
# RF Homework and Fieldwork

with Paul Nothnagel

# Binary Helix Technologies

- Started in 2011
- Young people with fresh ideas.
- High-tech
- Google integrated

- What we do:
  - Signal plotting
  - Platform simulators
  - System integrators
  - Large wireless deployments
  - Community networks

We create sustainable wireless!

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# What to learn in 45min

- Link feasibility.
- Estimating link capacity.
- Stability in all circumstances.
- Wireless from the RF perspective.

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# Multi-Zone Coverage

- High density urban

- Communities

- Industrial

- Rural and agriculture

- Long distance backhaul

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# Wireless is an art.

- RF propagation can be calculated in theory.
- Practice should be similar.
- Each location is different.
- Do thorough homework before deployment.

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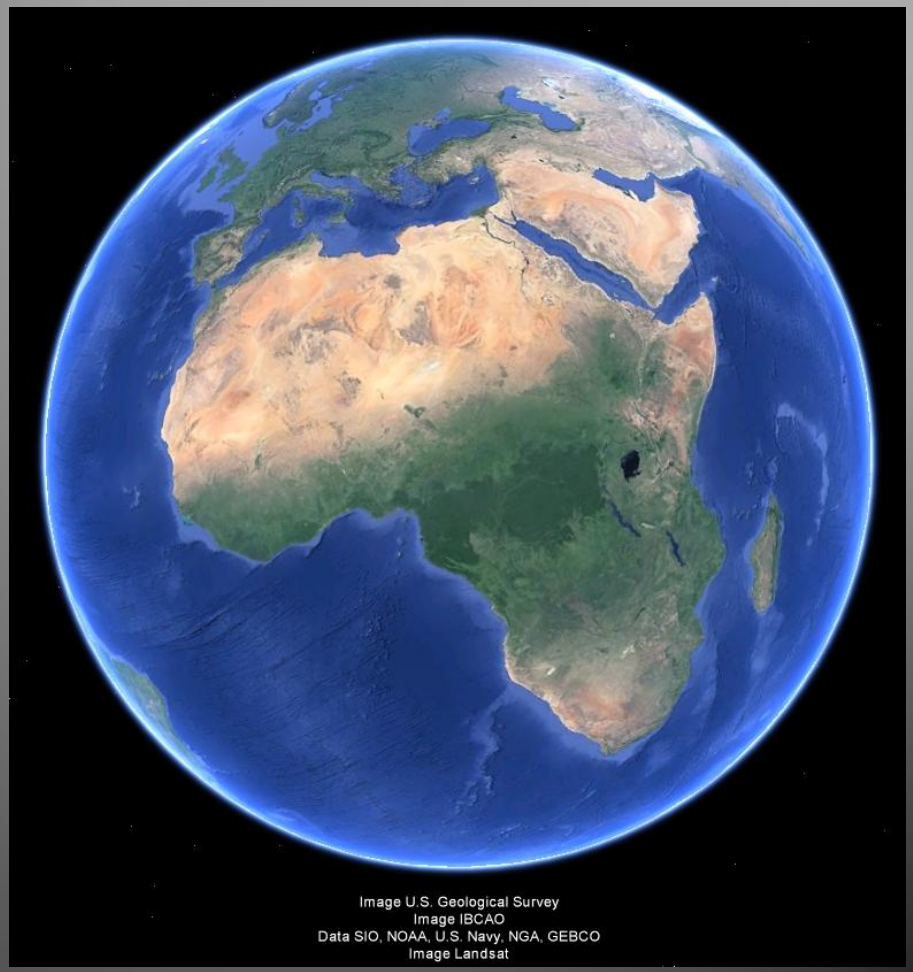
# Google Earth

- Satellite Imagery (Aerial Maps)
- Elevation Profile
- Pinpointing Features
- Streetview
- Location Accessibility
- 3D landscapes

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# Design for your environment

- Different types of terrain.
- Different end uses.
- Different deployments
- Do thorough homework before deployment.

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# Identify your deployment

- Range
- Elevation Profiles
- Desired Coverage
- Bandwidth Required
- Mobile/Stationary

- Point-to-point
- Point-to-multipoint
- Mesh
- Omni-directional
- Directional

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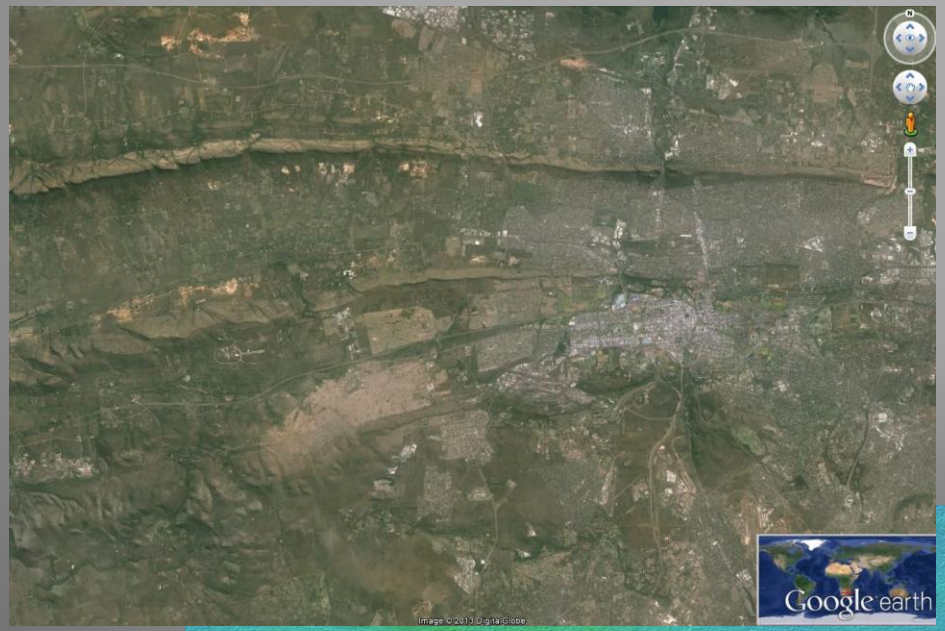
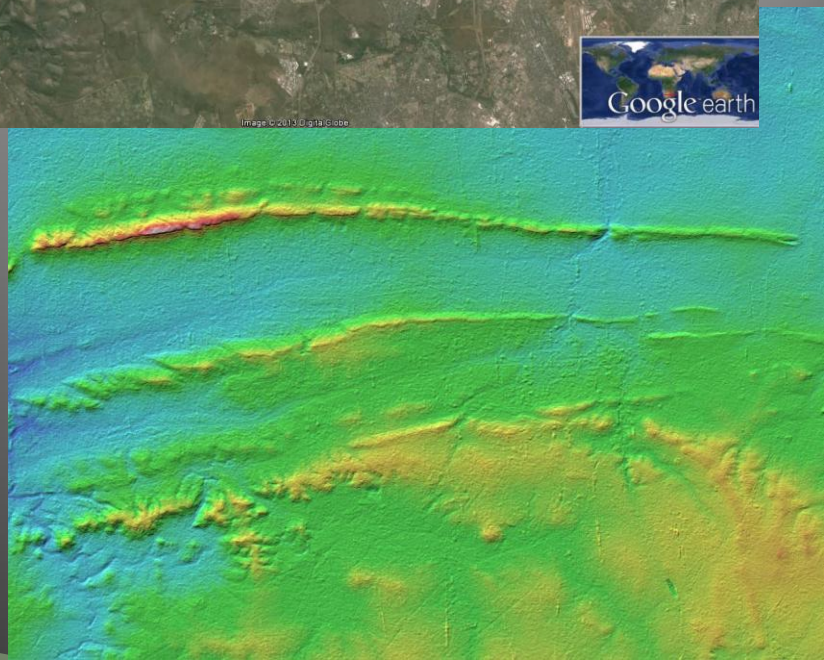
# Satellite Imagery

- Terrain Evaluation (Incl. Tree Density)
- Demographic Overview
- Obstacle Identification
- Land Cover



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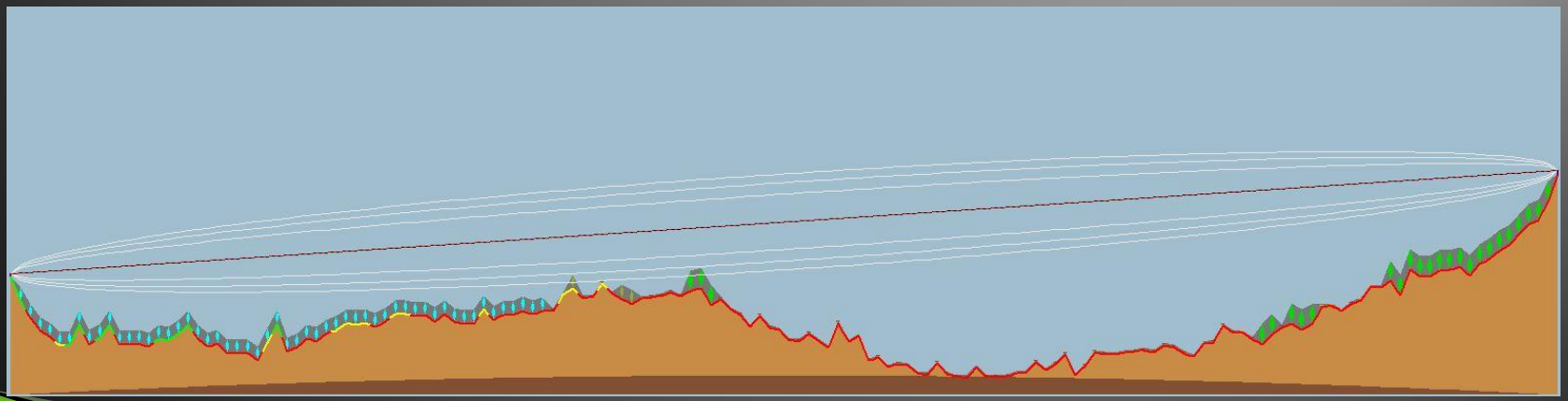
# Elevation Profile

- Google Earth Profile


- Satellite DEM profile



- Includes land cover

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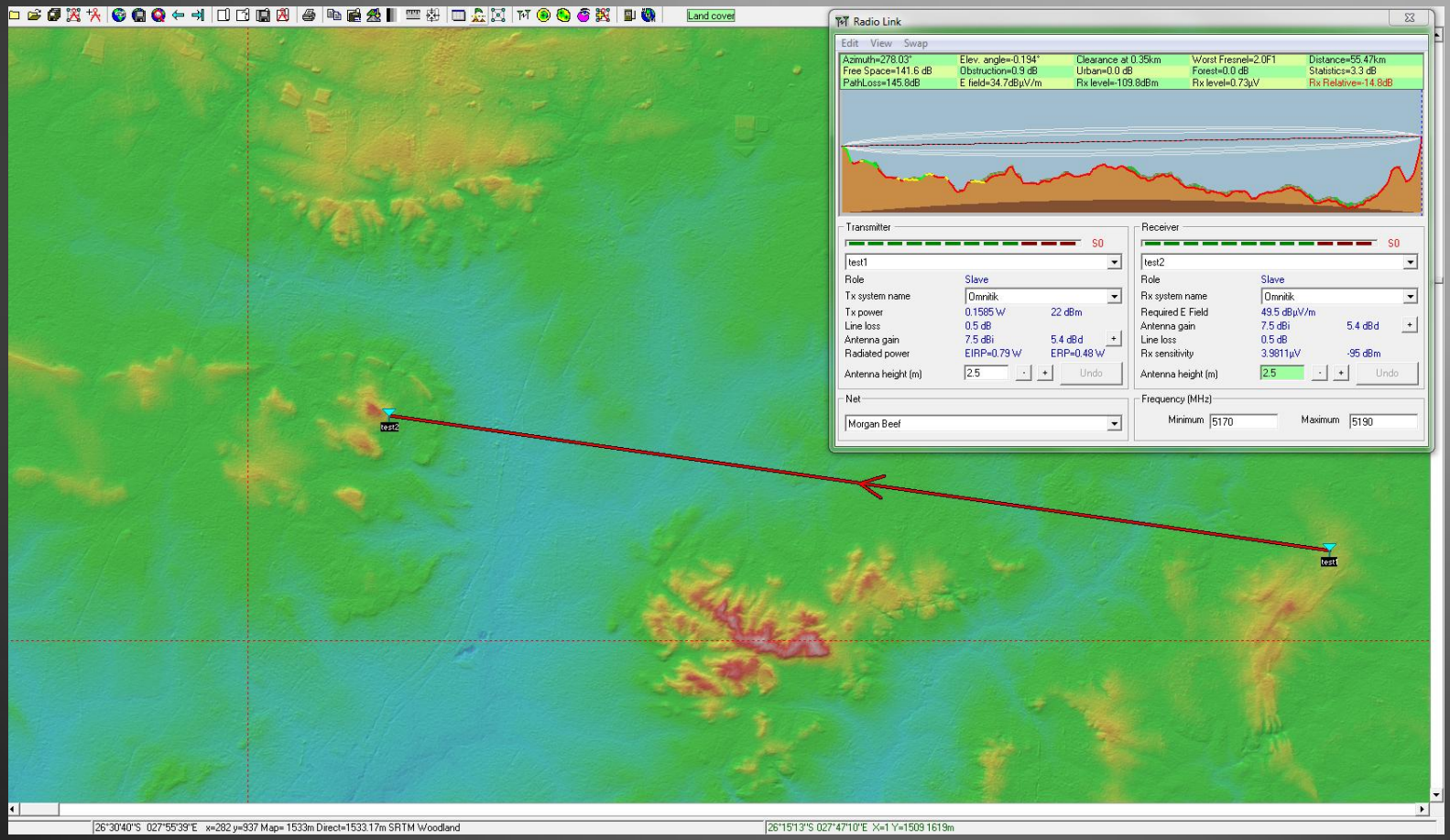
# The Earth's Curvature

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# The killers of wireless

- Diffraction (FSPL)
- Diffraction in fresnel zone
- Reflections and multipath
- Polarisation Mismatch
- Interference
- Inter symbol interference
- Trees
- Buildings
- Mountains
- Rain
- Snow

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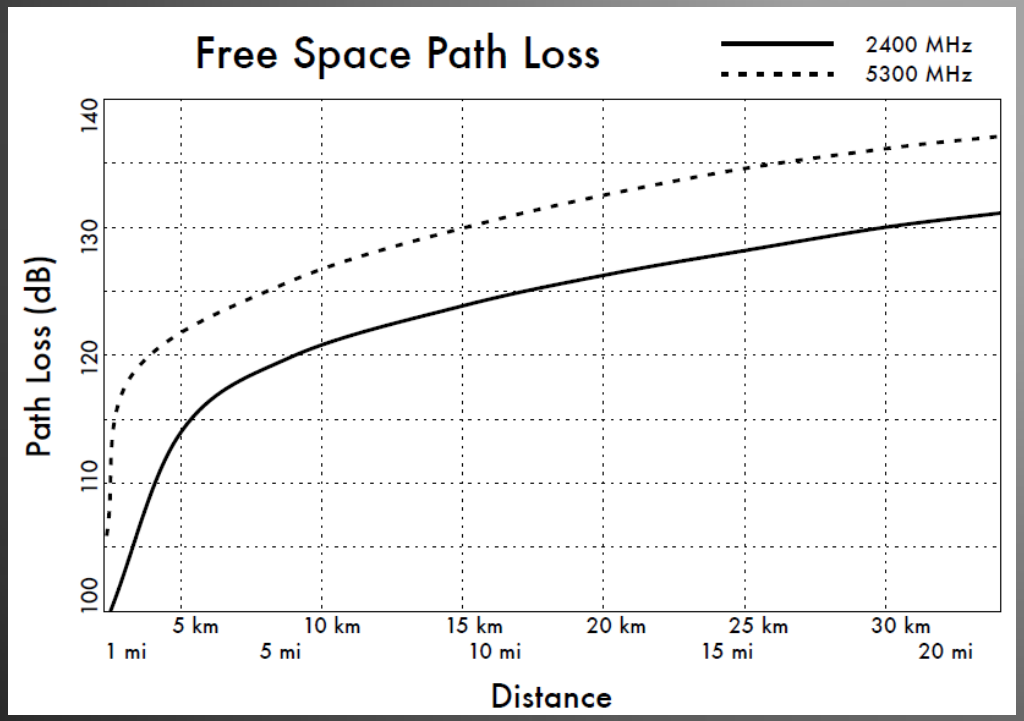
# Free Space Path Loss




$$\begin{aligned} \mathrm{FSPL} &= \left(\frac{4\pi d}{\lambda}\right)^2 \\ &= \left(\frac{4\pi df}{c}\right)^2 \\ &= 20\log_{10}\left(\frac{4\pi}{c}df\right) \end{aligned}$$

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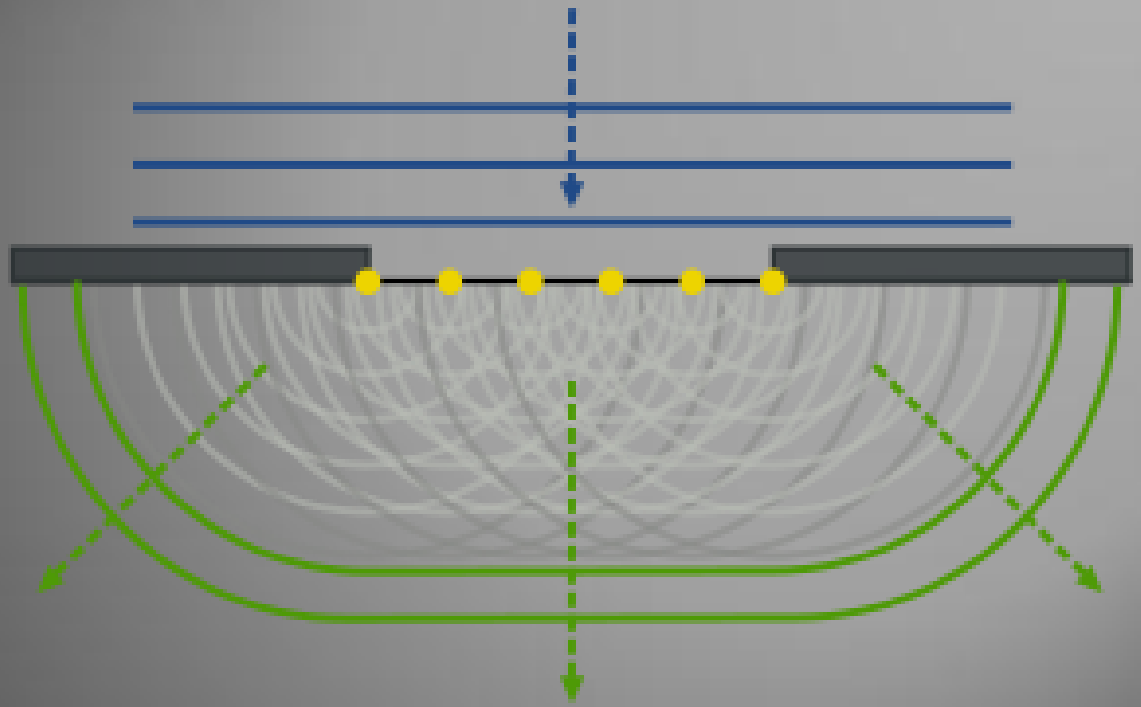
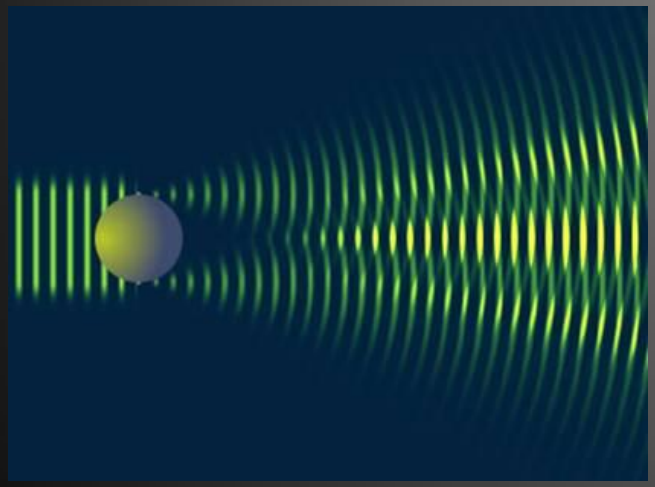
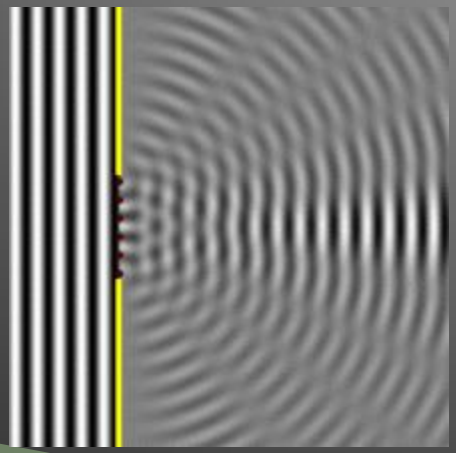
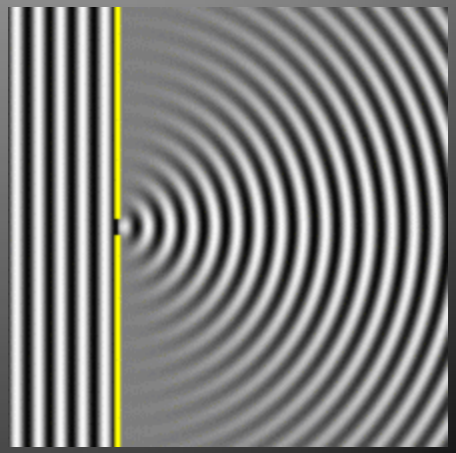
# Diffraction

Diffraction of light happens at every point in space.









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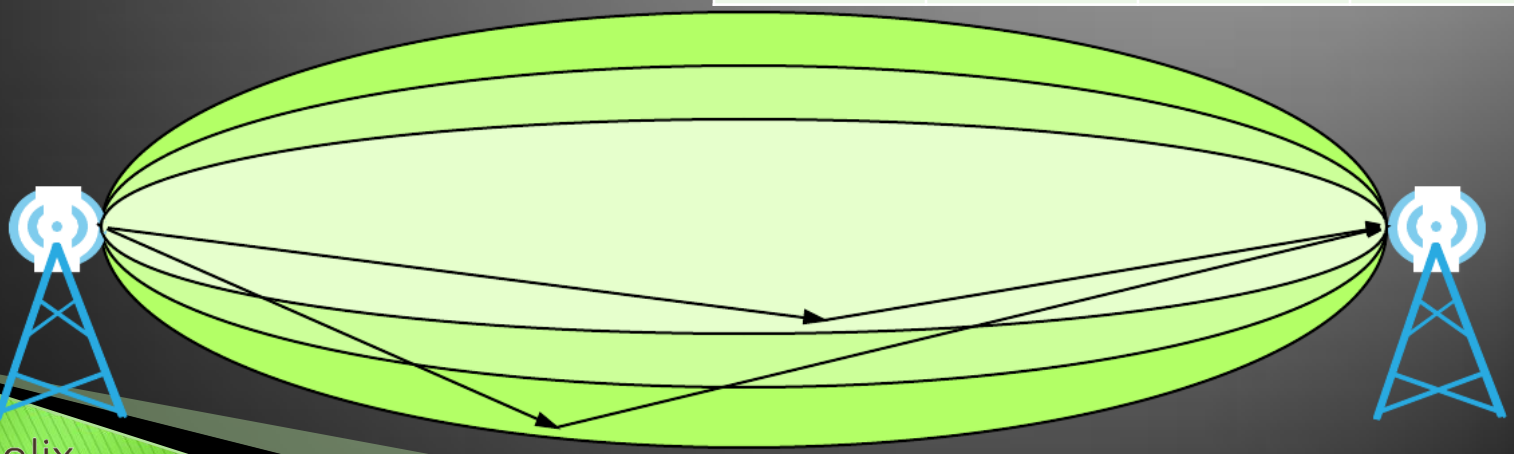
# Fresnel Zones

- Only first 3 affect signal

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

| Fresnel Zone | Phase Reflected | Path Length Phase | Total Phase Shift |
|---|---|---|---|
| F1 | 180° | 1*180° = 180° | 360° |
| F2 | 180° | 2*180° = 360 | 540° |
| F3 | 180° | 3*180° = 540° | 720° |
| F4 | 180° | 4*180° = 720° | 900° |



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# Fresnel Zones

- Diffraction
- Reflection
- Multipath

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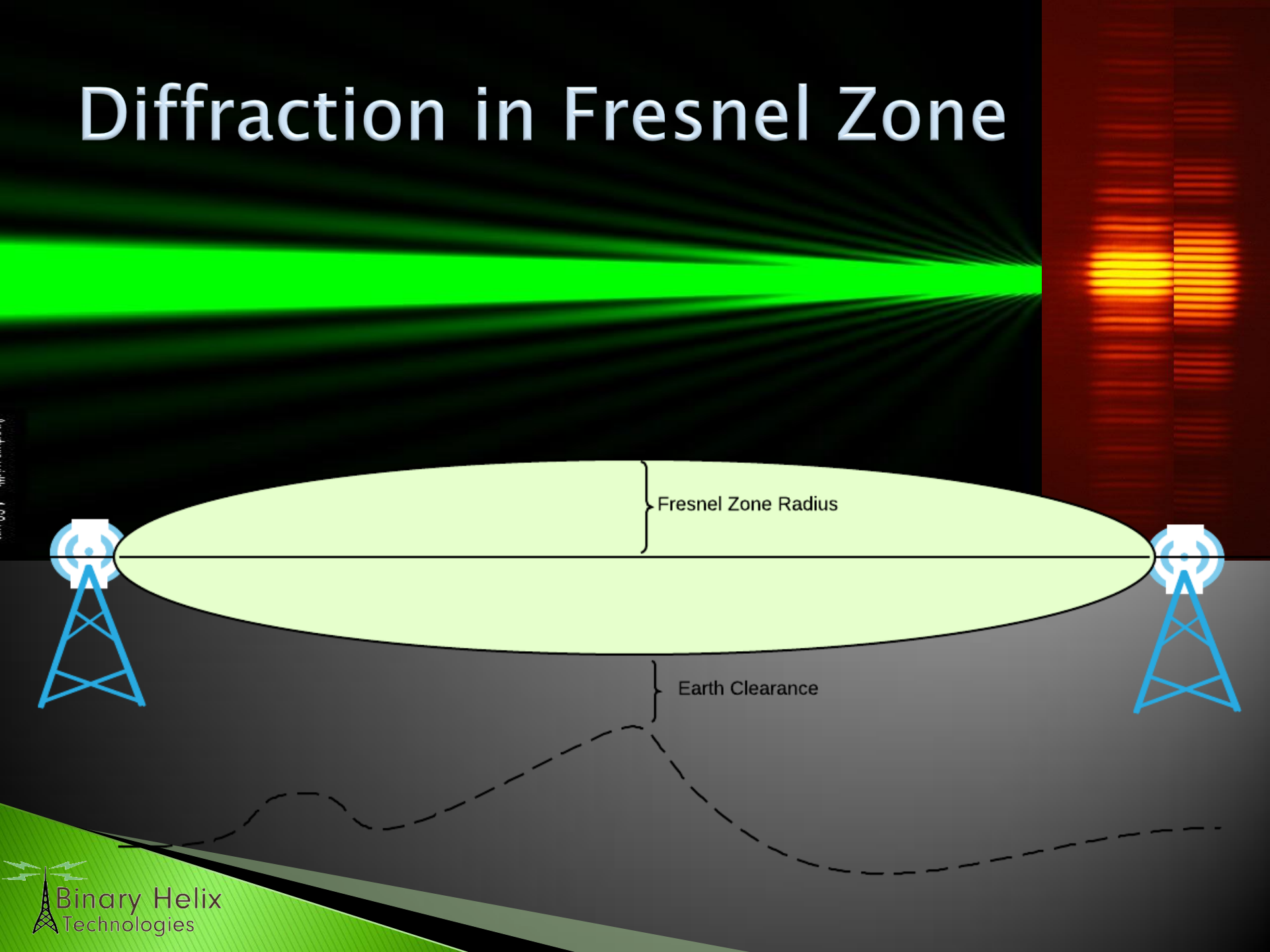
# Diffraction in Fresnel Zone

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# Reflections

- Reflections should be avoided
- F1,F3 can be constructive
- F2, F4 is destructive

- Antennas placed too high can cause multipath of F2

- Reflective objects
  - Lakes
  - Buildings
  - Roofs
  - Earth surface

- Indoors
  - Glass
  - Walls
  - Desks
  - Roof

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# Multipath Fading

- Multiple paths can interfere constructively or destructively.
- Can cause signal to fade.
- Fade could be rapid or over a day/season
- Signal strength will vary.
- Poor CCQ.

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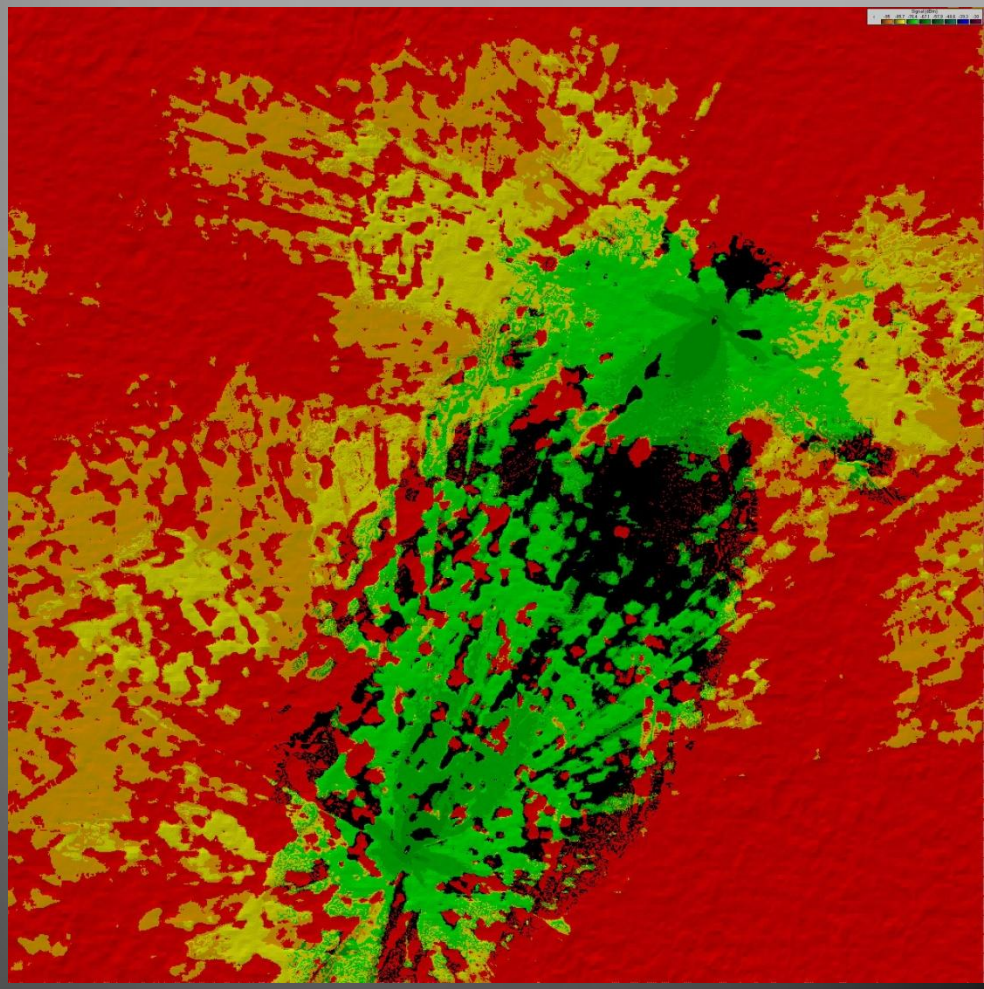
# Interference

- Interference is when another source of EM in the frequency range is above the receiver sensitivity.
- Channels close to each other can interfere.



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# The natural environment

- Rain
- Snow
- Cosmic Bursts
- Solar Flares

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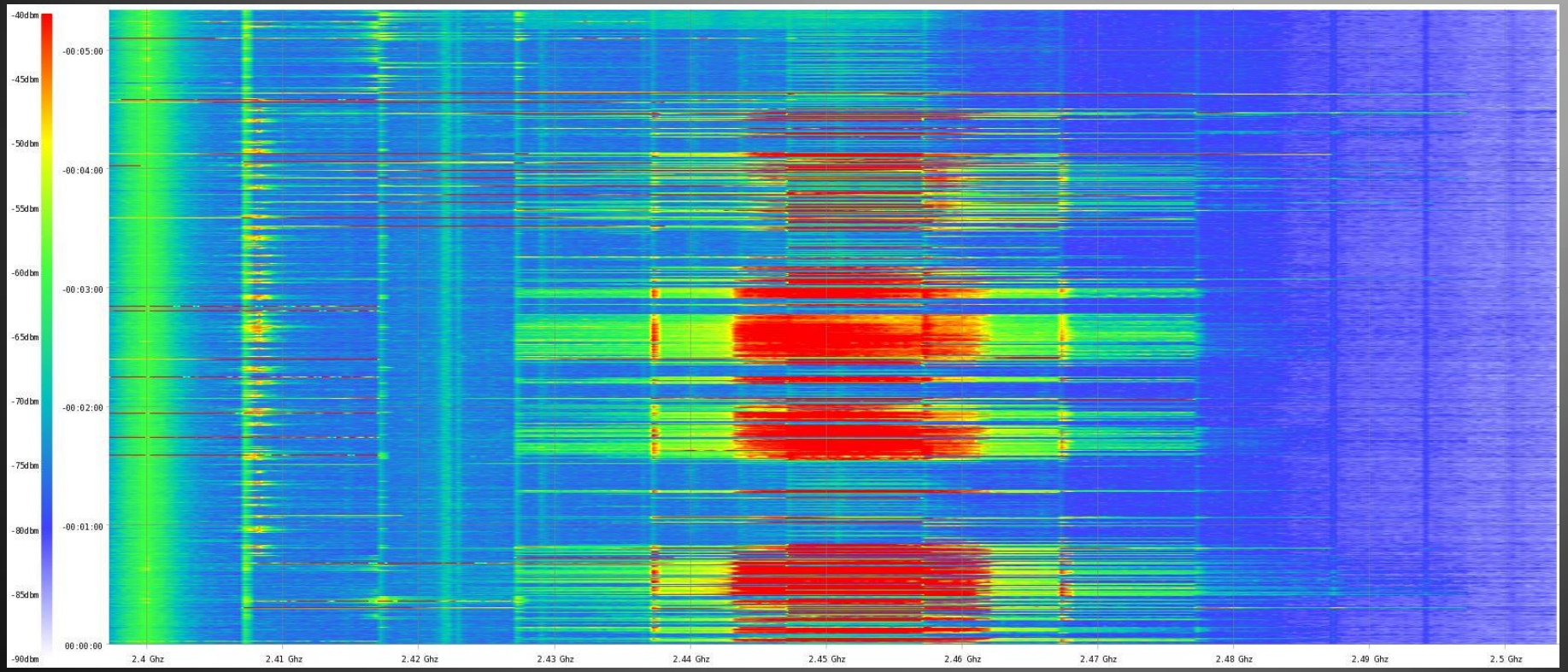
# The modern environment

- Cellphones
- Baby monitors
- Pagers
- Radar
- Other wireless
- EMI
- Dirty Power Sources

# Spectral Scan

- The Dude

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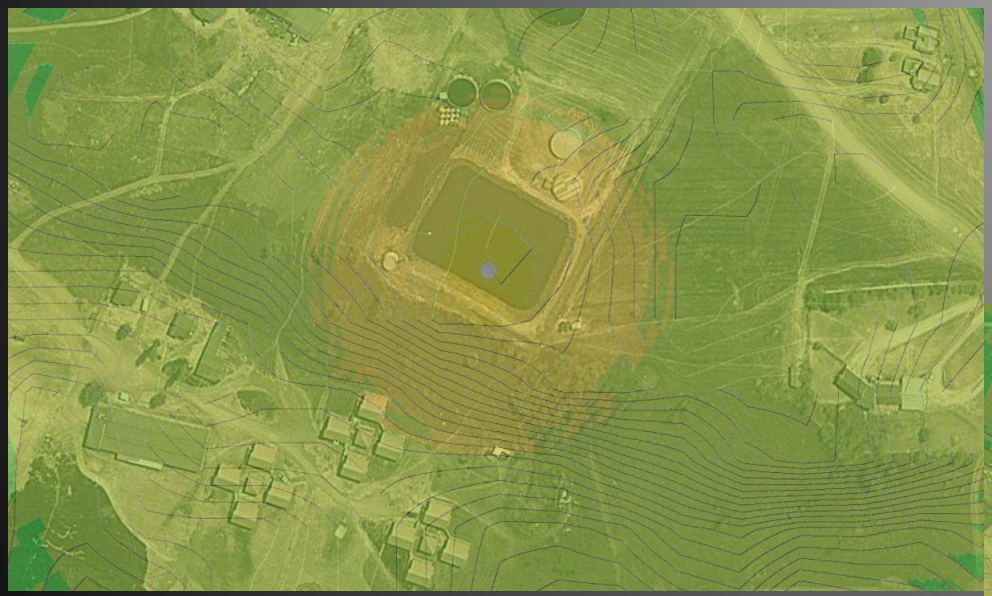
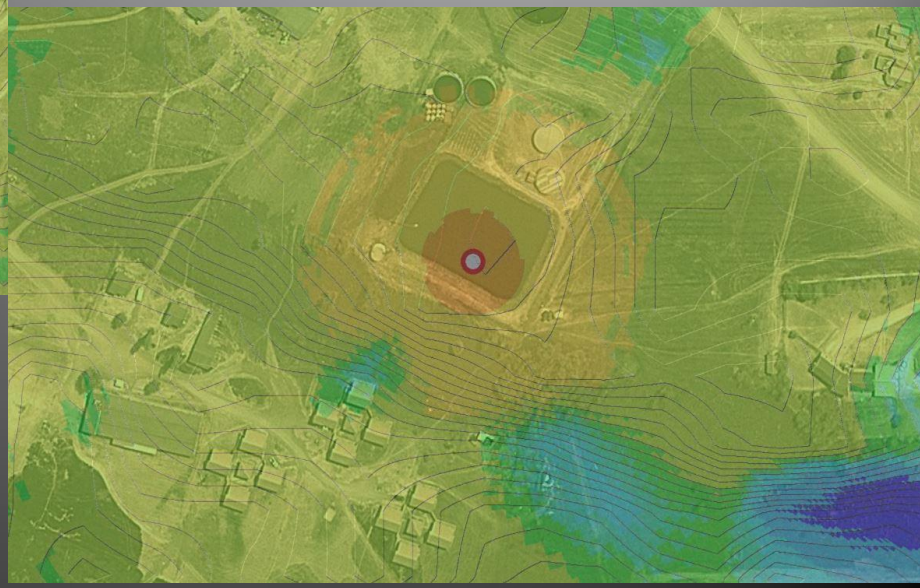
# Being Safe

- WHO set safety guidelines.



- Indoors
  - 0.2V/m
  - 105dbuV/m
- Outdoors
  - 0.6V/m
  - 115dbuV/m



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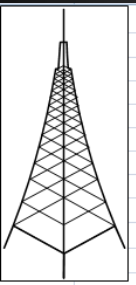
# Signal Calculator



| Tower | | | Client | | |
|---|---|---|---|---|---|
| Tower Output Power | 22 | dBm | Client Output Power | 22 | dBm |
| Cable Loss | 0.5 | dBi | Cable Loss | 0.5 | dBi |
| Antenna Gain | 7.5 | dBi | Antenna Gain | 7.5 | dBi |
| Rx Signal Strength | -71.2775 | dB | Rx Signal Strength | -71.2775 | dB |
| Receiver Sensitivity | -85 | dBm | Receiver Sensitivity | -85 | dBm |
| Signal to Noise Ratio | 187.1752 | mW | Signal to Noise Ratio | 187.1752 | mW |
| SNR | 22.72248 | dB | SNR | 22.72248 | dB |
| Fade Margin 15 dB | 13.72248 | dB | Fade Margin 15 dB | 13.72248 | dB |

| Bit Error Rate | | Bit Error Rate | |
|---|---|---|---|
| BPSK | 19.34813744 | BPSK | 19.34813744 |
| QPSK | 19.34813744 | QPSK | 19.34813744 |
| 16QAM | 8.652750112 | 16QAM | 8.652750112 |
| 64QAM | 7.312908572 | 64QAM | 7.312908572 |
| 256QAM | 4.197200314 | 256QAM | 4.197200314 |

| Bit Error Probability | | Bit Error Probability | |
|---|---|---|---|
| BPSK | 0.00E+00 | BPSK | 0.00E+00 |
| QPSK | 0.00E+00 | QPSK | 0.00E+00 |
| 16QAM | 1.42E-09 | 16QAM | 1.42E-09 |
| 64QAM | 4.95E-03 | 64QAM | 4.95E-03 |
| 256QAM | 2.42E-01 | 256QAM | 2.42E-01 |

| Packet Error Probability | | Packet Error Probability | |
|---|---|---|---|
| BPSK | 0.00% | BPSK | 0.00% |
| QPSK | 0.00% | QPSK | 0.00% |
| 16QAM | 0.00% | 16QAM | 0.00% |
| 64QAM | 100.00% | 64QAM | 100.00% |
| 256QAM | 100.00% | 256QAM | 100.00% |

| | | | | | |
|---|---|---|---|---|---|
| LOS Distance | 1 | km | Fresnel Zone at Max | | 3.750656 | m |
| Operating Frequency | 5325 | Mhz | Fresnel Ground Clearance | > | 2.250394 | m |
| Noise Floor | -109 | dB | Return Loss | 1.5 SWR | 9.542425 | dB |
| CCQ Percentage | 90 | % | Polarisation Mismatc | 15 degrees | -0.30112 | dB |
| Multipath Factor | 2.5 | | Multipath Loss | | 106.9764 | dB |
| | | | Free Space Loss | | 106.9764 | dB |
| | | | Total Loss | | 107.2775 | dB |

| | |
|---|---|
| MTU | 1500 |
| MCS | 0 |

| Normalizer | |
|---|---|
| k | - |
| k | - |
| k | 0.31622777 |
| k | 0.15430335 |
| k | 0.0766965 |

| MCS index | Spatial streams | Modulation type | Data rate (Mbit/s) | | | | Receive Sensitivity | |
|---|---|---|---|---|---|---|---|---|
| | | | 20 MHz channel | | 40 MHz channel | | 20Mhz | 40Mhz |
| | | | 800 ns GI | 400 ns GI | 800 ns GI | 400 ns GI | | |
| 0 | 1 | BPSK | 6.5 | 7.2 | 13.5 | 15 | -95/-91 | -90/-86 |
| 1 | 1 | QPSK | 13 | 14.4 | 27 | 30 | -94/-90 | -90/-86 |
| 2 | 1 | QPSK | 19.5 | 21.7 | 40.5 | 45 | -92/-88 | -89/-85 |
| 3 | 1 | 16-QAM | 26 | 28.9 | 54 | 60 | -88/-84 | -85/-81 |
| 4 | 1 | 16-QAM | 39 | 43.3 | 81 | 90 | -85/-81 | -82/-78 |
| 5 | 1 | 64-QAM | 52 | 57.8 | 108 | 120 | -80/-76 | -78/-74 |
| 6 | 1 | 64-QAM | 58.5 | 65 | 121.5 | 135 | -79/-75 | -77/-73 |
| 7 | 1 | 64-QAM | 65 | 72.2 | 135 | 150 | -77/-73 | -74/-71 |
| 8 | 2 | BPSK | 13 | 14.4 | 27 | 30 | -95/-91 | -90/-86 |
| 9 | 2 | QPSK | 26 | 28.9 | 54 | 60 | -94/-90 | -90/-86 |
| 10 | 2 | QPSK | 39 | 43.3 | 81 | 90 | -92/-88 | -89/-85 |
| 11 | 2 | 16-QAM | 52 | 57.8 | 108 | 120 | -88/-84 | -85/-81 |
| 12 | 2 | 16-QAM | 78 | 86.7 | 162 | 180 | -85/-81 | -82/-78 |
| 13 | 2 | 64-QAM | 104 | 115.6 | 216 | 240 | -80/-76 | -78/-74 |
| 14 | 2 | 64-QAM | 117 | 130 | 243 | 270 | -79/-75 | -77/-73 |
| 15 | 2 | 64-QAM | 130 | 144.4 | 270 | 300 | -77/-73 | -74/-71 |
| 16 | 3 | BPSK | 19.5 | 21.7 | 40.5 | 45 | -95/-91 | -90/-86 |
| 17 | 3 | QPSK | 39 | 43.3 | 81 | 90 | -94/-90 | -90/-86 |
| 18 | 3 | QPSK | 58.5 | 65 | 121.5 | 135 | -92/-88 | -89/-85 |
| 19 | 3 | 16-QAM | 78 | 86.7 | 162 | 180 | -88/-84 | -85/-81 |
| 20 | 3 | 16-QAM | 117 | 130.7 | 243 | 270 | -85/-81 | -82/-78 |
| 21 | 3 | 64-QAM | 156 | 173.3 | 324 | 360 | -80/-76 | -78/-74 |
| 22 | 3 | 64-QAM | 175.5 | 195 | 364.5 | 405 | -79/-75 | -77/-73 |
| 23 | 3 | 64-QAM | 195 | 216.7 | 405 | 450 | -77/-73 | -74/-71 |
| 24 | 4 | BPSK | 26 | 28.8 | 54 | 60 | -95/-91 | -90/-86 |
| 25 | 4 | QPSK | 52 | 57.6 | 108 | 120 | -94/-90 | -90/-86 |
| 26 | 4 | QPSK | 78 | 86.8 | 162 | 180 | -92/-88 | -89/-85 |
| 27 | 4 | 16-QAM | 104 | 115.6 | 216 | 240 | -88/-84 | -85/-81 |
| 28 | 4 | 16-QAM | 156 | 173.2 | 324 | 360 | -85/-81 | -82/-78 |
| 29 | 4 | 64-QAM | 208 | 231.2 | 432 | 480 | -80/-76 | -78/-74 |
| 30 | 4 | 64-QAM | 234 | 260 | 486 | 540 | -79/-75 | -77/-73 |
| 31 | 4 | 64-QAM | 260 | 288.8 | 540 | 600 | -77/-73 | -74/-71 |

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# Receiver Sensitivity

| 20Mhz | 40Mhz |
|---|---|
| MCS0 -95/-91 | MCS0 -90/-86 |
| MCS1 -94/-90 | MCS1 -90/-86 |
| MCS2 -92/-8 | MCS2 -89/-85 |
| MCS3 -88/-84 | MCS3 -85/-81 |
| MCS4 -85/-81 | MCS4 -82/-78 |
| MCS5 -80/-76 | MCS5 -78/-7 |
| MCS6 -79/-75 | MCS6 -77/-73 |
| MCS7 -77/-73 | MCS7 -74/-71 |

- Speed vs Range
- Should be 15dB lower than signal
- Must be above noise floor!

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# Transmit Power and Regulation

- SA Regulations
- 2.4-2.5Ghz - 20dBi (EIRP 100mW)
- 5-6Ghz - 30dBi (EIRP 1000mW)

- Too high transmit power can cause interferences.
- Creates strong reflections.

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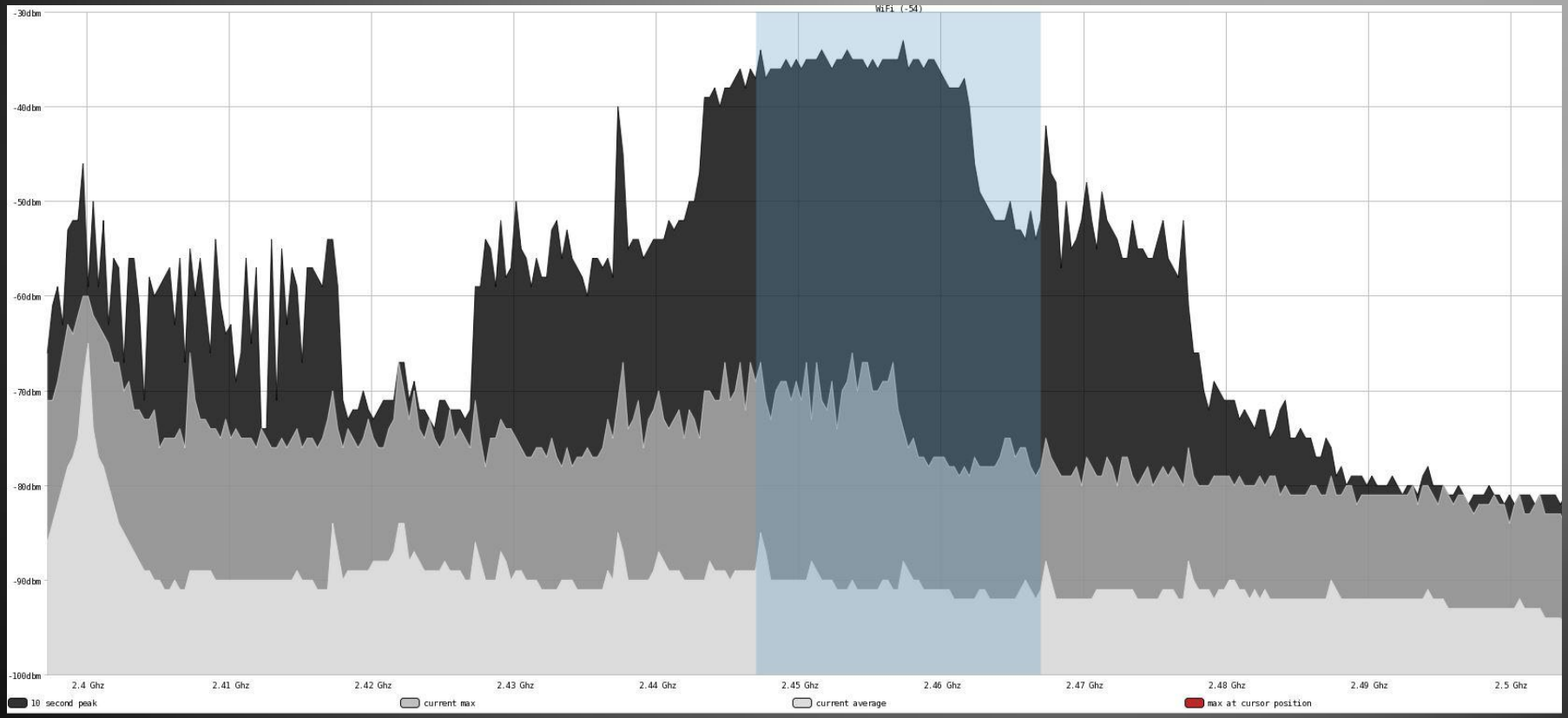
# Noise Floor

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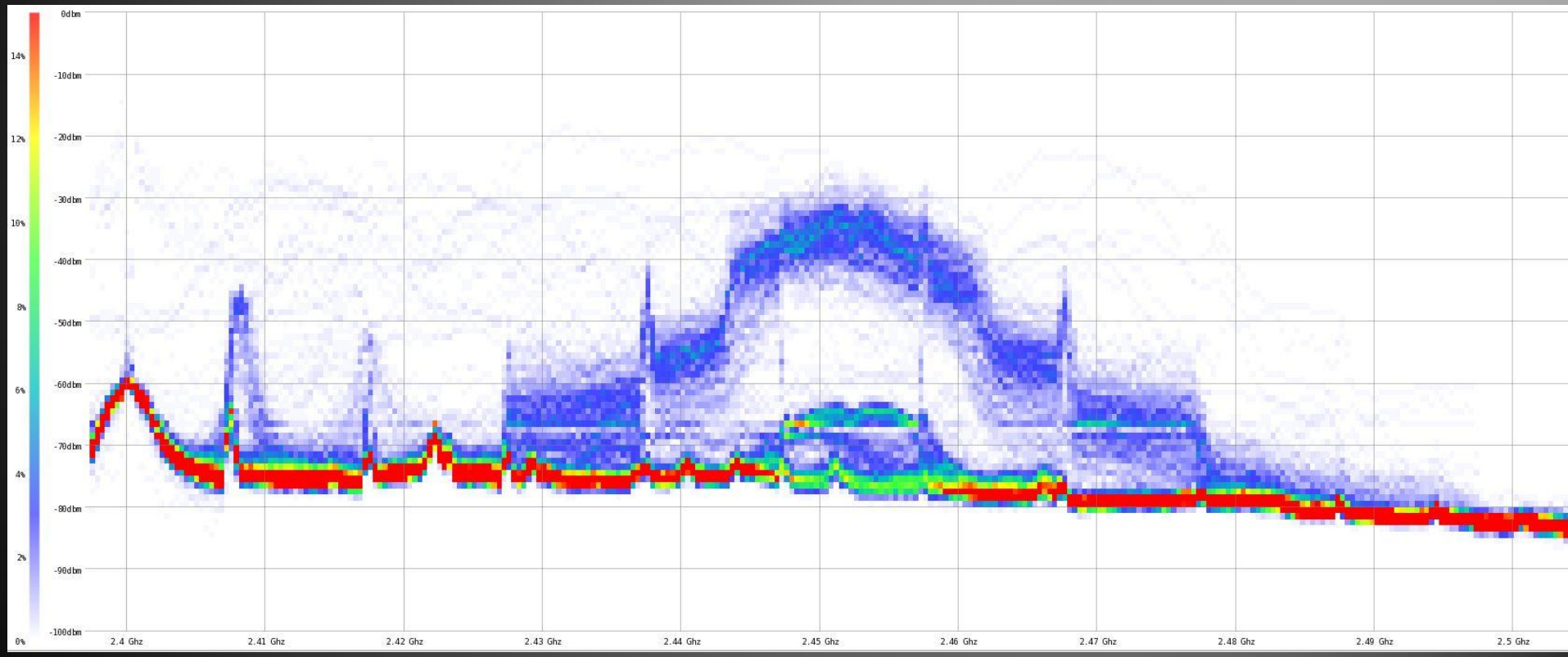
# Signal to Noise and Fading

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# Fade Margin

- Choose your MCSs wisely.
- Allow for a 15dB fade margin for stable links

| Safety Margin | Reliability |
|---|---|
| 6dB | 50% |
| 10dB | 90% |
| 20dB | 99% |
| 30dB | 99.9% |
| 40dB | 99.99% |

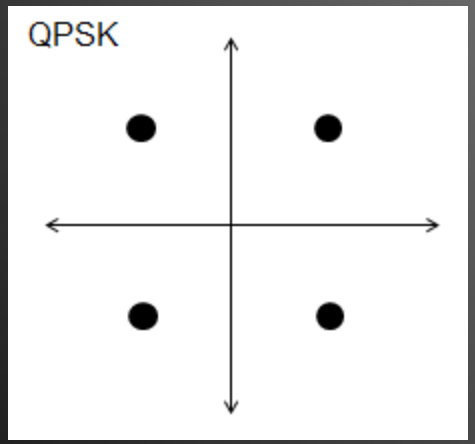
# Required SNR

| | SNR to meet | Including Fade Margin |
|---|---|---|
| BPSK | 10dB | 25dB |
| QPSK | 10dB | 25dB |
| 16QAM | 21dB | 36dB |
| 64QAM | 27dB | 42dB |
| 256QAM | 33dB | 48dB |

# BER and Packet Transmissions

- BPSK and QPSK

| SNR | BER | Packet Drops |
|---|---|---|
| 7 | 7.5E-04 | 99.99% |
| 9 | 3.2E-05 | 31.99% |
| 10 | 3.6E-06 | 4.29% |
| 11 | 2.4E-07 | 0.29% |

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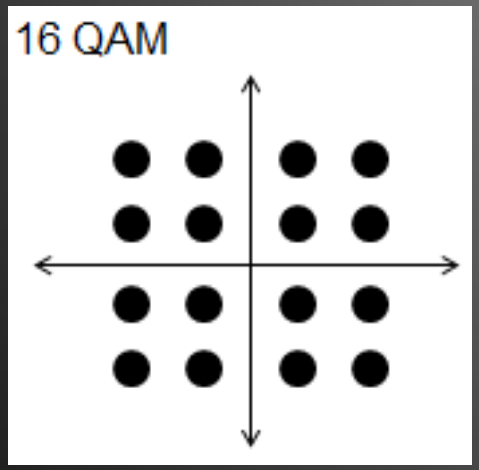
# 16-QAM

| SNR | BER | Packet Drops |
|---|---|---|
| 18dB | 5.5E-04 | 99.87% |
| 20dB | 1.1E-05 | 12.34% |
| 21dB | 7.3E-07 | 0.87% |
| 22dB | 2.4E-08 | 0.03% |

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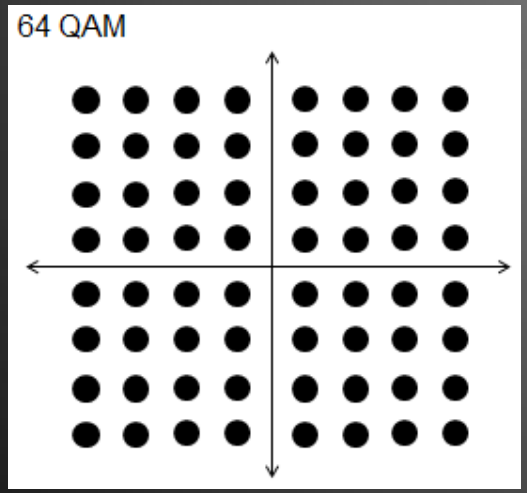
# 64-QAM

| SNR | BER | Packet Drops |
|---|---|---|
| 25dB | 1.75E-04 | 87.7% |
| 26dB | 2.22E-05 | 23.4% |
| 27dB | 1.69E-06 | 2.01% |
| 28dB | 6.8E-08 | 0.08% |

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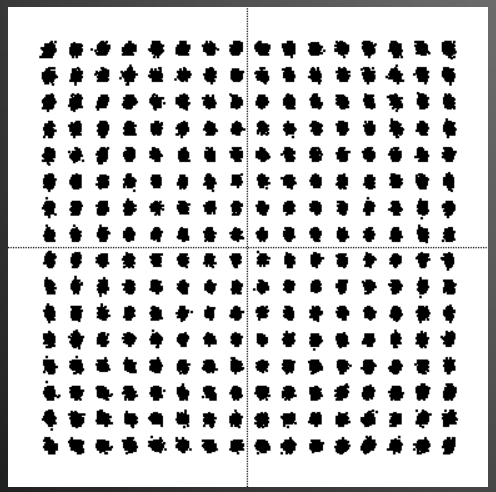
# 256-QAM

| SNR | BER | Packet Drops |
|---|---|---|
| 31dB | 2.13E-04 | 99.29% |
| 33dB | 2.8E-05 | 28.52% |
| 33dB | 2.22E-06 | 2.63% |
| 34dB | 9.39E-08 | 0.11% |



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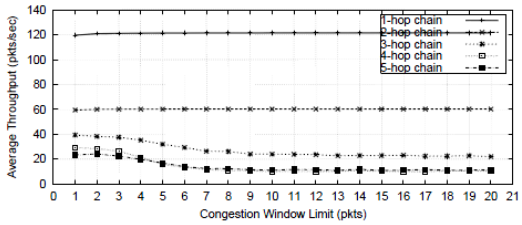
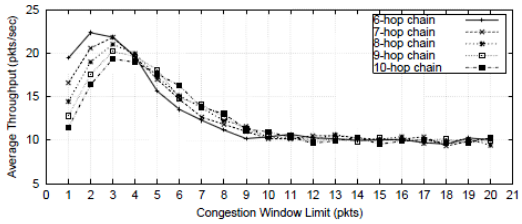
# Multihop and TCP woes

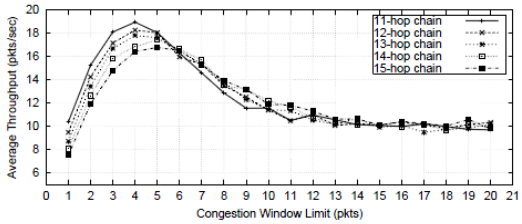
- TCP performs poorly.
- TCP Performance:  50% of UDP
- Scattered noise
- Half-duplex, acks
- Multiple wireless hops reduce
- TCP performance.
- Small TCP window size




(a) Chain 1 to 5 hops




(b) Chain 6 to 10 hops




(c) Chain 11 to 15 hops

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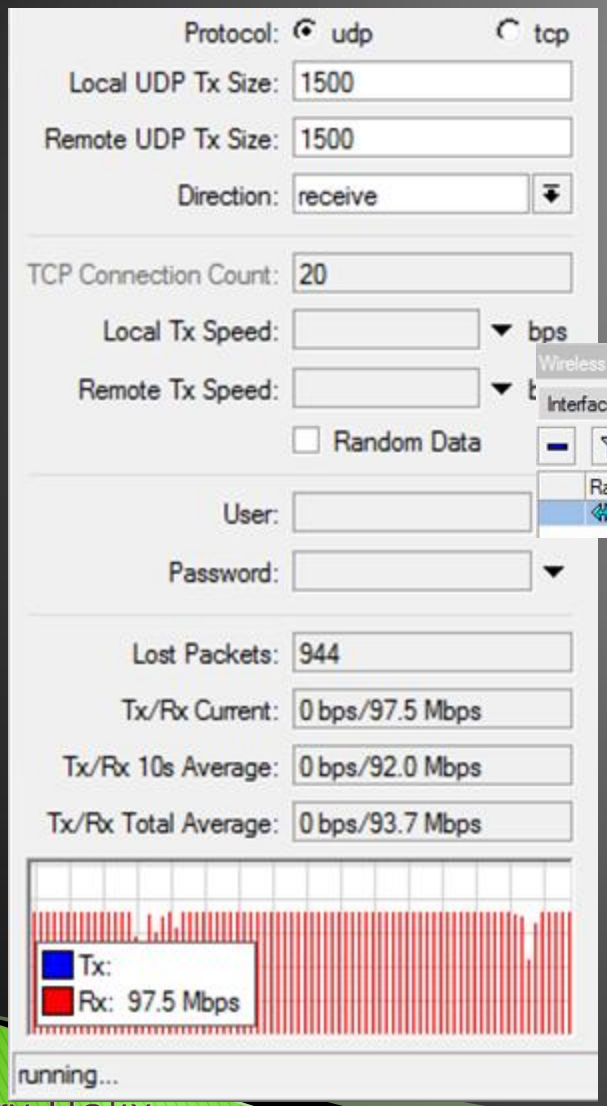
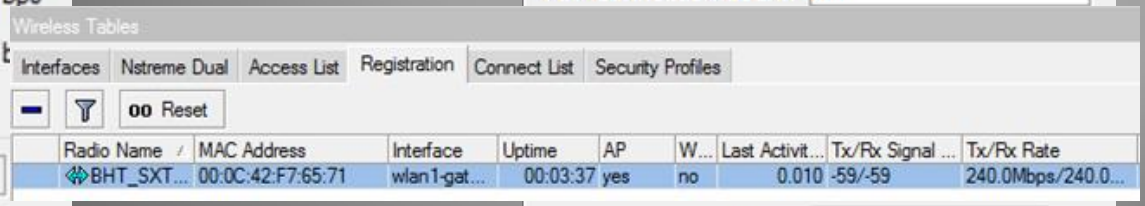
# UDP vs TCP







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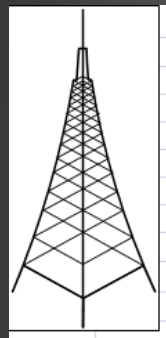
# SXT to Omnitik Example



| Tower | | | Client | | |
|---|---|---|---|---|---|
| Tower Output Power | 22 | dBm | Client Output Power | 14 | dBm |
| Cable Loss | 0.5 | dBi | Cable Loss | 0.5 | dBi |
| Antenna Gain | 7.5 | dBi | Antenna Gain | 16 | dBi |
| Rx Signal Strength | -70.7775 | dB | Rx Signal Strength | -62.7775 | dB |
| Receiver Sensitivity | -85 | dBm | Receiver Sensitivity | -85 | dBm |
| Signal to Noise Ratio | 83.6081 | mW | Signal to Noise Ratio | 527.5314 | mW |
| SNR | 19.22248 | dB | SNR | 27.22248 | dB |
| Fade Margin 15 dB | 14.22248 | dB | Fade Margin 15 dB | 22.22248 | dB |

| MTU | 1500 |
|---|---|
| MCS | 0 |

| Bit Error Rate | | Bit Error Rate | |
|---|---|---|---|
| BPSK | 12.93120998 | BPSK | 32.48173088 |
| QPSK | 12.93120998 | QPSK | 32.48173088 |
| 16QAM | 5.783012908 | 16QAM | 14.52627166 |
| 64QAM | 4.887537964 | 64QAM | 12.2769403 |
| 256QAM | 2.8051733 | 256QAM | 7.046276751 |

| Bit Error Probability | | Bit Error Probability | |
|---|---|---|---|
| BPSK | 0.00E+00 | BPSK | 0.00E+00 |
| QPSK | 0.00E+00 | QPSK | 0.00E+00 |
| 16QAM | 6.49E-05 | 16QAM | 0.00E+00 |
| 64QAM | 7.89E-02 | 64QAM | 9.42E-07 |
| 256QAM | 5.12E-01 | 256QAM | 2.37E-02 |

| Normalizer | |
|---|---|
| k | - |
| k | - |
| k | 0.31622777 |
| k | 0.15430335 |
| k | 0.0766965 |

| Packet Error Probability | | Packet Error Probability | |
|---|---|---|---|
| BPSK | 0.00% | BPSK | 0.00% |
| QPSK | 0.00% | QPSK | 0.00% |
| 16QAM | 54.12% | 16QAM | 0.00% |
| 64QAM | 100.00% | 64QAM | 1.12% |
| 256QAM | 100.00% | 256QAM | 100.00% |

| | | | | | | |
|---|---|---|---|---|---|---|
| LOS Distance | 1 | km | Fresnel Zone at Max | | | 3.750656 | m |
| Operating Frequency | 5325 | Mhz | Fresnel Ground Clearance | > | | 2.250394 | m |
| Noise Floor | -105 | dB | Return Loss | 1.5 | SWR | 9.542425 | dB |
| CCQ Percentage | 90 | % | Polarisation Mismatc | 15 | degrees | -0.30112 | dB |
| Multipath Factor | 4 | | Multipath Loss | | | 106.9764 | dB |
| | | | Free Space Loss | | | 106.9764 | dB |
| | | | Total Loss | | | 107.2775 | dB |

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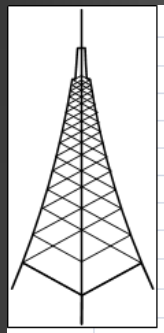
# Omnitik WDS example



| Tower | | | | Client | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tower Output Power | | 22 | dBm | Client Output Power | | 22 | dBm | | |
| Cable Loss | | 0.5 | dBi | Cable Loss | | 0.5 | dBi | | |
| Antenna Gain | | 7.5 | dBi | Antenna Gain | | 7.5 | dBi | MTU | 1500 |
| Rx Signal Strength | | -71.2775 | dB | Rx Signal Strength | | -71.2775 | dB | MCS | 0 |
| Receiver Sensitivity | | -85 | dBm | Receiver Sensitivity | | -85 | dBm | | |
| Signal to Noise Ratio | | 187.1752 | mW | Signal to Noise Ratio | | 187.1752 | mW | | |
| SNR | | 22.72248 | dB | SNR | | 22.72248 | dB | | |
| Fade Margin | 15 dB | 13.72248 | dB | Fade Margin | 15 dB | 13.72248 | dB | | |

| Bit Error Rate | | Bit Error Rate | |
|---|---|---|---|
| BPSK | 19.34813744 | BPSK | 19.34813744 |
| QPSK | 19.34813744 | QPSK | 19.34813744 |
| 16QAM | 8.652750112 | 16QAM | 8.652750112 |
| 64QAM | 7.312908572 | 64QAM | 7.312908572 |
| 256QAM | 4.197200314 | 256QAM | 4.197200314 |

| Bit Error Probability | | Bit Error Probability | | Normalizer | |
|---|---|---|---|---|---|
| BPSK | 0.00E+00 | BPSK | 0.00E+00 | k | - |
| QPSK | 0.00E+00 | QPSK | 0.00E+00 | k | - |
| 16QAM | 1.42E-09 | 16QAM | 1.42E-09 | k | 0.31622777 |
| 64QAM | 4.95E-03 | 64QAM | 4.95E-03 | k | 0.15430335 |
| 256QAM | 2.42E-01 | 256QAM | 2.42E-01 | k | 0.0766965 |

| Packet Error Probability | | Packet Error Probability |
|---|---|---|
| BPSK | 0.00% | BPSK 0.00% |
| QPSK | 0.00% | QPSK 0.00% |
| 16QAM | 0.00% | 16QAM 0.00% |
| 64QAM | 100.00% | 64QAM 100.00% |
| 256QAM | 100.00% | 256QAM 100.00% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LOS Distance | 1 | km | Fresnel Zone at Max | | | 3.750656 | m |
| Operating Frequency | 5325 | Mhz | Fresnel Ground Clearance | | > | 2.250394 | m |
| Noise Floor | -109 | dB | Return Loss | 1.5 | SWR | 9.542425 | dB |
| CCQ Percentage | 90 | % | Polarisation Mismatc | 15 | degrees | -0.30112 | dB |
| Multipath Factor | 2.5 | | Multipath Loss | | | 106.9764 | dB |
| | | | Free Space Loss | | | 106.9764 | dB |
| | | | Total Loss | | | 107.2775 | dB |

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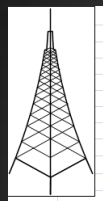
# SXT to SXT example



| Tower | | | | Client | | | |
|---|---|---|---|---|---|---|---|
| Tower Output Power | | 14 | dBm | Client Output Power | | 14 | dBm |
| Cable Loss | | 0.5 | dBi | Cable Loss | | 0.5 | dBi |
| Antenna Gain | | 16 | dBi | Antenna Gain | | 16 | dBi |
| Rx Signal Strength | | -59.1795 | dB | Rx Signal Strength | | -59.1795 | dB |
| Receiver Sensitivity | | -85 | dBm | Receiver Sensitivity | | -85 | dBm |
| Signal to Noise Ratio | | 1207.959 | mW | Signal to Noise Ratio | | 1207.959 | mW |
| | SNR | 30.82052 | dB | | SNR | 30.82052 | dB |
| Fade Margin | 15 dB | 25.82052 | dB | Fade Margin | 15 dB | 25.82052 | dB |

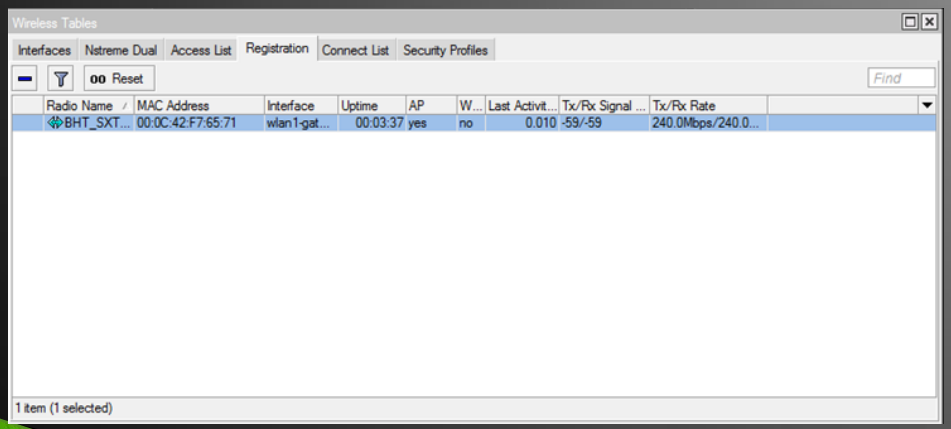
| MTU | 1500 |
|---|---|
| MCS | 0 |

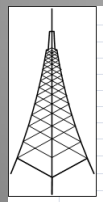
| Bit Error Rate | | Bit Error Rate | |
|---|---|---|---|
| BPSK | 49.15199205 | BPSK | 49.15199205 |
| QPSK | 49.15199205 | QPSK | 49.15199205 |
| 16QAM | 21.98143909 | 16QAM | 21.98143909 |
| 64QAM | 18.57770677 | 64QAM | 18.57770677 |
| 256QAM | 10.66256414 | 256QAM | 10.66256414 |

| Bit Error Probability | | Bit Error Probability | | Normalizer | |
|---|---|---|---|---|---|
| BPSK | 0.00E+00 | BPSK | 0.00E+00 | k | - |
| QPSK | 0.00E+00 | QPSK | 0.00E+00 | k | - |
| 16QAM | 0.00E+00 | 16QAM | 0.00E+00 | k | 0.31622777 |
| 64QAM | 5.85E-14 | 64QAM | 5.85E-14 | k | 0.15430335 |
| 256QAM | 3.06E-04 | 256QAM | 3.06E-04 | k | 0.0766965 |

| Packet Error Probability | | Packet Error Probability | |
|---|---|---|---|
| BPSK | 0.00% | BPSK | 0.00% |
| QPSK | 0.00% | QPSK | 0.00% |
| 16QAM | 0.00% | 16QAM | 0.00% |
| 64QAM | 0.00% | 64QAM | 0.00% |
| 256QAM | 97.47% | 256QAM | 97.47% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LOS Distance | | 0.7 | km | Fresnel Zone at Max | | 3.138024 | m |
| Operating Frequency | | 5325 | Mhz | Fresnel Ground Clearance | > | 1.882815 | m |
| Noise Floor | | -105 | dB | Return Loss | 1.5 SWR | 9.542425 | dB |
| CCQ Percentage | | 90 | % | Polarisation Mismatc | 15 degrees | -0.30112 | dB |
| Multipath Factor | | 2 | | Multipath Loss | | 103.8784 | dB |
| | | | | Free Space Loss | | 103.8784 | dB |
| | | | | Total Loss | | 104.1795 | dB |



| Tower | | | | Client | | | |
|---|---|---|---|---|---|---|---|
| Tower Output Power | | 14 | dBm | Client Output Power | | 14 | dBm |
| Cable Loss | | 0.5 | dBi | Cable Loss | | 0.5 | dBi |
| Antenna Gain | | 16 | dBi | Antenna Gain | | 16 | dBi |
| Rx Signal Strength | | -84.8548 | dB | Rx Signal Strength | | -84.8548 | dB |
| Receiver Sensitivity | | -85 | dBm | Receiver Sensitivity | | -85 | dBm |
| Signal to Noise Ratio | | 10.34007 | mW | Signal to Noise Ratio | | 10.34007 | mW |
| | SNR | 10.14523 | dB | | SNR | 10.14523 | dB |
| Fade Margin | 15 dB | 0.145234 | dB | Fade Margin | 15 dB | 0.145234 | dB |

| MTU | 1500 |
|---|---|
| MCS | 0 |

| Bit Error Rate | | Bit Error Rate | |
|---|---|---|---|
| BPSK | 4.547541595 | BPSK | 4.547541595 |
| QPSK | 4.547541595 | QPSK | 4.547541595 |
| 16QAM | 2.033722427 | 16QAM | 2.033722427 |
| 64QAM | 1.718809162 | 64QAM | 1.718809162 |
| 256QAM | 0.98650028 | 256QAM | 0.98650028 |

| Bit Error Probability | | Bit Error Probability | | Normalizer | |
|---|---|---|---|---|---|
| BPSK | 2.71E-06 | BPSK | 2.71E-06 | k | - |
| QPSK | 2.71E-06 | QPSK | 2.71E-06 | k | - |
| 16QAM | 2.13E-01 | 16QAM | 2.13E-01 | k | 0.31622777 |
| 64QAM | 6.67E-01 | 64QAM | 6.67E-01 | k | 0.15430335 |
| 256QAM | 8.99E-01 | 256QAM | 8.99E-01 | k | 0.0766965 |

| Packet Error Probability | | Packet Error Probability | |
|---|---|---|---|
| BPSK | 3.20% | BPSK | 3.20% |
| QPSK | 3.20% | QPSK | 3.20% |
| 16QAM | 100.00% | 16QAM | 100.00% |
| 64QAM | 100.00% | 64QAM | 100.00% |
| 256QAM | 100.00% | 256QAM | 100.00% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LOS Distance | | 8 | km | Fresnel Zone at Max | | 10.60846 | m |
| Operating Frequency | | 5325 | Mhz | Fresnel Ground Clearance | > | 6.365075 | m |
| Noise Floor | | -110 | dB | Return Loss | 1.5 SWR | 9.542425 | dB |
| CCQ Percentage | | 90 | % | Polarisation Mismatc | 15 degrees | -0.30112 | dB |
| Multipath Factor | | 2.5 | | Multipath Loss | | 129.5536 | dB |
| | | | | Free Space Loss | | 125.0382 | dB |
| | | | | Total Loss | | 129.8548 | dB |

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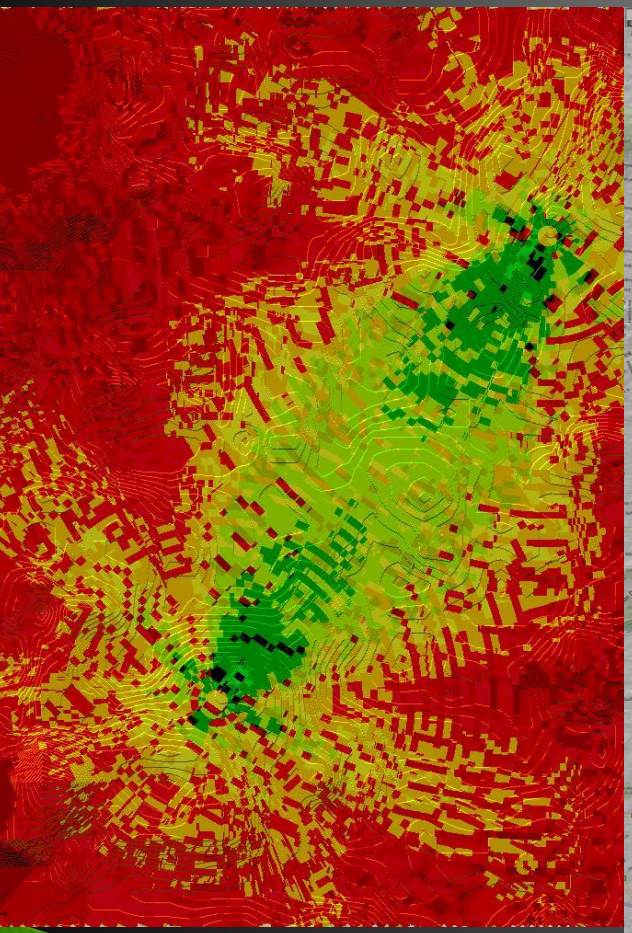
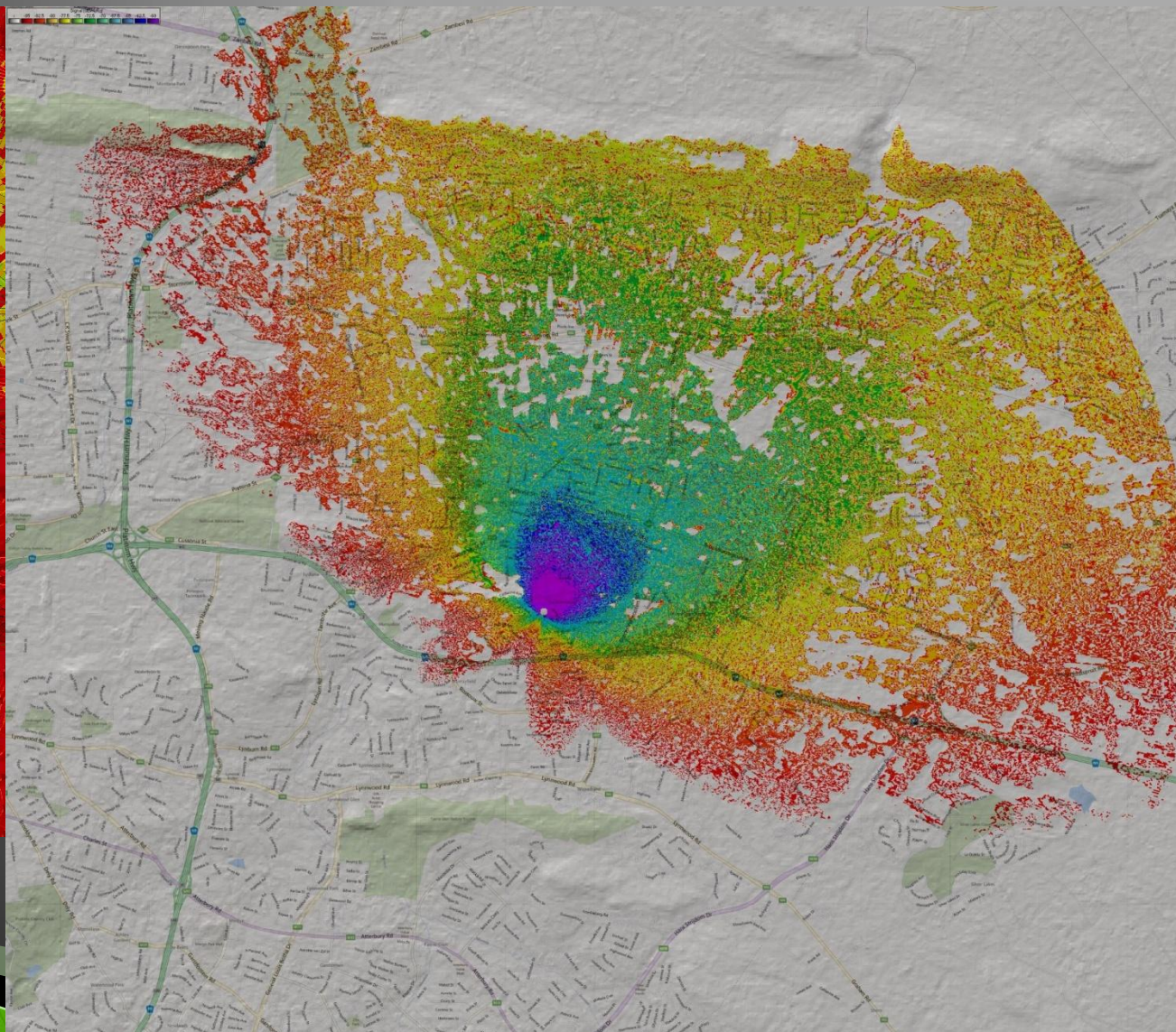
# Omnitik Coverage

# Directional





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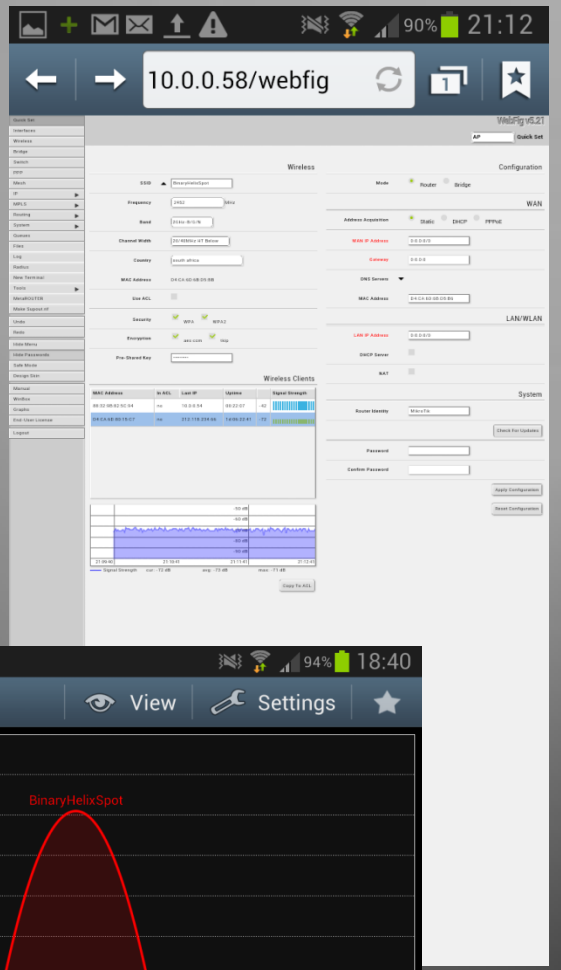
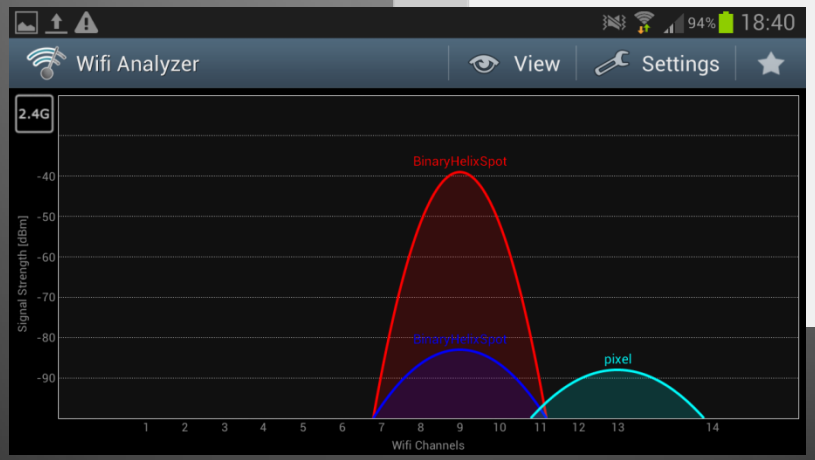
# Wireless Mesh

# Mobile devices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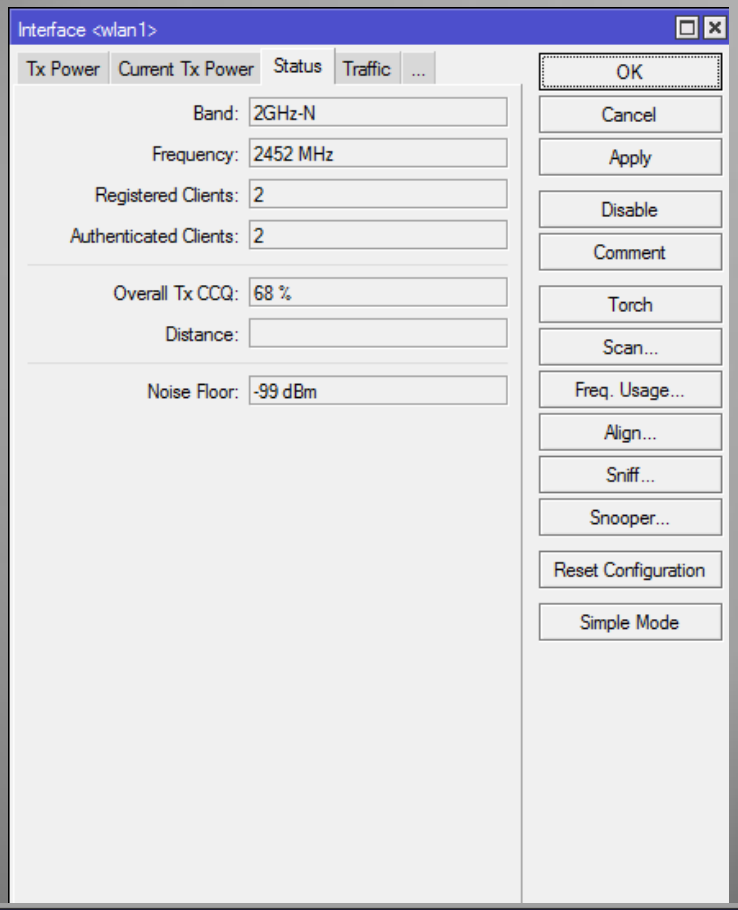
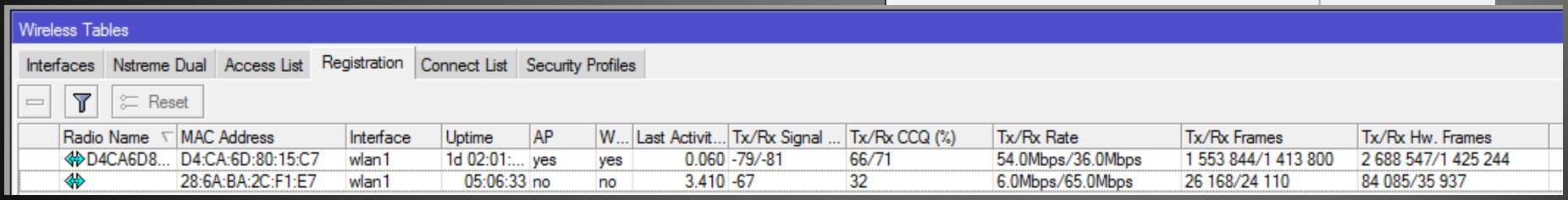
# Verifying Signals

- Signal Strength
- Fading
- CCQ
- Bandwidth Test

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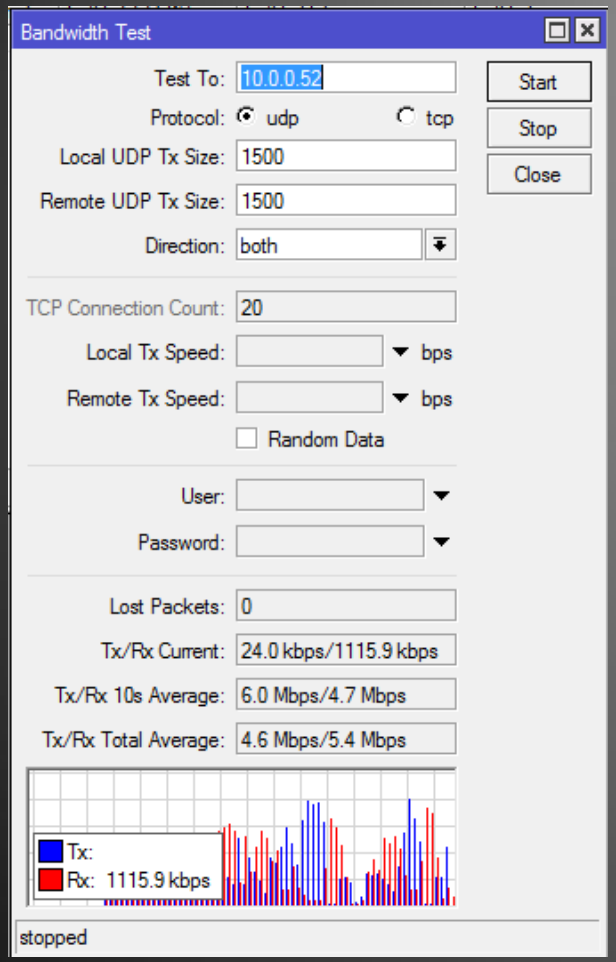
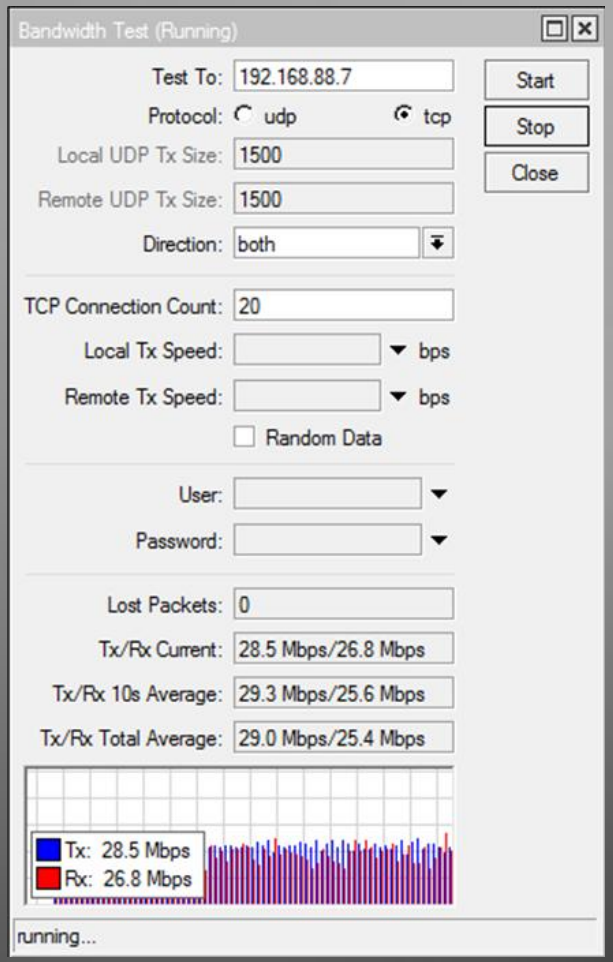
# Bad vs Good

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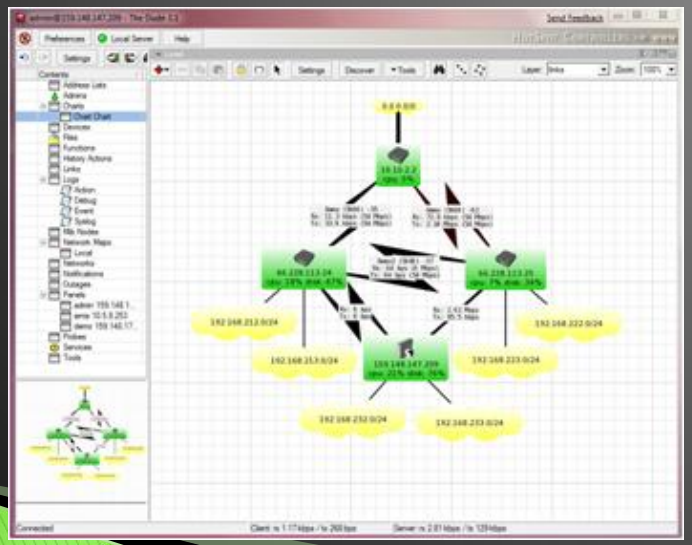
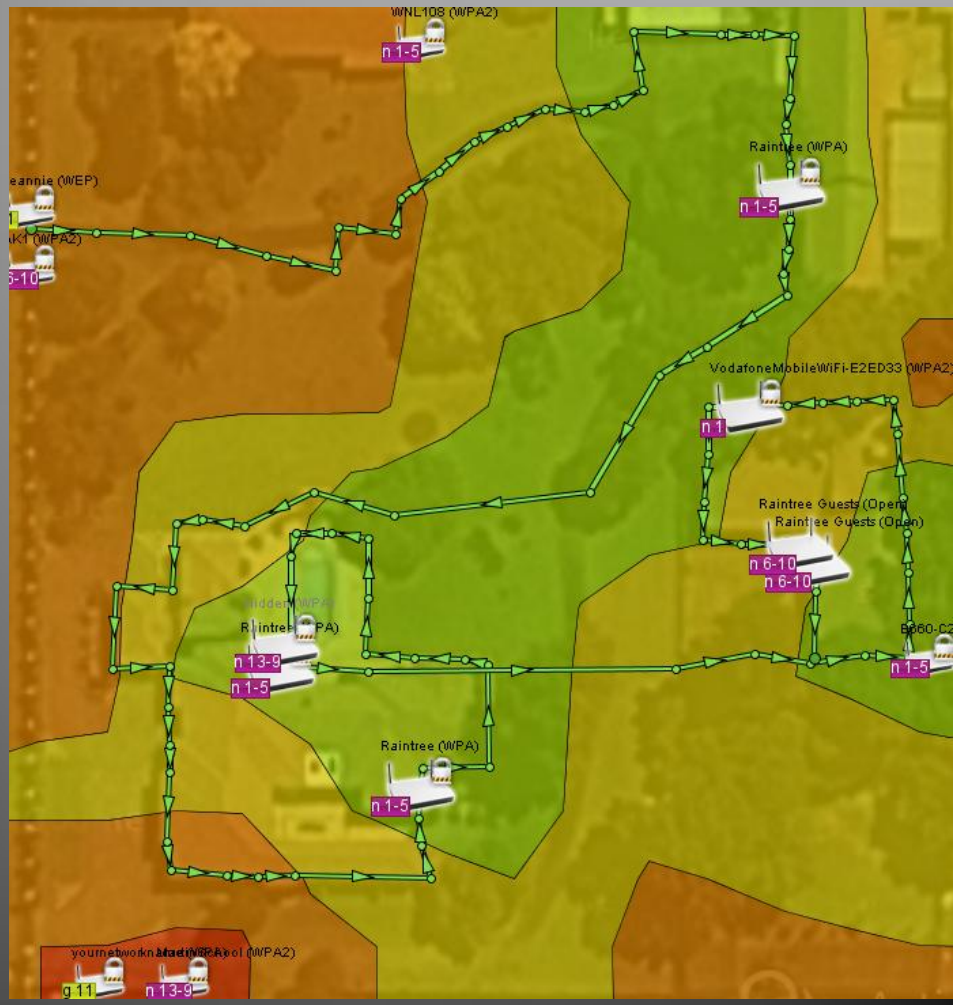
# Systems monitoring

- Live Heatmaps
- Mobile Heatmaps
- GPS Tracking
- Live monitoring (The Dude)



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# Thanks for watching »

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