CHAPTER **10**

Radio Frequency Fundamentals

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This part of the CVD discusses Radio Frequency (RF) fundamentals that are necessary to understand before deploying a Wireless LAN network that is location and CMX ready. The chapter explains various RF concepts like spectrum bands, power level, signal strength, RSSI, etc. and provides a simple example using these concepts to illustrate how RF impacts a client and Access Point perceived signal strength level. These components include Cisco wireless LAN controllers (WLCs), Cisco Prime Infrastructure (PI), and the Cisco Mobility Services Engine (MSE). In addition, the configuration of CMX services, specifically CMX Analytics and CMX Visitor Connect, are discussed.

A good WLAN deployment either in the 2.4 GHz spectrum or the 5 GHz spectrum is contingent on Radio Frequency Planning. As we noted, because WLAN technology operates in the unlicensed bands provided by the FCC, many other wireless technologies such as Bluetooth also use the same spectrum. It is important for WLAN deployments to consider RF characteristics, regulatory domains, maximum transmittable power by APs, and RF interference from other bands. This chapter explains the basic terminologies used in radio frequencies and how they tie into the WLAN deployment. General guidelines on designing a WLAN with RF in mind are covered in Chapter 14, "Pre-Deployment Radio Frequency Site Survey."

Power Level

The dB measures the power of a signal as a function of its ratio to another standardized value. The abbreviation dB is often combined with other abbreviations to represent the values that are compared. Here are two examples:

- dBm—The dB value is compared to 1 mW.
- dBw—The dB value is compared to 1 W.

You can calculate the power in dBs with the formula:

Power (in dB) = 10 * log10 (Signal/Reference)

The terms in the formula:

- log10 is logarithm base 10.
- Signal is the power of the signal (for example, 50 mW).
- Reference is the reference power (for example, 1 mW).

For example, if you want to calculate the power in dB of 50 mW, apply the formula to obtain:

Power (in dB) = 10 * log10 (50/1) = 10 * log10 (50) = 10 * 1.7 = 17 dBm

Because decibels are ratios that compare two power levels, you can use simple math to manipulate the ratios for the design and assembly of networks. For example, you can apply this basic rule to calculate logarithms of large numbers:

$\log 10 (A*B) = \log 10(A) + \log 10(B)$

If you use the formula above, you can calculate the power of 50 mW in dBs in this way:

Power (in dB) = $10 * \log 10 (50) = 10 * \log 10 (5 * 10) = (10 * \log 10 (5)) + (10 * \log 10(10)) = 7 + 10 = 17$ dBm

Table 10-1 lists some commonly used general rules.

Table 10-1   db Values and tx Power

An Increase of:	A Decrease of:	Produces:
3 dB		Double transmit power
	3 dB	Half transmit power
10 dB		10 times the transmit power
	10 dB	Divides transmit power by 10
30 dB		1000 times the transmit power
	30 dB	Decreases transmit power 1000 times

Table 10-2 provides approximate dBm to mW values.

Table 10-2   dBm to mW Values

dBm	mW
0	1
1	1.25
2	1.56
3	2
4	2.5
5	3.12
6	4
7	5
8	6.25
9	8
10	10
11	12.5
12	16
13	20
14	25
15	32
16	40

Table 10-2   dBm to mW Values

dBm	mW
17	50
18	64
19	80
20	100
21	128
22	160
23	200
24	256
25	320
26	400
27	512
28	640
29	800
30	1000 or 1 W

Here is an example:

If 0 dB = 1 mW, then 14 dB = 25 mW.

If 0 dB = 1 mW, then 10 dB = 10 mW, and 20 dB = 100 mW.

Subtract 3 dB from 100 mW to drop the power by half (17 dB = 50 mW). Then, subtract 3 dB again to drop the power by 50 percent again (14 dB = 25 mW).

Note   You can find all values with a little addition or subtraction if you use the basic rules of algorithms.

Effective Isotropic Radiated Power

The radiated (transmitted) power is rated in either dBm or W. Power that comes off an antenna is measured as effective isotropic radiated power (EIRP). EIRP is the value that regulatory agencies, such as the FCC or European Telecommunications Standards Institute (ETSI), use to determine and measure power limits in applications such as 2.4-GHz or 5-GHz wireless equipment. To calculate EIRP, add the transmitter power (in dBm) to the antenna gain (in dBi) and subtract any cable losses (in dB).

Table 10-3 shows an example.

Table 10-3   Tx Power Relationship

Part	Cisco Part Number	Power
A Cisco Access Point	AIR-CAP3702I	20 dBm
That uses a 50 foot antenna cable	AIR-CAB050LL-R	3.35 dB loss

Table 10-3   Tx Power Relationship

Part	Cisco Part Number	Power
And a solid dish antenna	AIR-ANT3338	21 dBi gain
Has an EIRP of		37.65 dBm (20 - 3.35 + 21)

Path Loss

The distance that a signal can be transmitted depends on several factors. The primary hardware factors that are involved are:

- Transmitter power (in dBm)
- Cable losses between the transmitter and its antenna (in dB)
- Antenna gain of the transmitter (in dBi)
- Signal Attenuation—This refers to how far apart the antennas are and if there are obstacles between them.
- Receiving antenna gain—Cable losses between the receiver and its antenna
- Receiver sensitivity

Receive Signal Strength Indicator—RSSI

Receiver sensitivity is defined as the minimum signal power level with an acceptable Bit Error Rate (in dBm or mW) that is necessary for the receiver to accurately decode a given signal. This is usually expressed in a negative number depending on the data rate. For example an Access Point may require an RSSI of at least negative -91 dBm at 1 MB and an even higher strength RF power -79 dBm to decode 54 MB.

Because 0 dBm is compared to 1 mW, 0 dBm is a relative point, much like 0 degrees is in temperature measurement. Table 10-4 shows example values of receiver sensitivity.

Table 10-4   dBm to mW Receiver Sensitivity

dBm	mW
10	10
3	2
0	1
-3	0.5
-10	0.1
-20	0.01
-30	0.001
-40	0.0001
-50	0.00001
-60	0.000001

Table 10-4   dBm to mW Receiver Sensitivity

dBm	mW
-70	0.0000001
-84	0.000000004

Signal to Noise Ratio—SNR Ratio

Noise is any signal that interferes with your signal. Noise can be due to other wireless devices such as cordless phones, microwave devices, etc. This value is measured in decibels from 0 (zero) to -120 (minus 120). Noise level is the amount of interference in your wireless signal, so lower is generally good for WLAN deployments. Typical environments range between -90dBm and -98dBm with little ambient noise. This value may be even higher if there is a lot of RF interference coming in from other non-802.11 devices on the same spectrum

Signal to Noise Ratio or SNR is defined as the ratio of the transmitted power from the AP to the ambient (noise floor) energy present. To calculate the SNR value, we add the Signal Value to the Noise Value to get the SNR ratio. A positive value of the SNR ratio is always better.

For example, say your Signal value is -55dBm and your Noise value is -95dBm.

The difference of Signal (-55dBm) + Noise (-95dBm) = 40db—This means you have an SNR of 40.

Note that in the above equation you are not merely adding two numbers, but are interested in the "difference" between the Signal and Noise values, which is usually a positive number. The lower the number, the lower the difference between noise and transmitted power, which in turn means lower quality of signal. The higher the difference between Signal and Noise means that the transmitted signal is of much higher power than the noise floor, thereby making it easier for a WLAN client to decode the signal.

The general rule of thumb for a good RF deployment of WLAN is that any SNR should be above 20-25.

Signal Attenuation

Signal attenuation or signal loss occurs even as the signal passes through air. The loss of signal strength is more pronounced as the signal passes through different objects. A transmit power of 20 mW is equivalent to 13 dBm. Therefore if the transmitted power at the entry point of a plasterboard wall is at 13 dBm, the signal strength will be reduced to 10 dBm when exiting that wall. Some common examples are shown in Table 10-5.

Table 10-5   Material and Signal Attenuation

Material/Object	Signal Attenuation[1]
Plasterboard wall	3 dB
Glass wall with metal frame	6 dB
Cinder block wall	4 dB
Office window	3 dB
Metal door	6 dB

Table 10-5   Material and Signal Attenuation

Material/Object	Signal Attenuation[1]
Metal door in brick wall	12 dB
Human Body	3 dB

1. Values are approximate.

Example Use Case

Here is an example to tie together this information to come up with a very simple RF plan calculator for a single AP and a single client.

- Access Point Power = 20 dBm

- 50 foot antenna cable = - 3.35 dB Loss

- Signal attenuation due to glass wall with metal frame = -6 dB

- External Access Point Antenna = + 5.5 dBi gain

- RSSI at WLAN Client = -75 dBm at 100ft from the AP

- Noise level detected by WLAN Client = -85 dBm at 100ft from the AP

Based on the above, we can calculate the following information.

- EIRP of the AP at source = 20 - 3.35 + 5.5 = 22.15 dBm

- Transmit power as signal passes through glass wall = 22.15 - 6 = 16.15 dBm

- SNR at Client = -75 + -85 = 10 dBm (difference between Signal and Noise)

We can see that an SNR of just 10 means a low quality signal connection between the AP and client. To correct this, there are several options:

- Move the client closer to AP, thereby increasing the RSSI at the client, which in turn gives a better SNR ratio.

- Increase the power transmitted from the AP, which increases the RSSI at the WLAN client.

- Increase the power transmitted with help of a higher gain antenna, which increases RSSI at WLAN client.

- Remove sources of interferences in the WLAN area to reduce the Noise level, thereby increasing the SNR at WLAN Client.

- Increase AP density by putting in an AP nearer to client, which increases RSSI at client and improve SNR ratio.

As we see, there is no one size fits all solution. Similarly, a good RF deployment involves a proper RF site survey to plan for good coverage, link estimation, and capacity. This includes planning for interference, materials and physical structure of the space, antennas, and power levels. Further sections provide details about a location-ready design.