Radio Frequency Fundamentals – Part 1

COMP3049 Intermediate Wireless Technology

Jorge Olenewa – Fall 2012

Objectives

- Define and explain the basic concepts of RF behaviour
  - Gain and loss
  - Reflection, refraction, diffraction, scattering and absorption
  - VSWR
  - Return loss
  - Amplification and attentuation
  - Wave propagation, free space path loss and delay spread

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Objectives

- Understand and apply the basic components of RF mathematics
  - Watts and mill watts
  - Decibel (dB), dBm, dBi and dBd
  - SNR and RSSI
  - System operating margin (SOM), fade margin and link budget
  - Intentional readiators and EIRP

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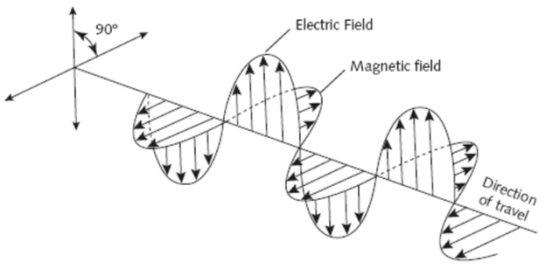
Electromagnetic Waves

- A fluctuation of energy consisting of electric and magnetic fields
- Fields oscillate and move back and forth at right angles to each other
- Waves travel through matter or vacuum



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Electromagnetic Waves

- The oscillating electrical signal, called EM waves, creates both an electric and a magnetic field
- A magnetic field, propagates (moves) away from the antenna
- This field can induce electricity into matter
- EM waves oscillating at frequencies in the radio spectrum are called Radio Frequency or RF waves

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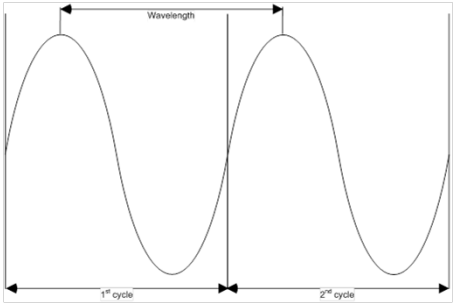
Characteristics of RF Waves

- Wavelength
  - The distance between two adjacent, identical points of the wave
  - Dictates the optimum size of an antenna



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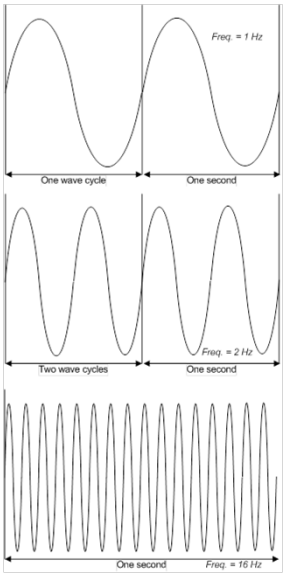
Characteristics of RF Waves

- Frequency
  - The number of wave cycles that occur in a given period of time
  - Usually measured in Hertz (Hz)
  - 1 Hz = 1 cycle per second



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Wavelength and Frequency

- Relative to the speed of light
  - λ (wavelength) = $c \div f$ (frequency)
    - c = speed of light or 299,792,458 in metres per second
  - $f = c \div \lambda$
- You do not have to memorize this for the GBC exam or for the CWNA certification exam
- Example: a Wi-Fi signal at 2,450,000,000 Hertz (2.45 GHz) has a wavelength of 0.123 metres or 12.3 centimetres

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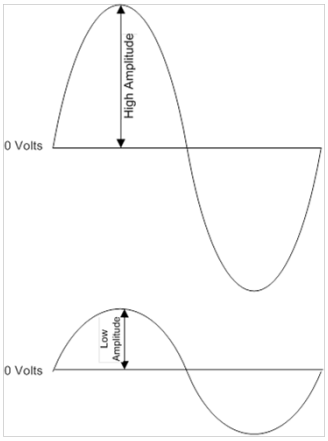
Characteristics of RF Waves

- Amplitude
  - The intensity (height or volume) of a wave
  - Usually measured in Volts
  - Affects how easy it is to detect a wave, at a distance
  - Higher amplitude waves travel farther through space
    - Also see attenuation, later
  - Overall power of a signal is measured in Watts



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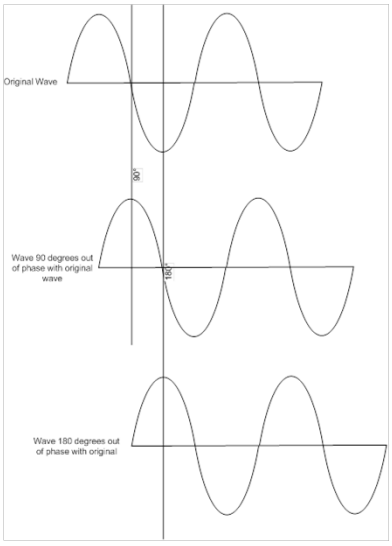
Characteristics of RF Waves

- Phase
  - A comparison between two RF waves
  - Measured in degrees (0° through 360°)



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RF Behaviour

- Gain
  - Positive relative amplitude difference between two signals (RF waves)
  - Amplification is an active process used to increase an RF signal's amplitude
  - Amplification results in *gain*
    - Intentional or active gain
  - Active gain is achieved through the use of an amplifier

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RF Behaviour

- Gain (cont'd.)
  - Passive gain: focusing or directing all the energy of a signal in one direction
    - Analogy: using the reflector in a flashlight to focus the light in one direction
  - Intentional passive gain: directional antennas
  - Unintentional passive gain: reflection or scattering

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RF Behaviour

- Loss
  - Negative relative amplitude difference between two RF signals
  - Intentional or unintentional (natural loss)
  - Intentional: limiting the output power of a RF wave through electrical or electronic components
  - Natural: spreading, reflection, scattering, diffraction and absorption

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RF Behaviour

- Reflection
  - Waves bounce off smooth, non-absorbing surfaces, changing direction
  - They reflect off objects that are smooth and larger than the wavelength of the waves that carry the RF signal
    - Objects between 5 and 13 centimetres made of metal

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RF Behaviour

- Refraction
  - Occurs when an RF signal changes speed and its path is *bent*, while moving through media of different densities
  - Different materials or mediums have different *refraction indexes*

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Reflection and Refraction

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RF Behaviour

- Diffraction
  - A change in direction and/or intensity of a wave as it passes by the edge of an obstacle

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Diffraction

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RF Behaviour

- Scattering
  - Happens when RF wave strikes an uneven surface, causing the signal to be scattered instead of absorbed or reflected
  - Rocky surfaces, smog, leafy trees, chain-link fencing, as well as rain and dust can also cause scattering

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Scattering

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RF Behaviour

- Absorption
  - Conversion of the RF signal energy into heat
  - Happens because the molecules in the medium through which the RF is passing cannot move *fast enough* to keep-up with the energy oscillations in the wave
  - Water (and everything that contains water), drywall, wood and human bodies absorb RF waves

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Absorption

- Microwave ovens use RF waves to heat food by bombarding materials that contain water with high-intensity RF waves
- The water molecules move slower than the RF waves
- The water molecules vibrate violently, while absorbing (slowing down) the waves and converting their energy into heat

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Absorption Rates for Different Materials

Material	Absorption Rate
Plasterboard/Drywall	3-5 dB
Glass wall and metal frame	6 dB
Metal door	6-10 dB
Window	3 dB
Concrete wall	6- 15 dB
Brick wall	4-6 dB

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RF Behaviour

- VSWR – Voltage Standing Wave Ratio
  - A measurement of mismatched impedance in an RF system
  - Stated as a ratio (x:1)
  - This subject will be covered in greater detail in the EM course (COMP3047)

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RF Behaviour

- Return loss
  - Energy reflected back toward the RF generator
  - Usually expressed in decibels (dB)
  - May damage or destroy the RF wave generator
  - To minimize, reduce impedance mismatches

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VSWR & Return Loss

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RF Behaviour

- Amplification
  - An increase in amplitude (or energy) of an RF signal
  - Can also be expressed as gain in dB
  - Many wireless devices include variable output power setting
  - Changing this setting results in a stronger RF signal

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RF Behaviour

- Attenuation
  - The process of reducing an RF signal's amplitude
  - Attenuation causes *loss*
  - Sometimes done intentionally, with attenuators, to meet regulatory requirements
  - RF cables, connectors and wireless device circuits also cause loss due to attenuation
  - EMANIM

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RF Behaviour

- Wave propagation
  - As RF waves move through an environment, this is referred to as propagation
  - Waves spread (disperse) as they propagate
  - Dispersion also causes attenuation, which reduces the strength of the wave

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Wave Propagation and Dispersion

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RF Behaviour

- Free space path loss (FSPL)
  - Also called Free Space Loss (FSL)
  - Weakening of the RF signal due to dispersion
  - Causes loss of amplitude as wave front becomes larger the farther away it moves from the antenna
    - Blowing bubbles with bubble gum, throwing a rock in pond
  - A 2.4 GHz signal will be attenuated by approx. 80 dB in the first 100 metres away from the antenna
  - Atttenuation is logarithmic: over the second 100 metres the signal only loses about 6 dB

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Wave Propagation and Dispersion

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Attenuation Due to FSL

Distance (miles)	2.4 GHz signal	5 GHz signal
0.5	98.36	104.56
1	104.38	110.58
1.5	107.91	114.10
2	110.40	116.60
2.5	112.34	118.54
3	113.93	120.12
4	116.42	122.62
5	118.36	124.56
10	124.38	130.58

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RF Behaviour

- Multipath and Delay Spread
  - Occurs when signals bounce around and get reflected, diffracted, etc.
  - Multiple signals arrive at the receiver within a small fraction of a second
  - Occurs more frequently indoors
  - Difference in time between the various copies of the same signal is called *delay spread*

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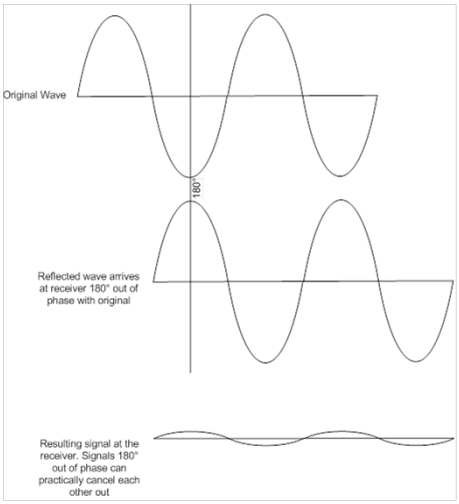
RF Behaviour

- Multipath and Delay Spread (cont'd.)
  - When signals arrive out of phase, this affects the amplitude or signal strength (results in an effective loss)



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Multipath

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