The Frequency Spectrum and Wireless LANs

The frequency spectrum ranges from very low frequencies at 1 Hz to gamma rays at 10^23 Hz. Within that very large range of frequencies are three frequency bands used for wireless LANs. Those three bands are collectively referred to as industrial, scientific, and medical (**ISM**) bands. These three bands represent unlicensed frequency bands on a worldwide basis.

ISM Bands

- Although ISM bands are unlicensed, they are not unregulated and a distinction between the two is important. The fact that an ISM band is unlicensed means that organizations can transmit using ISM equipment without having to obtain a license to use such equipment. However, both the power and transmission characteristics of equipment, such as the frequencies and dwell time for FHSS, are regulated for operation in an ISM band. In the United States, the FCC is responsible for such regulation.

Two additional ISM frequency bands are referred to as the 2.4-GHz and the 5.0-GHz bands.

The 2.4-GHz ISM band ranges from 2.4000 to 2.4835 GHz, resulting in 83.5 MHz of available bandwidth.

The IEEE 802.11b standards operate in the 2.4-GHz frequency band.

- The third ISM band, which is referred to as the 5.0-GHz band, has 300 MHz of spectrum allocated for unlicensed operations. The first 200 MHz occurs from 5.15 GHz to 5.35 GHz. The last 100 MHz is from 5.725 GHz to 5.825 GHz. The lower 200 MHz consists of two 100-MHz bands. The first 100 MHz from 5.15 GHz to 5.25 GHz is restricted to a maximum power output of 50 mW. The second 100 MHz, which ranges from 5.25 GHz to 5.35 GHz, has a more generous 250-mW power budget, while the top 100 MHz, which is restricted to outdoor operations, has a maximum 1-W power output.

Measurements

Measurements that can be used to qualify the level of received power as well as power gains and losses.

Basic Units of RF Measurement

The basic unit of measure for radio frequency is the **watt**. A wireless access point may be set to an output of 30 mW (milliwatts) of power. A milliwatt is 1/1000 of a watt.

Absolute Measurements of Power

The amount of power leaving a wireless access point is one example of an **absolute measure** of power. This is an actual power measurement and not a ratio or a relative value. A typical amount of output power from an access point is 100 mW.

- **Watt (W)**

  The watt is a basic unit of power measurement. This is an absolute value or measurable value. Most wireless networks function in the milliwatt range. Power level in watts is a common measurement in long distance point-to-point and point-to-multipoint applications.

Milliwatt (mW)

- One milliwatt is 1/1000 of a watt. This is a common value used in RF work and IEEE 802.11wireless LANs. The output power of an access point typically ranges from 1 mW to 100 mW. Most enterprise-grade access points allow you to change the output power. Most SOHO-grade access points have a fixed output power, typically 30 mW. The milliwatt is also an absolute unit of power measurement.

Decibel Relative to a Milliwatt (dBm)

- *dBm* represents an *absolute measurement of power* where the *m* stands for *milliwatts.* Effectively, dBm references decibels relative to 1 milliwatt such that 0 dBm equals 1 milliwatt. Once you establish that 0 dBm equals 1 milliwatt, you can reference any power strength in dBm. The formula to get dBm from milliwatts is:

dBm = 10 × log10(PowermW)

A **dB** is an example of a change in power or *relative measurement of power* where **dBm** is measured power referenced to 1 milliwatt or an *absolute measure* of power.

- **dBm** is

  output power measurement

Relative Measurements of Power

Changes in RF power are known as **relative**. dB and dBi are relative measurements of power.

1- An example would be an RF amplifier. If the input power to an amplifier is 10 mW and the output power is 100 mW, the gain of the amplifier is 10 dB—a change in power.

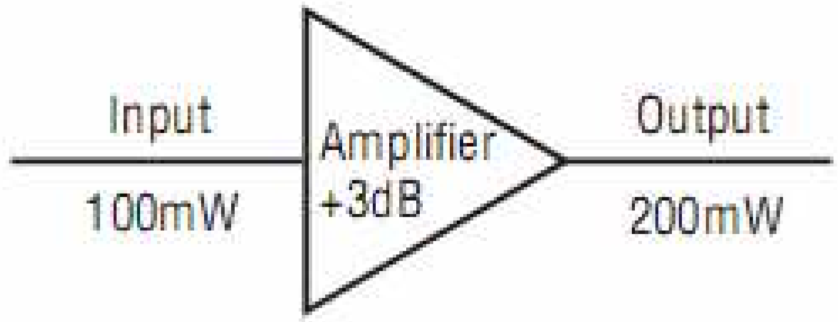
2- If the input power to an antenna is 100 mW and the output power is 200 mW, the gain of the antenna is 3 dBi—a change in power. Both of these are examples of changes in power and are known as relative.

Decibel (dB)

The *decibel* is a comparative measurement value. In other words, it is a measurement of the difference between two power levels. For example, it is common to say that a certain power level is 6 dB stronger than another power level or that it is 3 dB weaker. These statements mean that there has been 6 dB of gain and 3 dB of loss, respectively.

Decibel (dB)

- The decibel (dB) is a ratio of two different power levels caused by a change in power. Figure 1 shows how an amplifier will provide an increase or change in power.



Because a wireless receiver can detect and process very weak signals, it is easier to refer to the received signal strength in dBm rather than in mW. For example, a signal that is transmitted at 4 W of output power (4000 mW or 36 dBm) and experiences -63 dB of loss has a signal strength of 0.002 mW (−27 dBm). Rather than saying that the signal strength is 0.002 mW, we say that the signal strength is -27 dBm.

Decibel Isotropic (dBi)

- Decibel isotropic (dBi) is the unit that represents the gain or increase in signal strength of an antenna.
- The term *isotropic* in the RF world means energy broadcast equally in all directions in a spherical fashion.

Decibel Dipole (dBd)

- The gain of some antennas may be measured in decibel dipole (dBd). This unit of measurement refers to the antenna gain with respect to a reference dipole antenna. The gain of most antennas used in wireless LANs is measured in decibel isotropic (dBi); however some manufacturers may reference gain in dBd. The following simple formula derives the dBi value from the dBd value:

  dBi = dBd + 2.14

  This formula converts from dBi to dBd:

  dBd = dBi – 2.14

dBi

The abbreviation *dBi* (the *i* stands for isotropic) represents a measurement of power gain used for RF antennas. It is a comparison of the gain of the antenna and the output of a theoretical isotropic radiator. An *isotropic radiator* is an ideal antenna that we cannot create with any known technology. This is an antenna that radiates power equally in all directions. In order to do this, the power source would have to be at the center of the radiating element and be infinitesimally small. Since this technology does not exist, we call the isotropic radiator the ideal against which other antennas are measured. I'll provide more details about dBi in the later section titled "Isotropic Radiator". For now, just remember that dBi is a measurement of directional gain in power and is not a power reference. In other words, the dBi value must be calculated against the input power provided to the antenna to determine the actual output power in the direction in which the antenna propagates RF signals.

dBd

- Antenna manufacturers use both dBi, mentioned previously, and *dBd* to calculate the directional gain of antennas. Where dBi is a calculation of directional gain compared to an isotropic radiator, dBd is a calculation of directional gain compared to a dipole antenna. Therefore, the last *d* in dBd stands for *dipole.* Like dBi, dBd is a value calculated against the input power to determine the directional output power of the antenna.
- What is the difference between dBi and dBd, then? The difference is that a dBd value is compared with a dipole antenna, which itself has a gain of 2.14 over an isotropic radiator. Therefore, an antenna with a gain of 7 dBd has a gain of 9.14 dBi. In other words, to convert from dBd to dBi, just add 2.14. To convert from dBi to dBd, just subtract 2.14. To remember this, just remember the formula 0 dBd = 2.14 dBi.

SNR

One of the most important metrics in the field of communications is the signal-to-noise (S/N) ratio.

Background RF noise, which can be caused by all the various systems and natural phenomena that generate energy in the electromagnetic spectrum, is known as the *noise floor.* The power level of the RF signal relative to the power level of the noise floor is known as the **signal-to-noise ratio or SNR**.

- you might expect that a higher S/N ratio is preferable to a lower S/N ratio the **SNR** becomes a very important measurement. If the noise floor power levels are too close to the received signal strength, the signal may be corrupted or may not even be detected. It's almost as if the received signal strength is weaker than it actually is when there is more electromagnetic noise in the environment. You may have noticed that when you yell in a room full of people yelling, your volume doesn't seem so great; however, if you yell in a room full of people whispering, your volume seems to be magnified. In fact, your volume is not greater, but the noise floor is less. RF signals are impacted in a similar way.

1. What is the term defining the amount of times a cycle of an RF signal will oscillate in one

- second?

A. Phase

B. Frequency

C. Amplitude

D. Wavelength

2. Which are relative measures of RF power? (Choose two.)

- A. mW
- B. dB
- C. dBm
- D. dBi
- E. Watt

3. Which are absolute measures of RF power? (Choose two.)

- A. Watt
- B. dB
- C. mW
- D. dBi
- E. dBd

- What is the gain of an antenna measured in?
- A. dB
- B. dBc
- C. dBi
- D. dBm