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Certified Wireless Network Administrator (CWNA)
PW0-106

Chapter 3
Radio Frequency Components, Measurements, and Mathematics

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Chapter 3 Overview

- Components of RF Communications
- Units of Power and Comparison
- RF Mathematics
- Noise Floor
- Signal-to-Noise Ratio (SNR)
- Received Signal Strength Indicator (RSSI)
- Link Budget
- Fade Margin/System Operating Margin

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Three Requirements For Successful Communications

1. Two or more devices want to communicate
2. Medium, means, or method to communicate
3. Set of rules to use when communicating

- These rules apply to all forms of communications
- This chapter focuses on the second requirement

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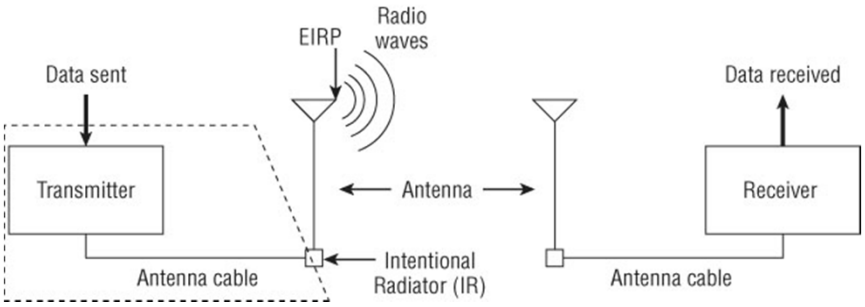
RF Components



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Transmitter

- Initial component in the creation of the wireless medium
- Receives data from the computer
- Generates an AC signal
- AC signal determines the frequency of the transmission
- Modulates the AC signal to contain the data (carrier signal)
- Determines the power/amplitude of the signal

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Antenna

- Performs two functions
  - Collects the carrier signal from the transmitter and directs or radiates it
  - Takes the RF waves that it receives through the air and directs the AC signal to the receiver
- Antennas direct or focus the RF signal
- Antenna transmissions are usually referenced to an isotropic radiator
- Isotropic radiator = a point source that radiates equally in all directions

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Receiver

- Final component in the wireless medium
- Takes carrier signal from the antenna
- Signal is often altered due to interference
- Translates the signal into 1s and 0s
- Passes the data to the computer to be processed

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Intentional Radiator (IR)

- FCC defines intentional radiator as
  - A device that intentionally generates and emits radio frequency energy by radiation or induction
- Basically, something that is specifically designed to generate RF
- IR = All components from the transmitter to the antenna (excluding the antenna)
- Regulatory bodies limit the amount of power allowed to be generated by an IR (measured to the input to the antenna)

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Equivalent Isotropically Radiated Power (EIRP)

- The highest RF signal strength that is transmitted from a particular antenna
- The maximum effective focused signal strength radiated from an antenna
- Also known as
  - Equivalent isotropic radiated power
  - Effective isotropic radiated power
- Regulatory bodies limit the amount of effective power radiate

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Units of Power

- Measures transmission amplitude and received amplitude
- Absolute power measurements
- Units of power
  - watt (W)
  - milliwatt (mW)
  - decibels relative to a milliwatt (dBm)

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Units of Comparison

- Measures difference between signals
- Relative power measurements
- Units of comparison
  - decibel (dB)
  - decibels relative to an isotropic radiator (dBi)
  - decibels relative to a dipole antenna (dBd)

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Watt (W)

- Basic unit of power
- Name after James Watt, 18th-century inventor
- Watt = 1 ampere of current flowing at 1 volt
- Watt = volts times amps

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Milliwatt (mW)

- Unit of power used to measure 802.11 RF
- 1/1,000 of a watt
- 802.11 indoor typically transmits at power levels between 1 mW and 100 mW
- 802.11outdoor equipment commonly transmits at power levels up to 300 mW

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Decibel (dB)

- Unit of comparison
- Measurement of change in power
- Derived from the term *bel*
- 1 bel = ratio of 10 to 1 between the power of two transmitters
- dB = 1/10 of a bel
- $10^2=100$ inverse is $\log_{10}(100)=2$
- dB = 10 x $\log_{10}(Power_1/Power_2)$

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Why Use Decibels?

- Decibels provide a linear scale to RF power, whereas milliwatts uses a logorithmic scale
- An indoor 802.11 device may transmit at 100 mW or 20 dBm
- That signal may be received at as low as 0.00000001 mW or -80 dBm

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dBi

- Relative measurement
- Decibel gain referenced to an isotropic radiator
- Think change in power cause by an antenna
- Typical rubber-encased half-wave dipole antenna has a dBi value of 2.14

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dBd

- Relative measurement
- Decibel gain relative to a dipole antenna
- 3 dBd = 3 dB greater than a dipole antenna (so 3 dB greater than 2.14 dBi, or 5.14 dBi)

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dBm

- Absolute measurement
- Decibels relative to 1 milliwatt
- Set dBm to 0 (zero) and equate it to 1 milliwatt of RF power
- $dBm = 10 \times \log_{10}(P_{mW})$
- $P_{mW} = 10^{(dBm \div 10)}$

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Inverse Square Law

- Change in power is equal to 1 divided by the square of the change in distance
- 2 x distance = $1/(2)^2$
- FSPL is based on Inverse Square Law
- Power at a specific distance = $P/(4\pi r^2)$, where P = initial EIRP power and r = initial distance

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RF Mathematics

- Logarithms are needed only for exact calculations
- Math skills necessary for RF math
  - Addition and subtraction using 3 and 10
  - Multiplication and division using 2 and 10
- Math is based on the *Rule of 10s and 3s*

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Rule of 10s and 3s

- Provides an approximate value (fairly accurate)
- Four basic rules
  - For every 3 dB gain, double the power
  - For every 3 dB loss, halve the power
  - For every 10 dB gain, power times 10
  - For every 10 dB loss, power divided by 10

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Rule of 10s and 3s Setup

- To make RF math easier, first build this chart

dBm	mW
0	1

- dBm is decibels relative to 1 mW, therefore
  - Set dBm column to value of 0
  - Set mW column to value of 1

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Rule of 10s and 3s Setup (continued)

- Next, add a reminder of the allowed numbers and mathematical symbols to each column

3 + 10 −	dBm	mW	× 2 ÷ 10
	0	1	

- Left column is the dB column
  - **Only** numbers that you can use are 3 and 10
  - **Only** math that you can use is + and -
- Right column is the mW column
  - **Only** numbers that you can use are 2 and 10
  - **Only** math that you can use is X and ÷

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Rule of 10s and 3s Setup (continued)

- Think of this chart as a balance scale
- If you change the left side of the scale, you must do something to the right to keep it balanced

3 + 10 −	dBm	mW	× 2 ÷ 10
	0	1	

+ or – 3 on left	requires	X or ÷ 2 on right
+ or – 10 on left	requires	X or ÷ 10 on right

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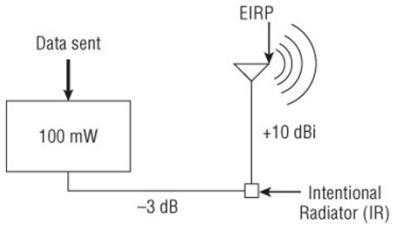
Rule of 10s and 3s: Example 2



- A wireless bridge generates a 100 mW signal
- The cable between the bridge and the antenna creates -3 dB of signal loss
- The antenna provides 10 dBi of signal gain

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Rule of 10s and 3s: Example 2 (step 1)

3 + 10 –	dBm	mW	× 2 ÷ 10
	0	1	

- The initial chart shows 1 mW, however the bridge generates 100 mW
- Increase the mW column to 100
- Then balance the scale by performing the partner calculations to the dBm column

❖ Remember to only use the allowed values and mathematical symbols on each side

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Rule of 10s and 3s: Example 2 (step 2)

3 + / 10 −	dBm	mW	× 2 / ÷ 10
	0	1	
+ 10	10	10	× 10
+ 10	20	100	× 10

- At this point the chart shows that 20 dBm is equal to 100 mW
- Now you need to calculate the -3 dB of loss that is introduced by the cable
- Decrease the dBm column by 3
- Again, do not forget to balance the scale

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Rule of 10s and 3s: Example 2 (step 3)

3 + / 10 −	dBm	mW	× 2 / ÷ 10
	0	1	
+ 10	10	10	× 10
+ 10	20	100	× 10
− 3	17	50	÷ 2

- At this point the chart shows that 17 dBm is equal to 50 mW
- Now you need to calculate the 10 dBi gain introduced by the antenna
- Increase the dBm column by 10
- Again, do not forget to balance the scale

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Rule of 10s and 3s: Example 2 (step 4)

3 + / 10 −	dBm	mW	× 2 / ÷ 10
	0	1	
+ 10	10	10	× 10
+ 10	20	100	× 10
− 3	17	50	÷ 2
+ 10	27	500	× 10

- At this point the chart shows that 27 dBm is equal to 500 mW
- The power at the IR is 17 dBm or 50 mW
- The EIRP is 27 dBm or 500 mW

❖ Think of dBm and mW as Celsius and Fahrenheit, two different scales that represent the same thing

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Rule of 10s and 3s: Other Examples

- CWNA book contains additional examples
- Animated explanation of the rule of 10s and 3s as well as explanations of the examples in the CWNA book has been created using Microsoft PowerPoint and can be downloaded from www.sybex.com/go/cwna3e

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dB Loss and Gain (-10 through +10)

- Any dB loss or gain can be calculated using 3 and 10

-10	-10	**1**	+10 -3 -3 -3
-9	-3 -3 -3	**2**	+3 +3 +3 +3 -1
-8	-10 -10 +3 +3 +3 +3 +3	**3**	+3
-7	-10 +3	**4**	+10 -3 -3
-6	-3 -3	**5**	+10 +10 -3 -3 -3 -3 -3
-5	-10 -10 +3 +3 +3 +3 +3 +3	**6**	+3 +3
-4	-10 +3 +3	**7**	+10 -3
-3	-3	**8**	+10 +10 -3 -3 -3 -3
-2	-3 -3 -3 -3 +10	**9**	+3 +3 +3
-1	+10 -3 -3 -3	**10**	+10

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dBm and milliwatt Conversions

dBm	milliwatts	Power Level
+ 36 dBm	4,000 mW	4 watts
+ 30 dBm	1,000 mW	1 watt
+ 20 dBm	100 mW	1/10th watt
+ 10 dBm	10 mW	1/100th watt
0 dBm	1 mW	1/1,000th watt
-10 dBm	0.1 mW	1/10th milliwatt
-20 dBm	0.01 mW	1/100th milliwatt
-30 dBm	0.001 mW	1/1,000th milliwatt
-40 dBm	0.0001 mW	1/10,000th milliwatt
-50 dBm	0.00001 mW	1/100,000th milliwatt
-60 dBm	0.000001 mW	1 millionth of 1 milliwatt
-70 dBm	0.0000001 mW	1 ten-millionth of 1 milliwatt
-80 dBm	0.00000001 mW	1 hundred-millionth of 1 milliwatt
-90 dBm	0.000000001 mW	1 billionth of 1 milliwatt

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RF Math Summary

- dBm = 10 x $\log_{10}(P_{mW})$
- $P_{mW}=10^{(dBm \div 10)}$
- Rule of 10s and 3s
  - 3 dB gain = mW X 2
  - 3 dB loss = mW ÷ 2
  - 10 dB gain = mW X 10
  - 10 dB loss = mW ÷ 10

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Noise Floor

- Ambient or background level of radio energy
- Noise floor includes
  - Includes modulated signals from nearby 802.11 devices
  - Unmodulated energy from non-802.11 devices (microwave ovens, portable telephones, etc.)
  - Potentially anything electromagnet
- 2.4 GHz and 5 GHz
  - Typical noise floor around -100 dBm
  - Noisier environment around -90 dBm
  - 5 GHz typically less noisy than 2.4 Ghz

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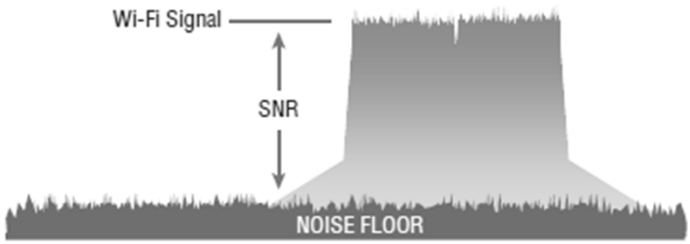
Signal-to-Noise Ratio (SNR)



- Difference in dB between received signal and background noise (noise floor)
- Low SNR will likely cause data corruption
- SNR > 25 dB is considered good
- SNR < 10 dB is considered very poor

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Received Signal Strength Indicator

- Power level of an RF signal required to be successfully received by the receiver radio
- Weakest signal that the transceiver can decode (not considering the noise floor)
- Defined by IEEE as a relative metric used by 802.11 radios to measure signal strength
- Metric values and scales can vary between vendors
- Indicator often used to initiate roaming or dynamic rate switching (DRS)

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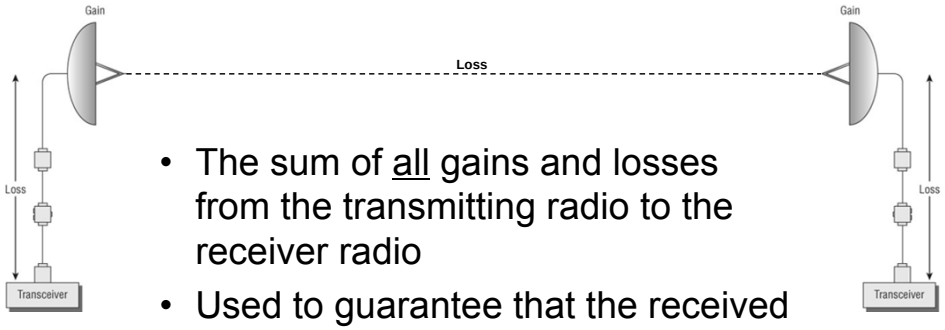
Link Budget



- The sum of <u>all</u> gains and losses from the transmitting radio to the receiver radio
- Used to guarantee that the received signal is above the receiver sensitivity threshold

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Fade Margin

- Level of desired signal above what is required
- Comfort zone
- Received signal fluctuates due to outside influences and interference
- Protects reception of signal due to fluctuation of the received signal
- 10 dB to 25 dB buffer is common practice
- System operating margin (SOM) is the difference between the actual received signal and the signal required for communications

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Chapter 3 Summary

- Components of RF Communications
  - Transmitter
  - Antenna
  - Intentional Radiator (IR)
  - Receiver
  - Equivalent Isotropically Radiated Power (EIRP)
- Units of Power
  - Watt
  - Milliwatt
  - dBm

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Chapter 3 Summary (continued)

- Units of Comparison
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  - dBd
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