



**Certified Wireless Network Administrator (CWNA)
PW0-106**

Chapter 2
Radio Frequency Fundamentals



Chapter 2 Overview

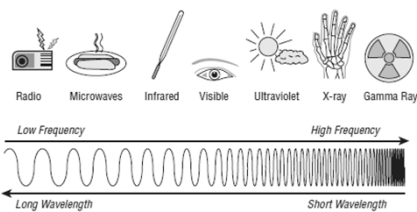
- What is a radio frequency signal?
- Radio frequency characteristics
- Radio frequency behaviors

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SYBEX **WILEY**

What is a radio frequency signal?

- Electromagnetic (EM) wave
- Operates in electromagnetic spectrum
- Can move through matter or space
- Types of electromagnetic waves include radio waves, gamma rays, X-rays, and visible light
- Begins as an alternating current (AC) signal sent through a copper conductor
- AC signal is radiated out of an antenna
- Travels at the speed of light



The diagram illustrates the electromagnetic spectrum with various types of waves and their corresponding frequencies and wavelengths. From left to right, the waves are: Radio (represented by a radio), Microwaves (represented by a microwave oven), Infrared (represented by a hand holding a pen), Visible (represented by an eye), Ultraviolet (represented by a sun), X-ray (represented by a hand holding a pen), and Gamma Ray (represented by a radiation symbol). Below the spectrum, a horizontal axis shows the relationship between frequency and wavelength. The left side is labeled 'Low Frequency' and 'Long Wavelength', while the right side is labeled 'High Frequency' and 'Short Wavelength'. The spectrum is shown as a series of waves that become increasingly compressed as they move from left to right.

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SYBEX **WILEY**

Radio Frequency Characteristic

- Wavelength
- Frequency
- Amplitude
- Phase

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SYBEX **WILEY**

Wavelength

- Distance between two successive points of a wave pattern
- Represented by the Greek symbol λ (lambda)
- Higher frequency = smaller wavelength
- 2.45 GHz wave = 4.82 inches (12.24 cm)
- 5.775 GHz wave = 2.04 inches (5.19 cm)

Wavelength (inches) = $11.811 / \text{frequency (GHz)}$

Wavelength (centimeters) = $30 / \text{frequency (GHz)}$

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SYBEX **WILEY**

Wavelength (continued)

Low Frequency High Frequency

Long Wavelength Short Wavelength

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SYBEX **WILEY**

Wavelength (continued)

750 KHz wavelength = 1,312 feet/400 meters

Radio tower (WSB-AM)

4.82 inches (12.24 centimeters) 2.45 GHz

252 GHz wavelength = 0.05 inches/1.2 millimeters

Satellite

2.04 inches (5.19 centimeters) 5.775 GHz

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SYBEX **WILEY**

Frequency



- Number of cycles or oscillations within a specified time interval
- Measured in hertz (Hz)
- 1 hertz = 1 cycle per second

High frequency radio waves

Low frequency radio waves

1 second



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Wavelength & Frequency Relationship

- There is an inverse relationship between wavelength and frequency
- Three components of this relationship
 - Frequency (f), measured in hertz (Hz)
 - Wavelength (λ), measured in meters (m)
 - Speed of light (c), constant value of 300,000,000 meters/sec
- $\lambda = c / f$ and $f = c / \lambda$
- The longer the wavelength, the lower the frequency (and vice versa)

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Amplitude

- Strength or power of the wave
- Defined as the maximum displacement of a continuous wave
- RF amplitude corresponds to the electrical field of the wave
- Transmit amplitude = initial amplitude that leaves the radio transmitter
- Receive amplitude = received signal strength
- Typical 802.11 transmit power (indoor devices)
 - 1 mW to 100 mW

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SYBEX **WILEY**

Amplitude (continued)

Strong amplitude

Less amplitude

$\lambda = \text{wavelength}$
 $a = \text{amplitude}$

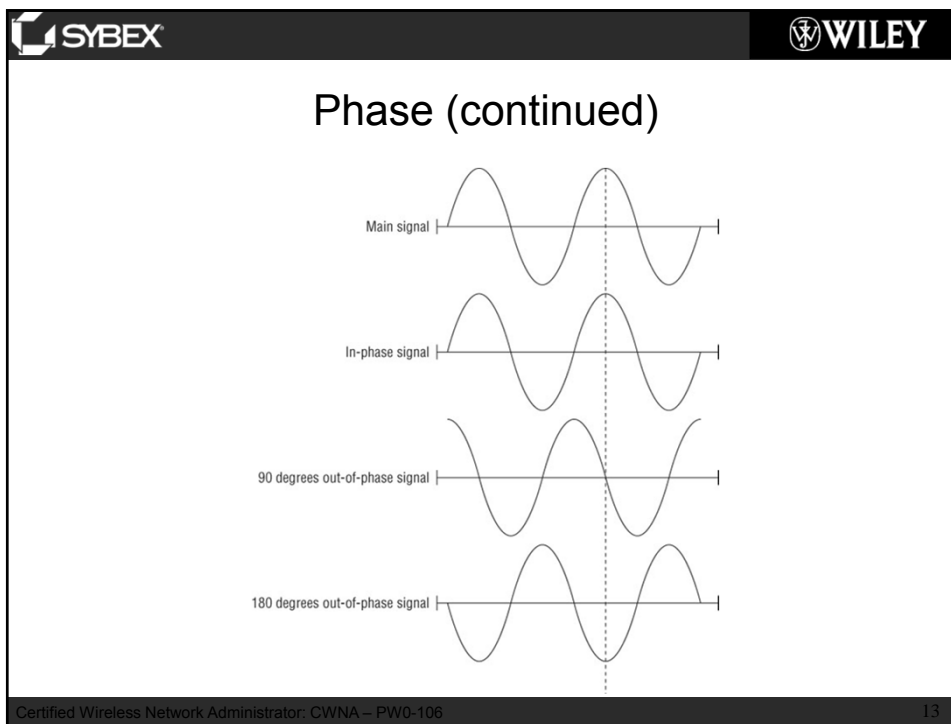
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SYBEX **WILEY**

Phase

- Involves the relationship between two or more signals that share the same frequency
- Measure in distance, time, or degrees
- Typically measure in degrees when referencing 802.11 waves
- In Phase = two waves with the peaks in exact alignment
- Out of Phase – two waves with the peaks not in exact alignment



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The diagram, titled "Effects of Phase on Amplitude", lists three scenarios for the combination of two waves:

- Two in-phase waves (0 degree separation) will combine their amplitude, resulting in a received signal with a greater signal strength
- Two waves 180 degrees out of phase will cancel each other out, resulting in an effective received signal strength of null
- With any other difference in phase, depending upon the amount of phase separation, the resulting signal could increase or decrease



At the bottom of the slide, the text "Certified Wireless Network Administrator: CWNA – PW0-106" is on the left and "14" is on the right.



Radio Frequency Behaviors

- Wave propagation
- Absorption
- Reflection
- Scattering
- Defraction
- Diffraction
- Loss (attenuation)
- Free space path loss
- Multipath
- Gain (amplification)



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Wave Propagation

- Waves move away from the antenna
- As the wave moves away from the antenna, it will broaden or spread
- Wave propagation can be affected by:
 - Absorption
 - Scattering
 - Diffraction
 - Multiplath
 - Gain (amplification)
 - Reflection
 - Refraction
 - Free space path
 - Loss (attenuation)



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Absorption

- Most common RF behavior
- Most materials will absorb some amount of an RF signal
- Denser materials will absorb more RF signal
- A leading cause of attenuation
- Directly effects the amplitude of the wave



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Reflection

- When a wave bounces off an object instead of traveling through it
- Sky wave reflection can occur in frequencies below 1 GHz (large wavelengths)
- Microwave reflection occur between 1 GHz and 300 GHz (smaller wavelengths)
- Cause of multipath signal



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Scattering

- Multiple reflections
- Occurs when the wavelength is larger than pieces of the medium the signal is hitting
- Can occur as a wave moves through an object, reflecting off minute particles with the medium
- Can also occur when a wave encounters an uneven surface

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Refraction

- The bending of an RF signal as it passes through a medium with a different density
- Most commonly occurs due to atmospheric conditions
- Three most common causes
 - Water vapor
 - Changes in air temperature
 - Changes in air pressure

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SYBEX **WILEY**

Refraction

Cool pool of air

Refracted signal

Main signal

Water vapor

Refracted signal

Main signal



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SYBEX **WILEY**

Diffraction

- The bending of an RF signal around an object
- It is the bending and spreading of an RF signal when it encounters an obstruction
- Typically caused by a partial blockage of the RF signal
- Sitting directly behind the obstruction is an area known as the RF shadow



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Loss (Attenuation)

- Decrease of amplitude or signal strength
- Causes include:
 - Absorption
 - Distance
 - Negative effects of multipath
- Water is a major source of absorption



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Free Space Path Loss (FSPL)

- Attenuation of a signal as it travels
- Loss of signal strength caused by the natural broadening of the waves (beam divergence)
- Loss of signal strength is logarithmic, not linear
- 6 dB rule = doubling the distance will result in a loss of amplitude of 6 dB

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Free Space Path Loss (FSPL) (continued)

$FSPL = 36.6 + (20\log_{10}(f)) + (20\log_{10}(D))$
 FSPL = path loss in dB
 f = frequency in MHz
 D = distance in miles between antennas

$FSPL = 32.44 + (20\log_{10}(f)) + (20\log_{10}(D))$
 FSPL = path loss in dB
 f = frequency in MHz
 D = distance in kilometers between antennas

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Multipath

- When two or more paths of a signal arrive at a receiving antenna at the same time or within nanoseconds of each other
- Caused by
 - Reflection - Scattering
 - Refraction - Diffraction
- Delay Spread = Time differential between multipath signals

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SYBEX WILEY

Multipath





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SYBEX WILEY

Multipath (continued)

- Four possible results of multipath
 - Upfade – increased signal strength
 - Downfade – decreased signal strength
 - Nulling – signal cancellation
 - Data corruption (most common)
- Intersymbol interference (ISI) = corruption caused by bits overlapping due to delay spread



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Gain (amplification)

- Increase of amplitude or signal strength
- Two types of gain
 - Active gain
 - Passive gain
- Active gain = increase caused by adding additional power
- Passive gain = increase caused by focusing the RF signal, typically by an antenna

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Chapter 2 Summary

- Radio frequency signal
- Radio frequency characteristics
- Radio frequency behaviors

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