Wireless Communications

for ITS/Traffic.

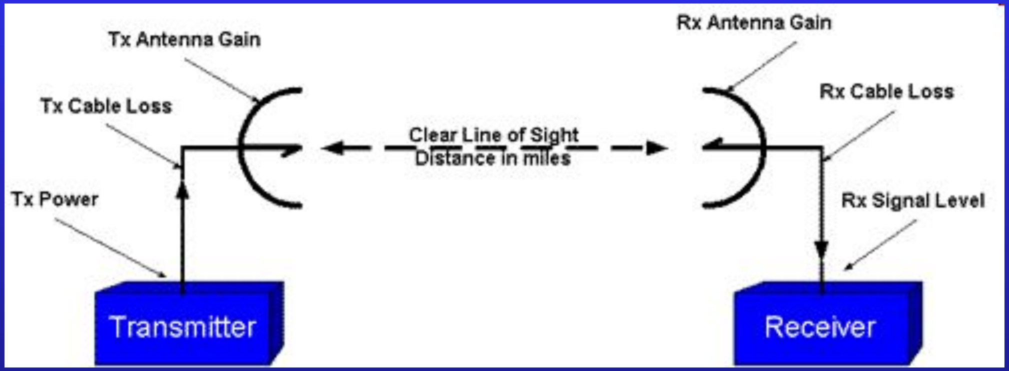
Resolving Difficult Wireless Paths in Obstructed Corridors and Best Practices for Successful Implementations

Wireless Basics

- The **Link Budget** and the resultant **Fade Margin**
- **Fresnel zone** clearance
- Wireless Path Report Card (**Unmodeled Losses**)

The Link Budget

- **Predicting RF SIGNAL Strength**
  - Like a balance sheet with line items that add or detract from your ability to have a viable link.
  - The units of measure are dB for gain and loss, and dBm for Power
  - GOOD: RF power, antenna gain, more receiver sensitivity.
  - BAD: RF cable losses, distance, higher frequency.
  - A good path check and essential for later calculation of unmodeled losses.



The Link Budget and Fade Margin

- **Fade Margin (a.k.a. System Operating Margin)**
  - The bottom line of the Link budget.
  - The number of dB that the link can afford to lose before the radio disconnects or has an unacceptable error rate.

- **The MATH**

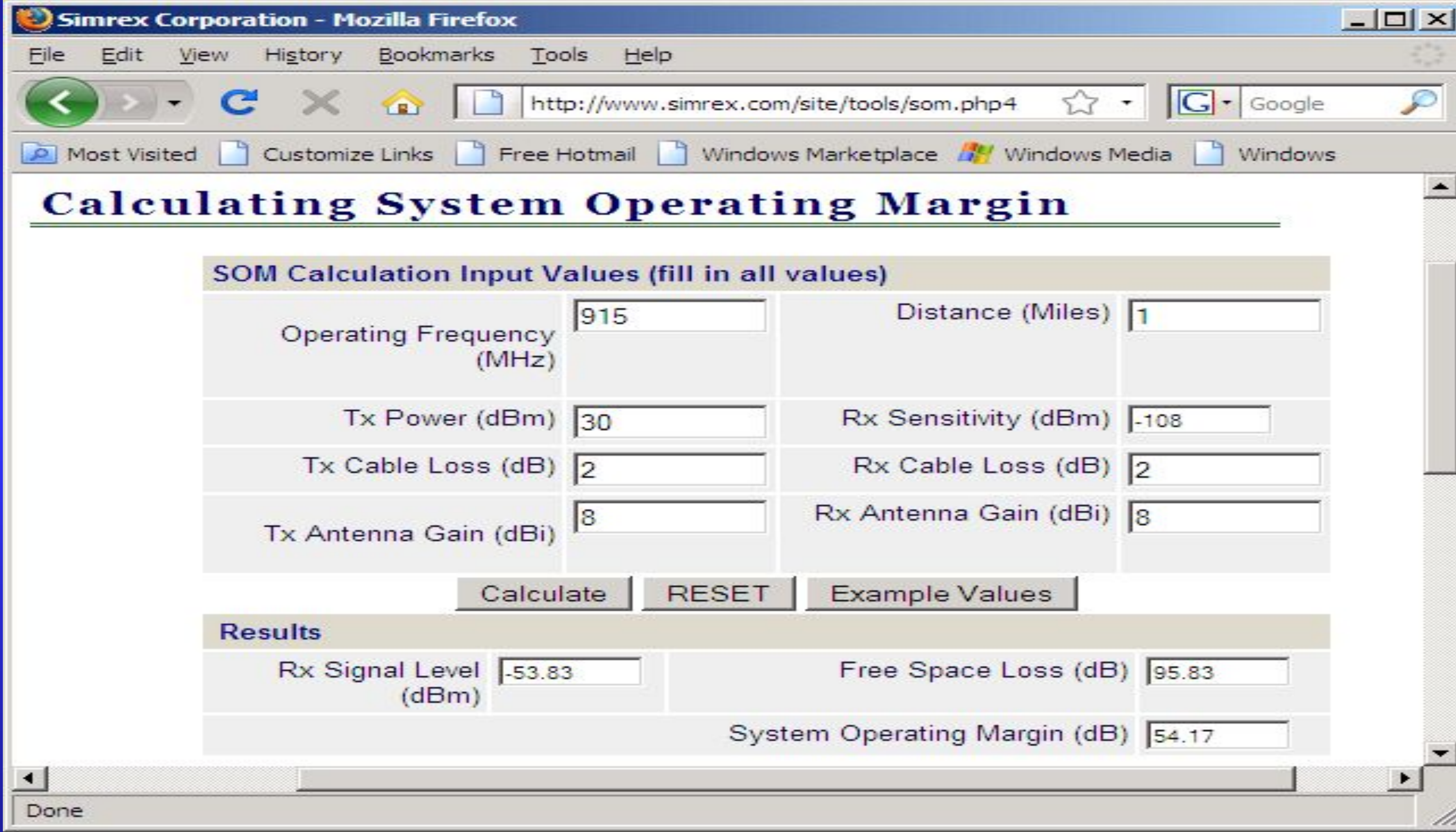
Free Space Loss = 20Log10(Frequency in MHz) + 20Log10 (Distance in Miles) + 36.6

RSL=Tx Power- Tx Cable Loss + Tx Antenna Gain - FSL + Rx Antenna Gain - Rx CableLoss

FADE Margin = Radio Sensitivity – RX Signal

20+ dB is a good target in traffic/ITS. 30+ dB is common in clear paths.

The Link Budget



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Your trusted wireless solution provider.

The Link Budget

CALCULATING SYSTEM OPERATING MARGIN

SOM Calculation Input Values (fill in all values)			
Operating Frequency (MHz)	5800	Distance (Miles)	1
Tx Power (dBm)	25	Rx Sensitivity (dBm)	-78
Tx Cable Loss (dB)	.25	Rx Cable Loss (dB)	.25
Tx Antenna Gain (dBi)	23	Rx Antenna Gain (dBi)	23

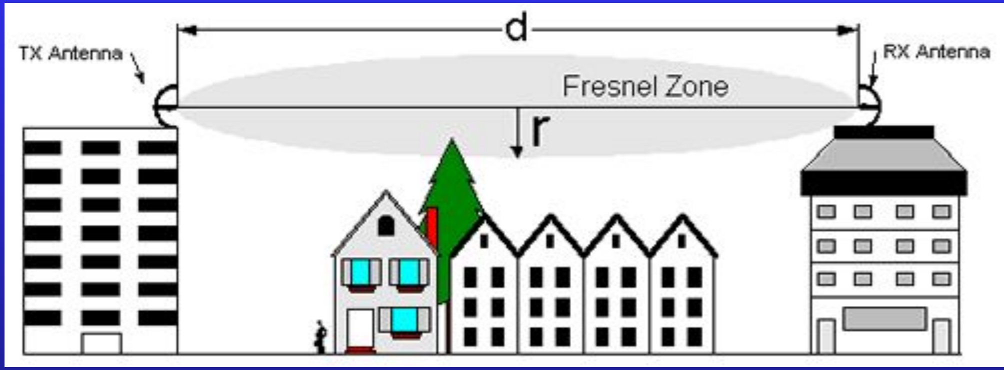
Calculate | RESET | Example Values

Results			
Rx Signal Level (dBm)	-42.37	Free Space Loss (dB)	111.87
		System Operating Margin (dB)	35.63

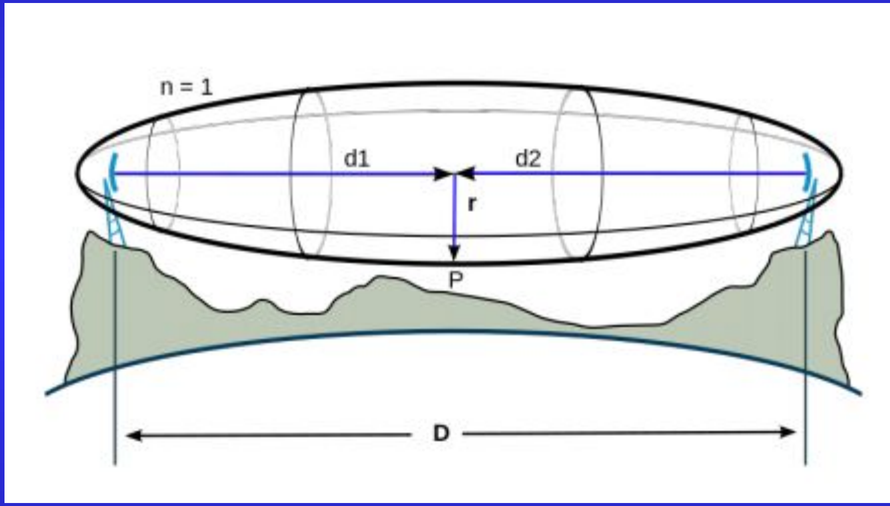
Fresnel Zone Clearance

- Direct visual path (line of sight) is important but it is not enough
- You need some need some extra clearance “r” in all directions around the direct path line.
- r increases for lower frequencies or longer distance.

Fresnel Zone = 72.1 * Sqrt (d / (f * 4))   where d is in miles and f in GHz



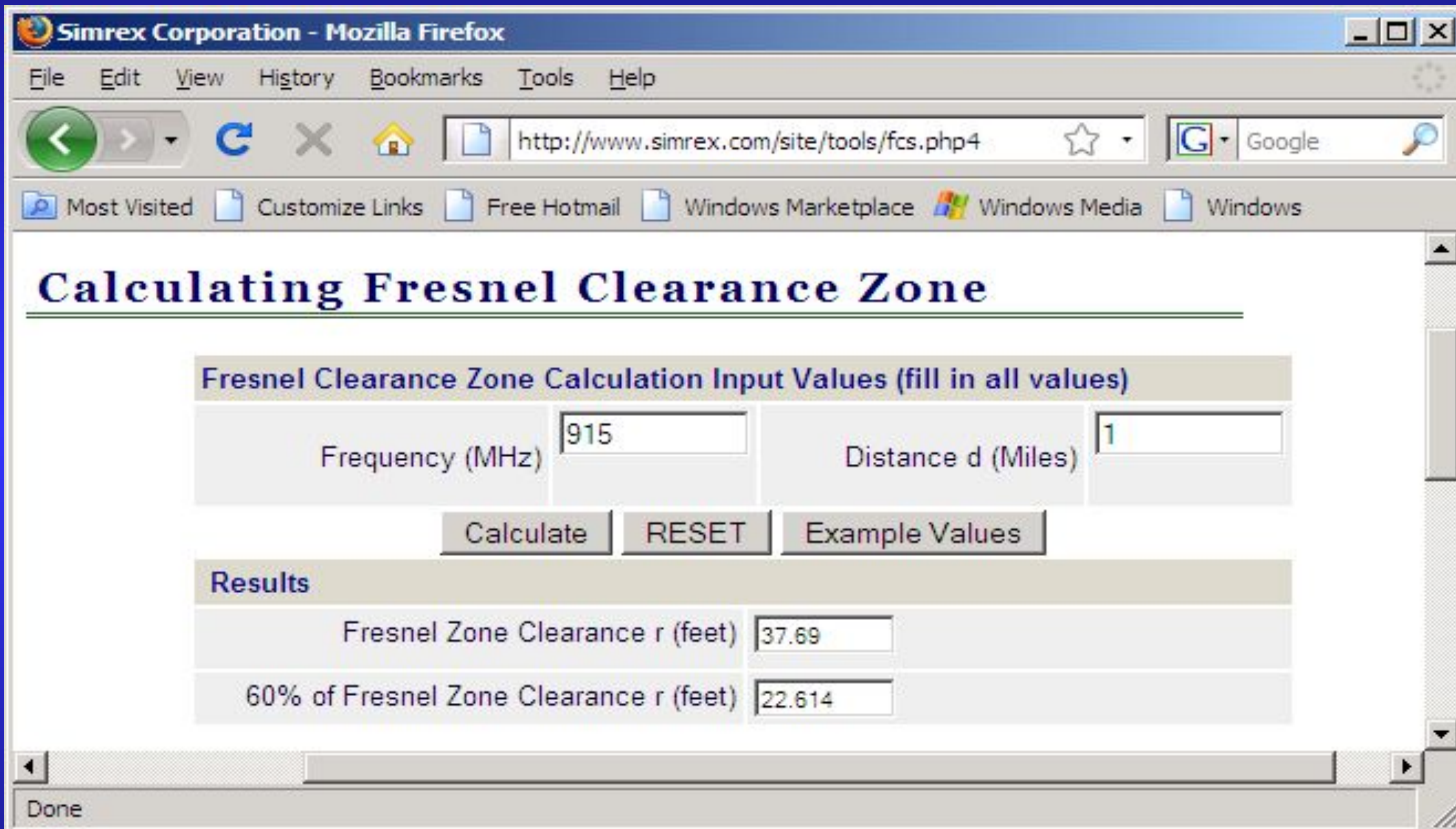
Fresnel Zone Clearance



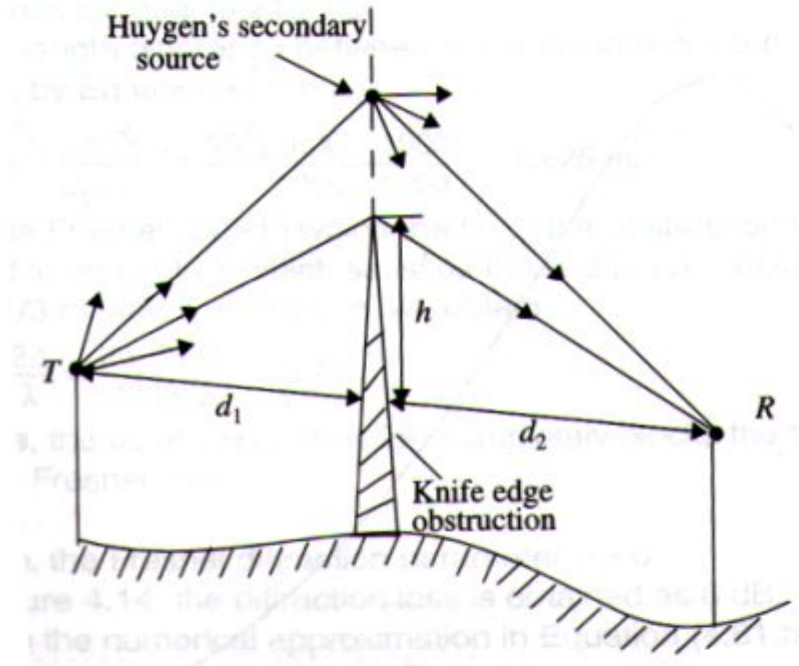
Fresnel Zone Clearance

- Because of the wave nature of radio signals, grazing an edge can increase or decrease the strength of signals that are above or below the edge. The mechanism operates by constructive and destructive interference.
- The edge can be anything. Sideways: A building very close to the street. Above: A sign or bridge above the line of sight.
- If you can see from one antenna to the other, you have **OPTICAL or VISUAL line of sight.**
- If you have adequate Fresnel clearance to any obstructions, you have **RF line of sight**.

Fresnel Zone Clearance



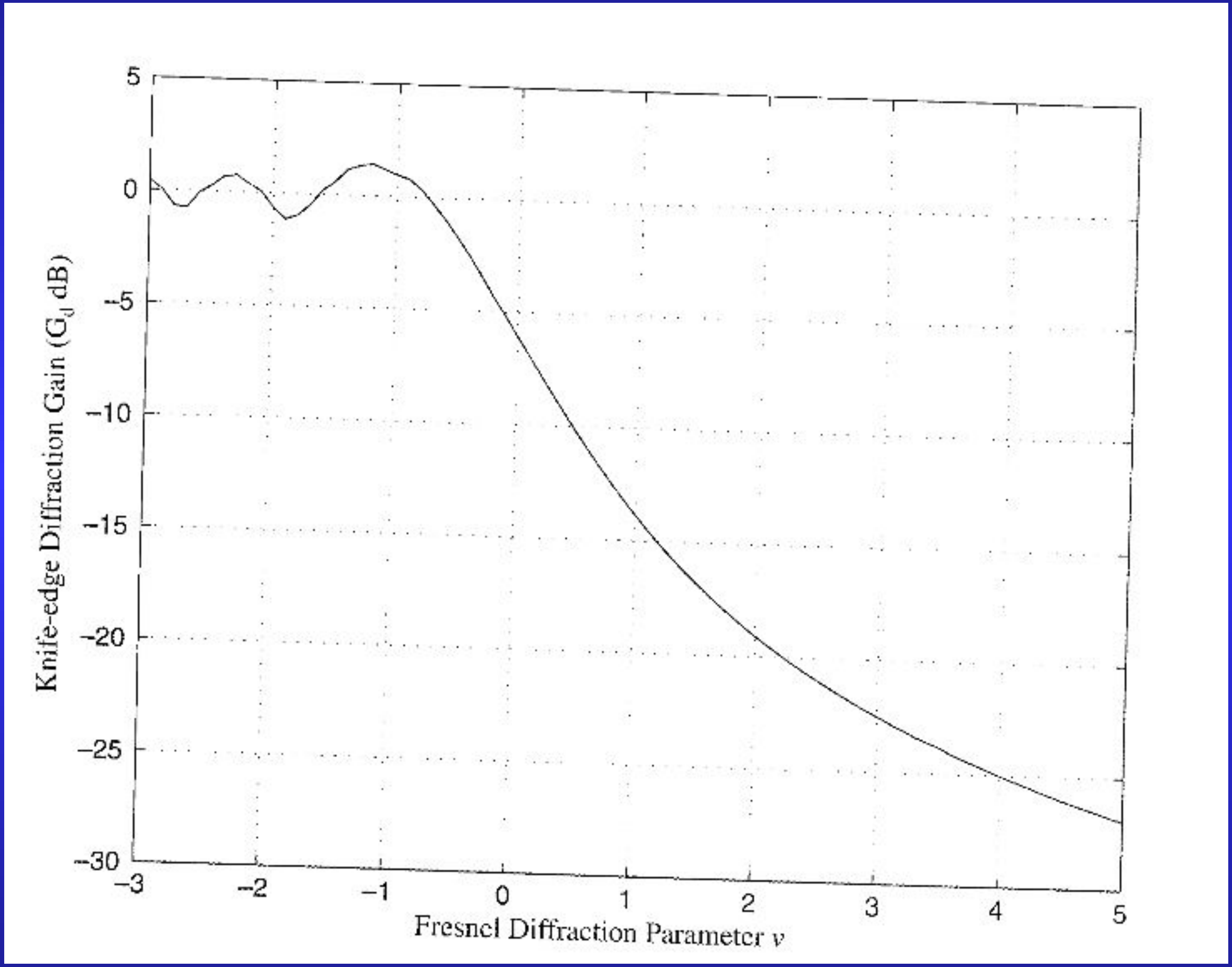
Fresnel Loss Details



For this geometry we can compute a parameter called the Fresnel-Kirchoff diffraction parameter, ν:

$$\nu = h\sqrt{\frac{2(d_1 + d_2)}{\lambda d_1 d_2}}$$

Fresnel Loss Quantified



Unmodeled losses

What if the measured RSSI (signal strength) is less than the predicted received signal level with the fade margin calculator?

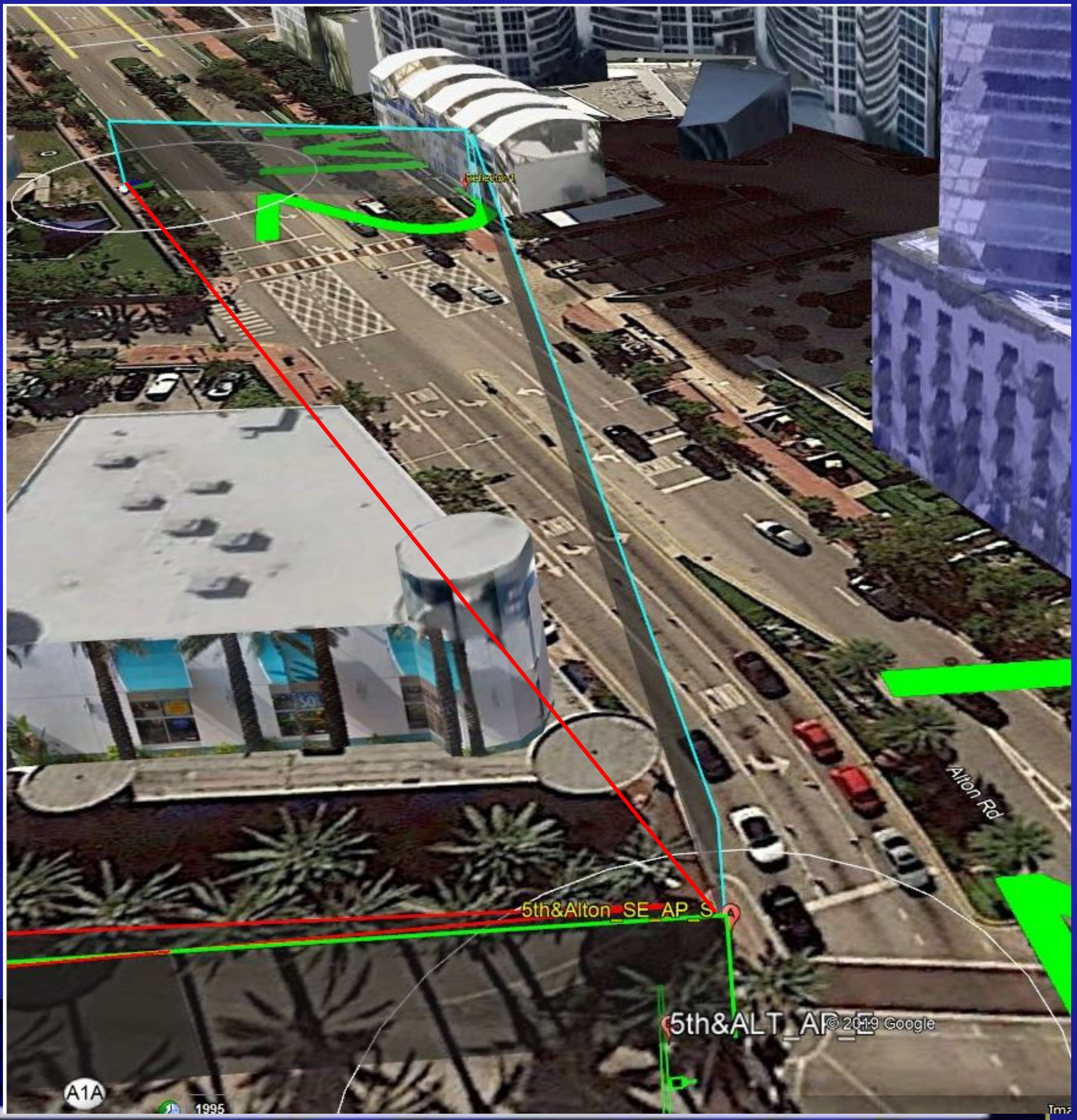
This difference is either a faulty component or antenna alignment or other unmodeled loss.

Common causes of unmodeled loss:

- Foliage
- Fresnel loss due to terrain or buildings
- Other more complex NLOS loss
- Desensitization due to strong signal nearby that is within the receiver bandwidth, but not on the exact channel you are on.

As you experience these unmodeled error types, catalog them on crib sheet to build your RF path engineering experience.

Unconventional Method for Obstructed Paths. Reflection Path



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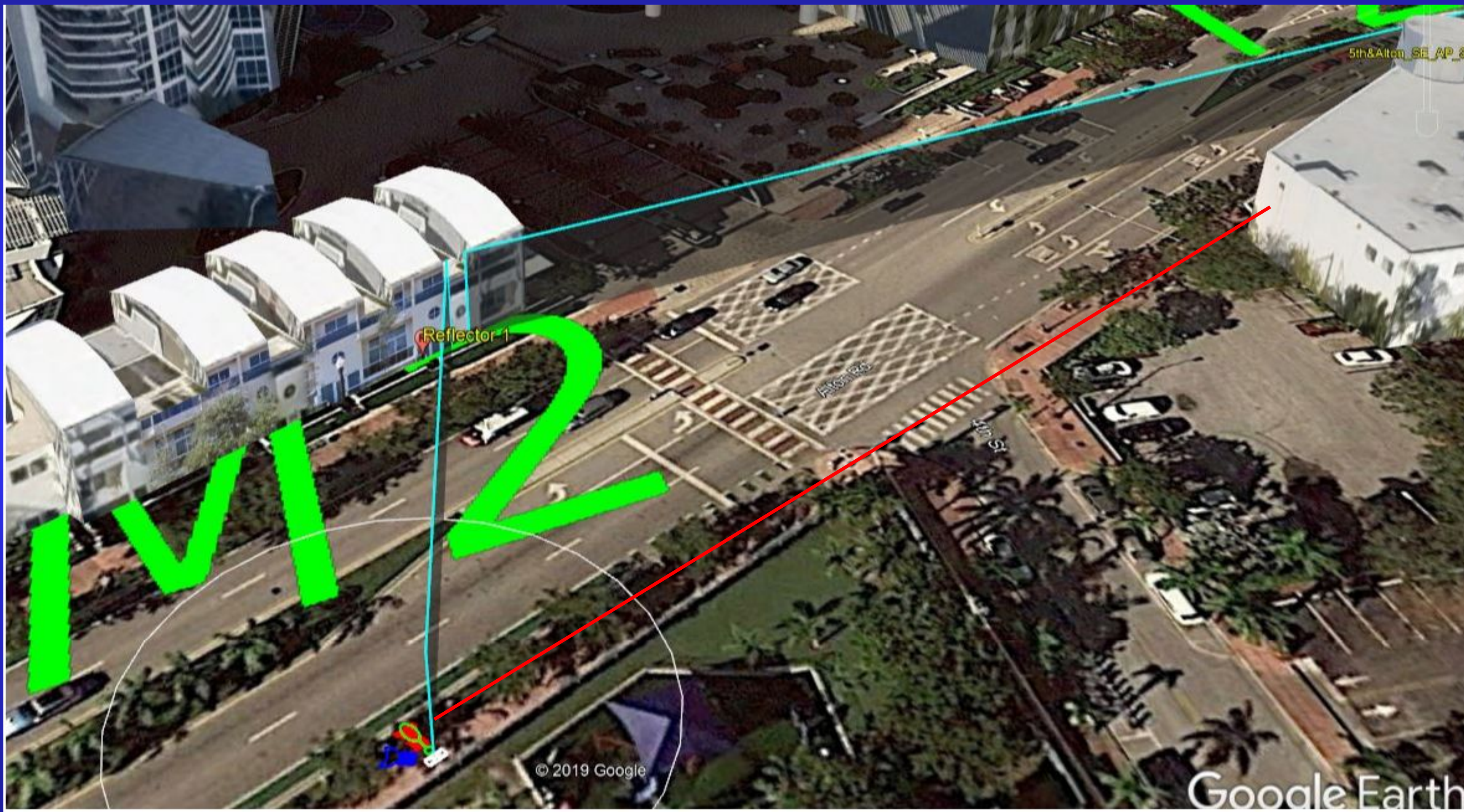
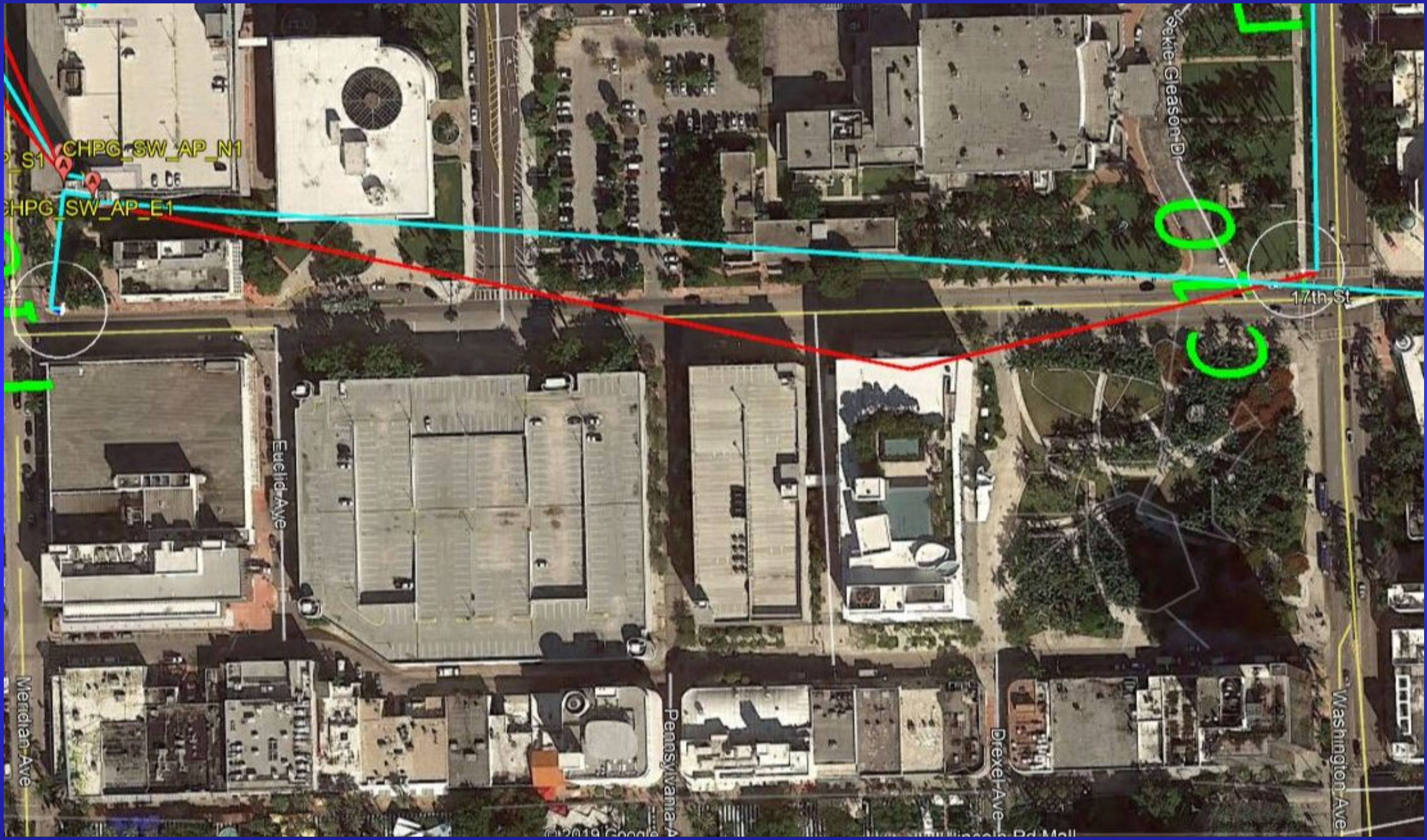
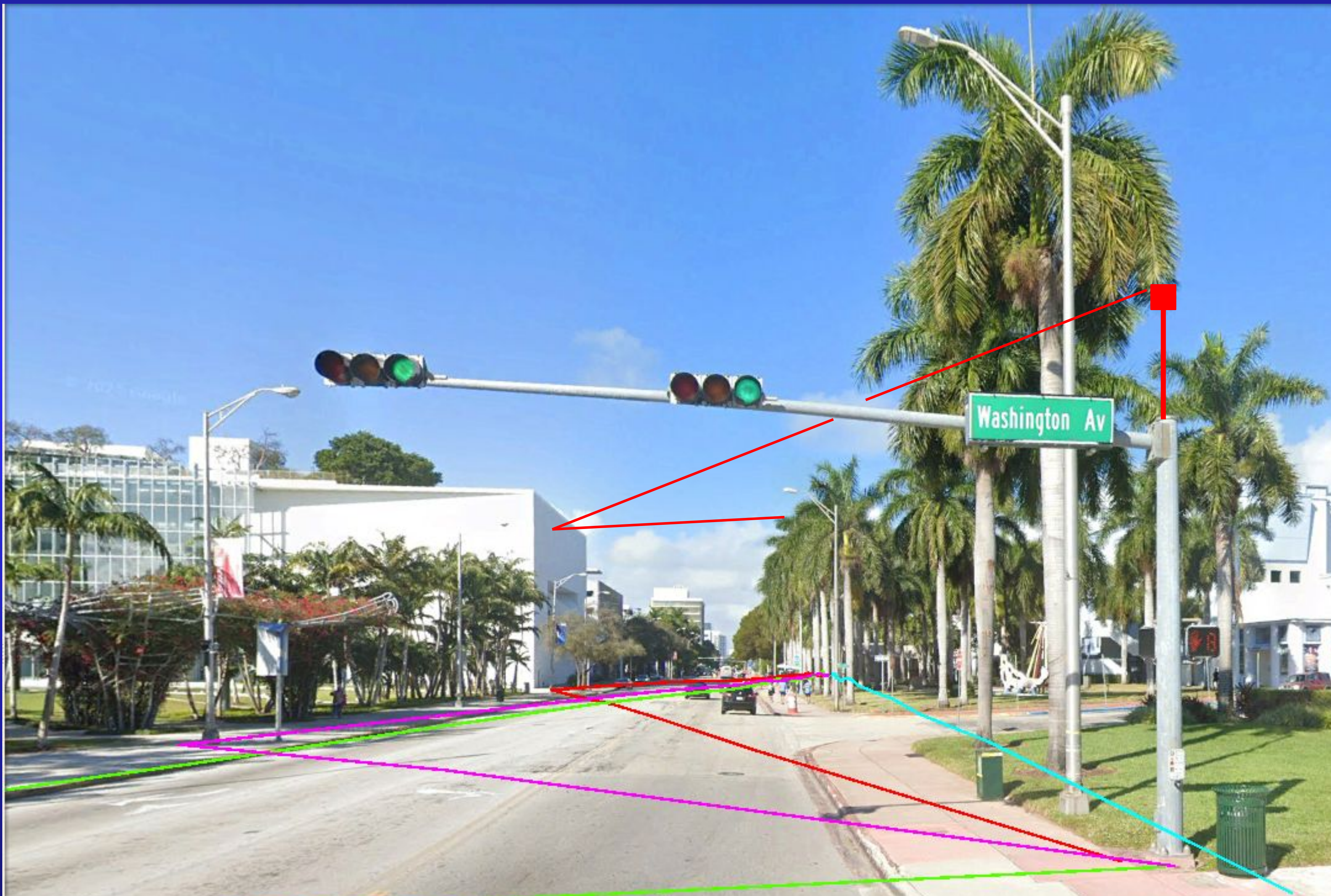
Unconventional Method for Obstructed Paths. Reflection Path



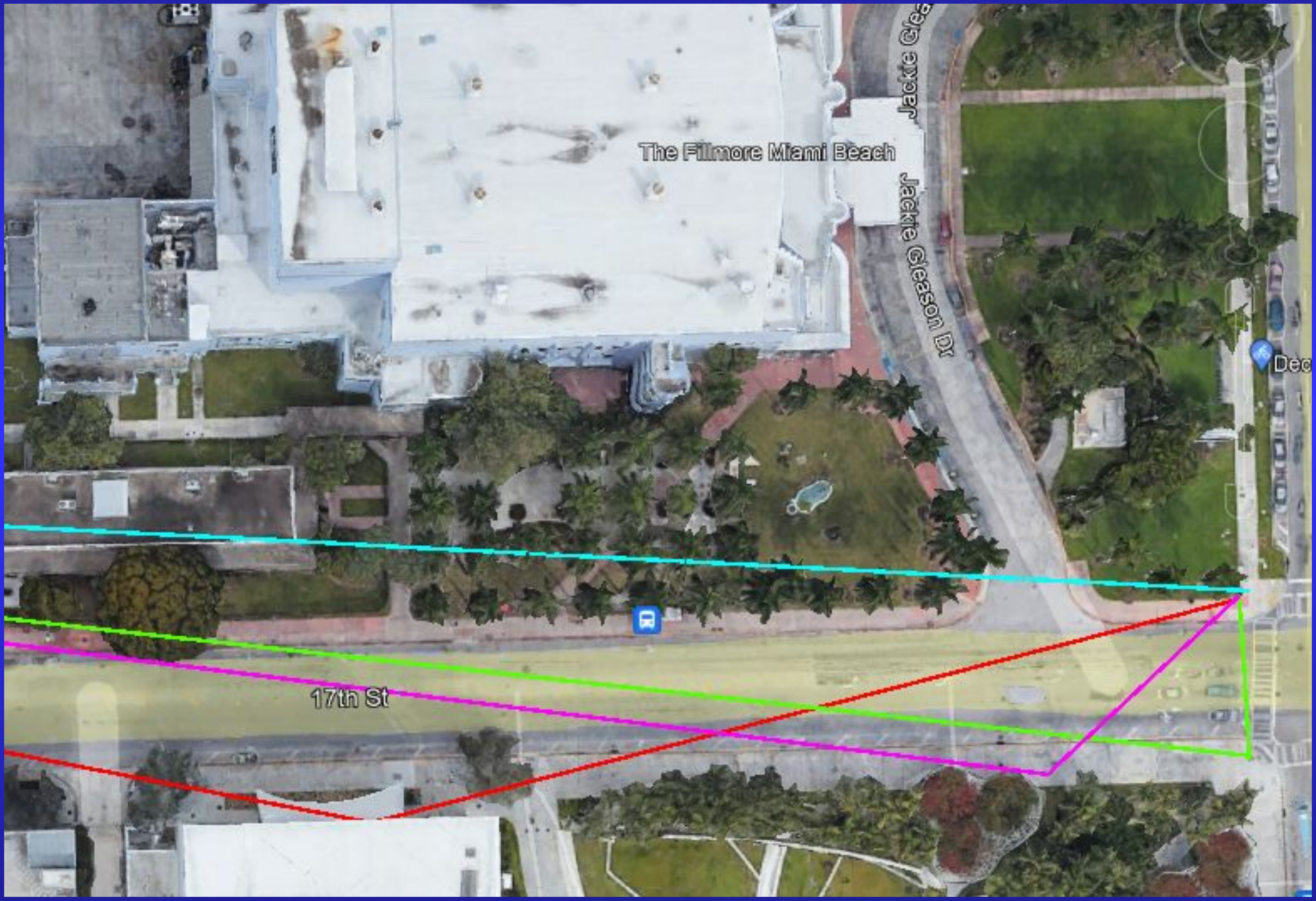
Unconventional Method for Obstructed Paths. Reflection Path off building face



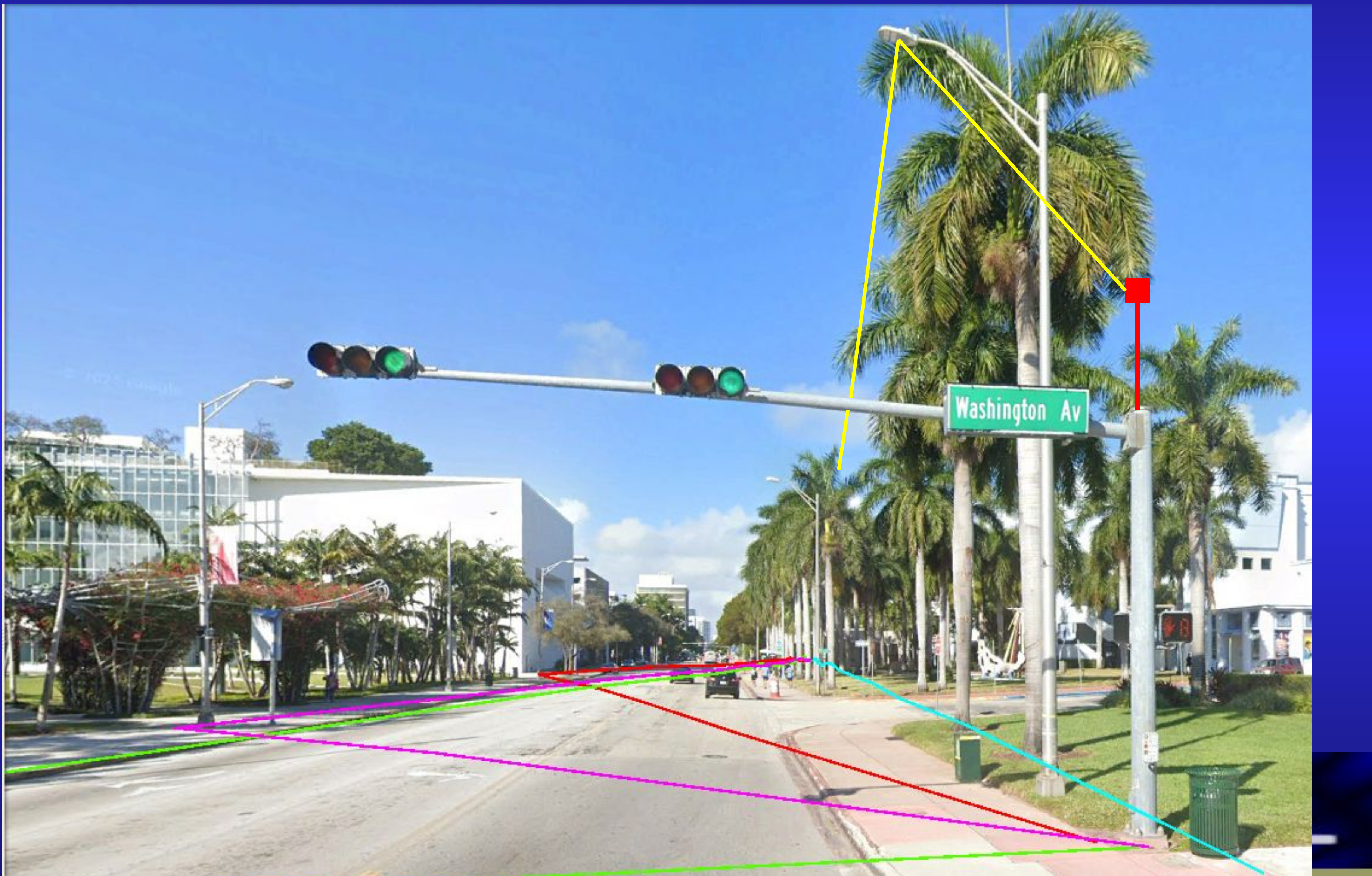
Unconventional Method for Obstructed Paths. **Ground View.**



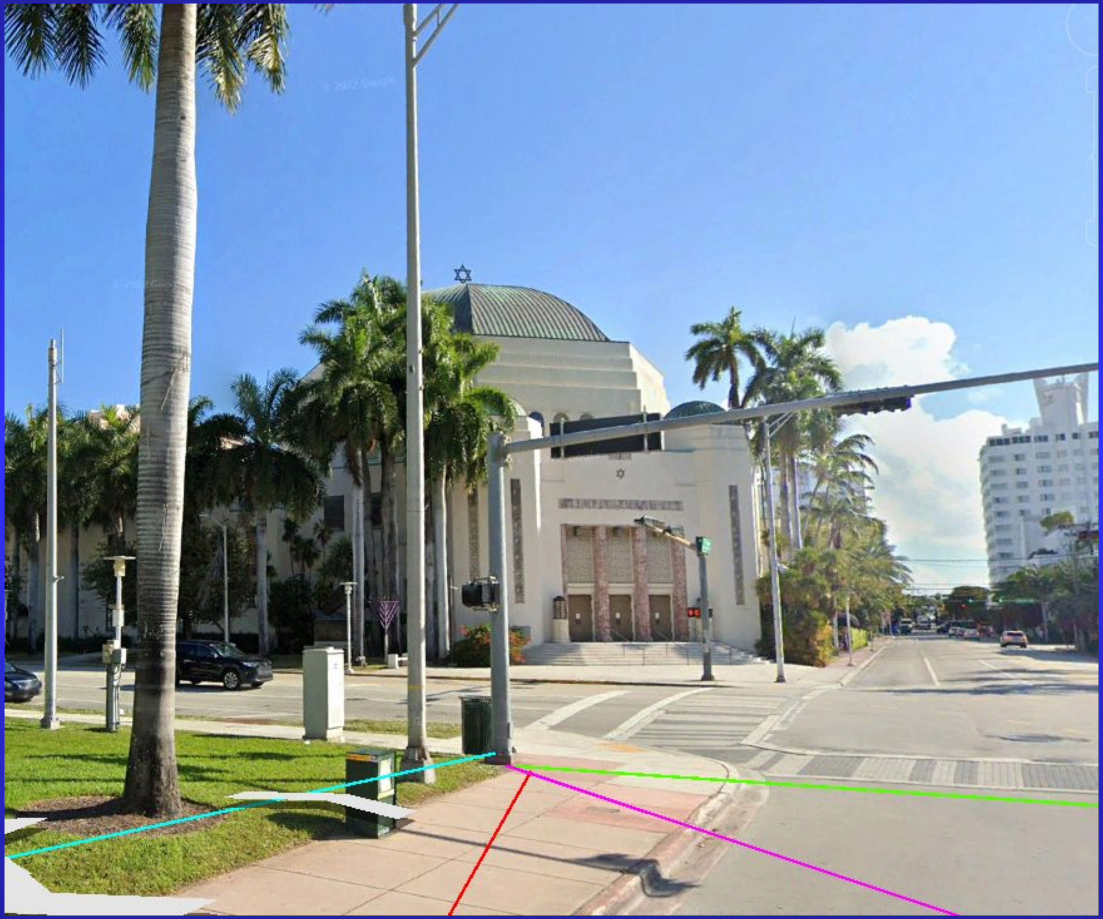
Unconventional Method for Obstructed Paths. Reflection Path from Poles



Unconventional Method for Obstructed Paths. Reflection from luminaire Head.



Unconventional Method for Obstructed Paths. Reflected Path from Irregular Structure.

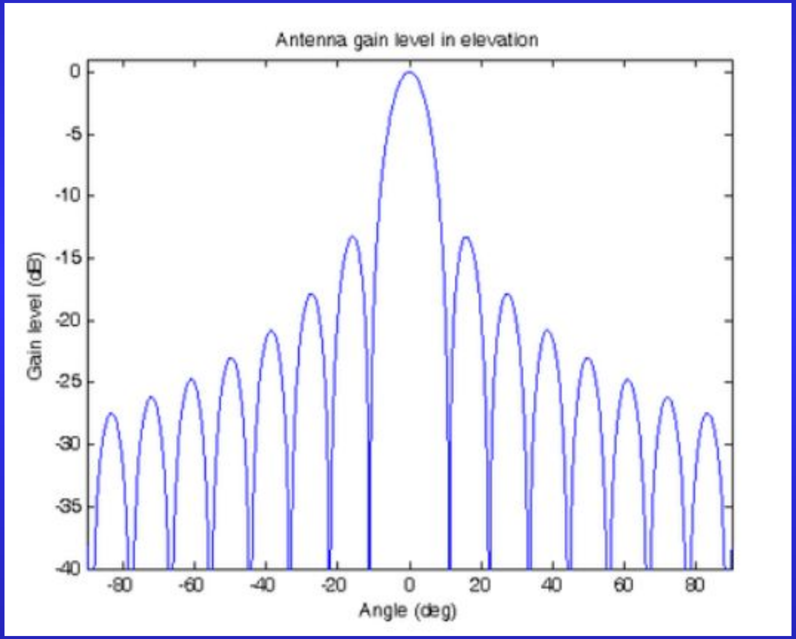


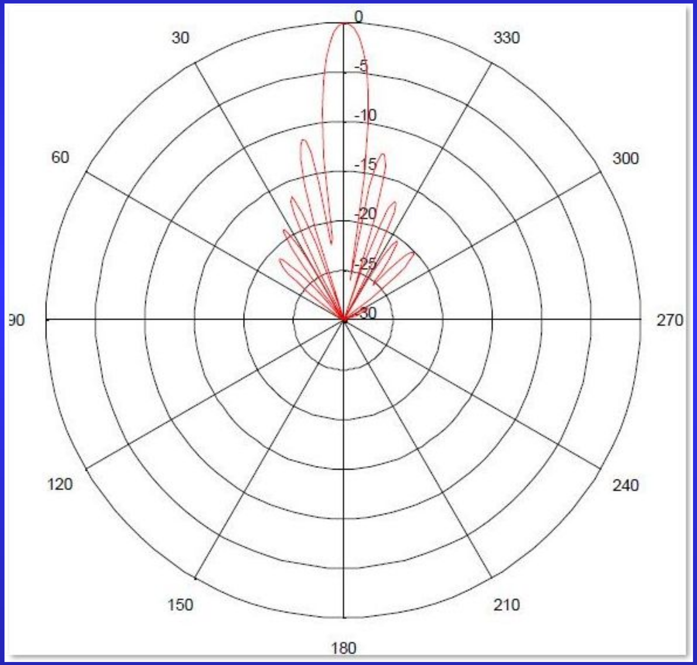
Unconventional Method for Obstructed Paths.

- 20 dB Reflected Path Improvement
- 9 dB Improvement by Using 900 MHz instead of 5800MHz

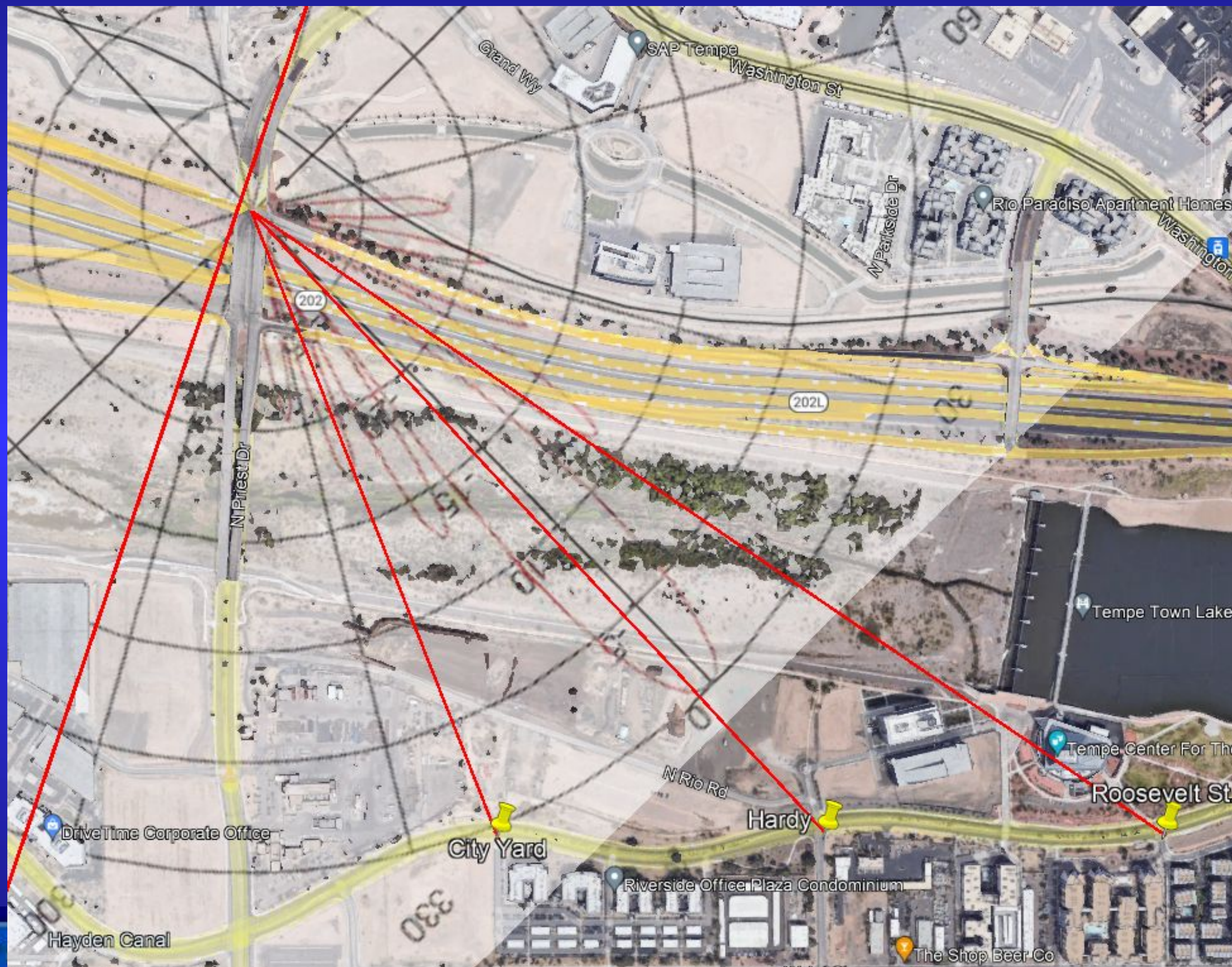
COMMENT	height	Frequency	dist (mi)	TX Power dBm	modeled RSSI (dBm)	measured RSSI min dBm	measured RSSI max dBm	Unmodeled Loss min dB	Unmodeled Loss max dB	unmodeled loss avg dB	t T
direct and/or bounce due to beamwidth	M+6=24	915 MHz	0.35	30	-32.21	-55	-45	22.79	12.79	17.79	
direct with little reflection.	M+12=30	5765 MHz	0.35	23	-34.2	-63	-59	28.8	24.8	26.8	
bounce off white wall South side to avoid foliage	M+6=24	5765 MHz	0.35	23	-34.2	-42	-40	7.8	5.8	6.8	

Typical sin/x Antenna Pattern





Hitting multiple remotes over a wide angle using a narrow beam radio.



Installation Best Practices:

Aiming

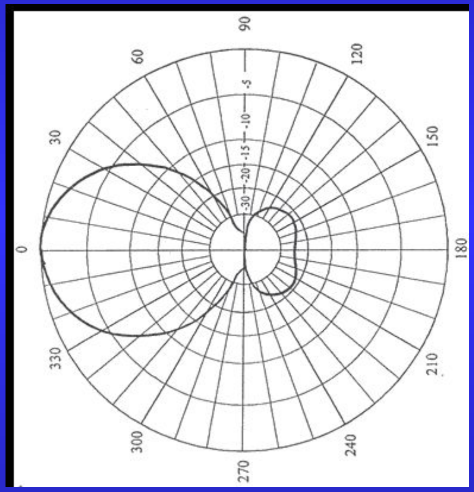
- Use an optical aiming device.

Interference Remedies (null steer)

- Antenna is aimed directly at the desired carrier but also sees equal power interference at 30 degrees off of the main beam.

C=carrier

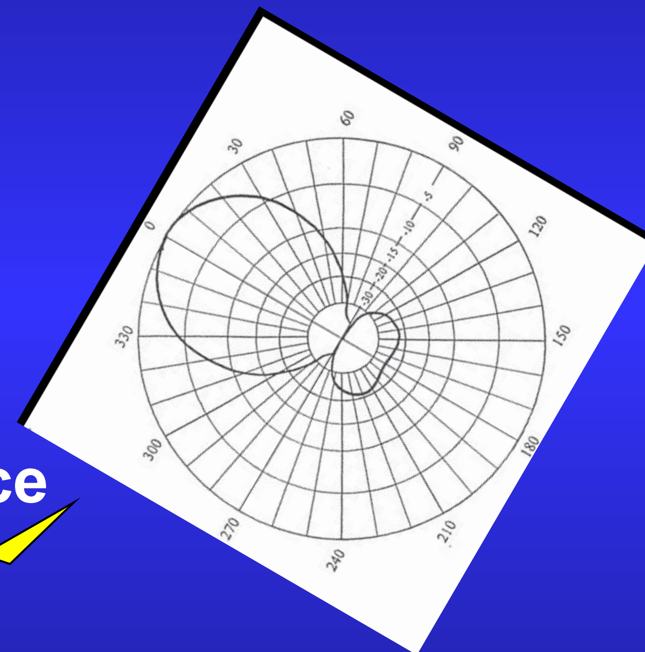
I=interference



- C=0 dB   I= -4 dB
- C/I is   4 dB in this case, marginal

Interference Remedies (null steer)

- Steer the null of antenna to suppress co-channel or desensitization interference. Rotate by ~ 30 degrees
- Sacrifice 4 dB of carrier



C=carrier

I=interference

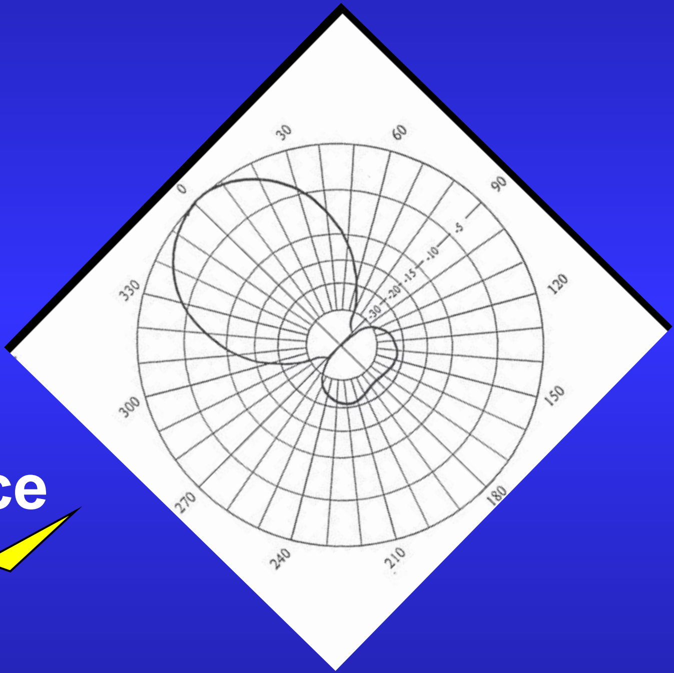
- C= -4 dB   I= -17 dB
- C/I is   13 dB in this case, 9 dB (8x) improvement

Interference Remedies (null steer)

- Steer the null of antenna even more to suppress co-channel or desensitization interference.
- Sacrifice 8 dB of carrier

C=carrier

I=interference



- C= -8 dB   I= -30 dB
- C/I is   22 dB in this case, 18 dB (64x) improvement

Path Planning Tips for ITS/Traffic:

- AP's (Access points or Bases) for point to multi point corridor systems should have the AP's on taller elevated risers.
- Keep all antennas to the (RF) open centroid of the corridor.
- Validate any challenging paths with super zoom photography.
- Test any risky challenging paths and try alternatives (eg. bounce).

Testing Results Spreadsheet should have:

- Speed of each RF link in each direction.
- Signal Quality of each link if available
- Measured RSL/RSSI of each RF link. Yellow flag if 20 db lower than theory or stronger than -25 dBm.
- Theoretical free space RSI/RSSI of each RF link (and calculated UL).
- TX/RX speed of ETH link to each radio (validate new cable install).

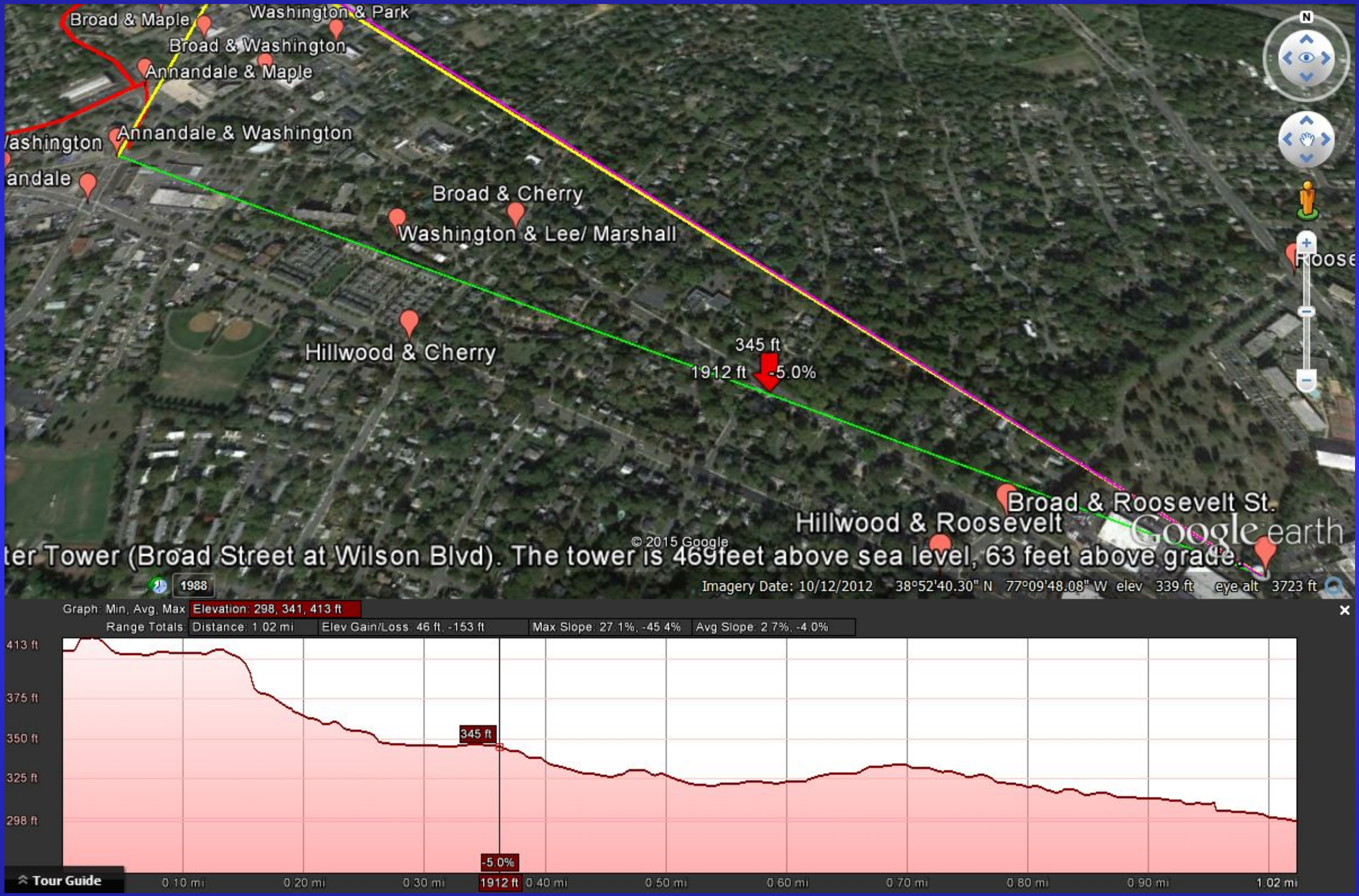
Path Planning in Traffic/ITS

- **Use Google Earth aided by telephoto photography with high zoom 10 to 30x** to visualize/validate the clear centroid and any midpath obstructions.
- **Locate the AP (master)antennas at each end so that the path is centered in the corridor.** Locating on signal arms is best. Locate 6+ feet above the signal arms to avoid shadowing from of other sidearms midpath.
- **Less desirable is diagonal shots from corners** at side of street due to close range Fresnel obstructions such as lamp head of the next luminaire. Locate well above or below luminaires if forced to do this.

Path Planning with Zoom Photography

Path Planning with Zoom Photography

Path Planning with Google Earth



Antenna Location Tips for ITS/Traffic:

- Use telephoto photography with high zoom (10 to 20x) to visualize/validate the clear centroid and any midpath obstructions.

- Locate the AP (master)antennas at each end so that the path is centered in the clear tunnel. Locating on side-arms mid street or mid-lane incase of median with corridors is best. Locate 8+ feet above the side-arms to avoid shadowing of other side-arms midpath.

- Less desirable are diagonal shots from luminaires at side of street due to close range Fresnel obstructions such as lamp head of the next luminaire. Locate well above luminaire if forced to do this.

Antenna Location Tips for ITS/Traffic:

- If throughput is critical, separate Client and AP at repeater nodes. Put them on separate poles or side arms to minimize desensitization.

Path Benchmarking Tips for ITS/Traffic:

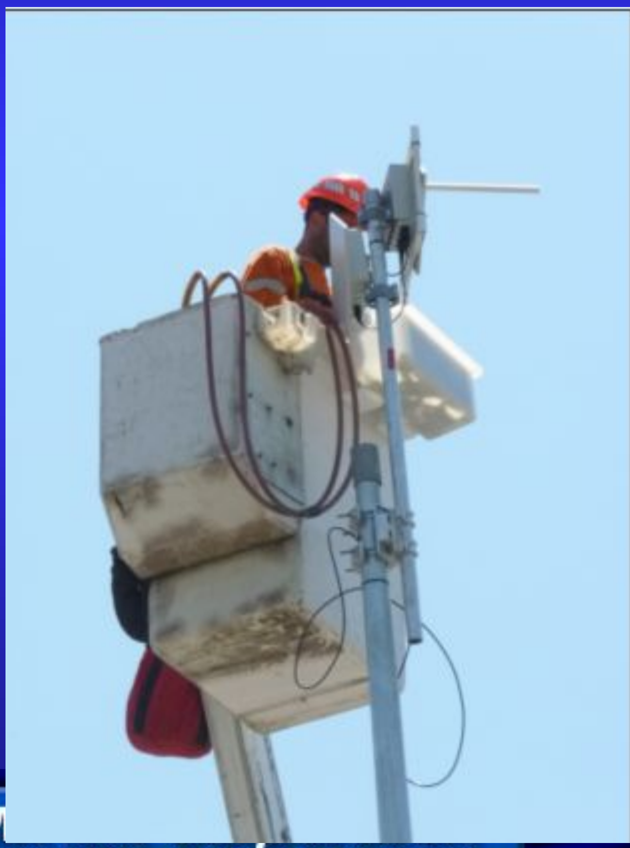
Benchmarking report from radio should have:

- Frequency and channel width
- Speed of each RF link in each direction (min, max, avg).
- Signal Quality in each direction.
- Theoretical free space RSI/RSSI of each RF link.
- Measured RSL/RSSI of each direction (min, max, avg). Yellow flag if 20 db lower than theory or stronger than -25 dBm.
- TX/RX measured speed of ETH link to each radio (to validate new cable). Some radios will test the cable.

Installation Best Practices:

Aiming

- Use an optical aiming device.



For a full session version of this presentation contact Frank Neuperger at Simrex Corporation.

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