WF103:
Site Surveys for Wireless Networks

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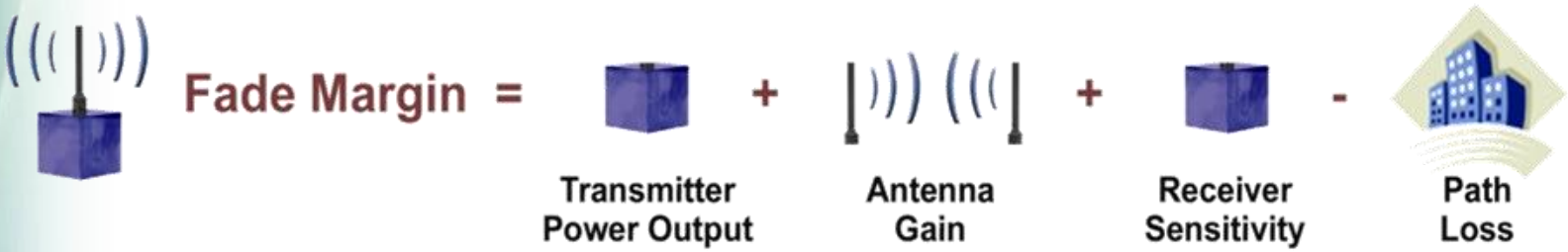
Agenda

- Theory
- Practice
- Application

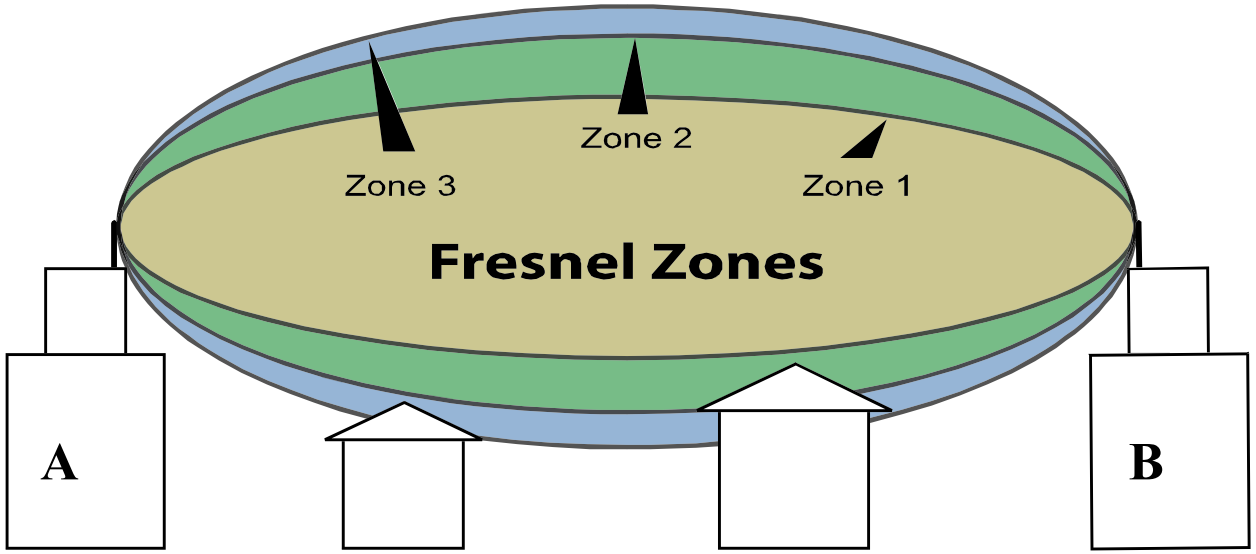
Theory

- Link budget



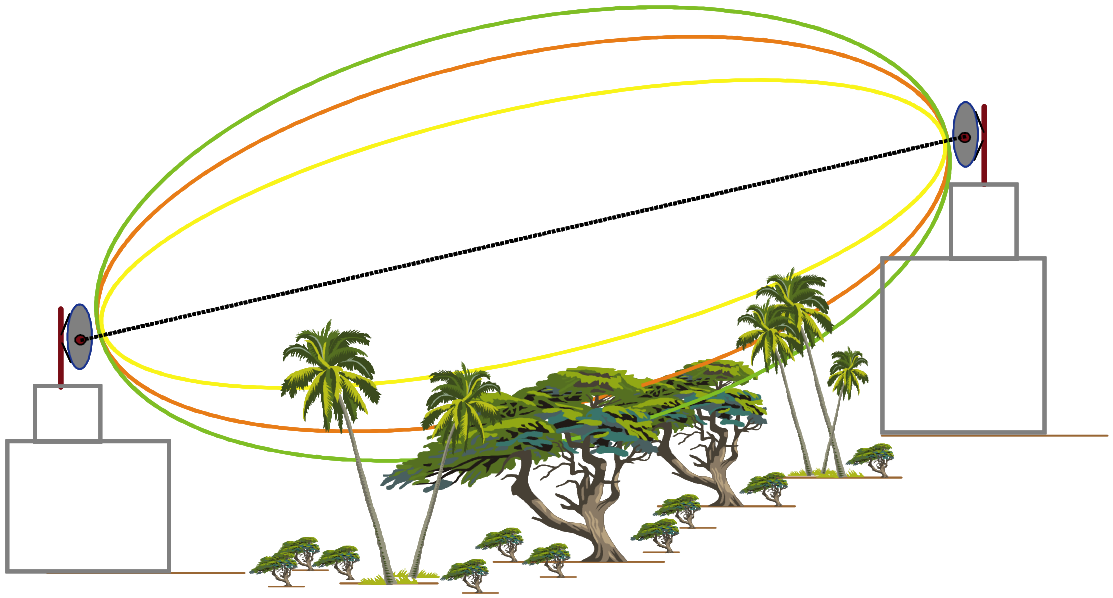
Theory

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



Theory

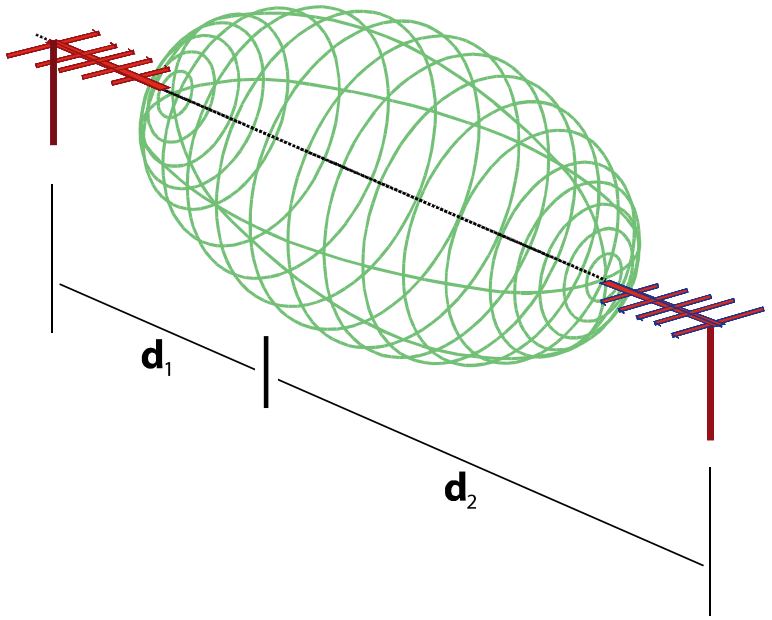
- Fresnel Zone
  - Football-shaped path
  - Acceptable = 60% of Zone 1 + 3 meters
  - Raise antennas to help clear the zone



Theory

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

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



Theory

- 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)**

Theory

- Free Space Loss

$$36.56 + 20\text{Log}_{10}(\text{Frequency}) + 20\text{Log}_{10}(\text{Dist in miles})$$

  - Use an online Free Space Loss calculator

Range Distance	900 MHz Free Space Loss	2.4 GHz Free Space Loss
1000 ft. (300 m)	**81 dB**	**90 dB**
1 Mile (1.6 km)	**96 dB**	**104 dB**
5 Miles (8 km)	**110 dB**	**118**
10 Miles (16 km)	**116 dB**	**124**

Theory

- Link budget – path loss

Material	Attenuation @900 MHz
Glass 0.25” (6mm)	0.8 dB
Glass 0.5” (13mm)	2 dB
Lumber 3” (76mm)	2.8 dB
Brick 3.5” (89mm)	3.5 dB
Brick 7” (178mm)	5 dB
Brick 10.5” (267mm)	7 dB
Concrete 4” (102mm)	12 dB
Masonry Block 8” (203mm)	12 dB
Brick faced concrete 7.5“ (192mm)	14 dB
Masonry Block 16” (406mm)	17 dB
Concrete 8” (203mm)	23 dB
Reinforced Concrete 3.5” (203mm)	27 dB
Masonry Block 24” (610mm)	28 dB
Concrete 12” (305mm)	35 dB

Theory

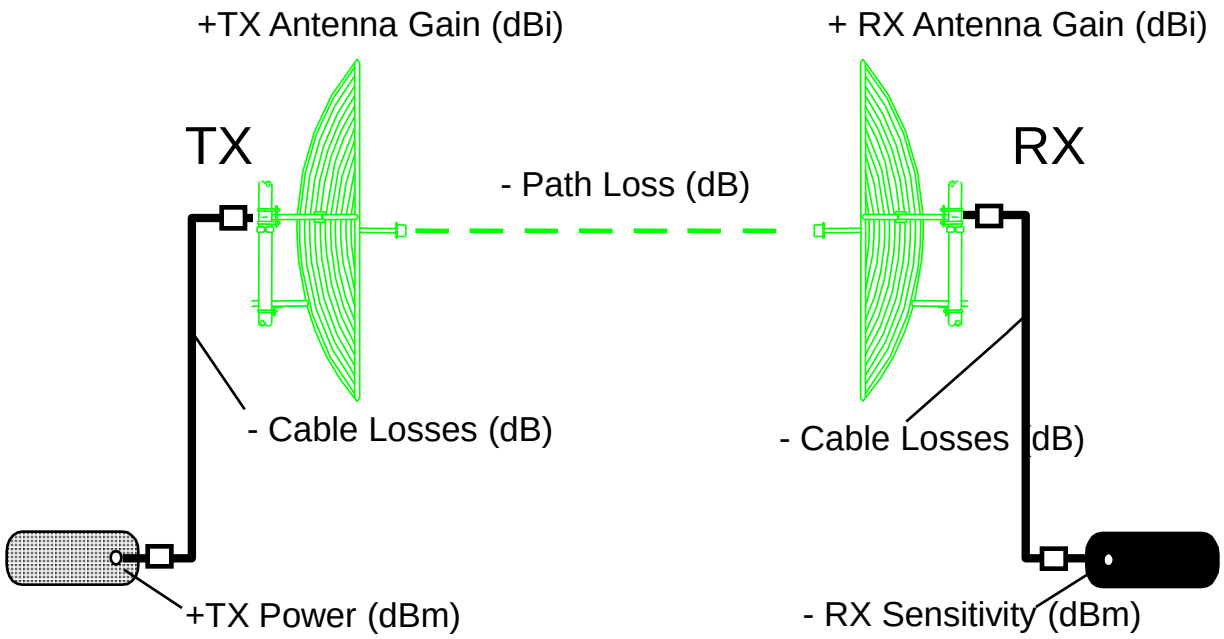
- Antenna cables
  - Mounting and cable considerations

Cable Type	dB Loss at 900 MHz per 100' (dB loss per 100m)	dB Loss at 2.4 GHz per 100' (dB loss per 100m)	Diameter Inches (mm)
RG-58	14.5 (47.4)	25.3 (83.2)	0.195 (4.95)
RG-174	25.9 (85.0)	44.4 (145.84)	0.100 (2.54)
RG-316	24.7 (81.0)	42.4 (139.0)	0.102 (2.59)
LMR-195 *	11.1 (36.5)	19.0 (62.4)	0.195 (4.95)
LMR-240	7.6 (24.8)	12.9 (42.4)	0.240 (6.10)
LMR-600	2.5 (8.2)	4.4 (14.5)	0.590 (14.99)

* We often use LMR-195

Theory

- Link budget



Fade Margin (dB) = TX power + TX antenna - path Loss
+ RX antenna - RX sensitivity - total connector and cable losses

- Design for 20 dB Fade Margin

Theory

- Pop quiz

Frequency:	900 MHz
TX Power:	20 dBm
RX Sensitivity:	-102 dBm
RF Cables:	2 dB on TX side; 0 dB on RX side
Antenna Gain:	8 dBi on TX side; 2 dBi on RX side

- Link budget = ?

  20 - (-102) – 2 + 8 + 2 = 130 dB

- How far can we transmit?

  Design for 20 dB fade margin → We can spend 110 dB

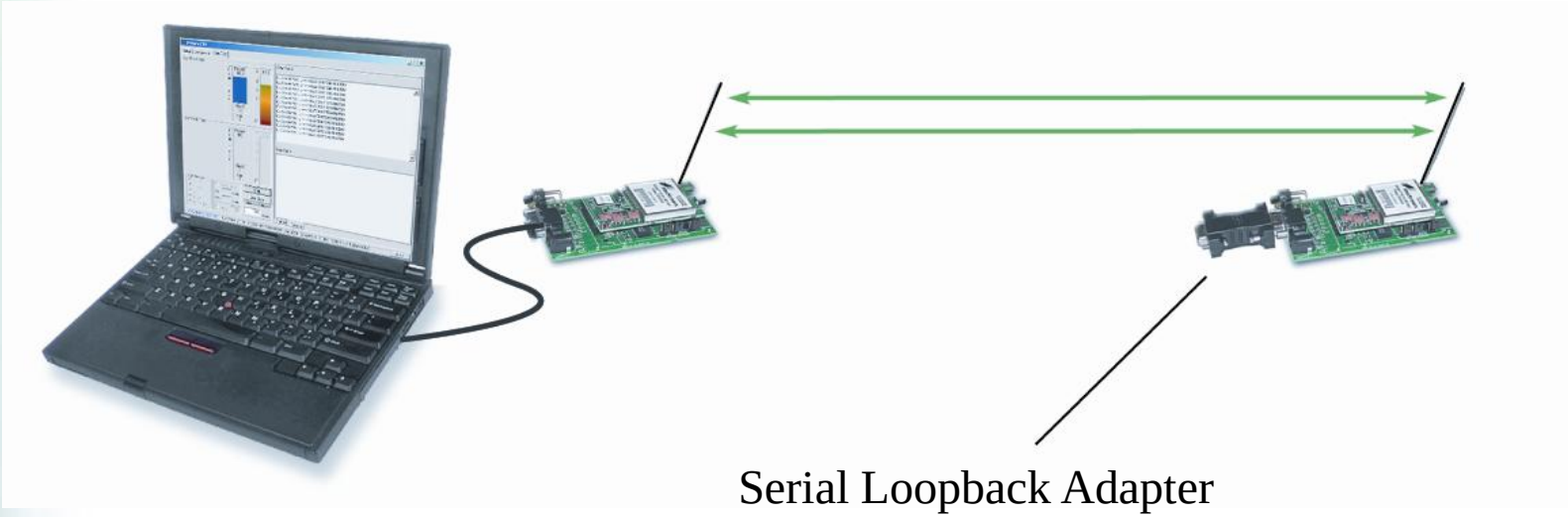
  Answer: 5 miles line-of-sight

  Bonus – How high do antennas need to be off the ground?

  Answer: 34 feet (68 ft Fresnel Zone diameter)

Practice

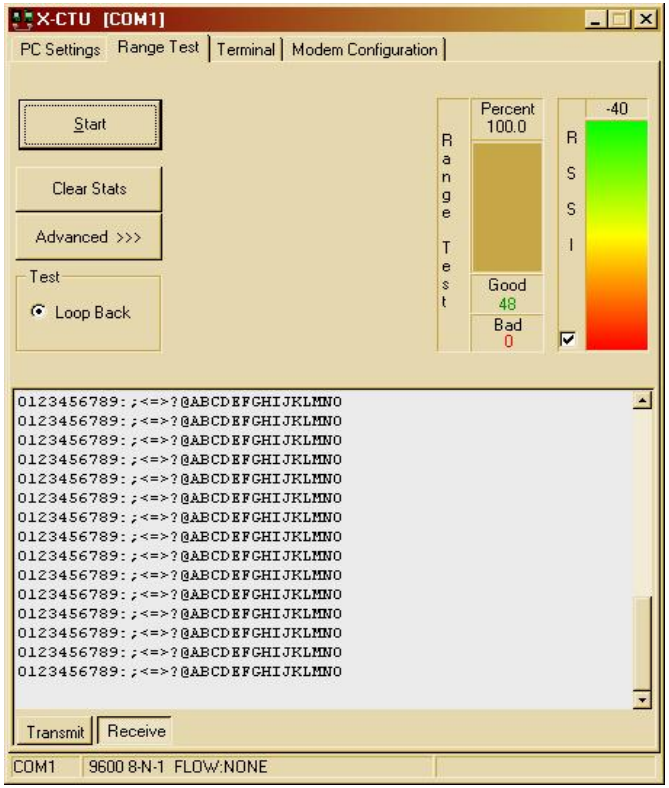
- Site Survey = Range + Interference Testing
- Why Range Test?



Range Test Setup

Practice

Live Demo – X-CTU “Range Test”

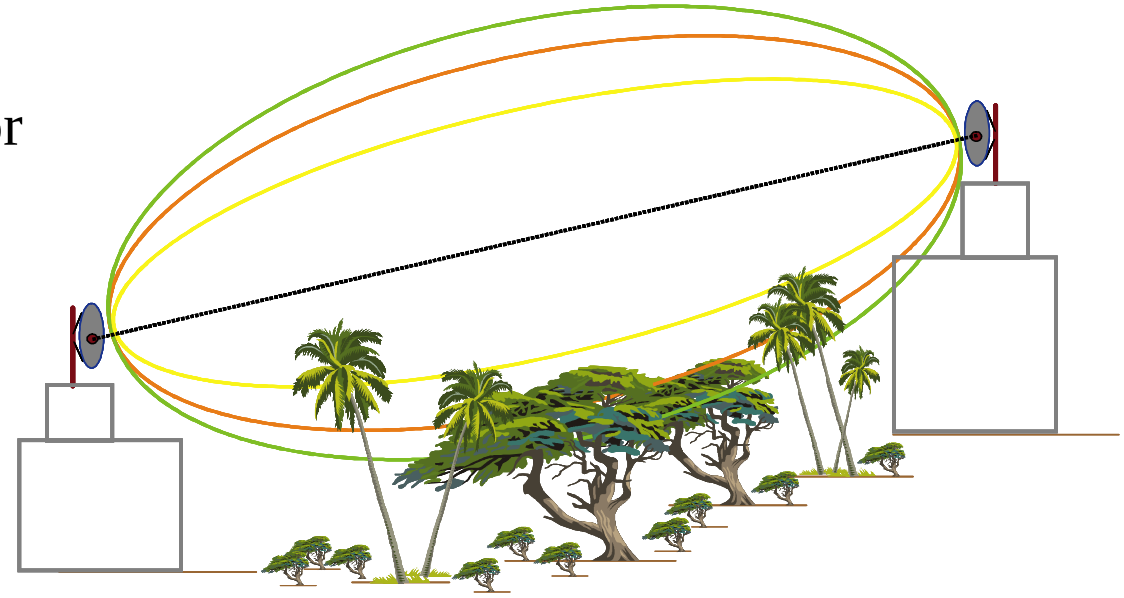


Practice

- Fresnel Zone
  - Football-shaped path
  - Raise antennas to help clear the zone
  - Expected ranges:

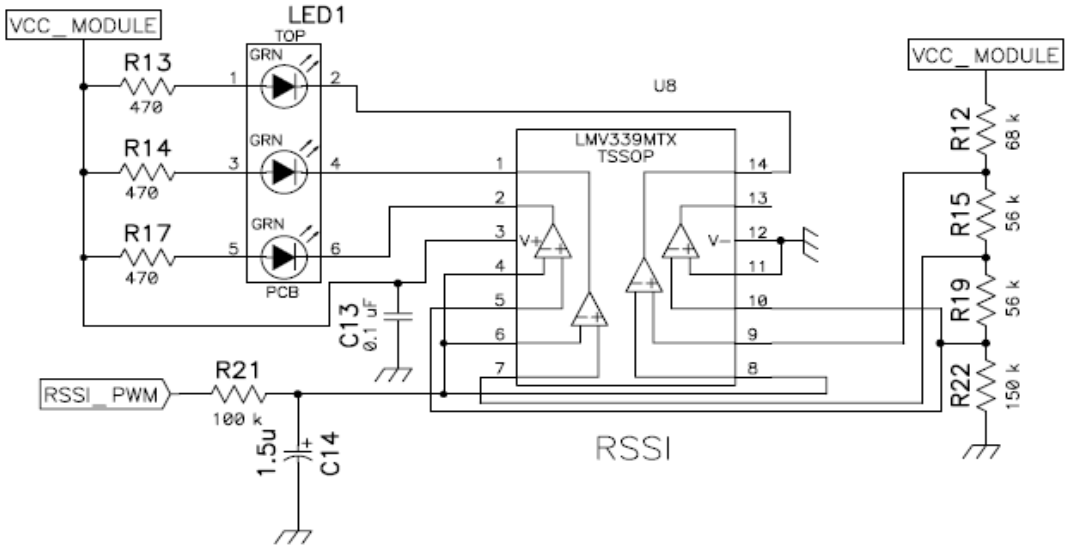
    1) Indoor

    2) Outdoor



Practice

- RSSI – Received Signal Strength Indicator
  - Read memory register (e.g. X-CTU “Range Test”)
  - Connect PWM output (e.g. green “RSSI” LEDs)

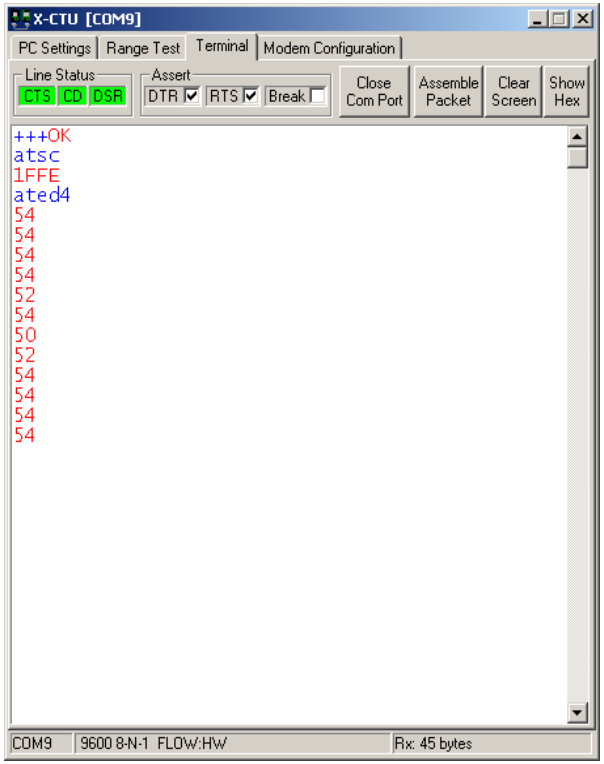


Practice

- Identify interference
  - RSSI's dirty little secret: Interference
  - Take a look around

Practice

- Identify interference
  - ATED (XBee 802.15.4) displays ambient RF noise level of all channels on the XBee



Practice

- Identify interference
  - Spectrum analyzer

Practice

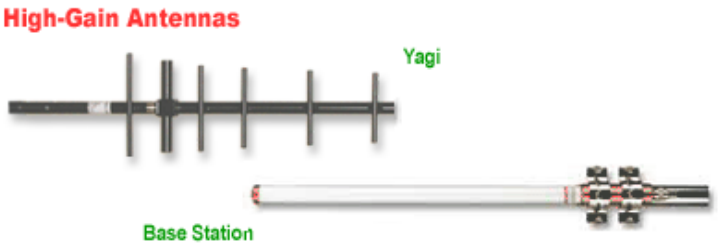
Site Survey = Range + Interference Testing

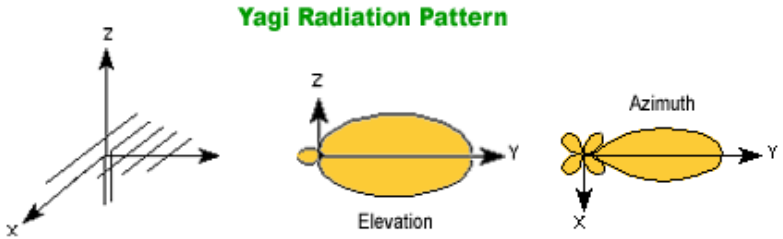
Bottom Line:

Packets received more important than RSSI

Application

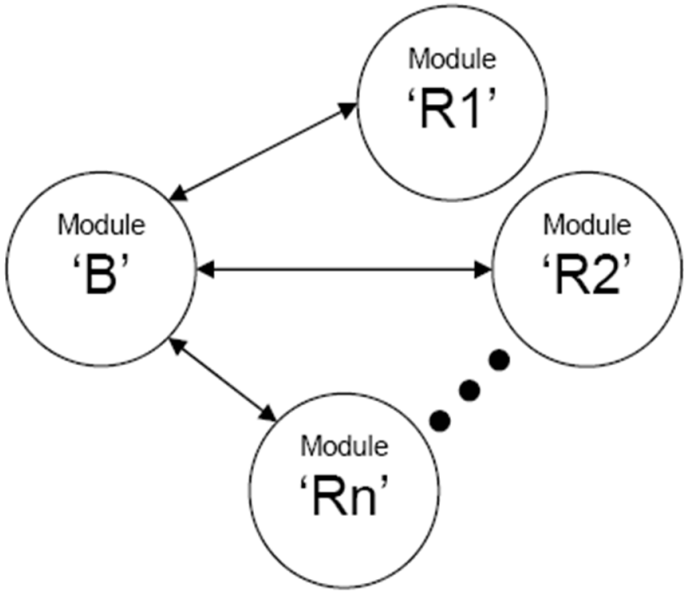
- Overcome interference: Hardware
  - Proximity to interferer
  - Antenna antidotes
  - Filters





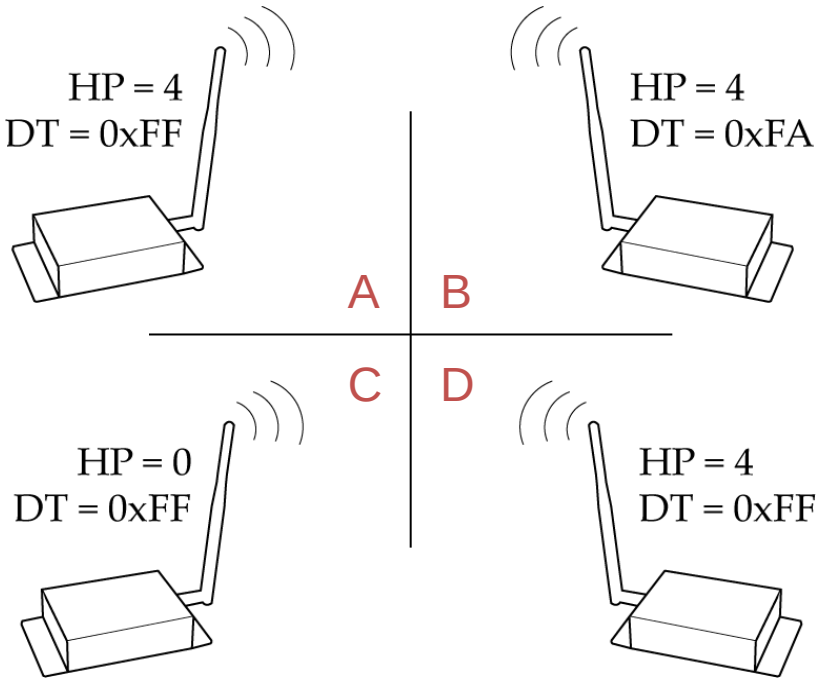
Application

- Overcome interference: Software
  - Channel/Hopping Pattern/Address
  - Retries/Acknowledgements
  - Protocol/Timing/Packetizing/Payload (Number of Bytes)



Application

- Overcoming interference: Channel/Address
  - Which 2 will communicate?
    Match channels (HP) and addresses (DT)
  - Isolate networks using unique channel (HP)
  - XBee: set DH & DL on transmitter to match SH & SL on receiver



Application

- Overcoming interference: Retries/Acknowledgements
  - Broadcast
  - Unicast
  - Do you want retries?