WF101:
RF Essentials

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RF Embedded Product Manager

RF Essentials

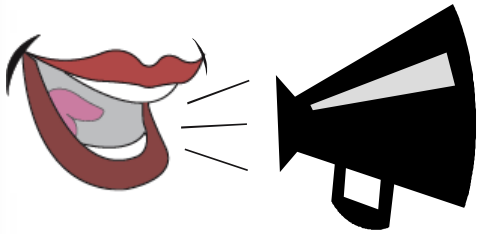
- Basic communication system
  - Transmitter & receiver

Transmitter

Receiver

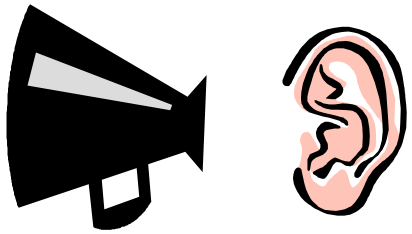
RF Essentials

- Basic communication system
  - Transmitter & receiver
  - Transmitting antenna
  - Receiving antenna



Antenna 1

Transmitter



Antenna 2

Receiver

RF Essentials

- Basic communication system
  - Transmitter & receiver
  - Transmitting antenna
  - Receiving antenna
  - Environment

RX Sensitivity

- How low can you go?

  - Receiver sensitivity is a measure of how well the receiver performs and is defined as the power of the weakest signal the receiver can detect

TX Power

- Total net output power of transmitter
- Typically measured in dBm or mW

- mW: milliwatts are a measurement of power (1000 mW = 1 Watt).
- dB: decibel is a unit for expressing the ratio of two amounts of signal power equal to 10 times the common logarithm of this ratio. So, a power measurement in dB has to be relative to something.
- dBm: dB(mW) is power relative to 1 milliwatt (mW to dBm = $10\text{Log}_{10}(\text{mW}/1000) + 30$).
- dBi: dB(isotropic) is the forward gain of an antenna compared to the hypothetical isotropic antenna, which uniformly distributes energy in all directions.
- dBd: dB(dipole) is the forward gain of an antenna compared to a half-wave dipole antenna.

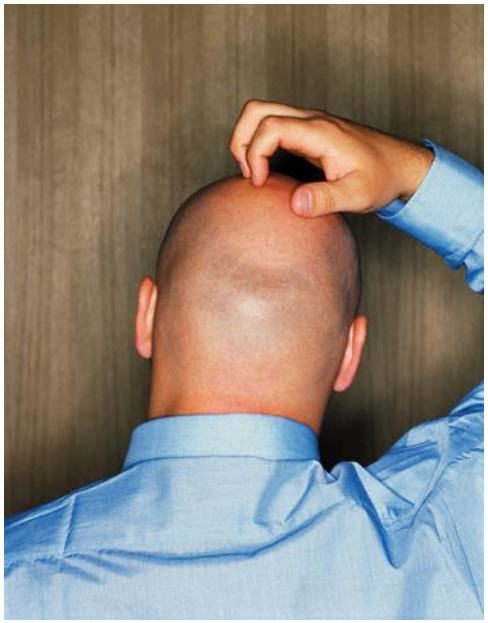
dBm to mW Conversion

dBm	Watts
0	1.0 mW
1	1.3 mW
2	1.6 mW
3	2.0 mW
4	2.5 mW
5	3.2 mW
6	4 mW
7	5 mW
8	6 mW
9	8 mW
10	10 mW
11	13 mW
12	16 mW
13	20 mW
14	25 mW
15	32 mW

dBm	Watts
16	40 mW
17	50 mW
18	63 mW
19	79 mW
20	100 mW
21	126 mW
22	158 mW
23	200 mW
24	250 mW
25	316 mW
26	398 mW
27	500 mW
28	630 mW
29	800 mW
30	1.0 W
31	1.3 W

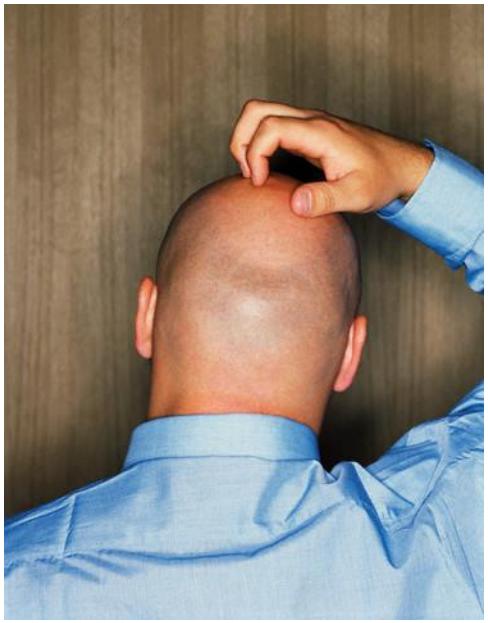
dBm	Watts
32	1.6 W
33	2.0 W
34	2.5 W
35	3.2 W
36	4.0 W
37	5.0 W
38	6.3 W
39	8.0 W
40	10 W
41	13 W
42	16 W
43	20 W
44	25 W
45	32 W
46	40 W
47	50 W

Pop Quiz



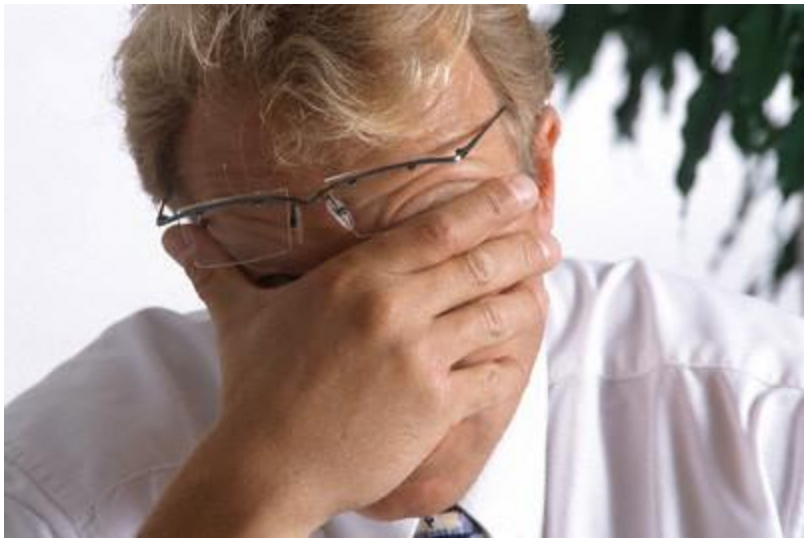
0 dBm = ?

Pop Quiz



30 dBm = ?

Pop Quiz



-10 dBm = ?

RF Essentials

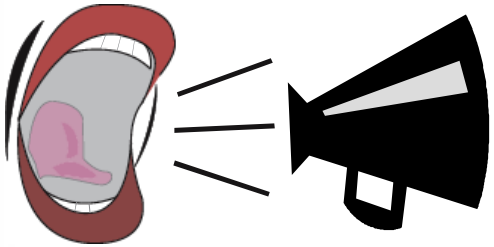
- Maximizing range
  - Increase TX (transmit) power
    - Government regulated
    - Low-powered applications

RF Essentials

- Maximizing range
  - Increase TX (transmit) power
  - Improve RX (receive) sensitivity
    - Specified in dBm
    - Every 6 dB doubles RF link's range (line-of-sight)
    - Every 12 dB doubles RF link's range in indoor/urban environments

RF Essentials

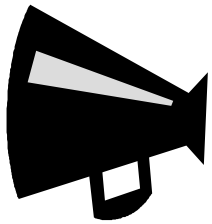
- Maximizing range
  - Increase TX (transmit) power
  - Improve RX (receive) sensitivity
  - Increase antenna gain
    - More gain means more directionality (good and bad)
    - Antenna cables should be as short as possible
    - Government regulated EIRP (TX pwr + antenna gain)



Increase Power

Increase Gain

Environment



Increase Gain

Improve RX Sensitivity

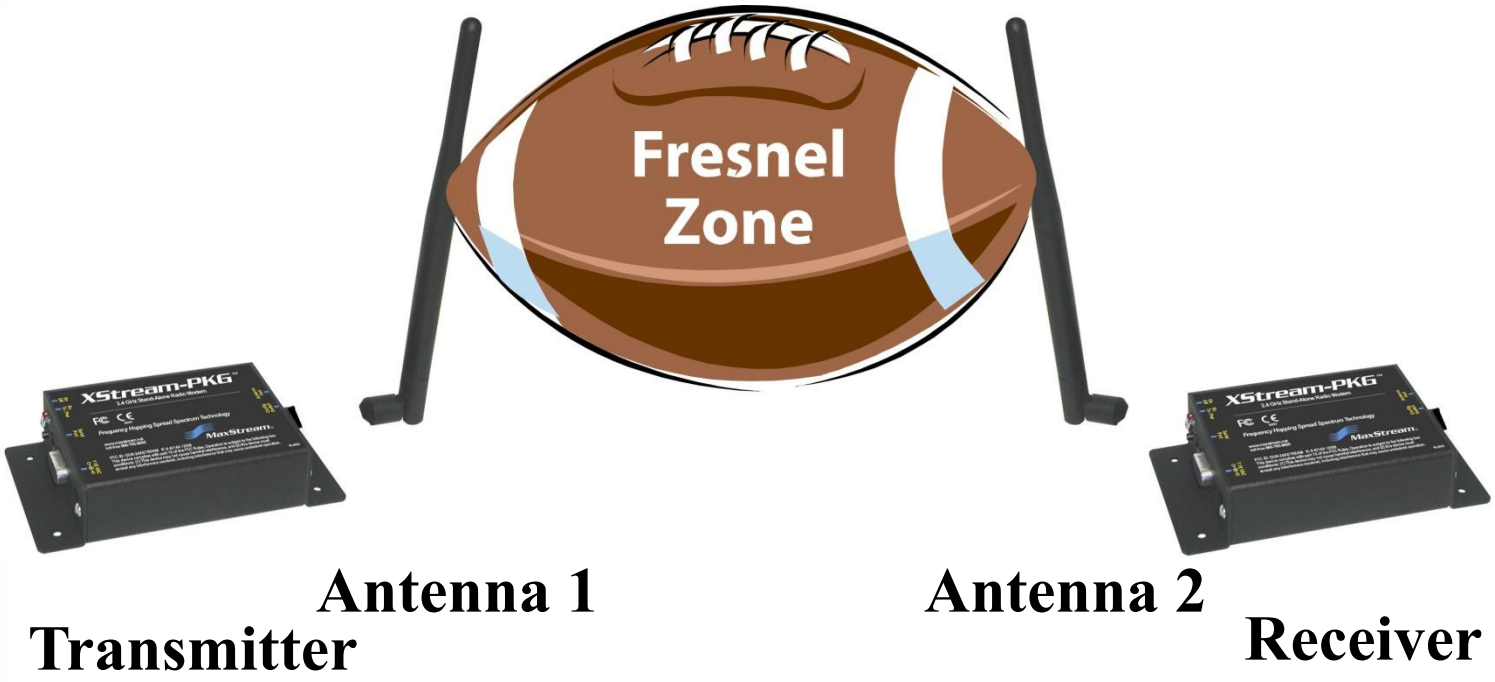
RF Essentials

- Maximizing range
  - Increase TX (transmit) power
  - Improve RX (receive) sensitivity
  - Increase antenna gain
  - Clear environment of obstructions
    - Visual (linear) line-of-sight vs. RF (radio) line-of-sight

Increase Power **Increase Gain** ~~**Environment**~~ **Increase Gain** **Improve RX Sensitivity**

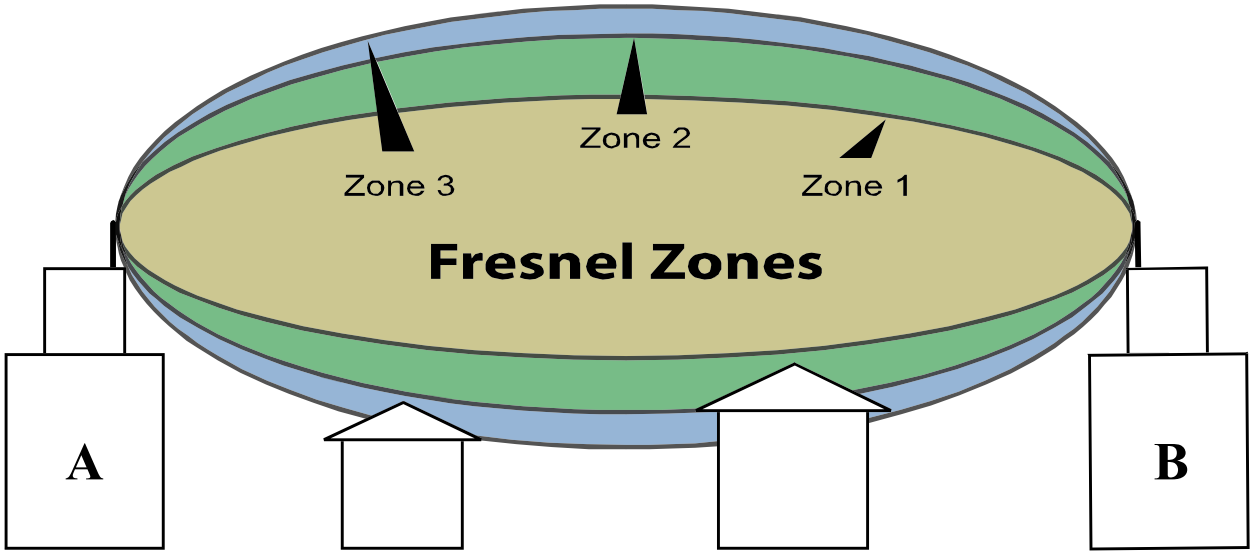
RF Essentials

- Fresnel Zone
  - Football-shaped path



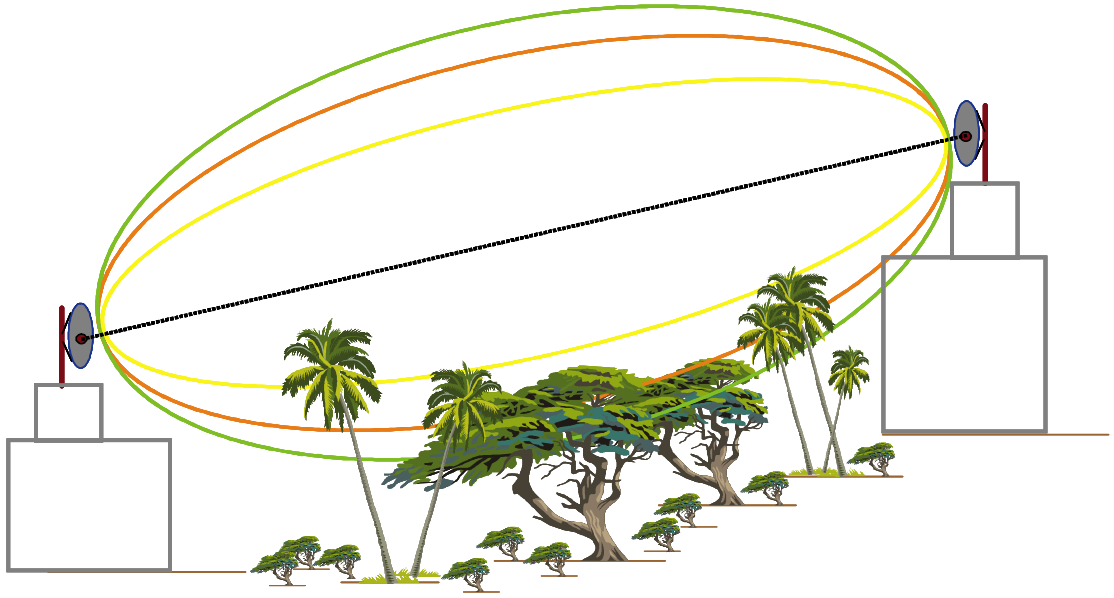
RF Essentials

- Fresnel Zone
  - Football-shaped path
  - Acceptable = 60% of Zone 1 + 3 meters



RF Essentials

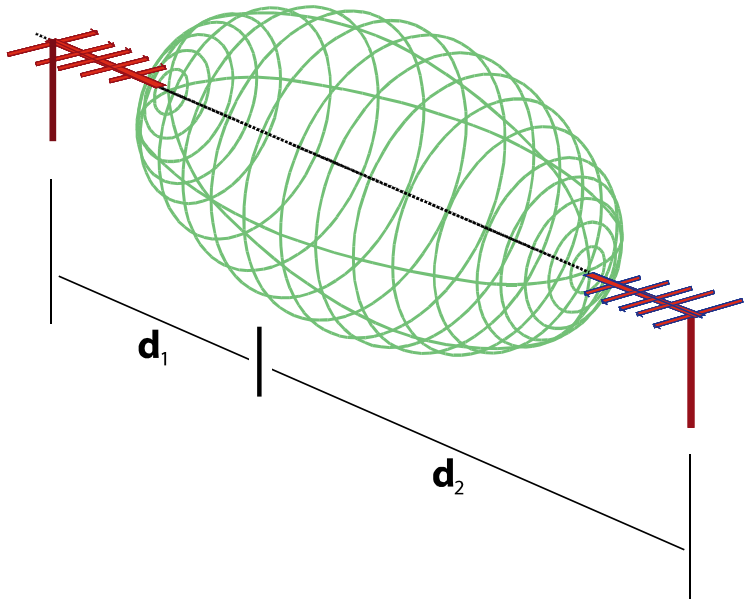
- Fresnel Zone
  - Football-shaped path
  - Acceptable = 60% of Zone 1 + 3 meters
  - Raise antennas to help clear the zone



RF Essentials

- Fresnel Zone
  - Football-shaped path
  - Acceptable = 60% of Zone 1 + 3 meters
  - Raise antennas to help clear the zone
  - Formula - use an online Fresnel Zone calculator

$$r_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}}$$



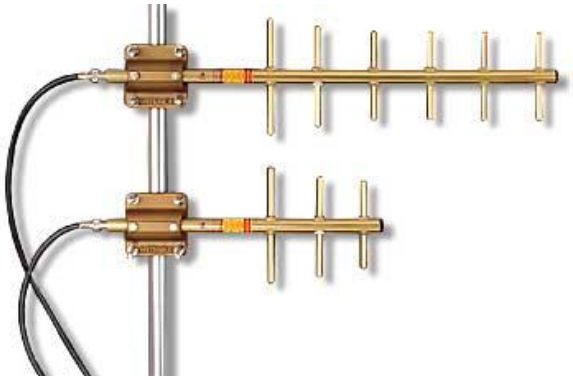
RF Essentials

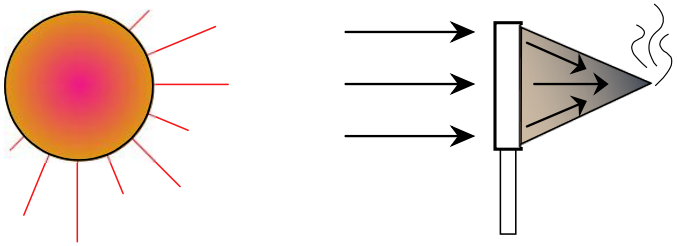
- Fresnel Zone diameters

Range Distance	900 MHz Modems Required Fresnel Zone Diameter	2.4 GHz Modems Required Fresnel Zone Diameter
1000 ft. (300 m)	**16 ft. (5 m)**	**11 ft. (3.4 m)**
1 Mile (1.6 km)	**32 ft. (10 m)**	**21 ft. (6.4 m)**
5 Miles (8 km)	**68 ft. (21 m)**	**43 ft. (13 m)**
10 Miles (16 km)	**95 ft. (29 m)**	**59 ft. (18 m)**

Antennas

- Antenna gain
  - Directional antennas FOCUS energy: they DO NOT ADD energy





Antennas

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  - Omni-directional antennas FOCUS energy: they DO NOT ADD energy

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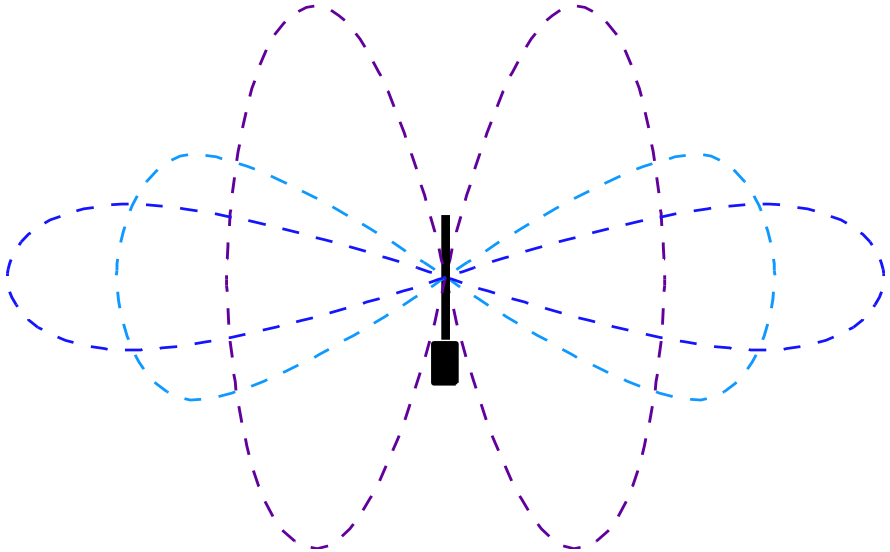

Conducted Power vs. EIRP

- Conducted: the TX Power of the RF module

- EIRP: EIRP (Effective Isotropic Radiated Power) is the effective power of radio + antenna

The Datasheet War

- TX Power: Is this conducted or EIRP?

Output power (w/ 3dBi antenna)	5mW-200mW variable	5mW-1000mW variable

- RX Sensitivity: dB for dB, RX Sensitivity increases range as much as TX Power

Add TX Power + (-RX Sensitivity) for full link budget

- Current Draw: Is this the full TX current draw?

†Current consumption assumes 50% transmitter on-time.