Analysis and Development of High Integrity Wireless Systems

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Overview

- Problem
- Wireless Standard
- Channel Effects
  - Spatial Error
  - Coexistence
- Model
- Higher integrity
  - Amplifier
  - Encoder
  - PN Sequencer with correlator
  - Detect and Avoid

Problem (Test equipment specs)

- Bit error rate of 10^{-6} (1 out of a million bits in error)
- Range of 30 meters
- Inexpensive
- Hardware commercially available
- Low Battery Power
- Needs to operate in unlicensed frequency band (2.4 or 5 gig bands)

Standard

- Choices:
  - Bluetooth
  - Zigbee
  - 802.11
  - UWB 802.15.3

Standard: Zigbee 802.15.4

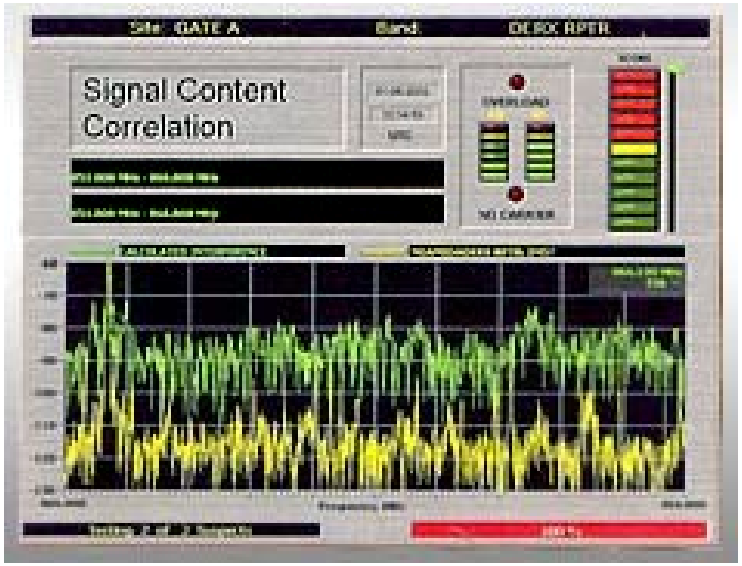
- Operation Band: 2.4-2.483.5 GHz
- Number of Non Overlapping channels: 3
- Technology: DSSS (direct spread spectrum) PN sequencer
- Max data rate: 250 Kbps
- Lowest Power

Test Hardware: Zigbee

- Two chip solution
  - Radio→ Baseband, RF module
  - Radio Controller→ Microcontroller
- Antenna
  - Planar
- Battery (lithium ion)

Interference

- Know thy enemy (Modeling approach)
  - Distance Effects (Rayleigh)
  - Coexistence
  - Phase shift (Rice)→ negligible



- Open Field Signal to Noise Ratio

$$\lambda = \frac{c}{f} \qquad k = \frac{\lambda^2}{(4\pi)^2}$$

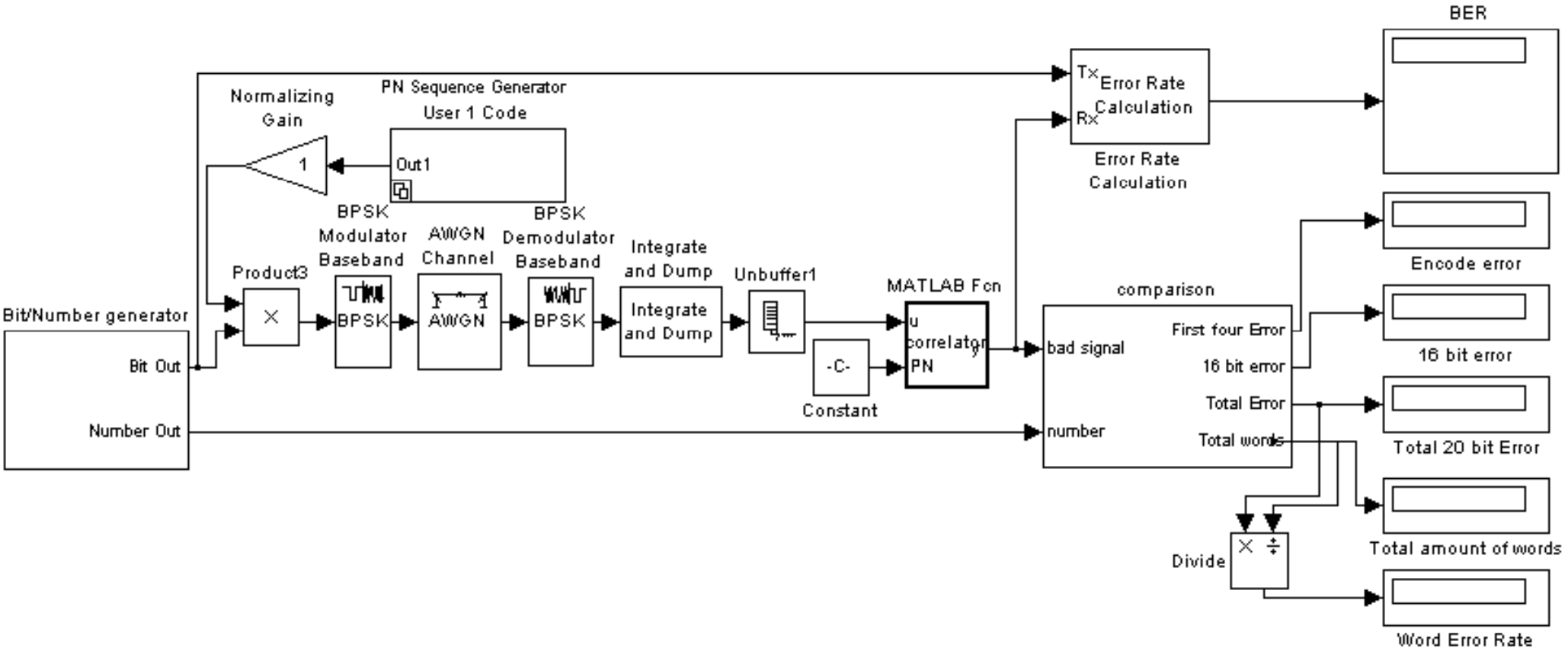
$$O = 10\log_{10}\left[k\left(\frac{1}{D}\right)^{2.7}\right]$$

•Open Field Signal to Noise Ratio cont.

$$\rho = P - O$$

$$T = y + \left(\sqrt{10^{\frac{\rho - 30}{10}}} \right) r$$

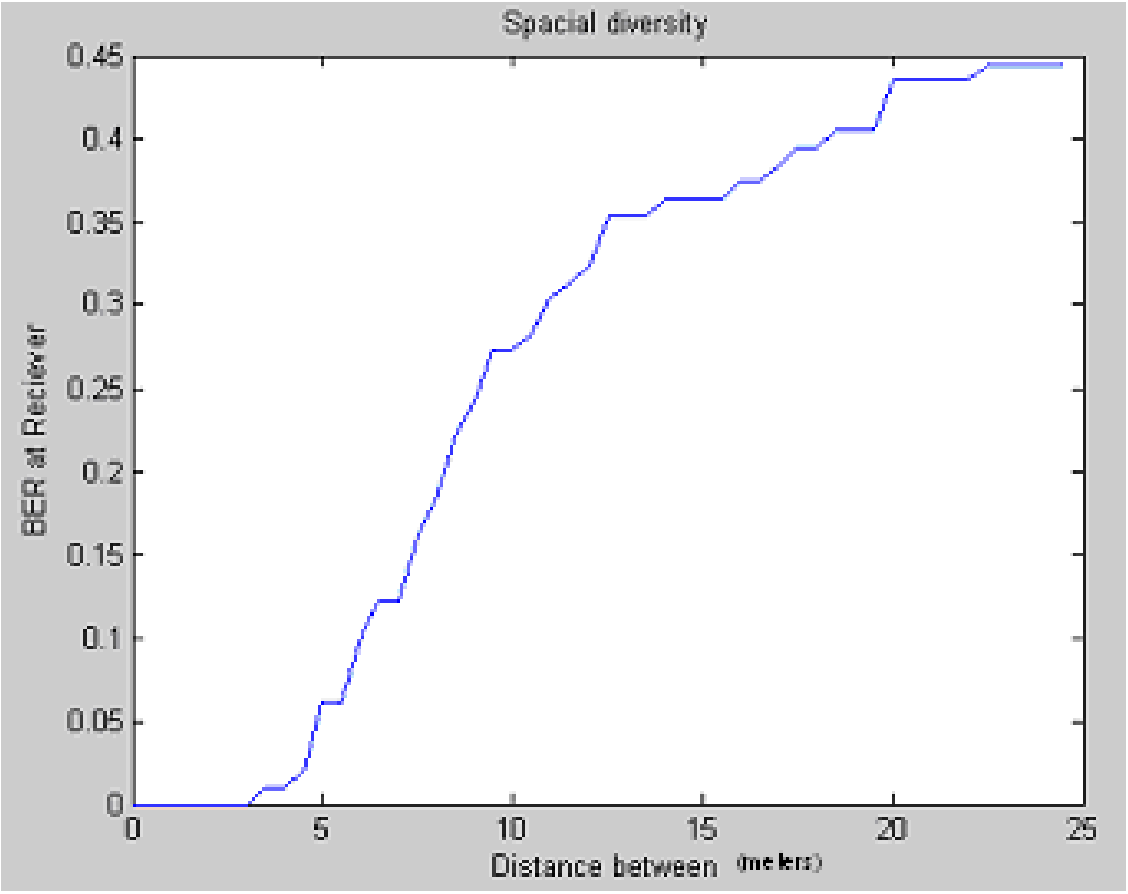
Model (Spatial Error)



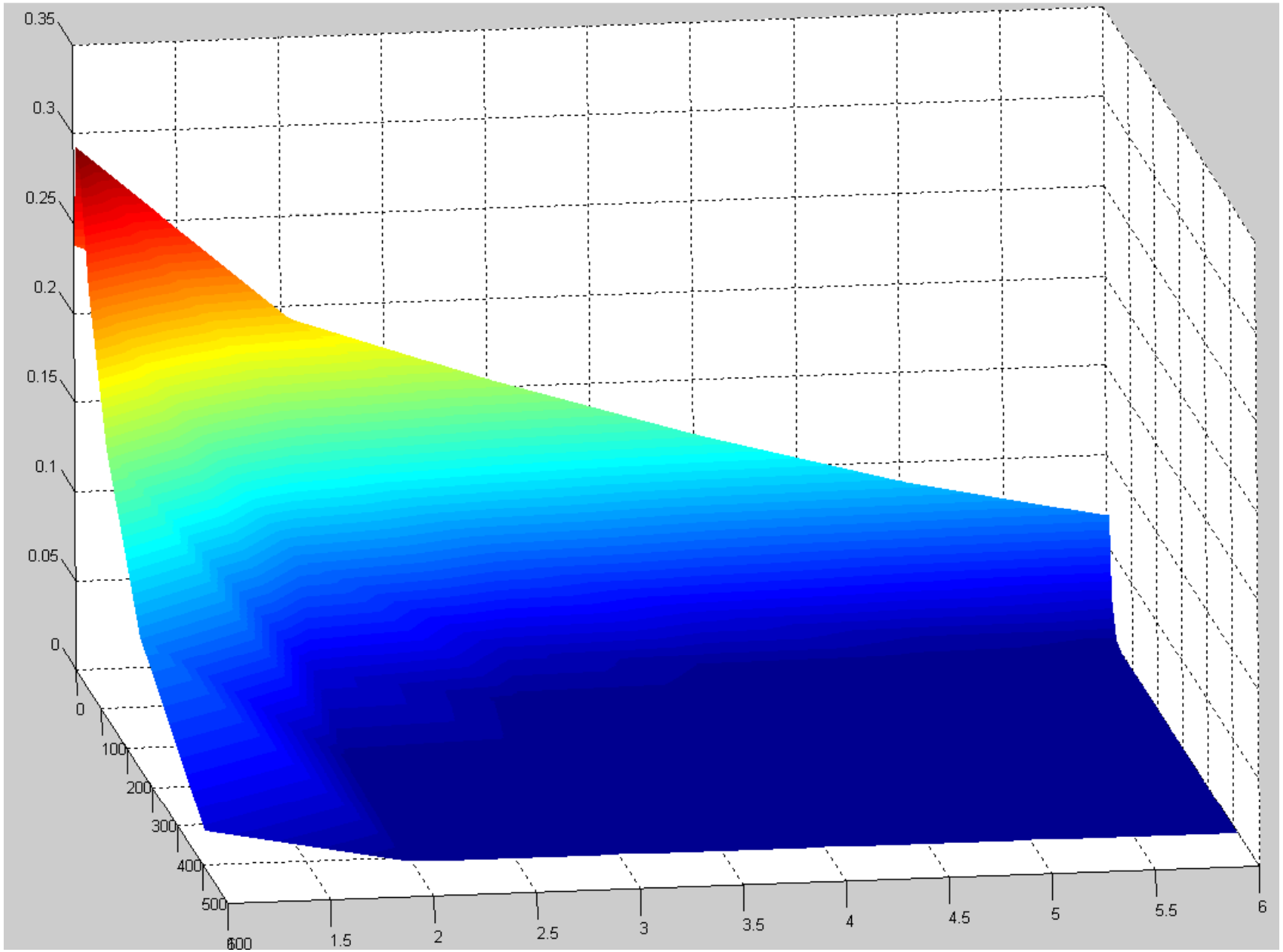
Model (Spatial Error Justification)

Test #	4.25 m	Bit Error Rate
1	1000 pts	0.016
2	1000 pts	0.014
3	1000 pts	0.015
4	1000 pts	0.015

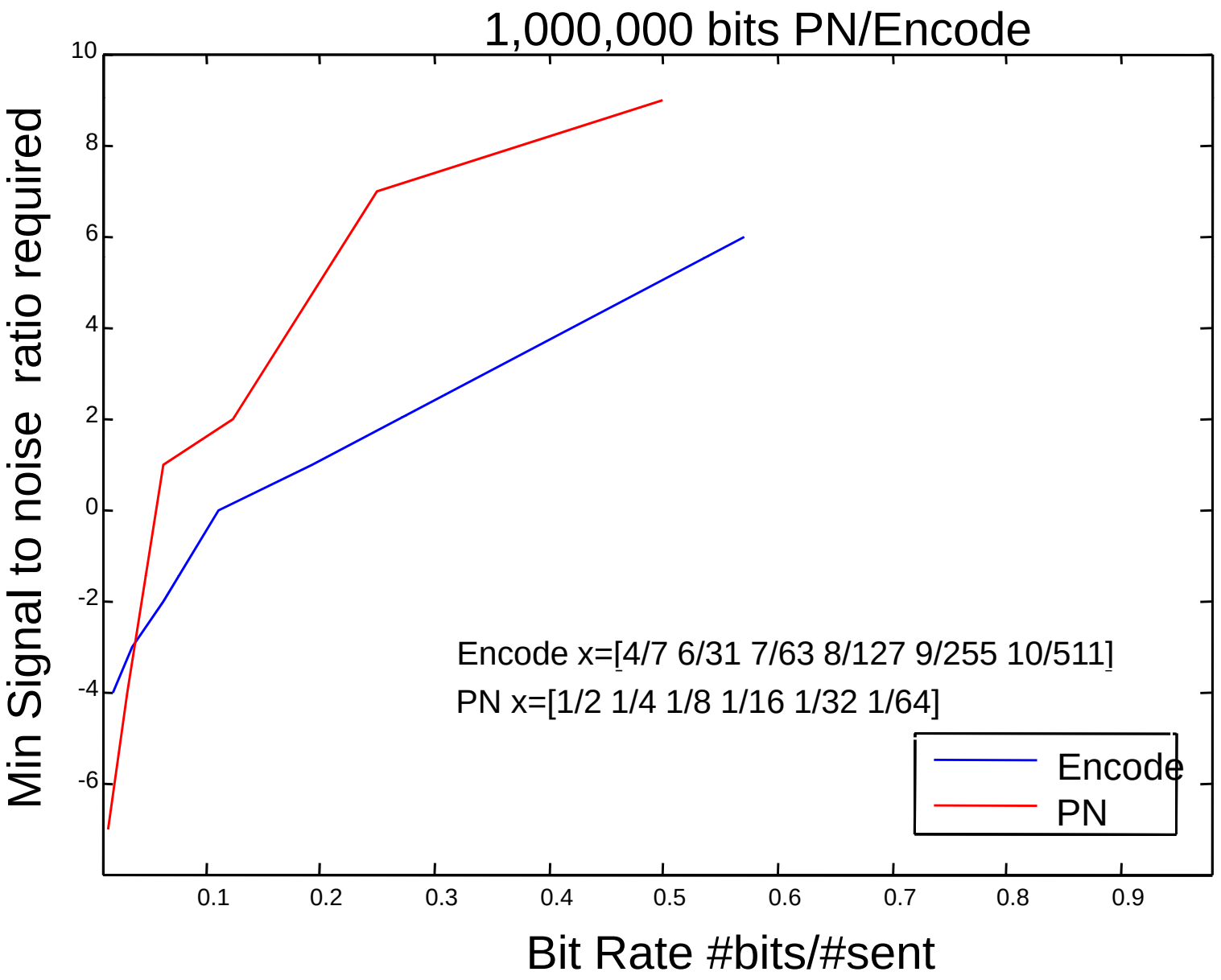
Test #	11.58 m	Bit Error Rate
1	1000 pts	0.42
2	1000 pts	0.031
3	1000 pts	0.25
4	1000 pts	0.44



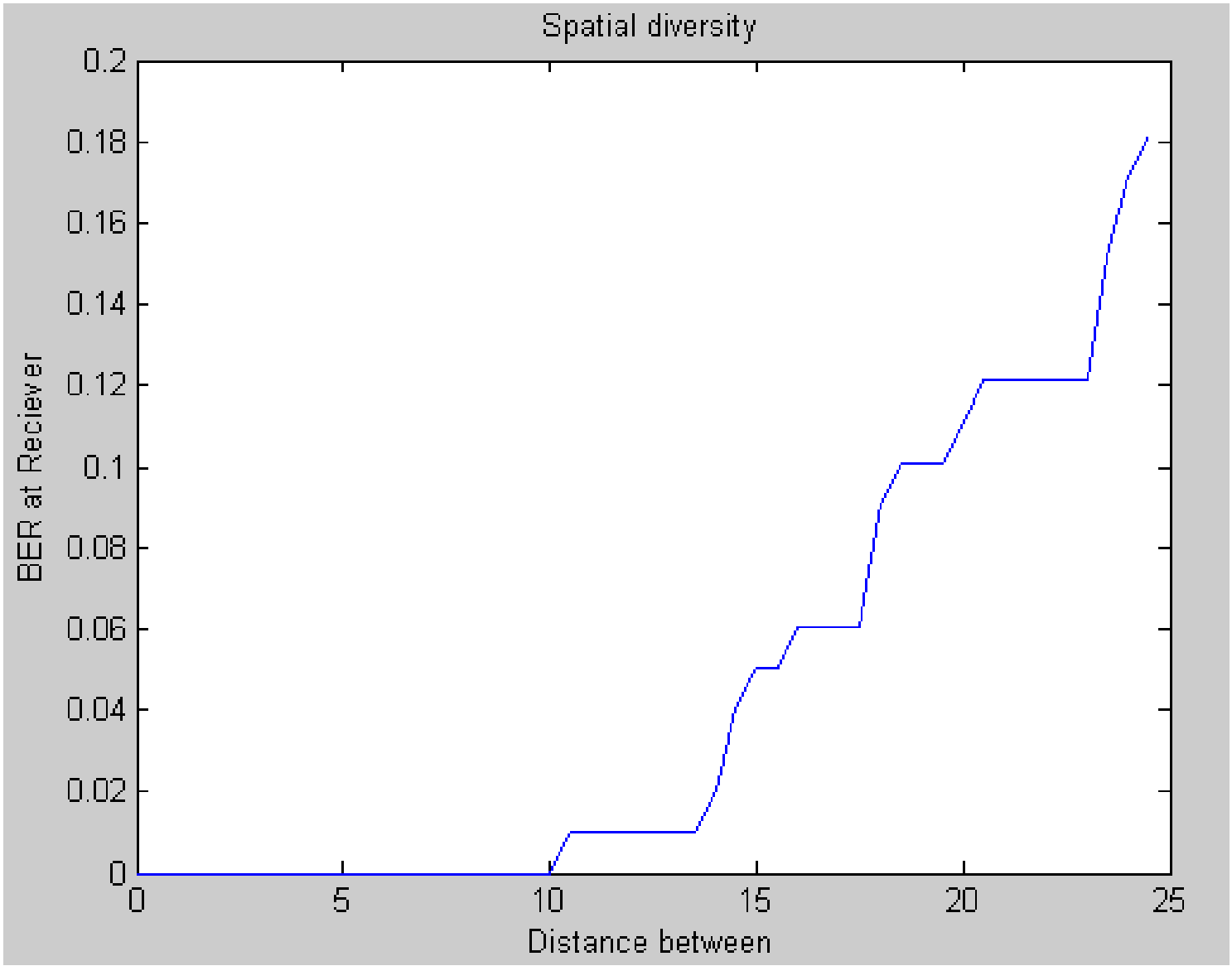
Chip Number vs. Interference Level



PN or Encoder

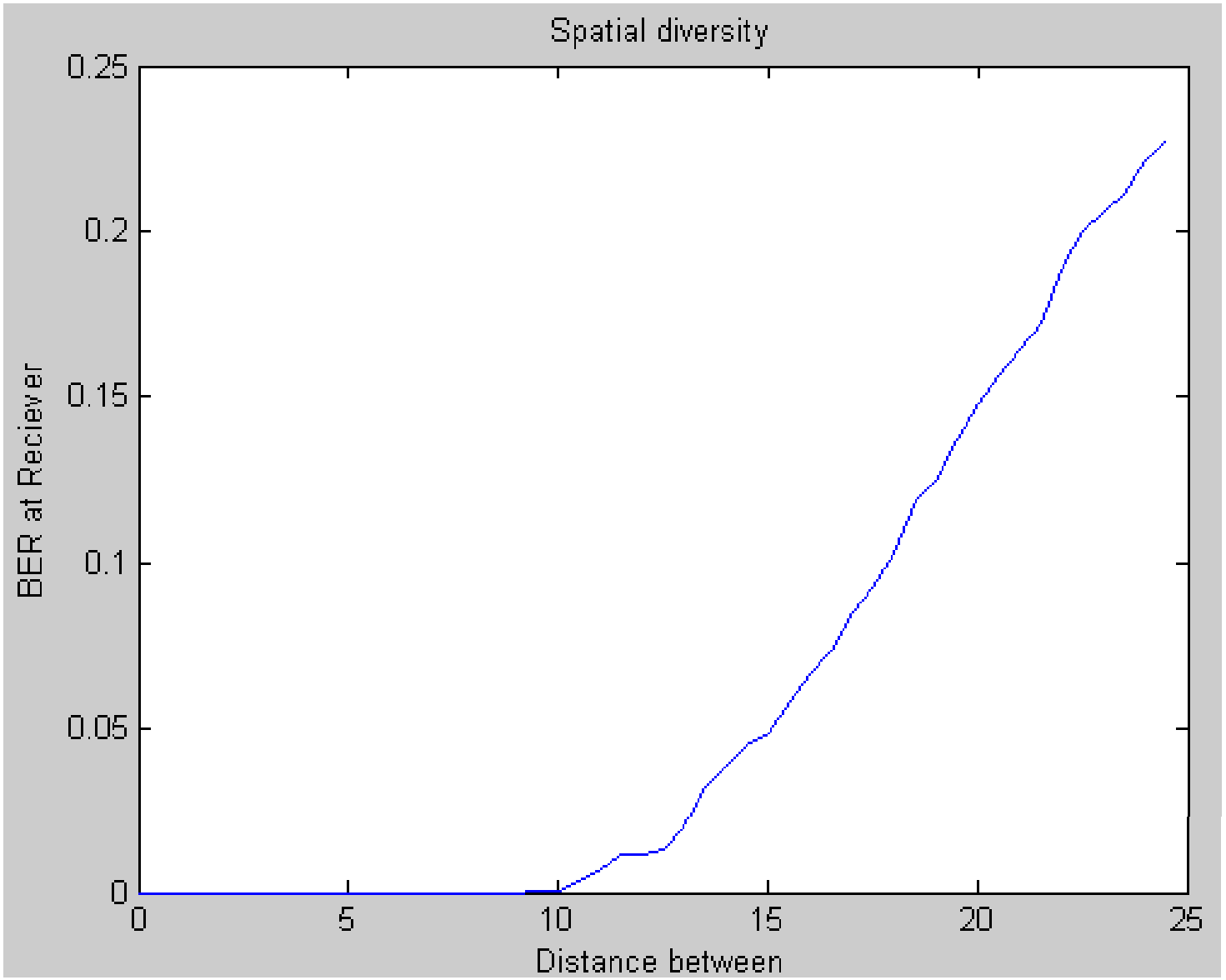


Amplifier or Directional Antenna



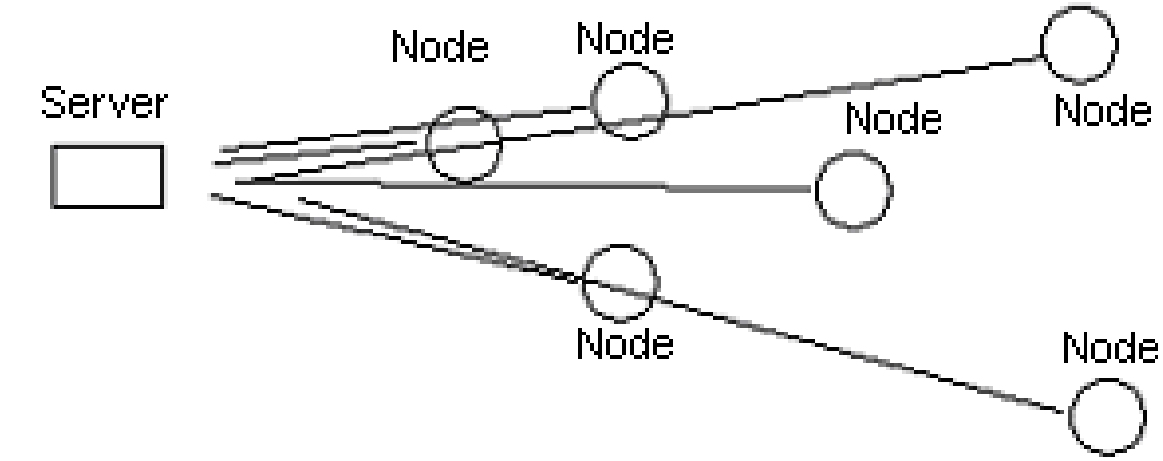
Amplifier

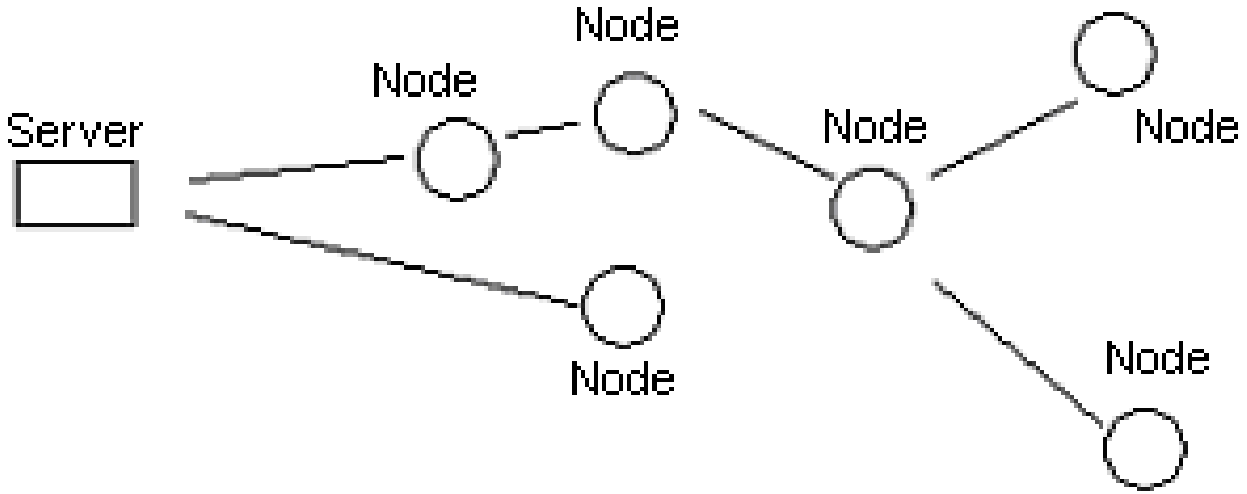
Model Upgrades



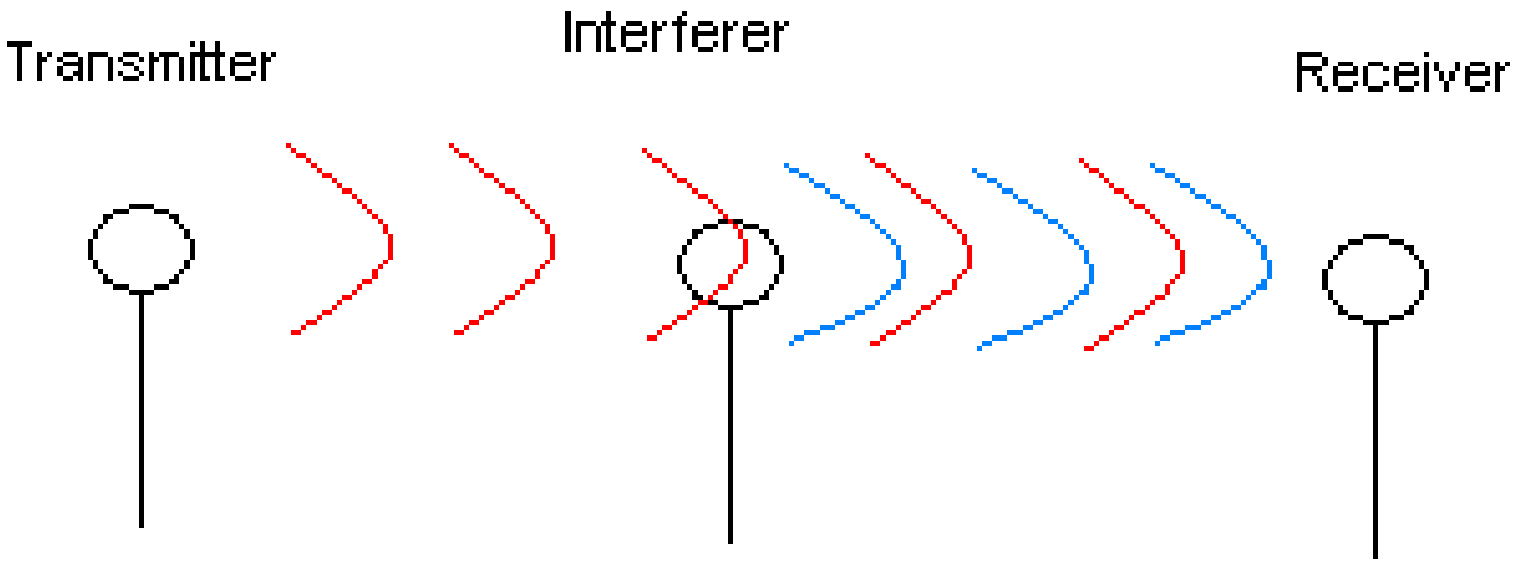
Encoder and Amplifier

Distance Solution

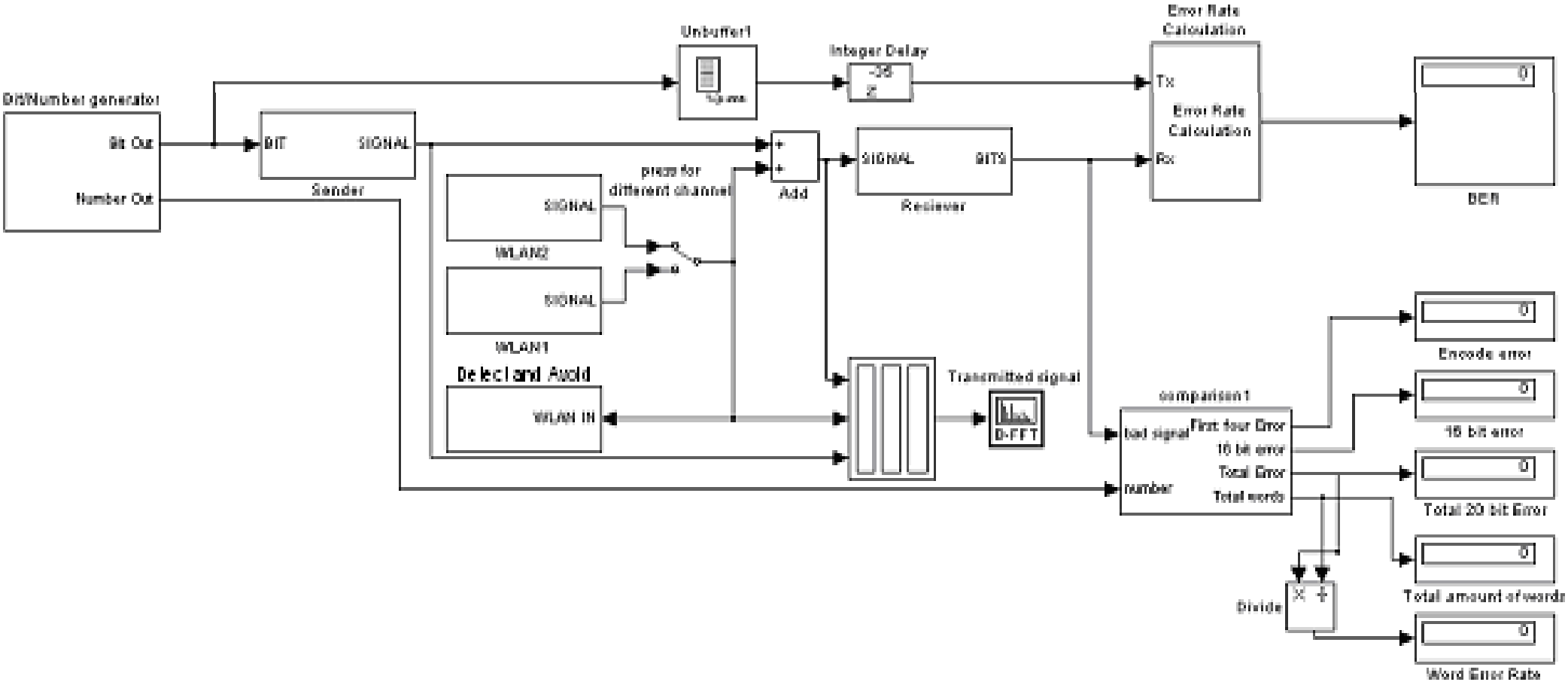




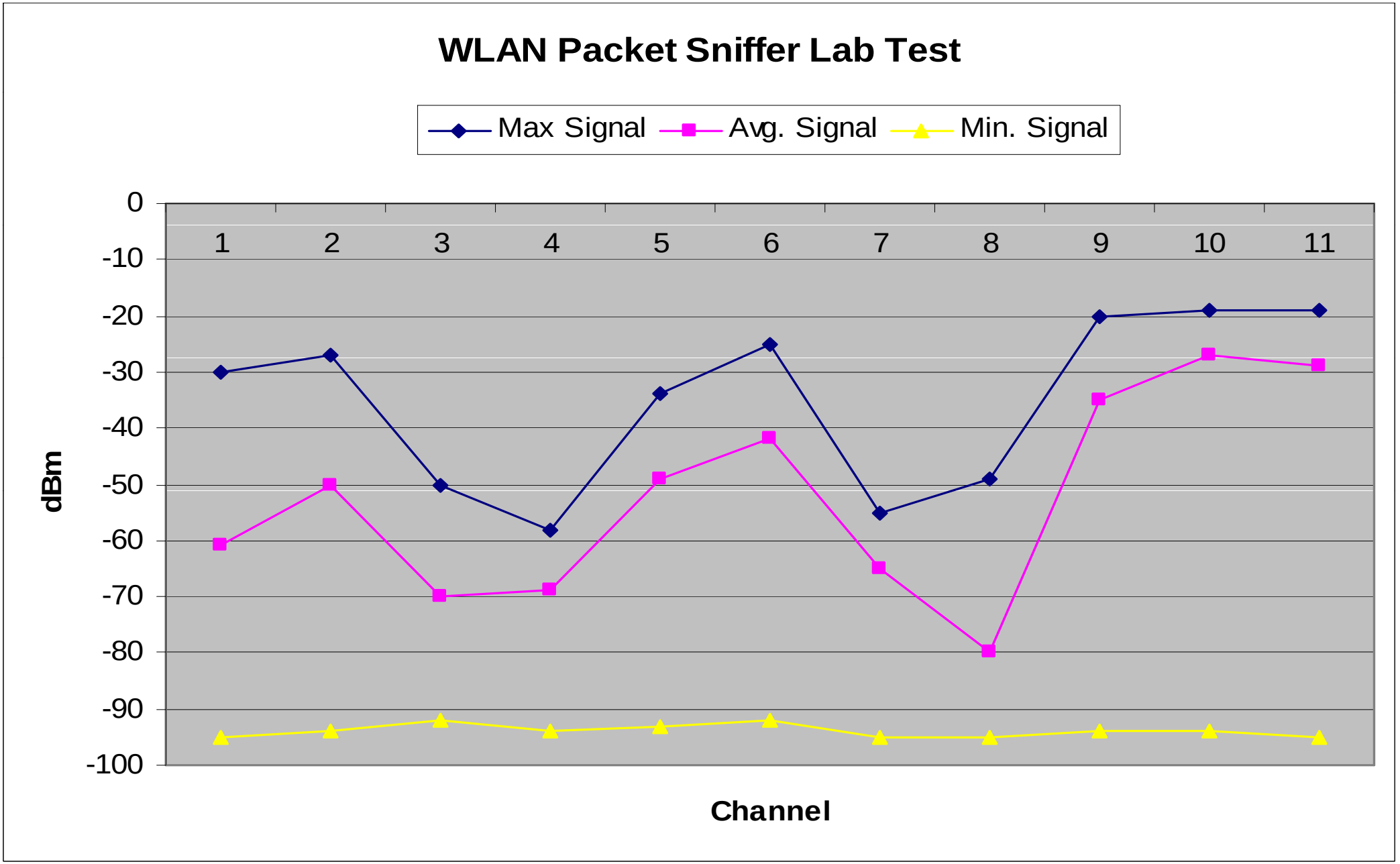
Coexistence



Model Coexistence

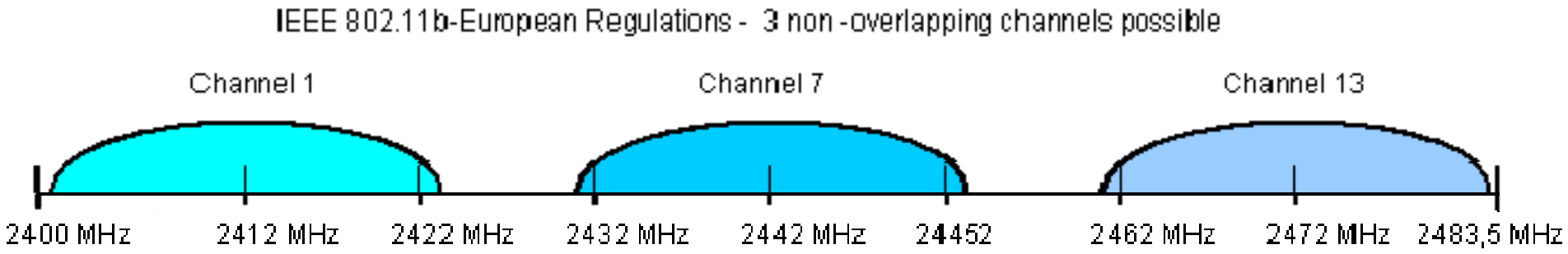


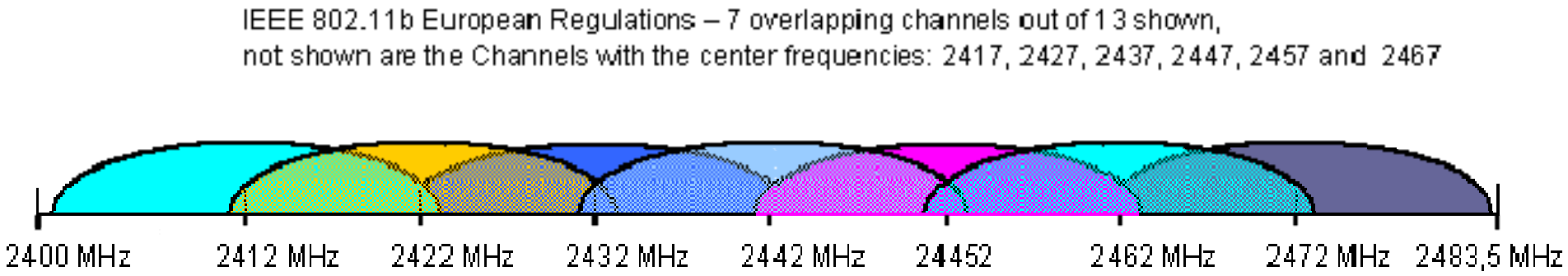
Typical WLAN Power Output

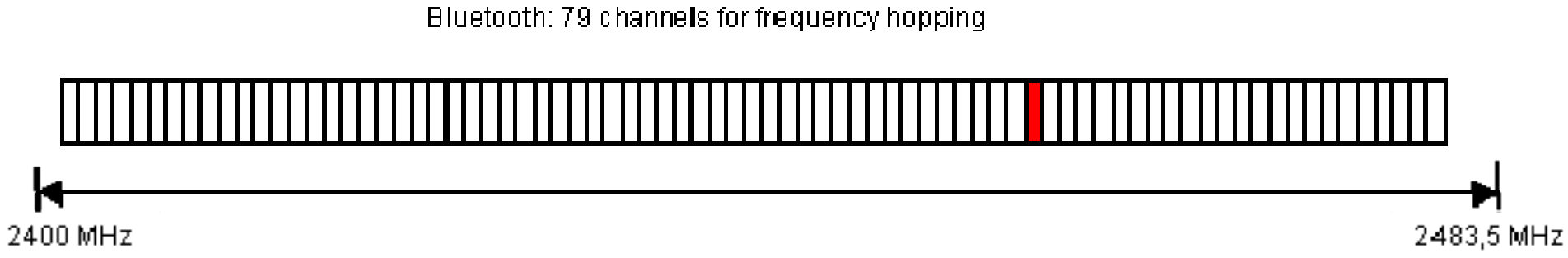


Solution: Detect and Avoid

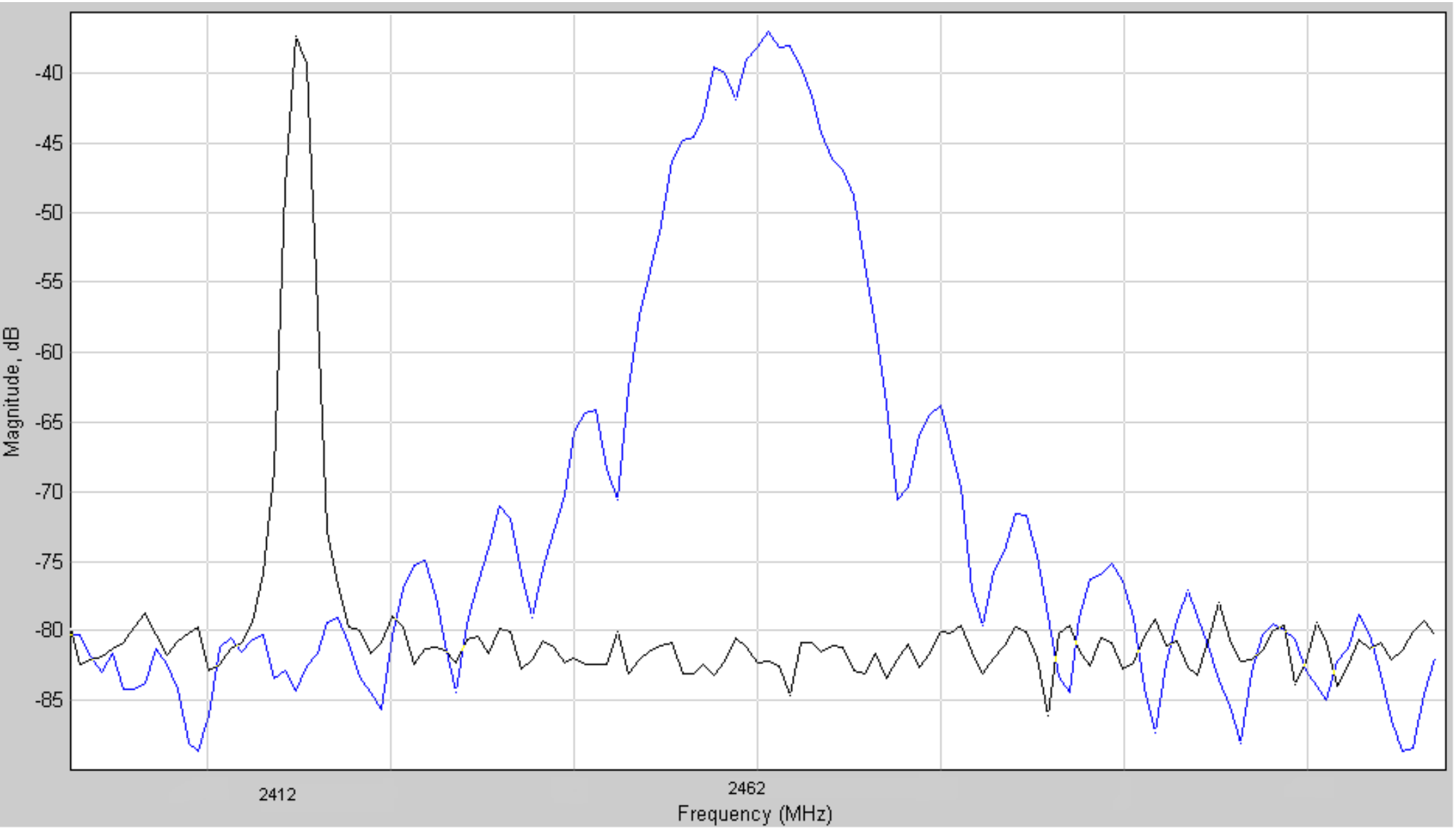
- Frequency Band Hopping
- Listen then send on other frequency





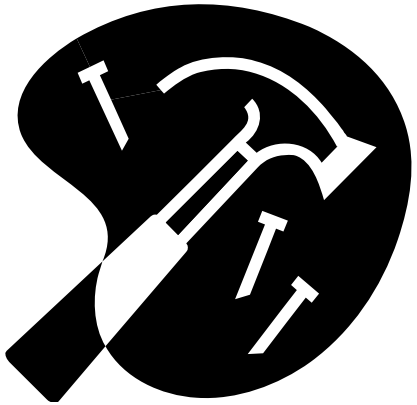


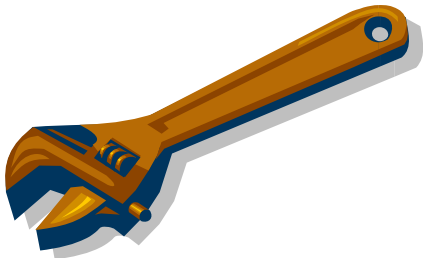
Model Output



Uses

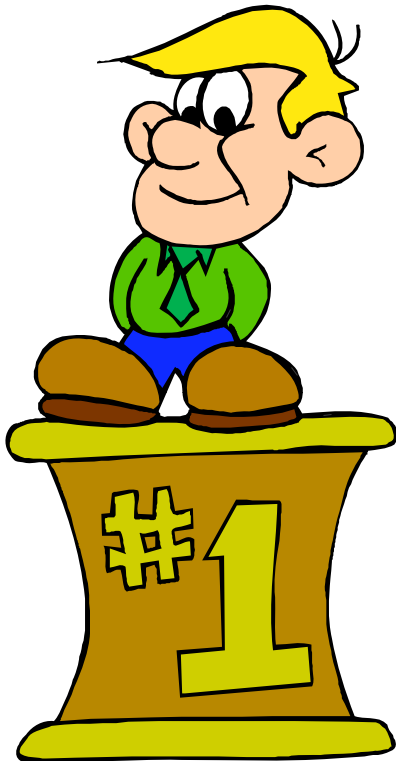
- Industrial applications
- Control Systems
- When the signal REALLY needs to get there
- Theoretically BER can compete with wires (10^-9)
  - More analysis would be needed
- Data Rate not an issue





Best way?

- Mesh Network
- Amplifier or Directional Antenna
- “Good” Encoder
- Detect and Avoid
- Depends on the need
- Trade offs



Special Thanks

- Goodrich Aerospace Vergennes, VT
- Lockheed Martin Owego, NY