



# WF103: Site Surveys for Wireless Networks

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# Agenda

- Theory
- Practice
- Application



**Do you think you know wireless?**

*Mesh+Cellular = Drop-in Networking*

*802.15.4*

*Wi-Fi vs. ZigBee*

*Common Wireless Uses:*  
WPA/WPA2  
Backup connectivity  
Cable replacement  
Asset management/M2M

**Think you know? Prove it.**  
Go to [www.digi.com/???](http://www.digi.com/???) and take the challenge.  
Participants save 20% on any wireless product in the Digi Online Store.

**WIRELESS SPOTLIGHT**  
**XTend™ RF Modem**  
The 900 MHz RF modem provides long range wireless communications in point-to-point, peer-to-peer and peer-to-peer mesh topologies. Available in multiple interface options, including RS-485, serial and USB, and with an optional NEMA 4 rated enclosure, XTend is an ideal wireless solution for applications with no industrial experience, asset management, security and remote monitoring.

**Digi does.**  
Leveraging expertise in cellular, Wi-Fi, ZigBee®/802.15.4 and proprietary RF technologies, Digi offers wireless solutions to fit all of your device connectivity needs. From simple cable replacement, to sophisticated end-to-end wireless device connectivity and management with our unsurpassed Drop-in Networking family of products, Digi knows wireless.

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When **RELIABILITY** Matters™



# Theory

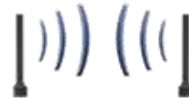
- Link budget



Fade Margin =



+



+



-



Transmitter  
Power Output

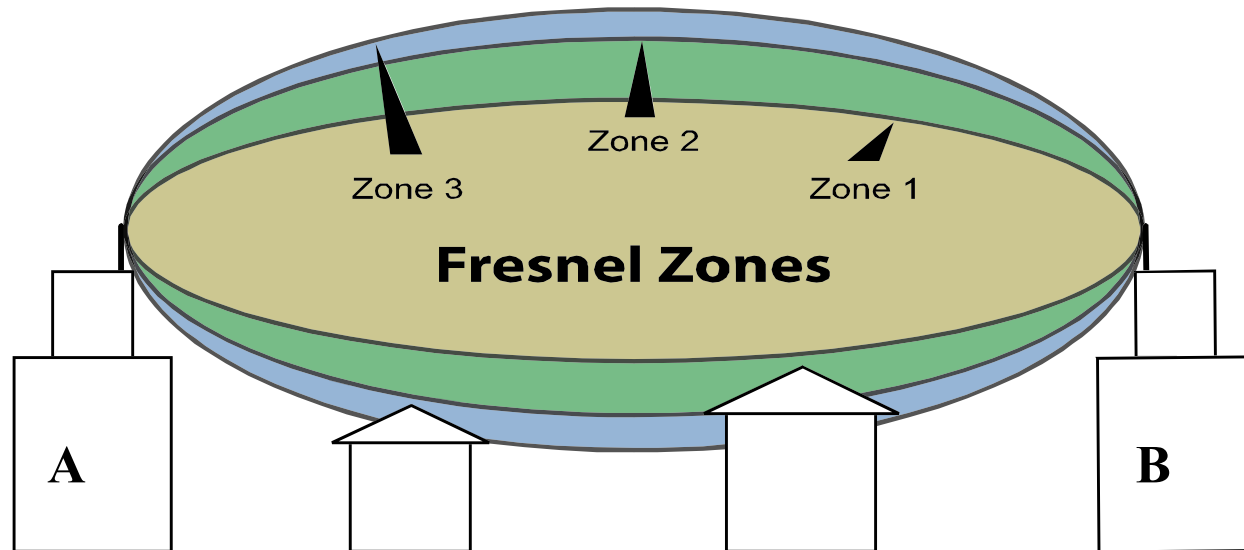
Antenna  
Gain

Receiver  
Sensitivity

Path  
Loss

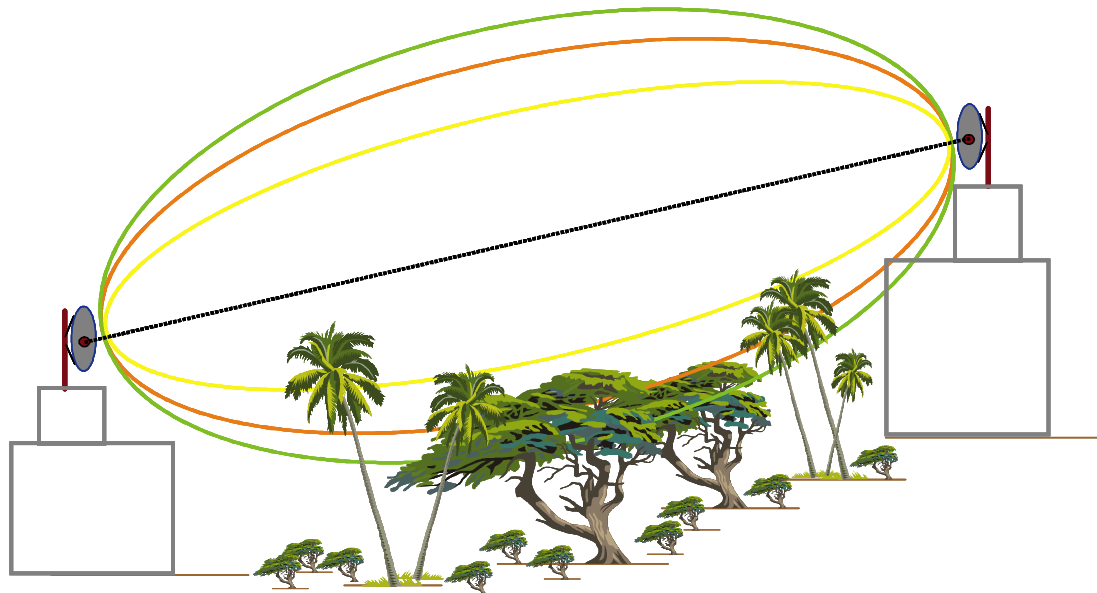
# Theory

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



# Theory

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  - Raise antennas to help clear the zone

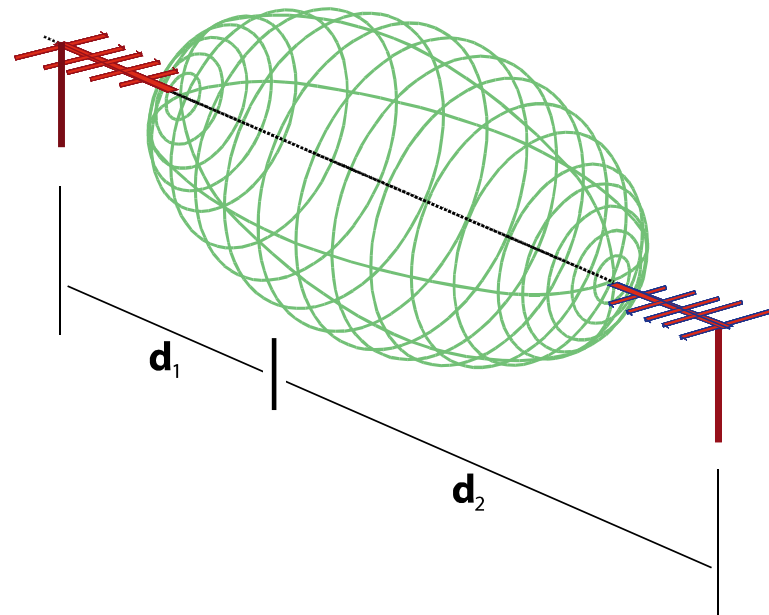




# Theory

- 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
<b>1000 ft. (300 m)</b>	<b>16 ft. (5 m)</b>	<b>11 ft. (3.4 m)</b>
<b>1 Mile (1.6 km)</b>	<b>32 ft. (10 m)</b>	<b>21 ft. (6.4 m)</b>
<b>5 Miles (8 km)</b>	<b>68 ft. (21 m)</b>	<b>43 ft. (13 m)</b>
<b>10 Miles (16 km)</b>	<b>95 ft. (29 m)</b>	<b>59 ft. (18 m)</b>

# 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
<b>1000 ft. (300 m)</b>	<b>81 dB</b>	<b>90 dB</b>
<b>1 Mile (1.6 km)</b>	<b>96 dB</b>	<b>104 dB</b>
<b>5 Miles (8 km)</b>	<b>110 dB</b>	<b>118</b>
<b>10 Miles (16 km)</b>	<b>116 dB</b>	<b>124</b>



# 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

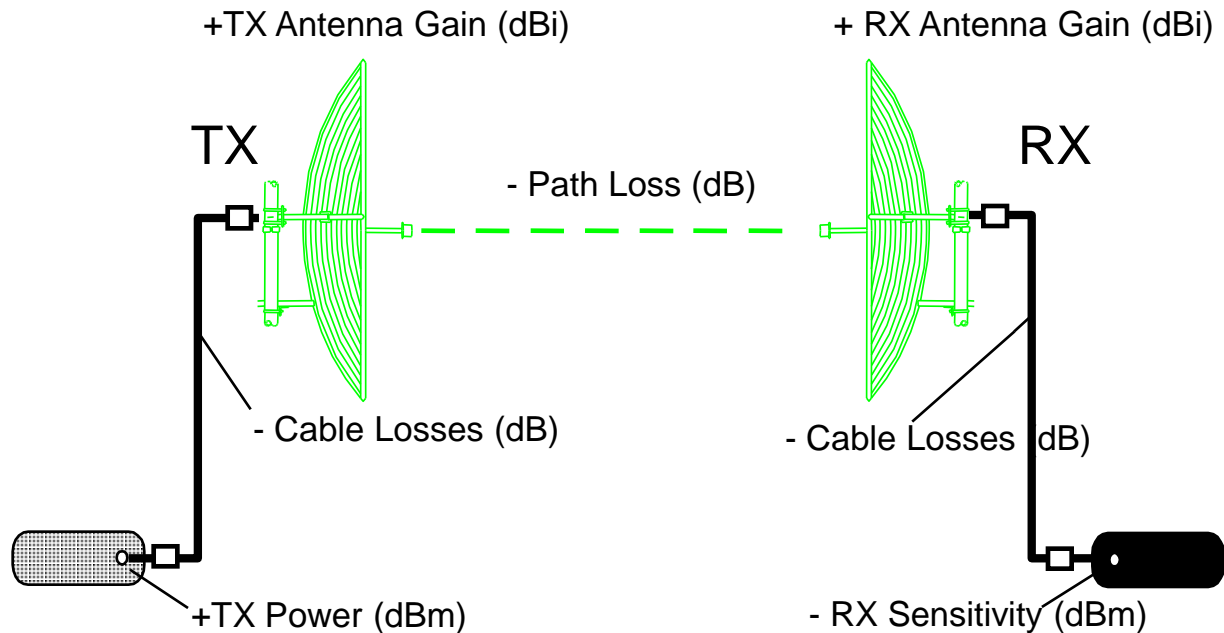
- Antenna cables
  - Mounting and cable considerations

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 = ?

$$20 - (-102) - 2 + 8 + 2 = 130 \text{ dB}$$

- How far can we transmit?

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

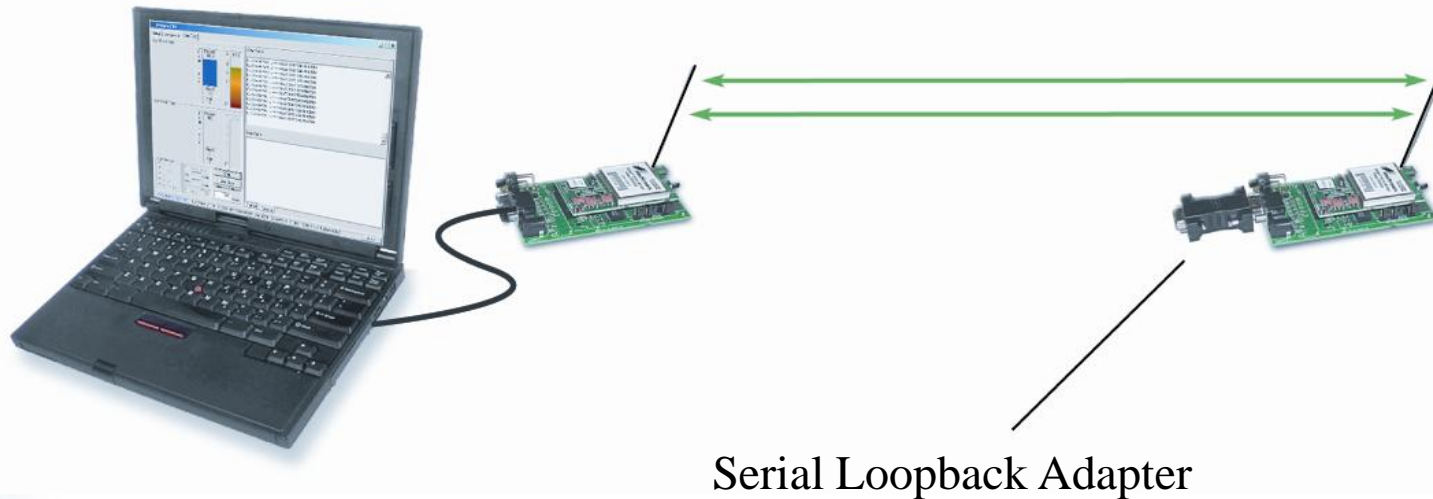
**Answer: 5 miles line-of-sight**

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”

X-CTU [COM1]

PC Settings | Range Test | Terminal | Modem Configuration

Start

Clear Stats

Advanced >>>

Test

Loop Back

Range Test

Percent 100.0

-40

R  
S  
S  
I

Good 48

Bad 0

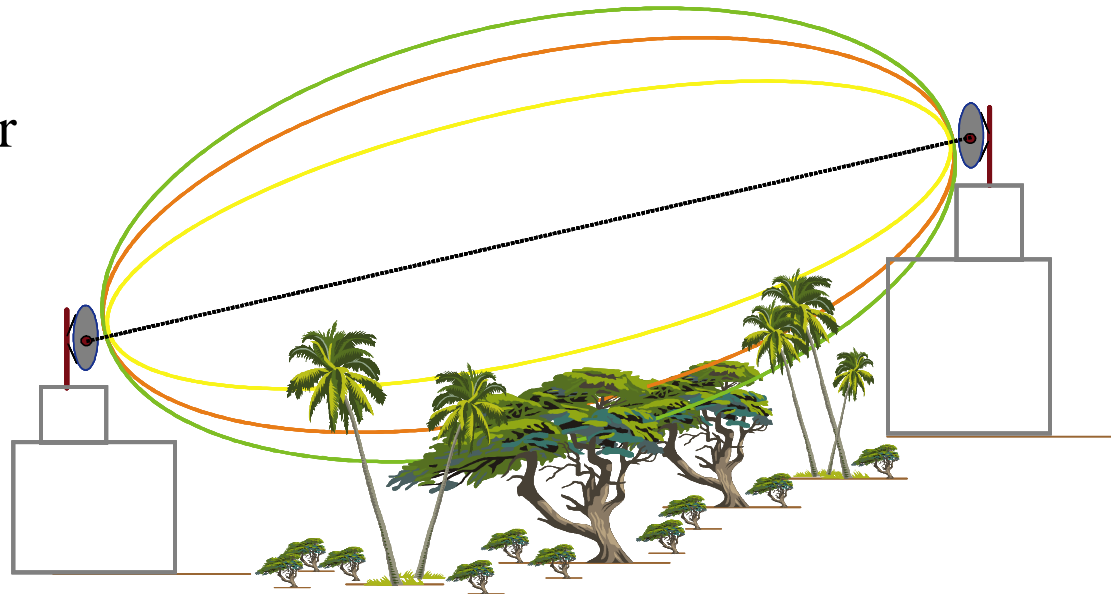
```
0123456789: ;<=>?@ABCDEFGHIJKLMNO
0123456789: ;<=>?@ABCDEFGHIJKLMNO
0123456789: ;<=>?@ABCDEFGHIJKLMNO
0123456789: ;<=>?@ABCDEFGHIJKLMNO
0123456789: ;<=>?@ABCDEFGHIJKLMNO
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```

Transmit | Receive

COM1 9600 8-N-1 FLOW:NONE

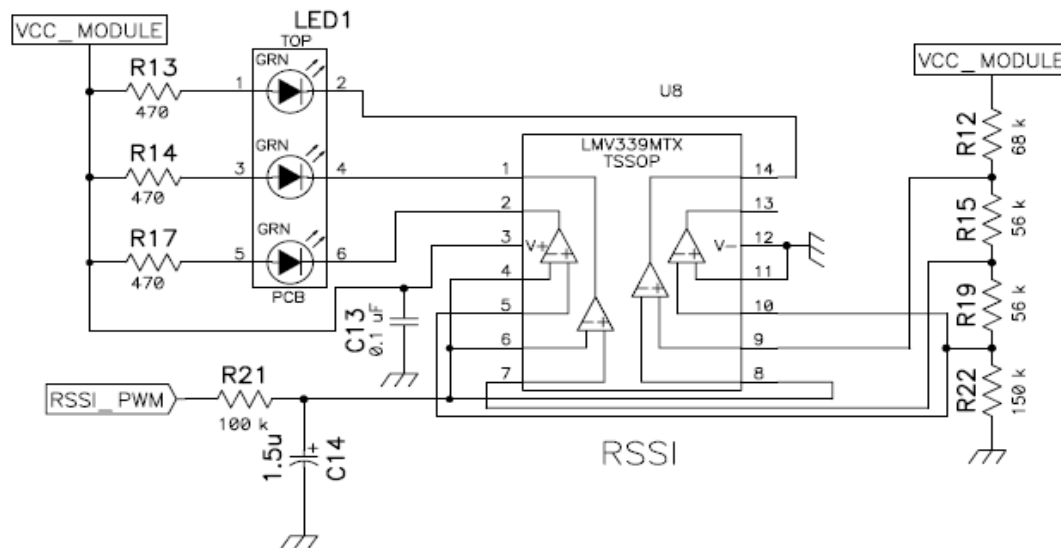
# Practice

- 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)



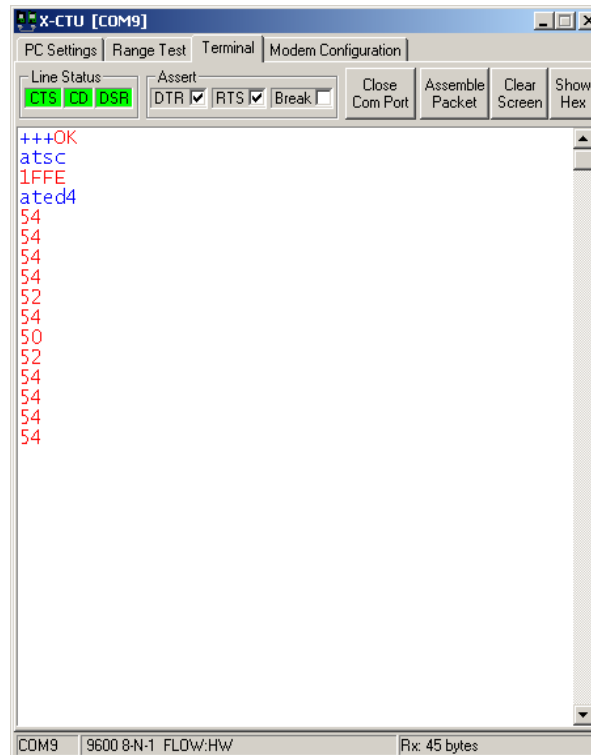
# Practice

- 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



The screenshot shows a terminal window titled "X-CTU [COM9]". The window has tabs for "PC Settings", "Range Test", "Terminal", and "Modem Configuration". The "Terminal" tab is active. The terminal interface includes a "Line Status" section with "CTS", "CD", and "DSR" indicators, and an "Assert" section with "DTR", "RTS", and "Break" checkboxes. Below these are buttons for "Close Com Port", "Assemble Packet", "Clear Screen", and "Show Hex". The terminal output shows the following text:

```
+++OK
atsc
1FFE
ated4
54
54
54
54
52
54
50
52
54
54
54
54
```

At the bottom of the window, the status bar displays "COM9 | 9600 8-N-1 FLOW:HW | Rx: 45 bytes".



# Practice

- Identify interference
  - Spectrum analyzer



# Practice

Site Survey = Range + Interference Testing

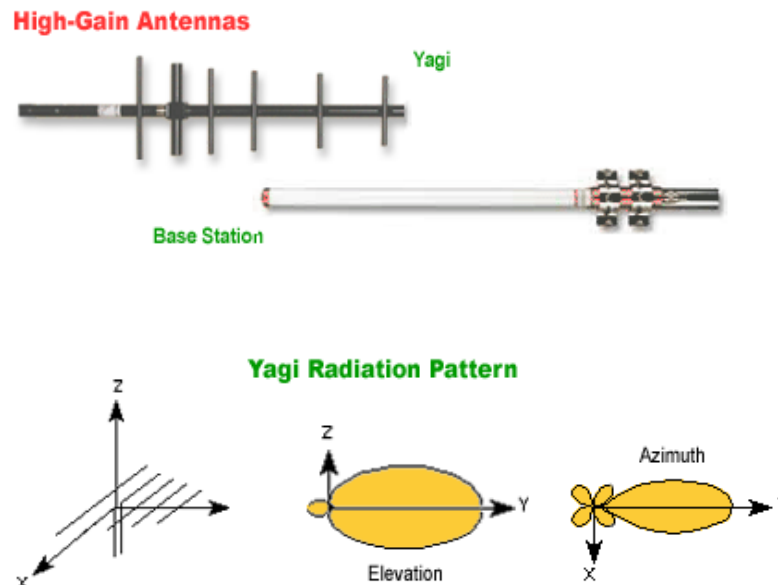
Bottom Line:



Packets received more important than RSSI

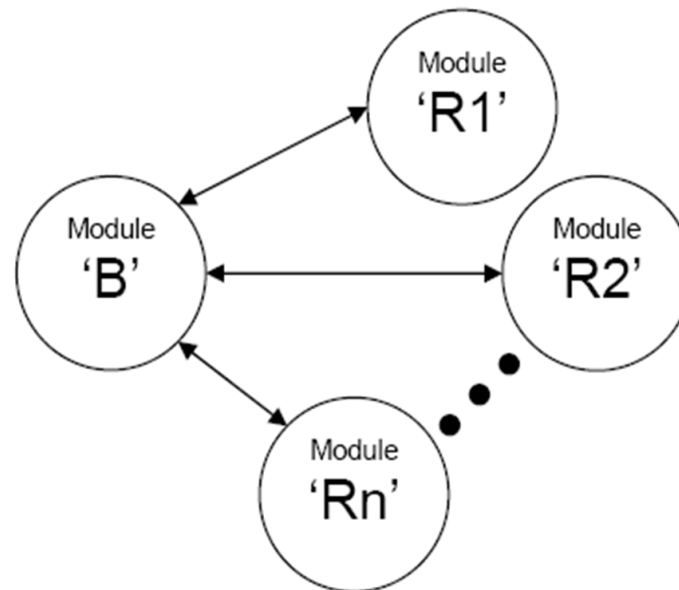
# Application

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



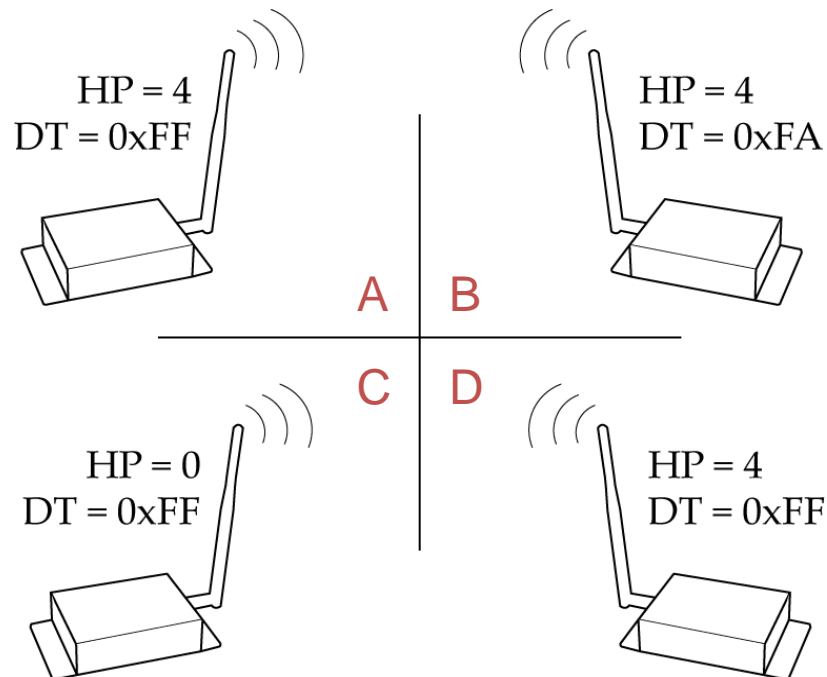
# Application

- 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?

