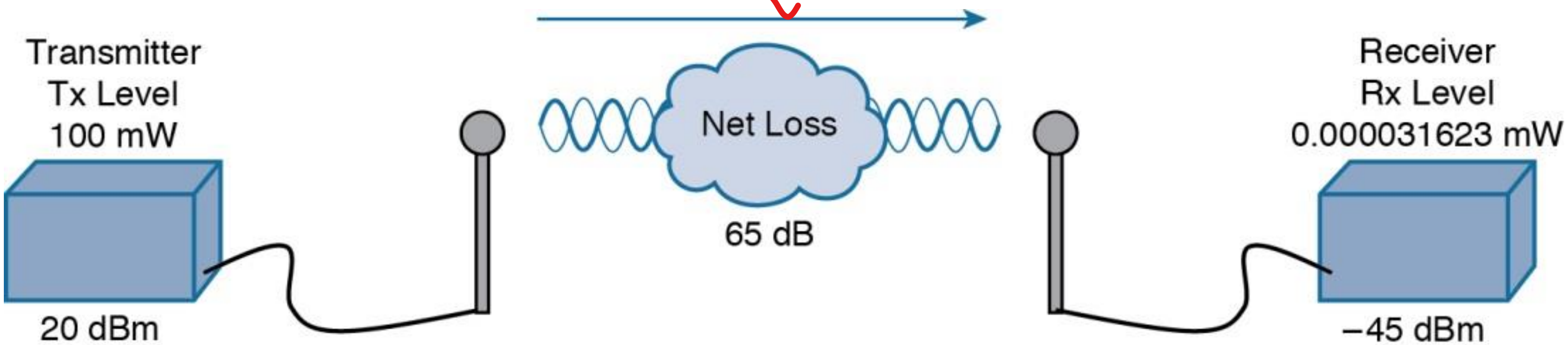
- the dB unit is obtained with respect to 1 watt and the dB values are expressed as dBW.

$$\mathrm{dBW} = 10\log_{10}\frac{P_2}{1\ \mathrm{W}}$$

Comparing Power Against a Reference: dBm



$$dB = 10log_{10}\left(\frac{0.000031623\,mW}{100\,mW}\right) = -65\,dB$$

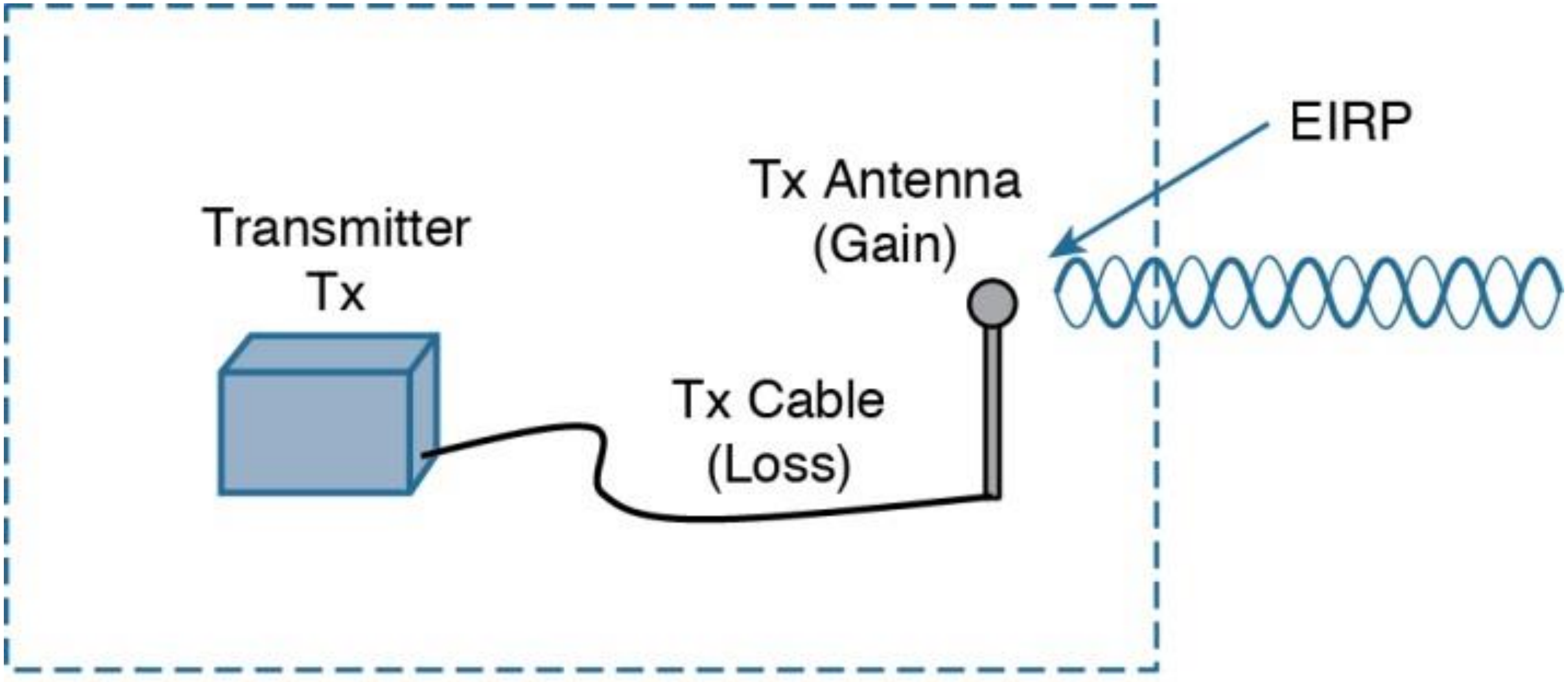


20 dBm – 65 dB = –45 dBm

$dBm = 10log_{10}\left(\frac{100}{1}\right)$=20 dBm

$dBm = 10log_{10}\left(\frac{0.000031623}{1}\right)$=-45dBm

Measuring Power Changes Along the Signal Path

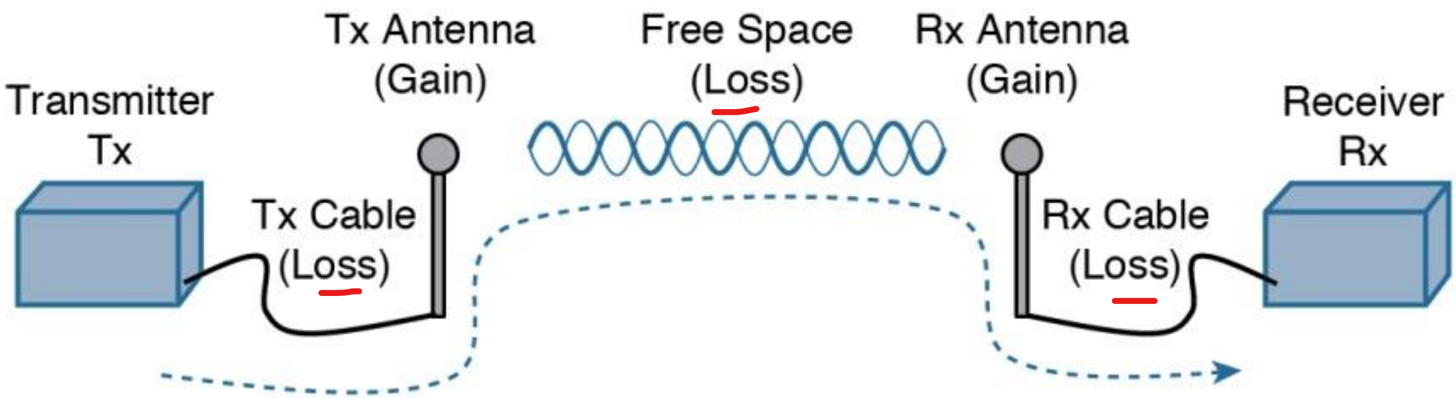


EIRP = Tx Power – Tx Cable + Tx Antenna

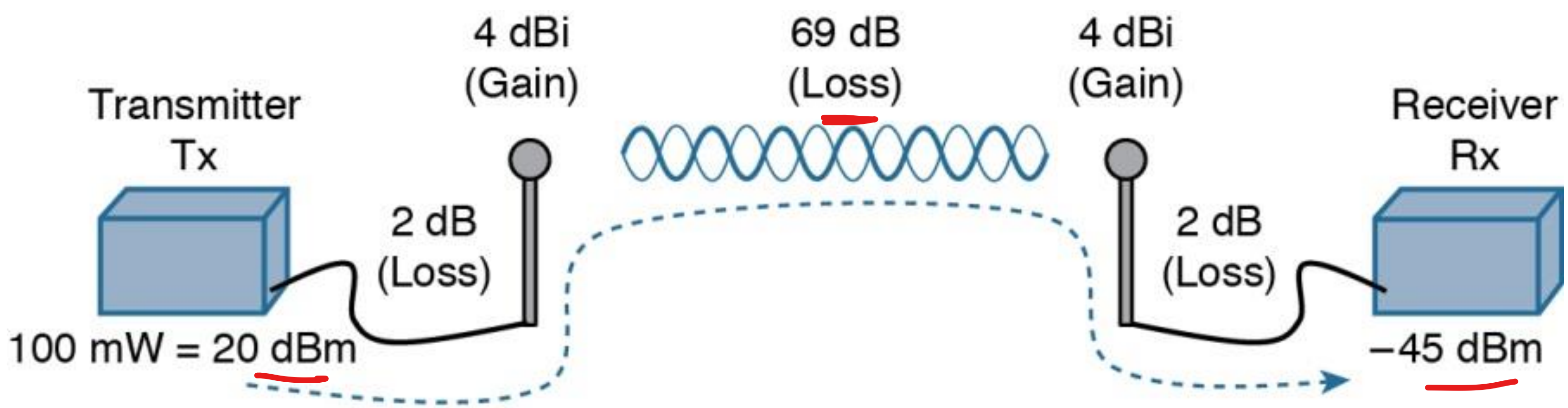
Effective isotropic radiated power (EIRP),

Figure 1-20 Calculating EIRP

Measuring Power Changes Along the Signal Path



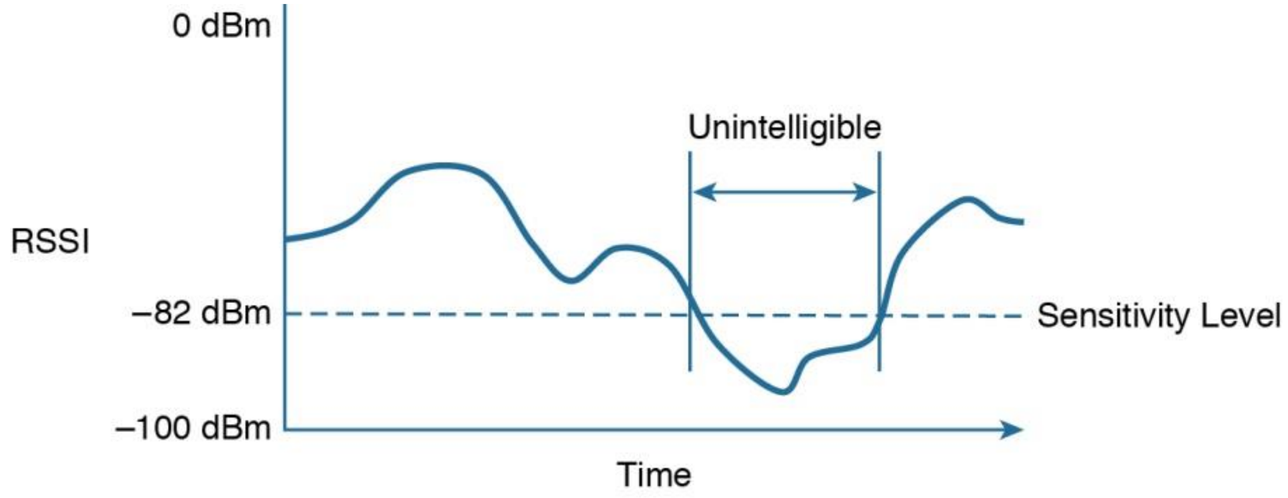
Rx Signal = Tx Power – Tx Cable + Tx Antenna – Free Space + Rx Antenna – Rx Cable



Rx Signal = 20 dBm – 2 dB + 4 dBi – 69 dB + 4 dBi – 2 dB = –45 dBm

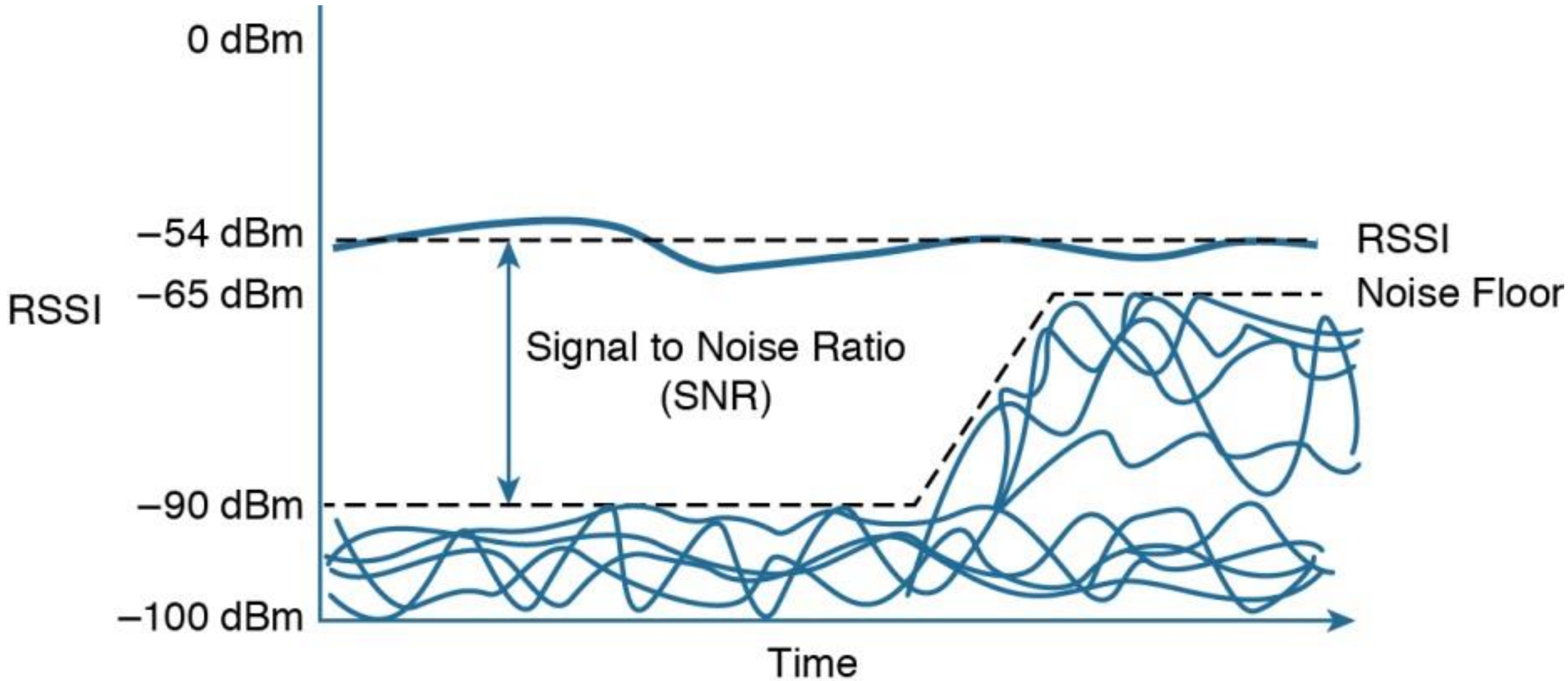
Understanding Power Levels at the Receiver

- Receivers measure a signal's power in dBm according to the received signal strength indicator (RSSI) scale.
- In WLAN devices, the EIRP levels Tx is normally range from +20 dBm down to 0 dBm.
- At Rx , the power levels of received signal ranges from 0 dBm down to about –100 dBm.
- Therefore, the RSSI of a received signal can range from 0 to –100.
- At the Rx, the data from the signal can be understood correctly as long as a signal is received with a power level that is greater than the Rx sensitivity level,.



Understanding Power Levels at the Receiver

- The received signal strength must be greater than the noise floor by a decent amount so that it can be received and understood correctly.
- The difference between the signal and the noise is called the signal-to-noise ratio (**SNR**), measured in dB. A higher SNR value is preferred.



Carrying Data Over an RF Signal

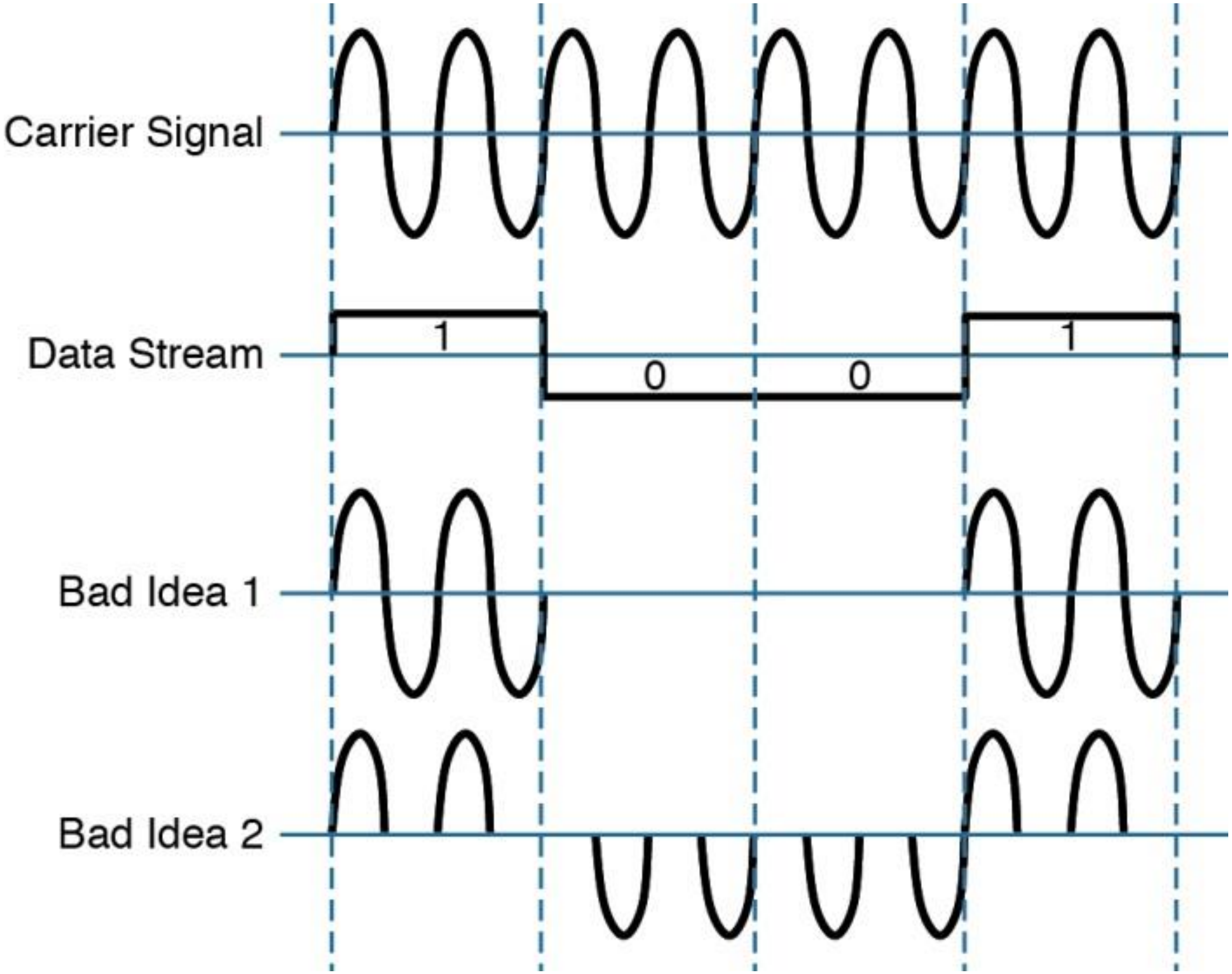


Figure 1-25 Poor Attempts at Sending Data Over an RF Signal

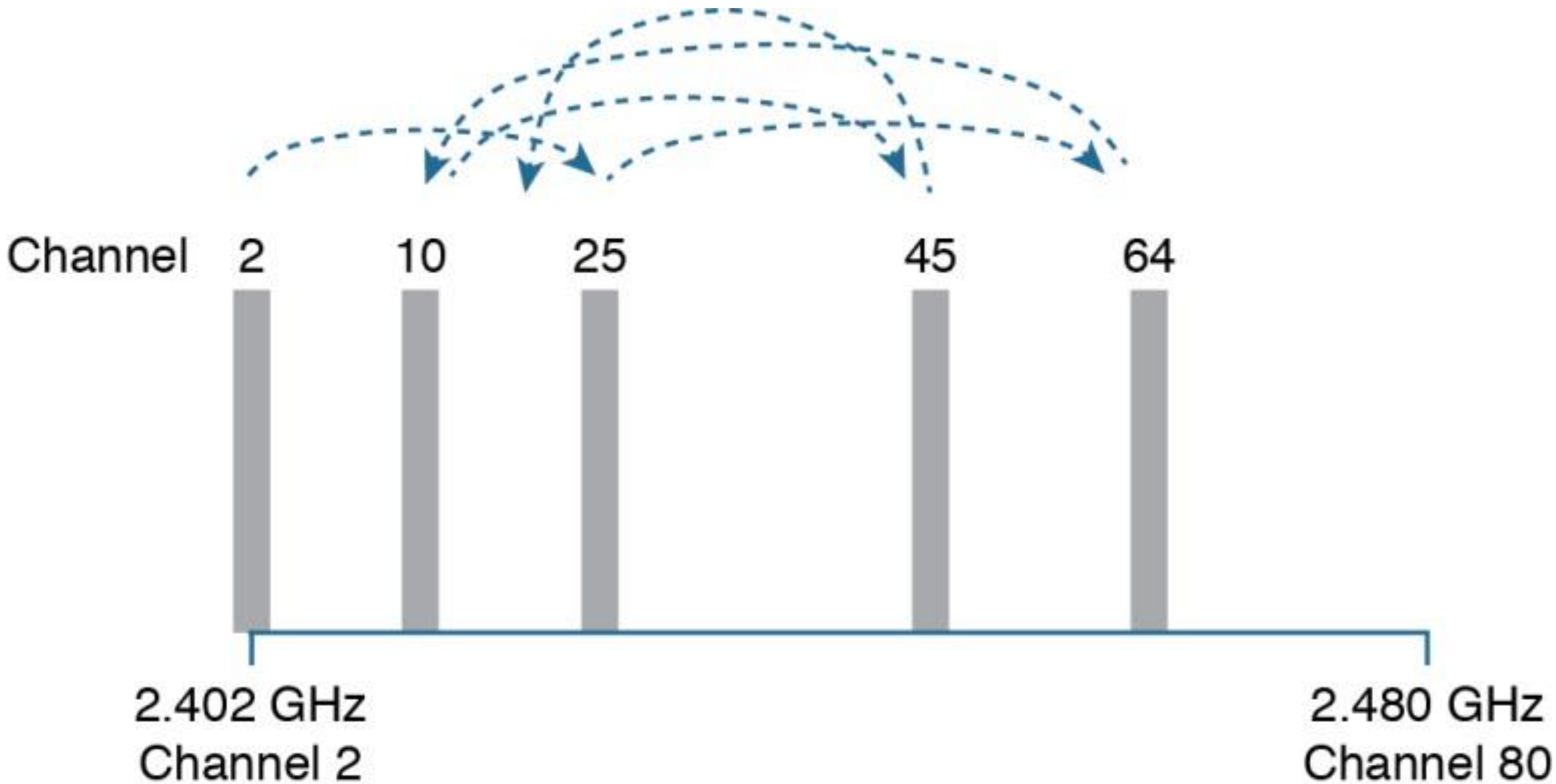


Figure 1-26 Example FHSS Channel-Hopping Sequence

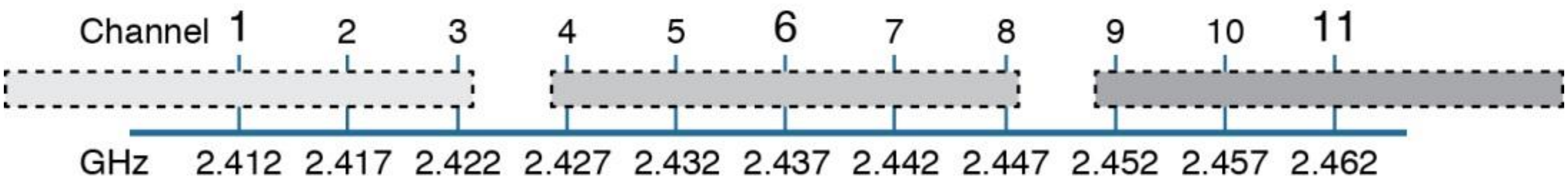


Figure 1-27 Example Non-overlapping Channels Used for DSSS

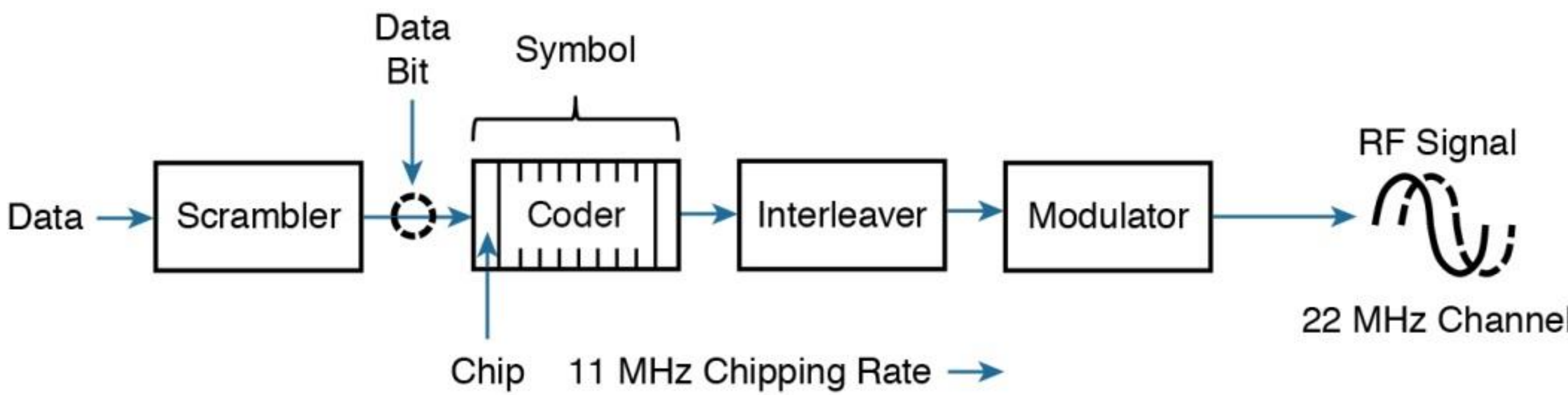


Figure 1-28 Functional Blocks Used in a DSSS Transmitter

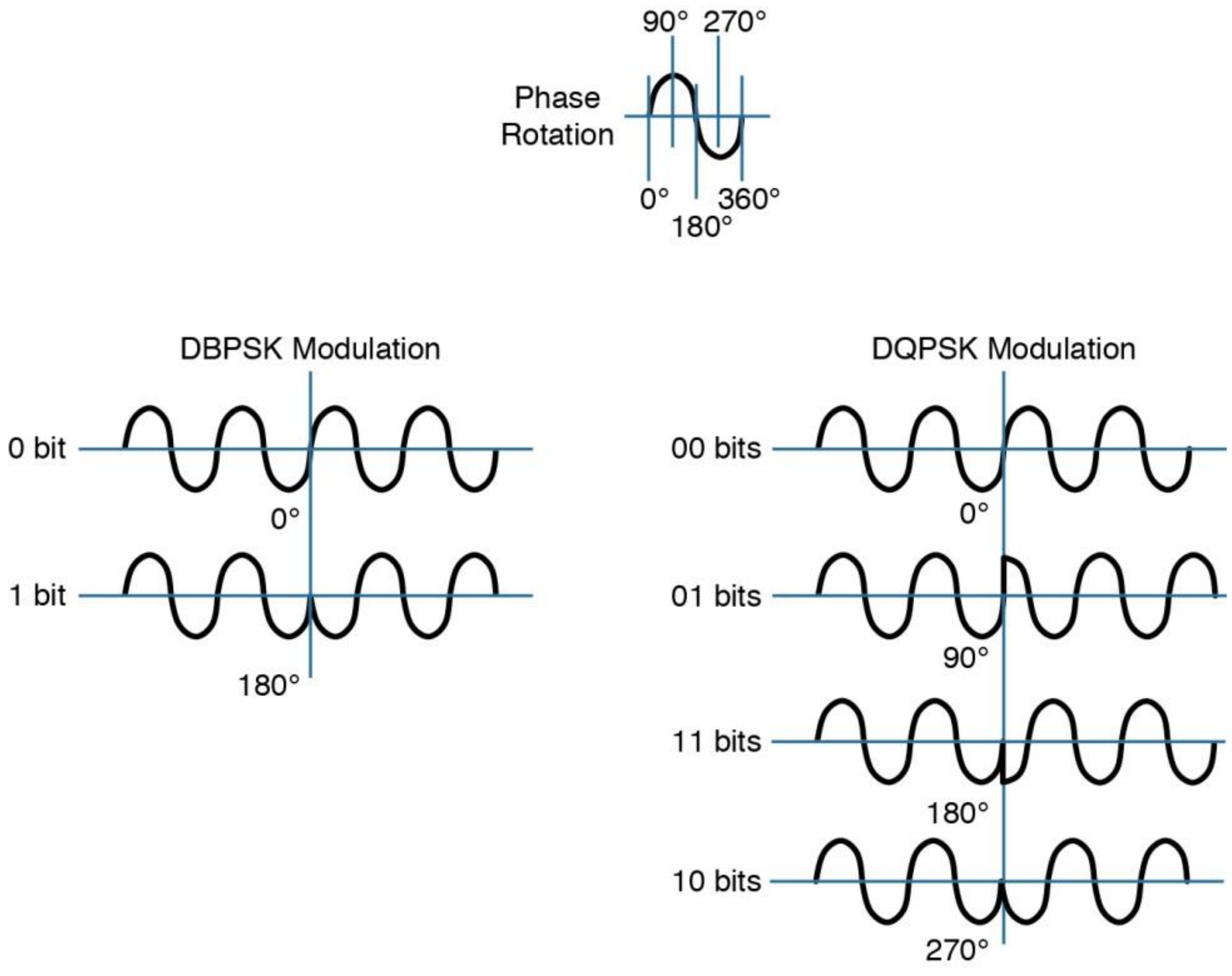


Figure 1-29 Example Phase Changes During DBPSK and DQPSK Modulation

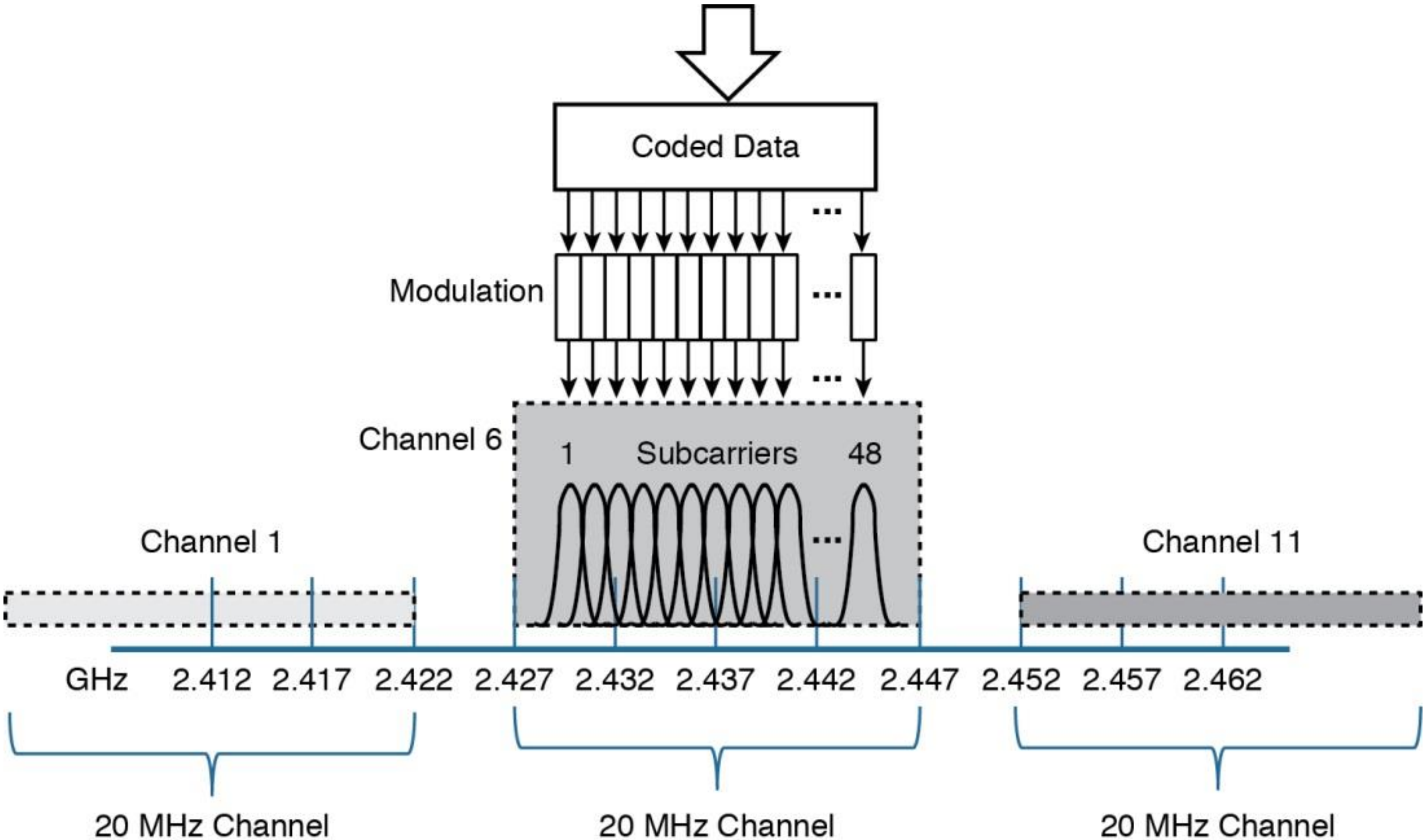


Figure 1-30 OFDM Operation with 48 Parallel Subcarriers

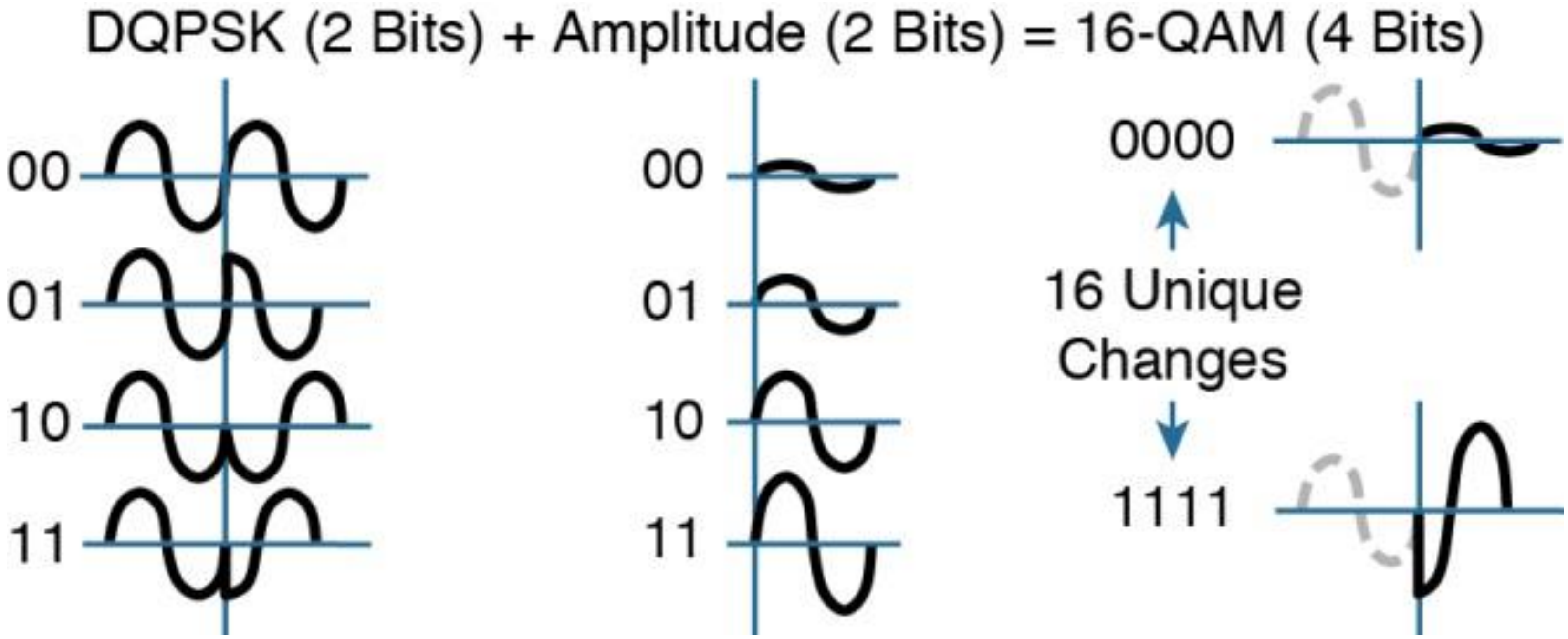


Figure 1-31 Examples of Phase and Amplitude Changes with 16-QAM