

Reliable Mobile Services



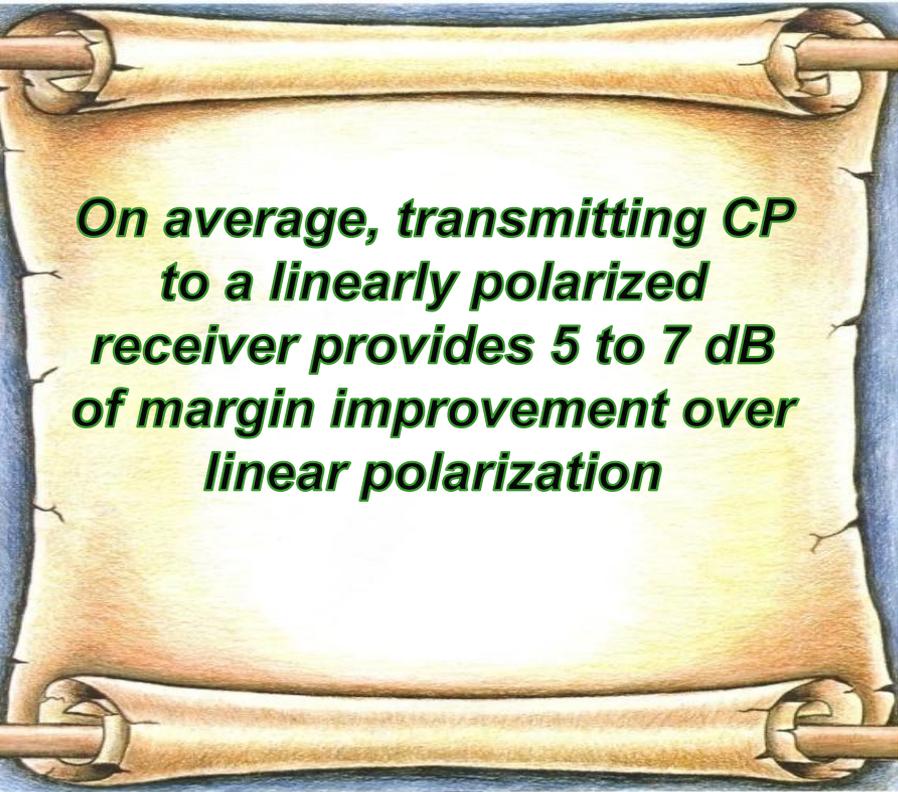
New Experiments Comparing Linear and Circular Polarization Performance for Mobile Services

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Review

Over the last 4 years, SPX has conducted extensive testing to quantify the benefit of transmitting circular polarization in mobile applications.

A scroll with a yellowish, aged appearance, tied with wooden rings at the corners. The text is written in a bold, green, sans-serif font.

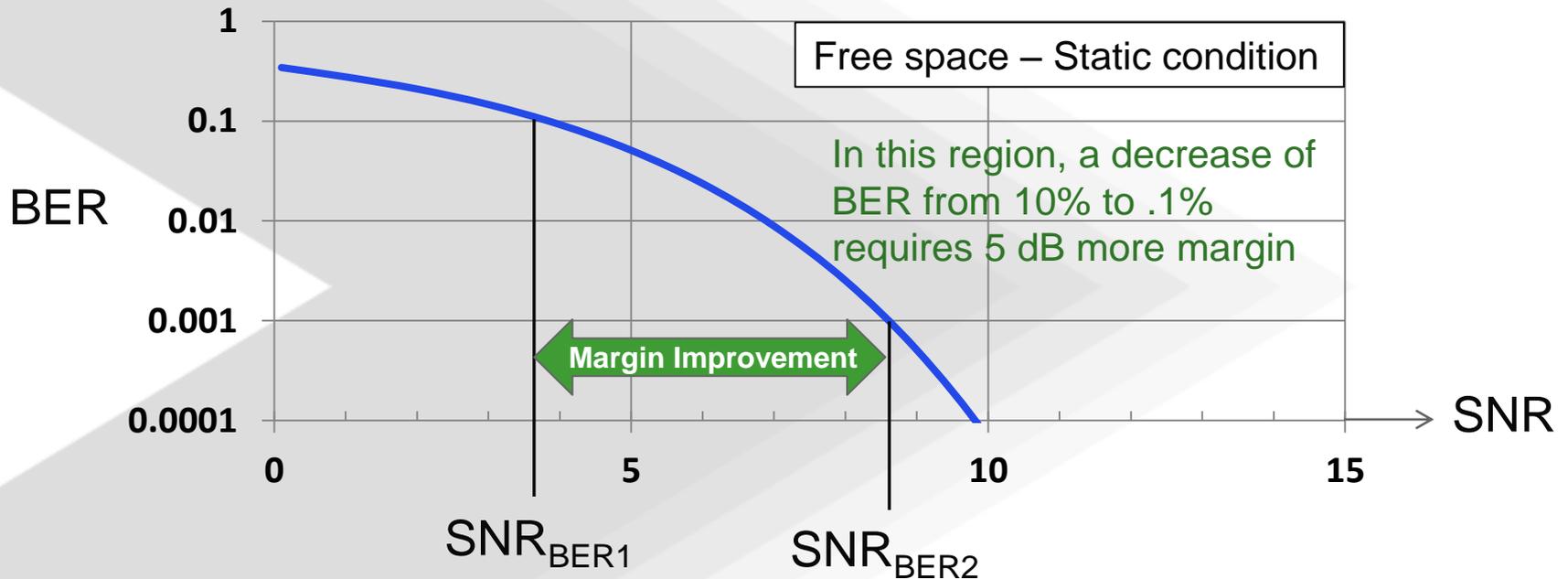
On average, transmitting CP to a linearly polarized receiver provides 5 to 7 dB of margin improvement over linear polarization

“All your test results are based on RSSI. What about BER? If CP truly provides margin then prove it by measuring BER.”



Relationship between BER and Margin Improvement

BER and SNR are inversely related



Define:

$$\text{Margin Improvement} = \text{SNR}_{\text{BER2}} - \text{SNR}_{\text{BER1}}$$

Margin = Reliability

Adjust SNR vs. BER for “real life” conditions

Rayleigh Fading

A fading channel is estimated with a Rayleigh distribution when there is no dominant line of sight.

Modulation Scheme

ICOM LMR system based on non-coherent 4 level frequency shift keying.



“4FSK”



In a Rayleigh fading environment when using non-coherent 4FSK it can be shown that the probability of signal is given by:

$$P_r = \frac{1}{2} \left(1 - \sqrt{1 - \frac{2\gamma}{m+1}} \right) \quad \text{Where} \quad \left(\frac{\gamma}{m} \right) = \frac{P_r}{P_s}$$

Non-coherent 4FSK

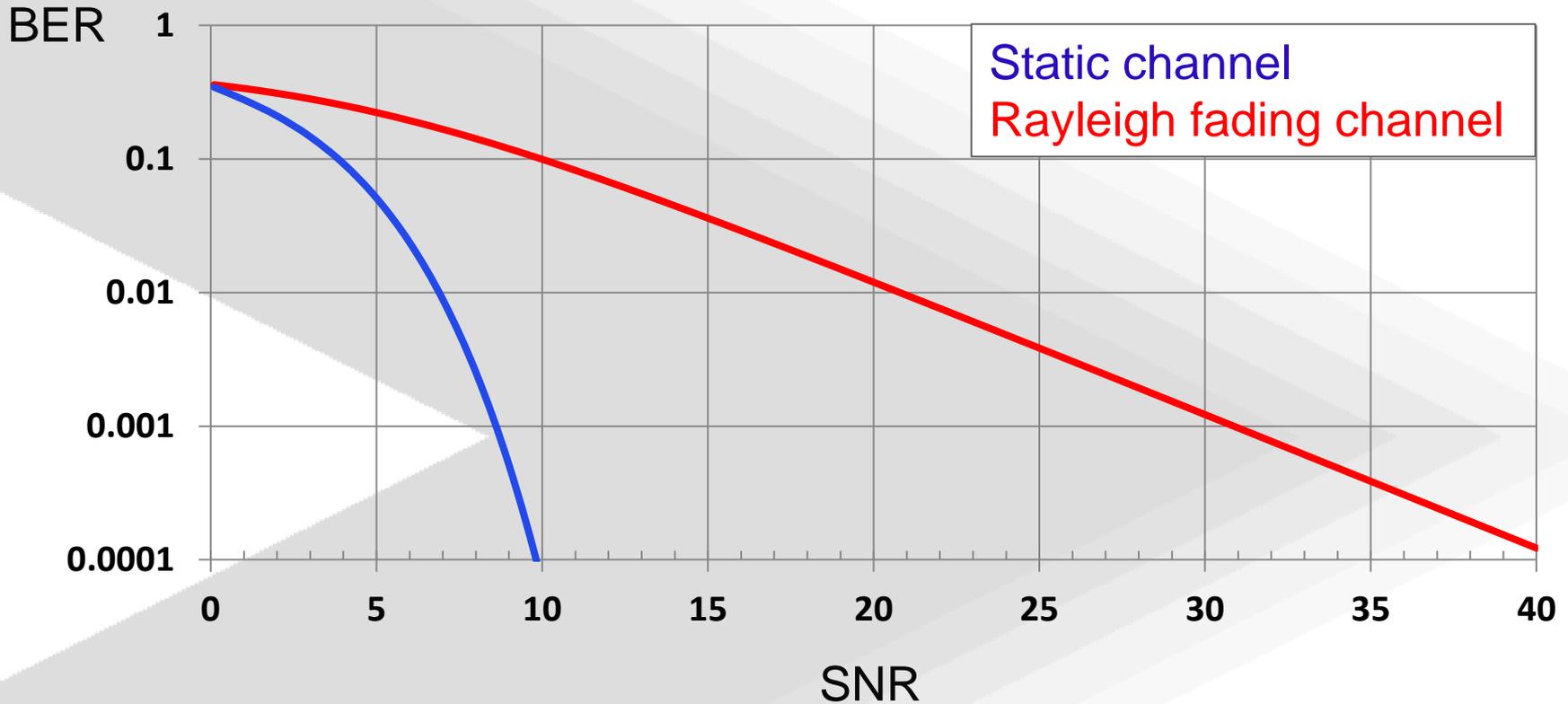
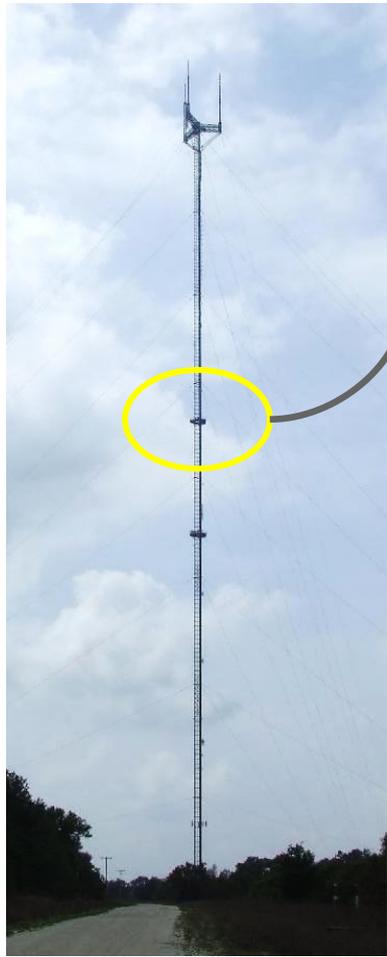


Chart will be the basis for determining margin improvement from measured average bit error rates.

Design of Experiment

Joint effort with West Central Florida Group Inc.



Base station antennas: Switchable between a vertically polarized and a circularly polarized antenna.
Frequency 447 MHz

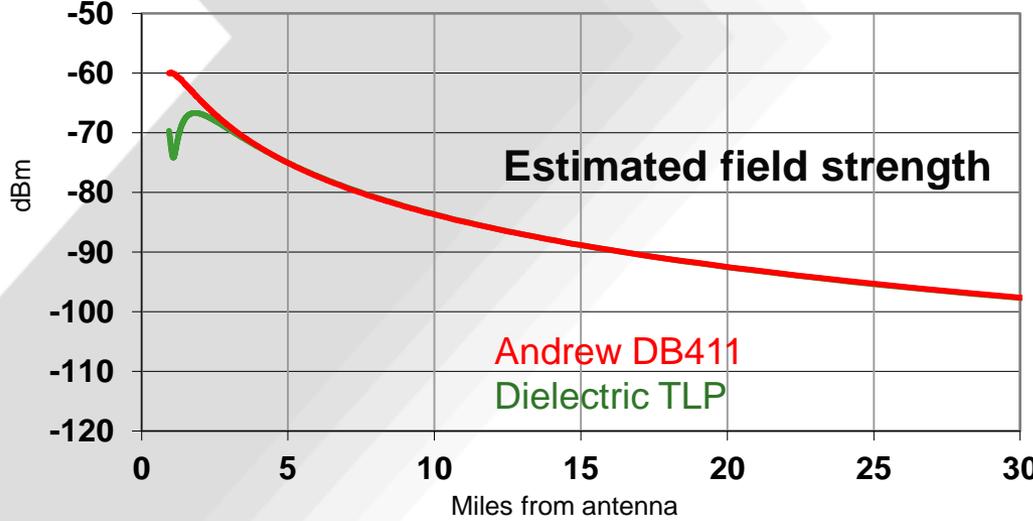
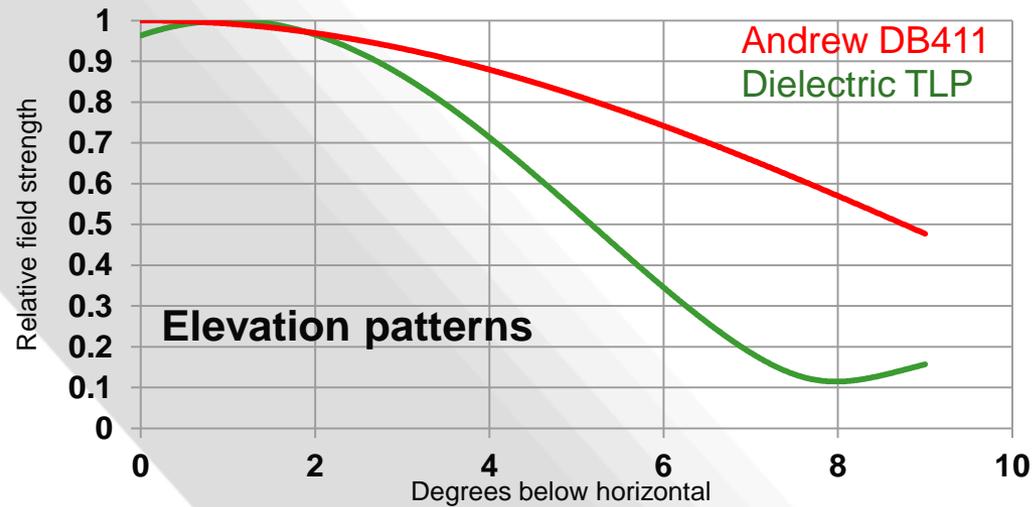
Mobile unit simulates a linearly polarized mobile handheld



Continuously sampled the BER and GPS while varying the receive antennas orientation and location

ATC Broadcast Tower – Riverview, FL

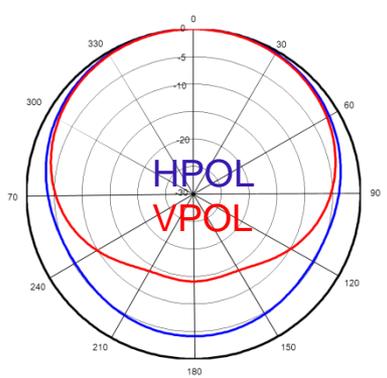
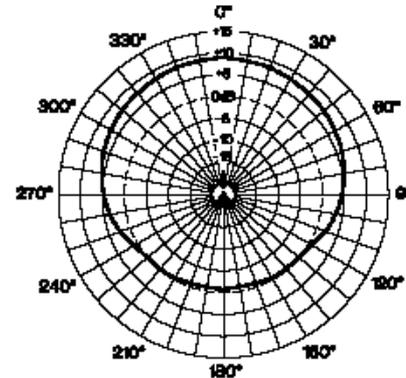
Dielectric TLP8B-CP vs. Andrew DB411



Andrew DB411
Vertically polarized
Gain 9 dBd



Dielectric TLP8B-CP
Circularly polarized
Gain 9 dBd per pol

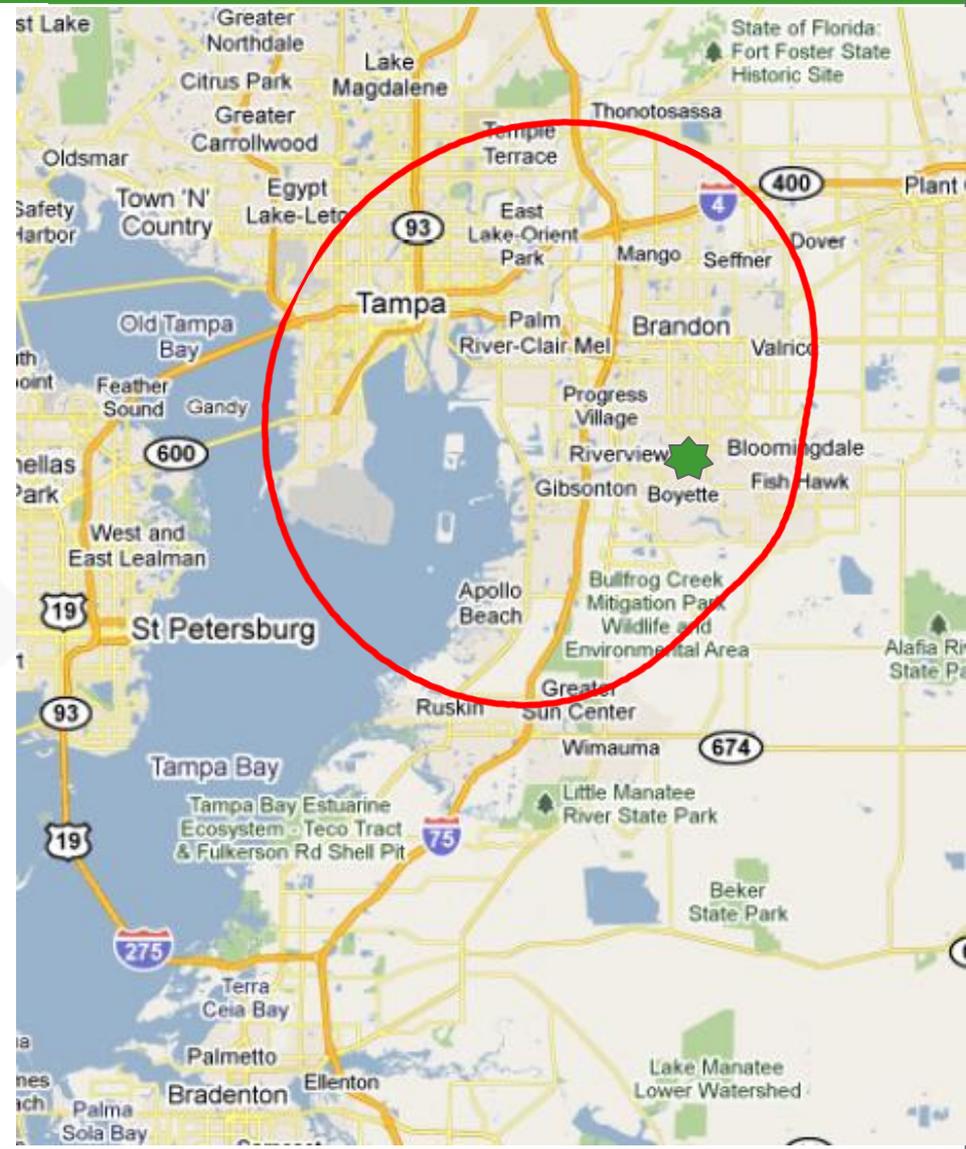


Azimuth patterns

Environments

Collected data in 3 different environment categories

- Outdoor
 - Open areas
 - City
- Indoor
 - Mall
 - Office complex
- Driving
 - Reception inside the vehicle
 - Small exterior antenna
 - Large exterior antenna

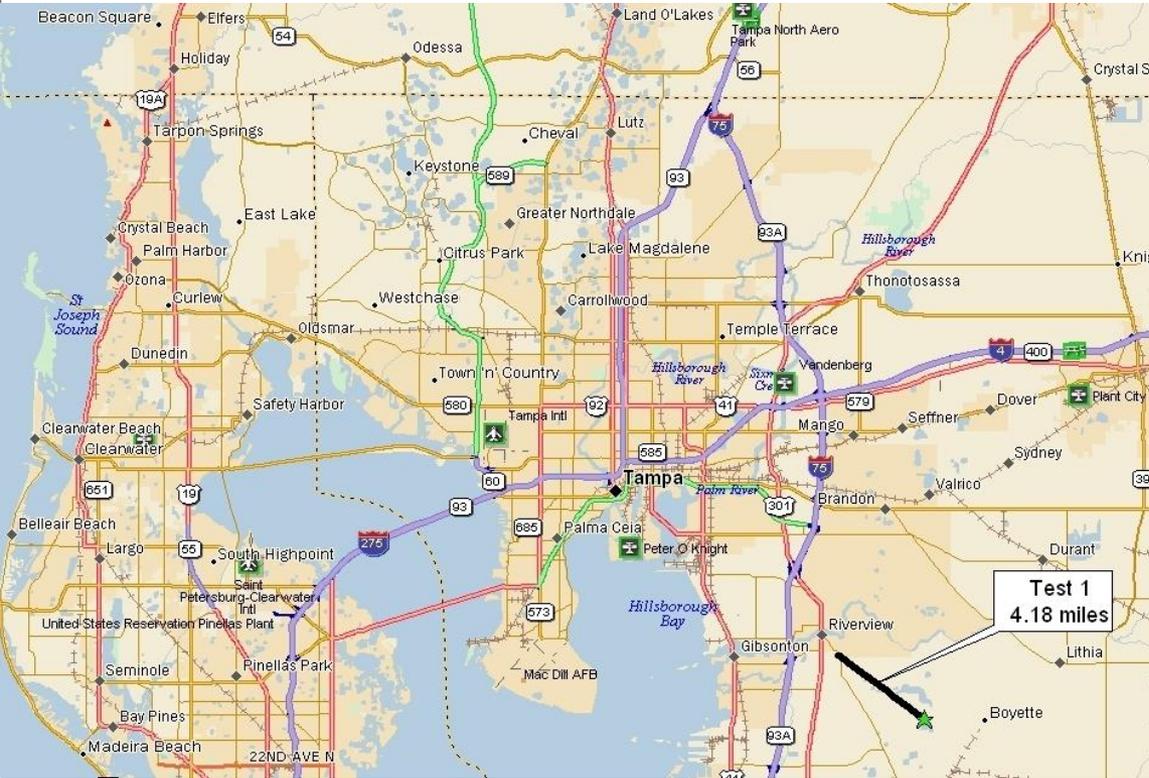


Outdoor Test 1

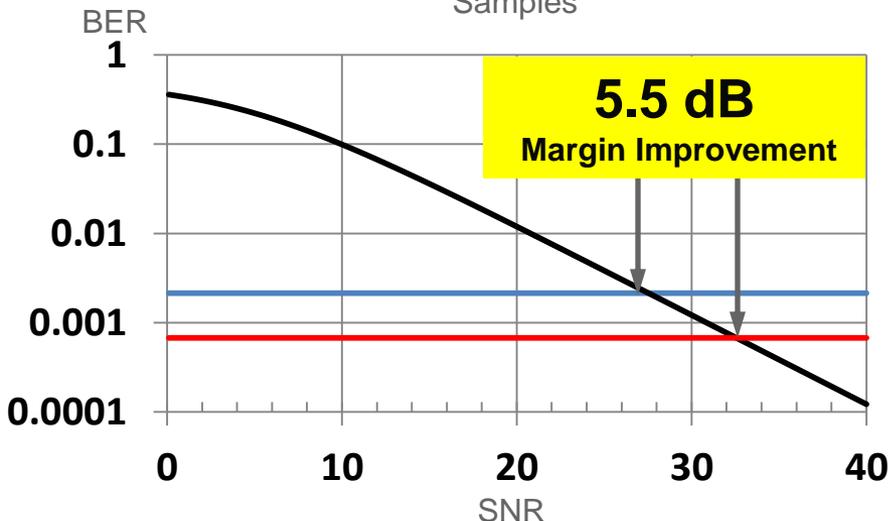
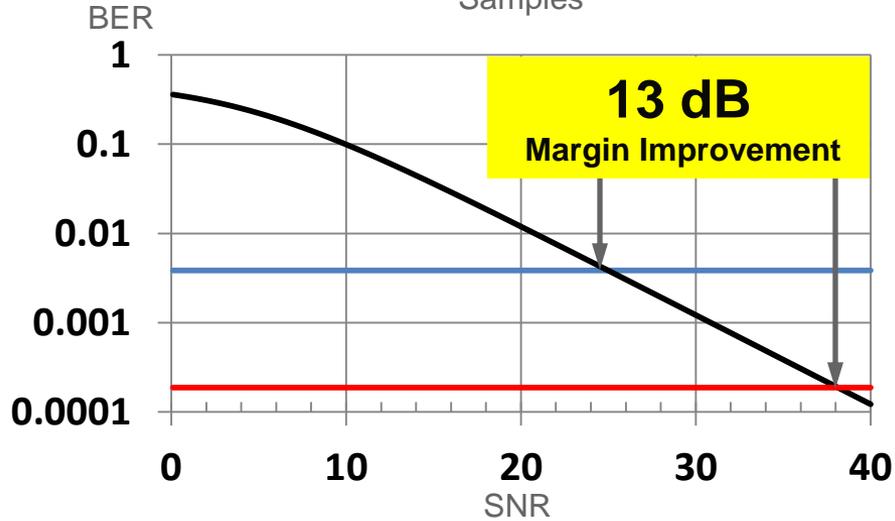
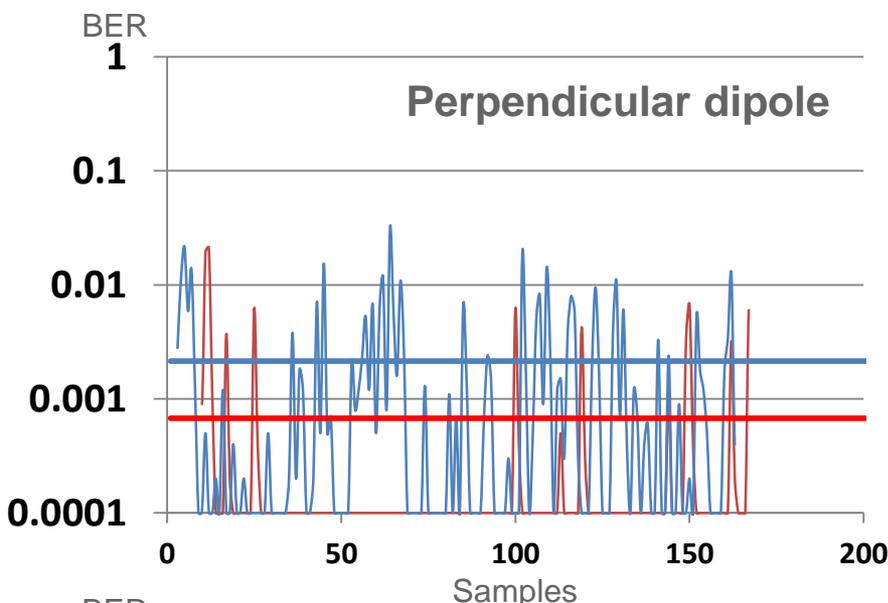
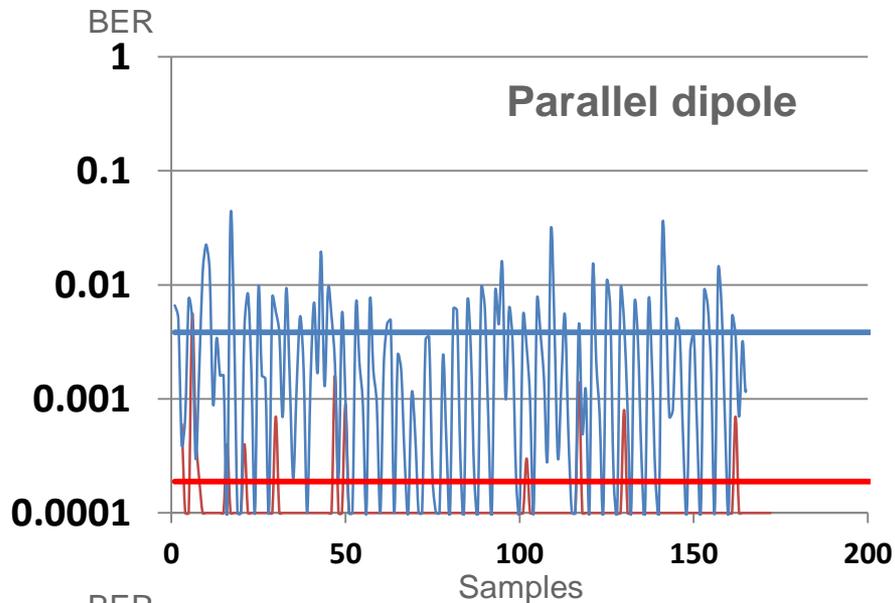
Description – Outdoor open area
Distance – 4.2 miles
Note – Parking lot



Mobile antenna unit

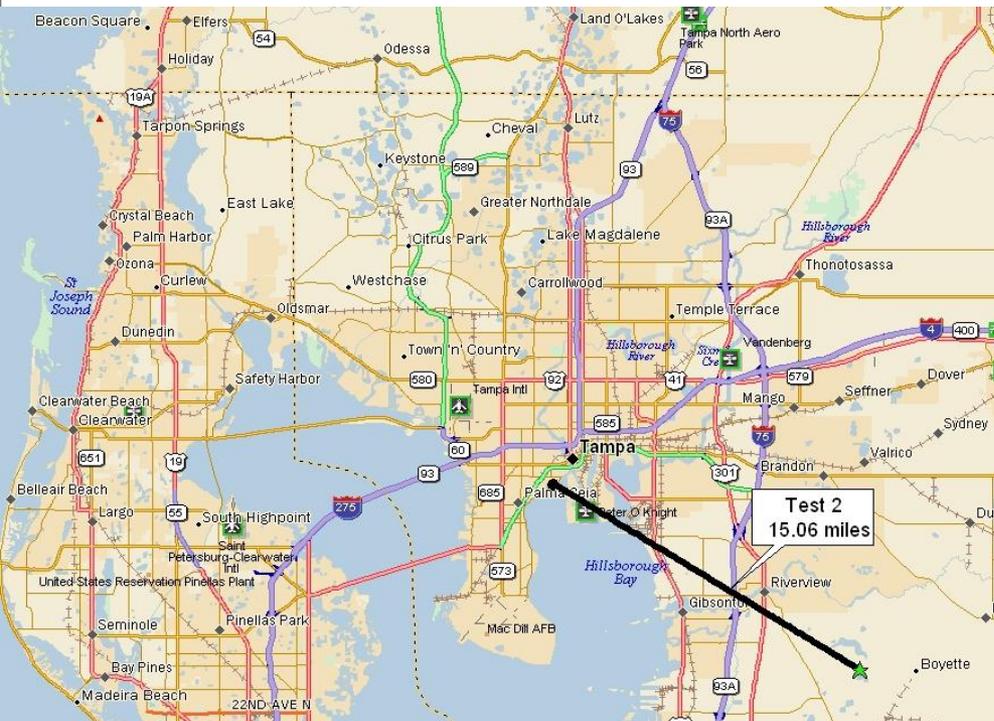


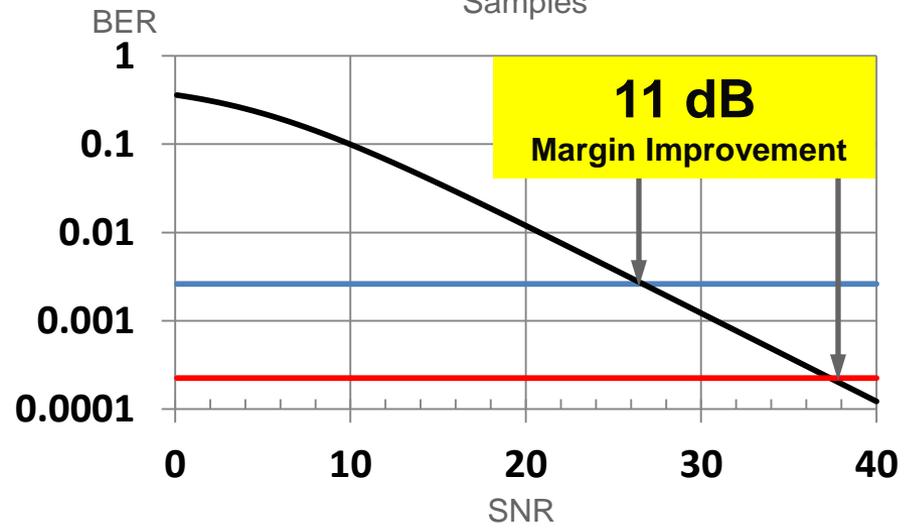
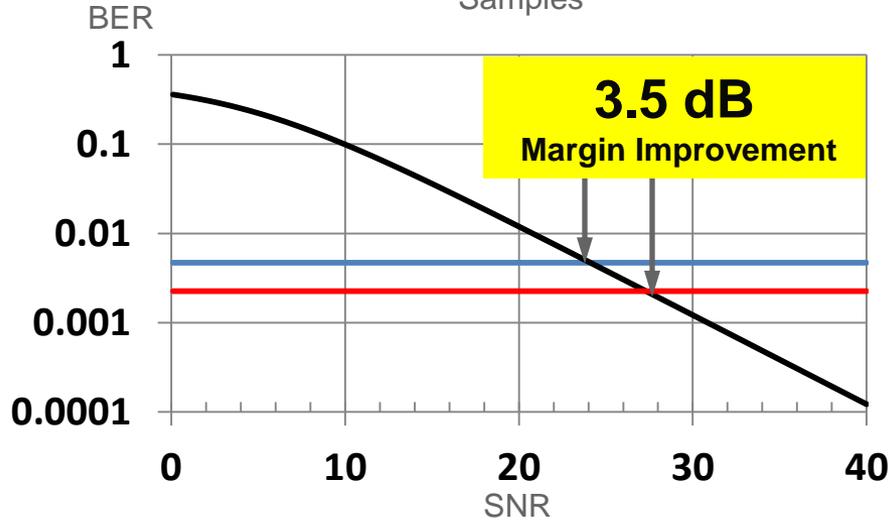
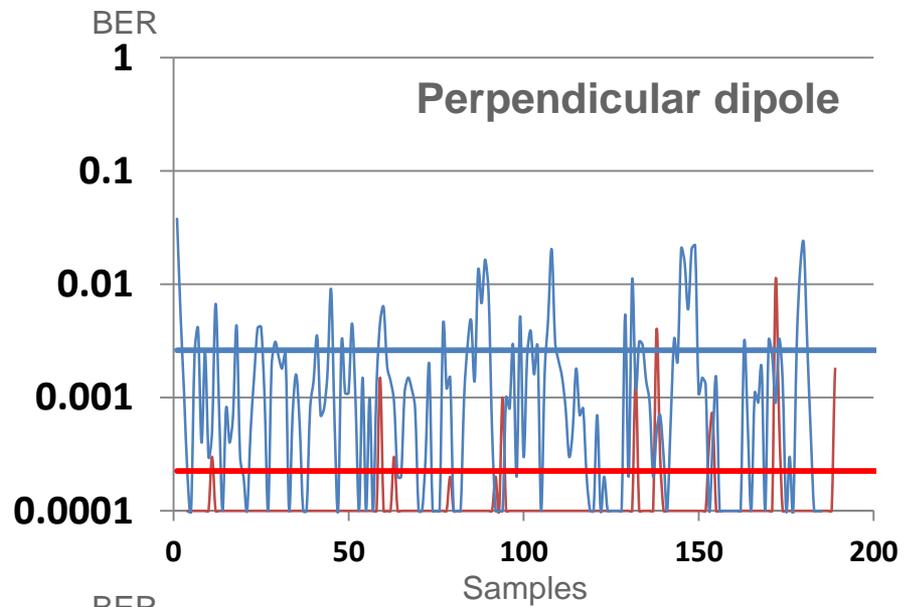
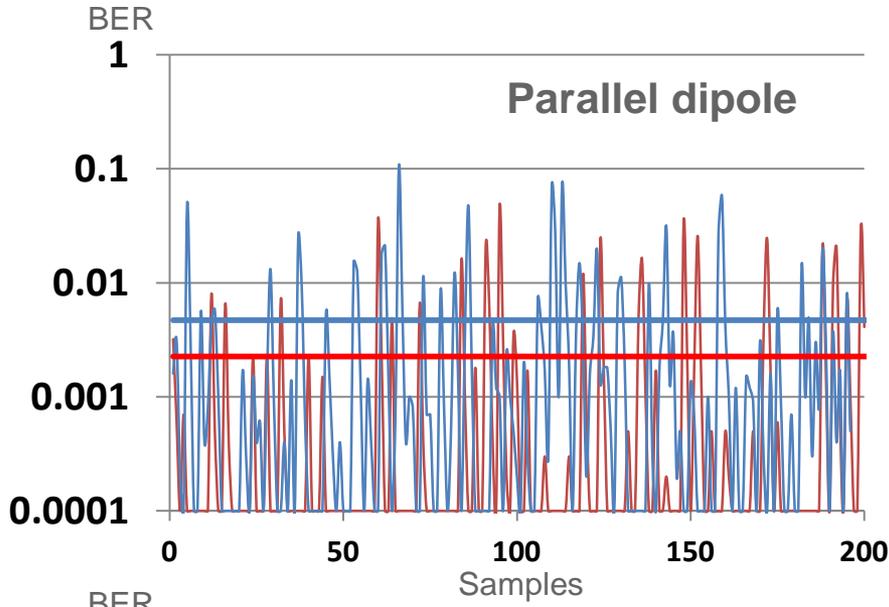
Aerial satellite view with GPS route



Outdoor Test 2

Description – Outdoor open area
Distance – 15.1 miles
Note – Walk along the water



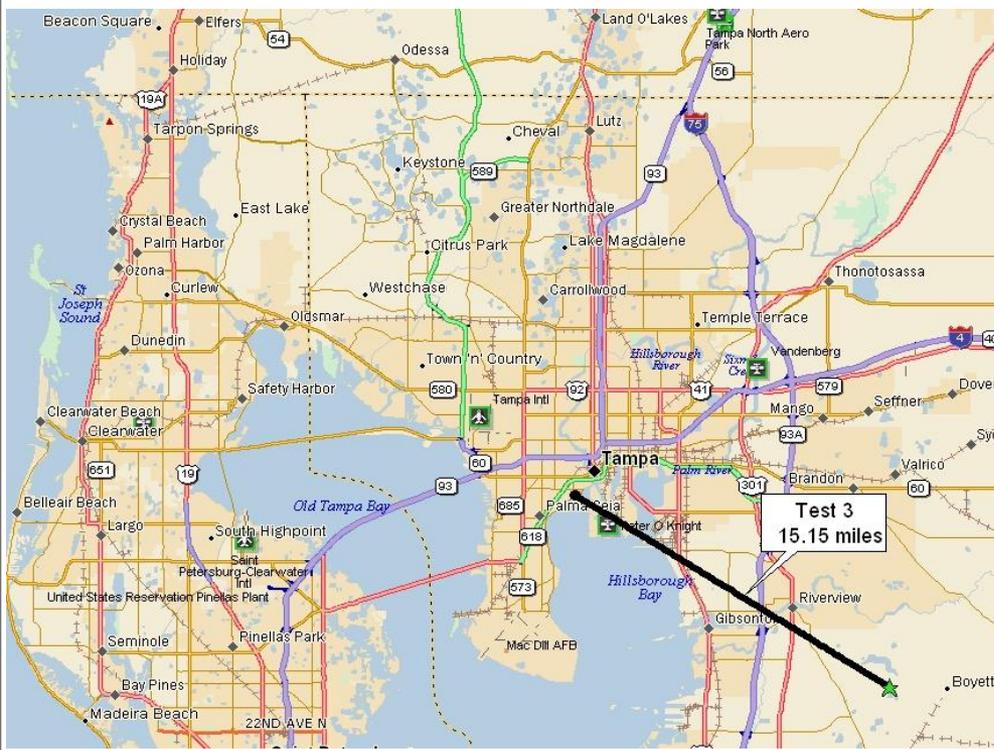


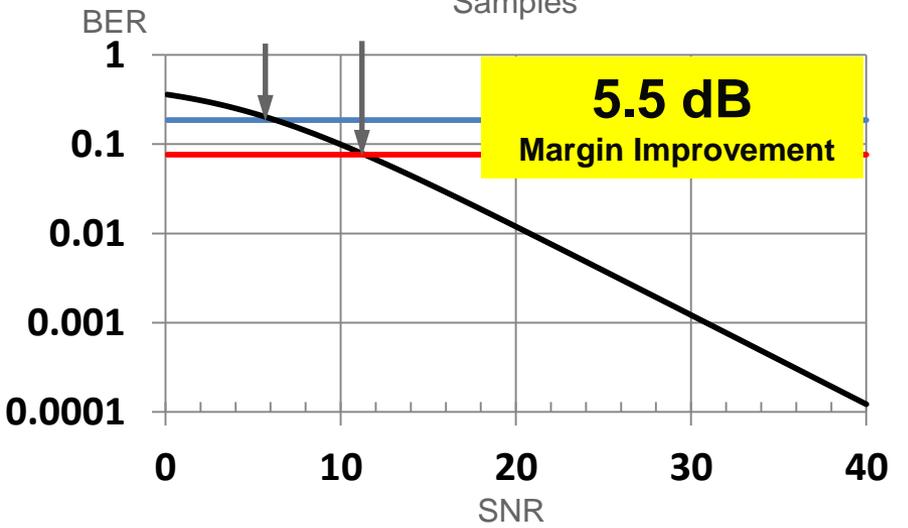
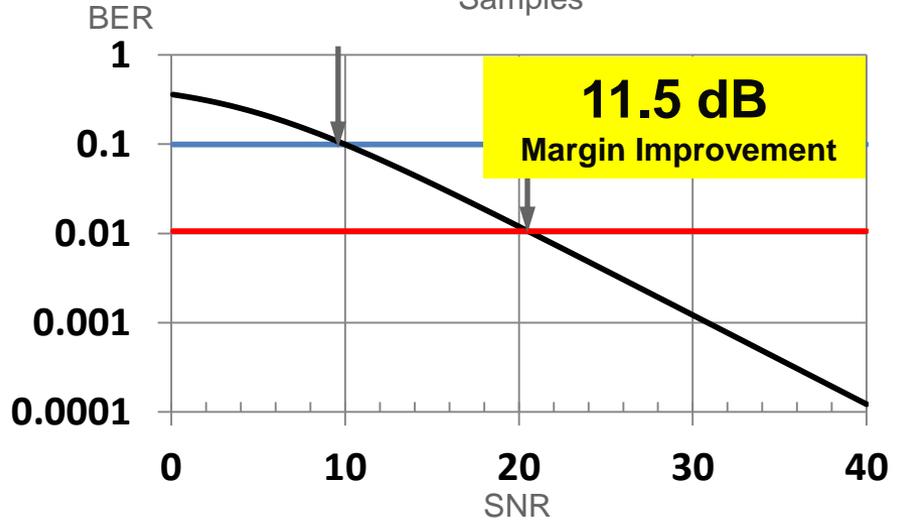
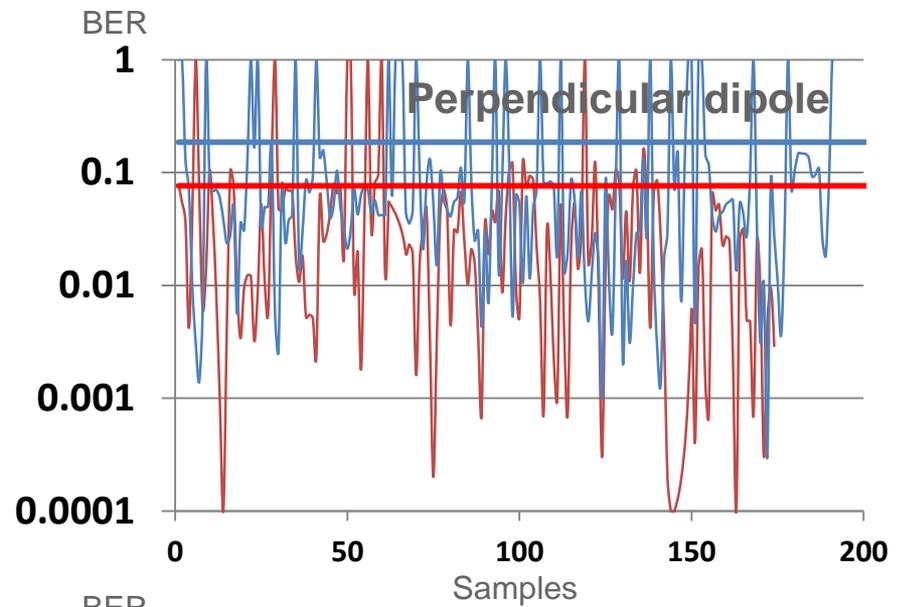
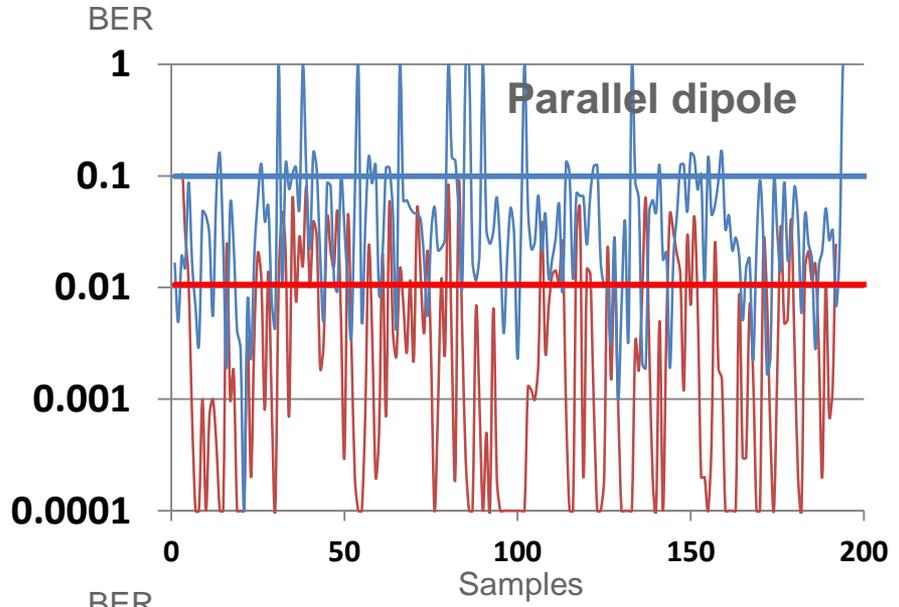
Outdoor Test 3

Description – Outdoor residential area

Distance – 15.2 miles

Note – Numerous trees and houses



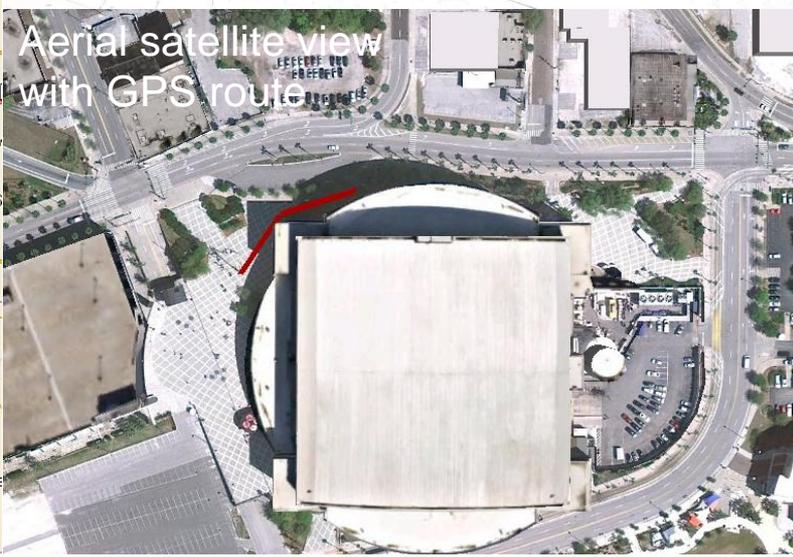
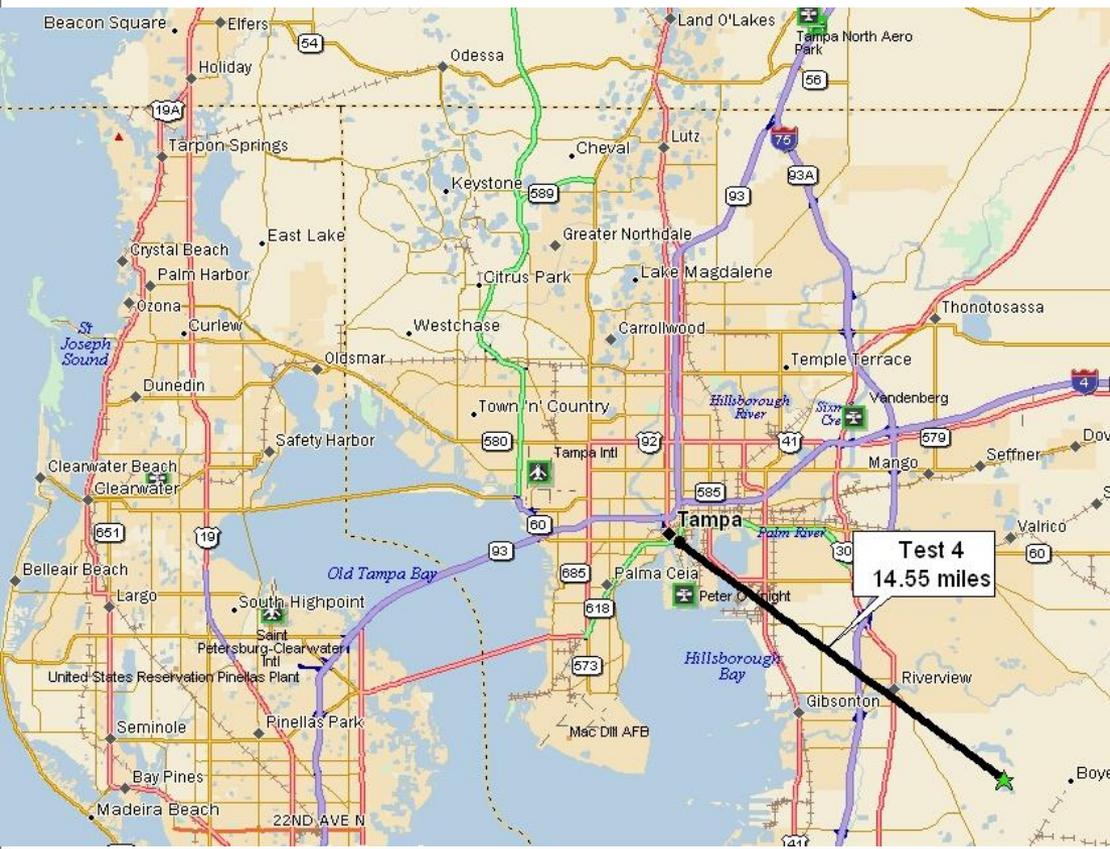


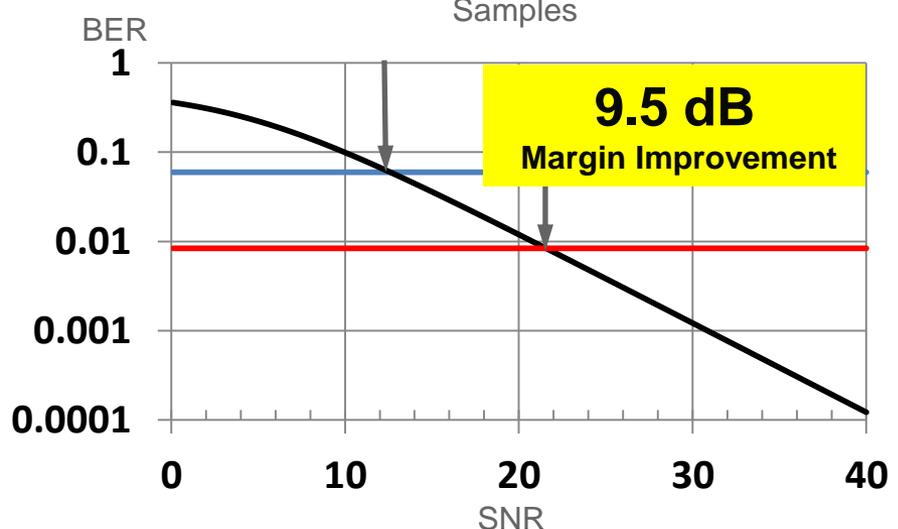
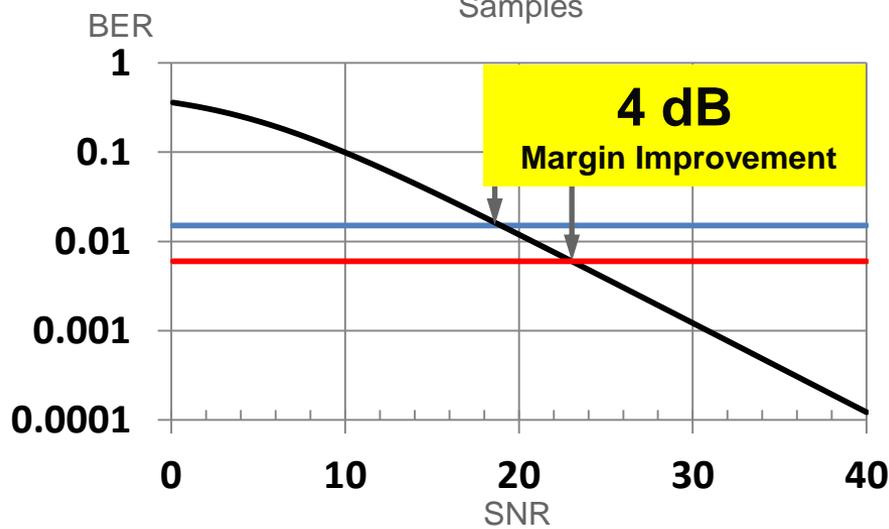
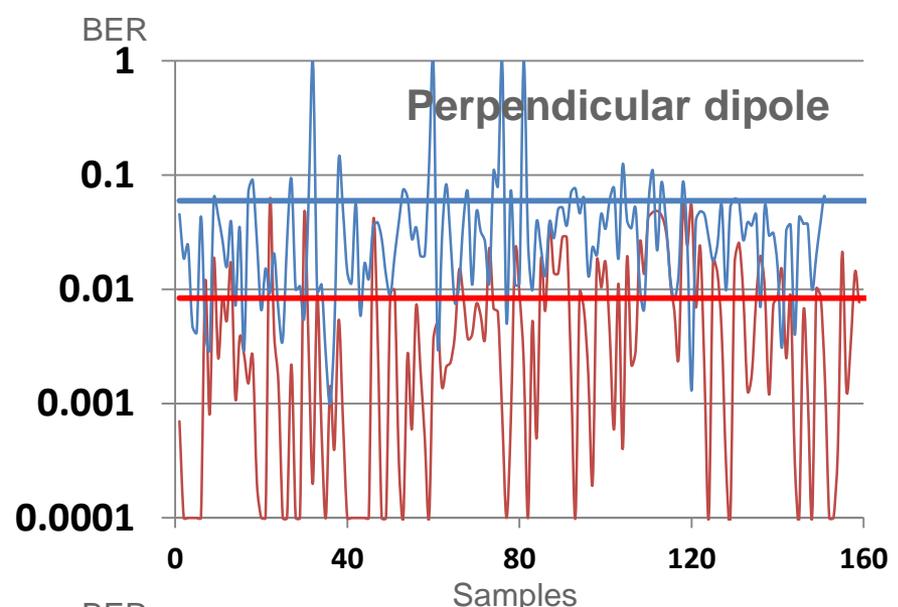
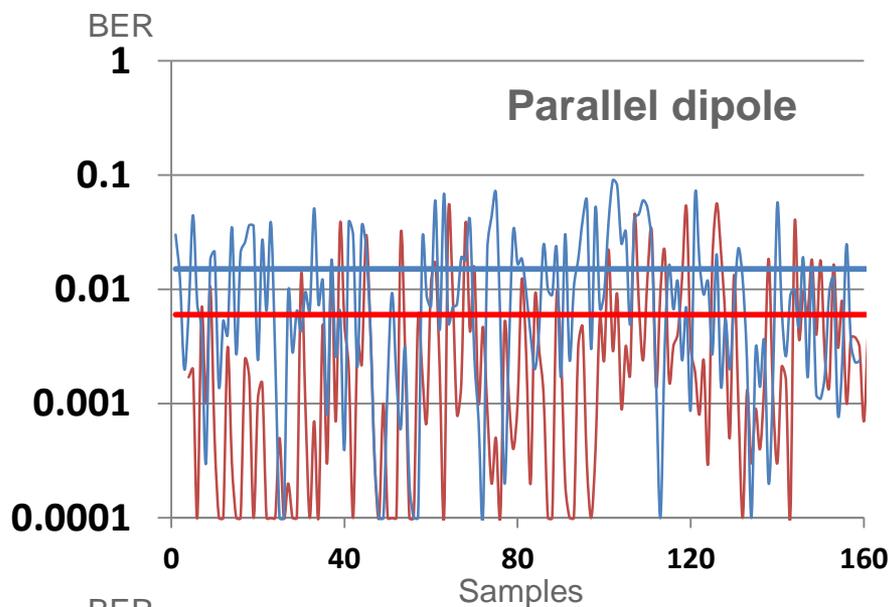
Outdoor Test 4

Description – Outdoor downtown Tampa

Distance – 14.6 miles

Note – Shadowed by St. Pete Times Forum





Outdoor Tests Summary and Observations

	Parallel	Perpendicular
Average Margin Improvement of CPOL	8.0 dB	7.9 dB

Observations

- ❑ On average, both parallel and perpendicular reception produced the same (8 dB) margin improvement. Why is the margin improvement for the perpendicular mode not much higher than the parallel mode?

Small scale fading has created as much vertical component in the horizontal plane as there is in the vertical. Multipath has completely depolarized the signals.

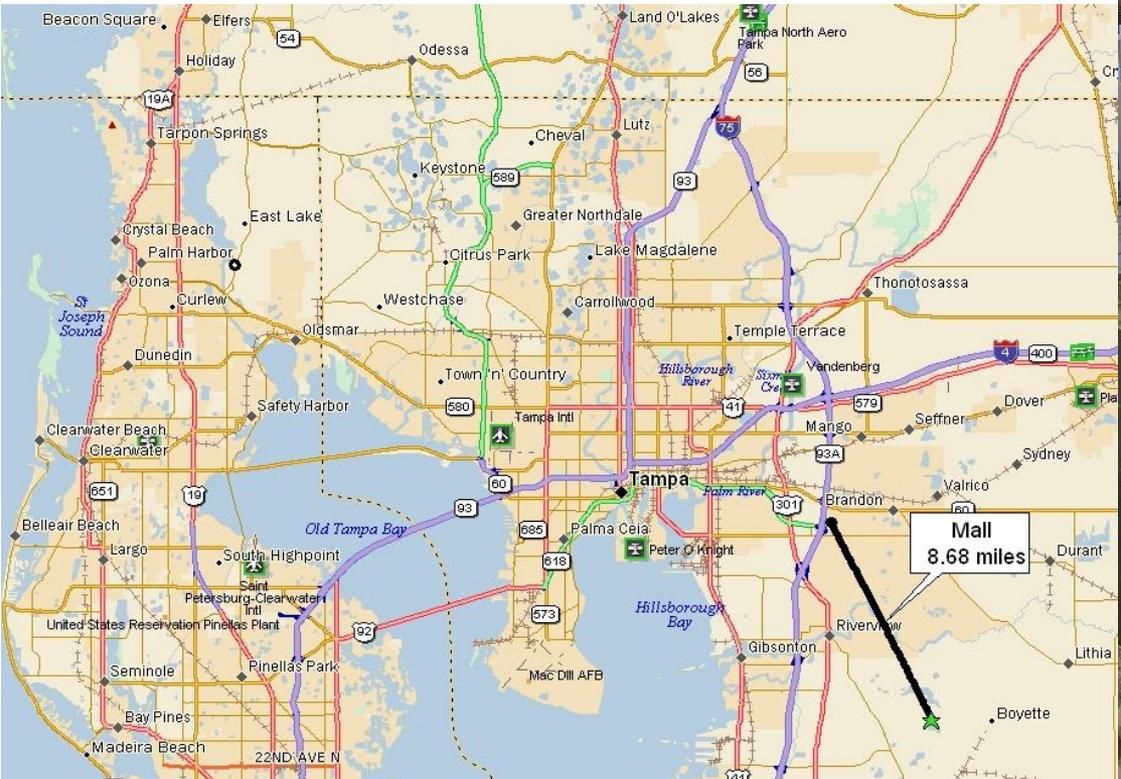
- ❑ If the VPOL signals are so depolarized then why does CPOL show 8 dB of margin improvement over VPOL?

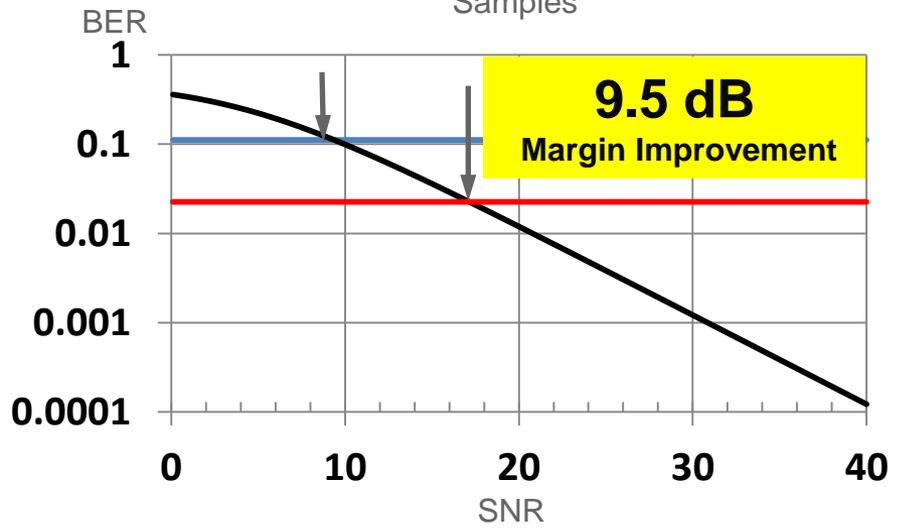
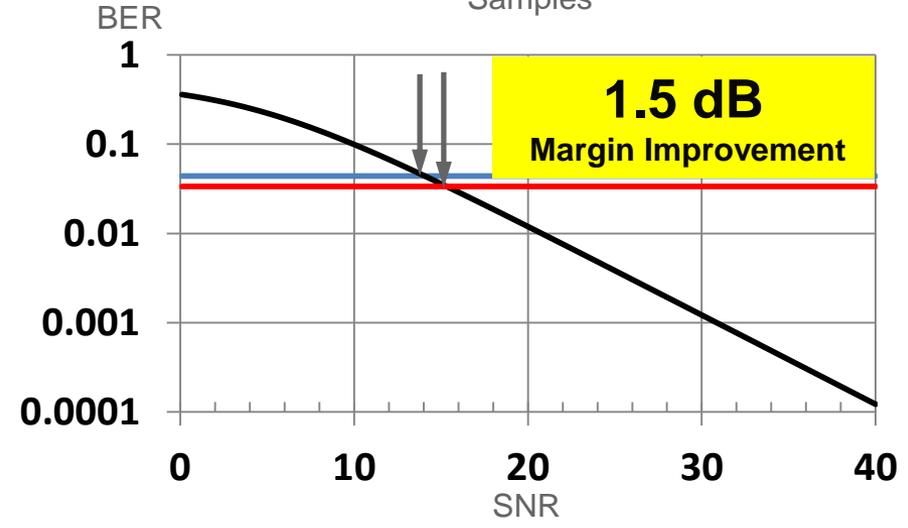
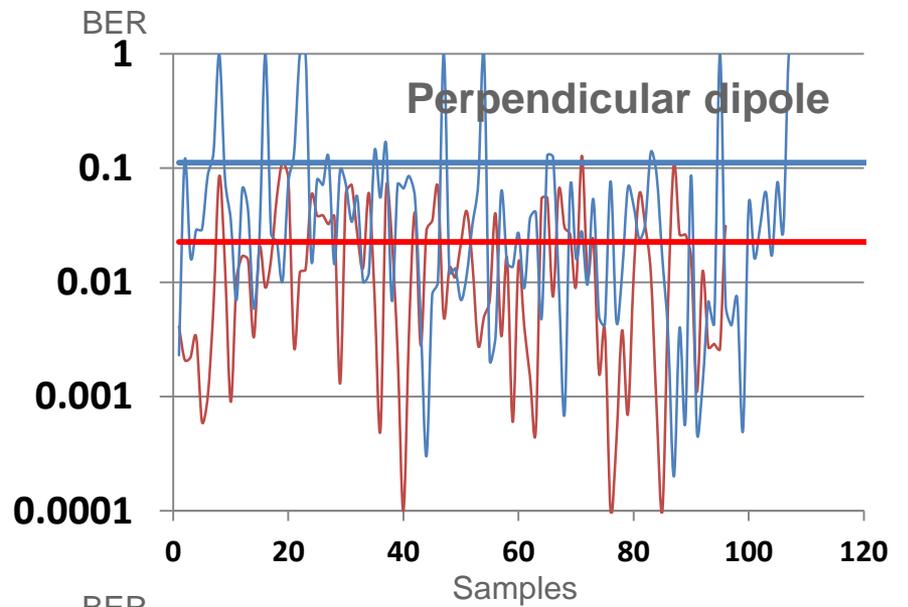
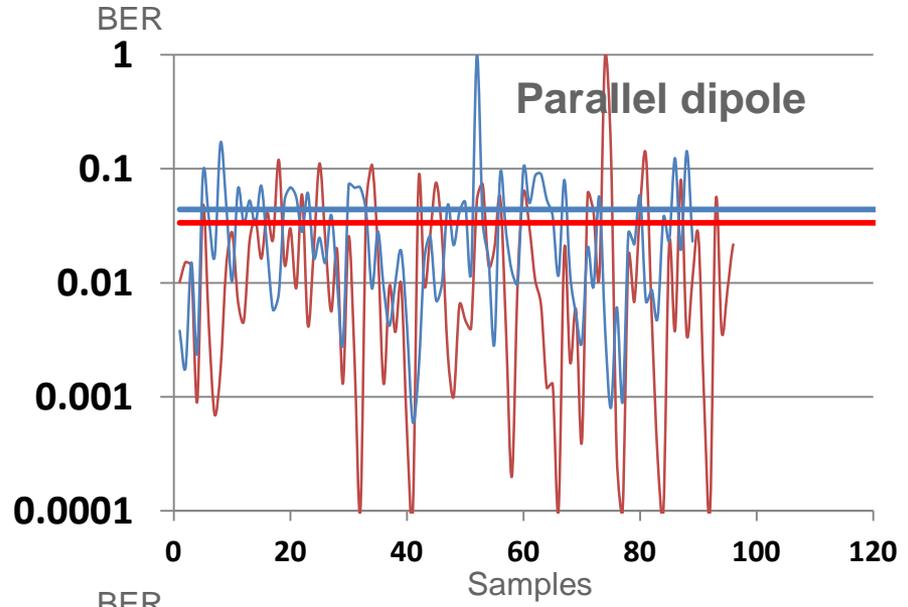
CPOL is made up of two orthogonal polarizations time shifted by 90 degrees. The odds of both polarizations destructively interfering at the same time and at the same location is much smaller than a single polarization.



Indoor Test 1

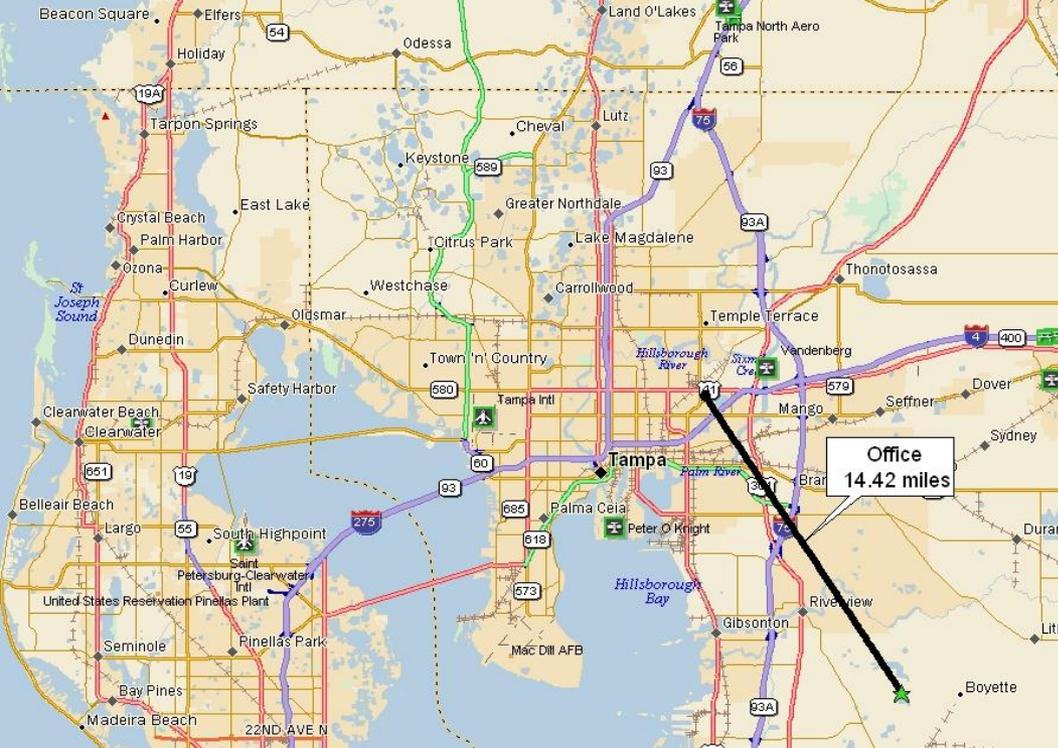
Description – Indoor mall
Distance – 8.7 miles
Note – Heavy small scale fading

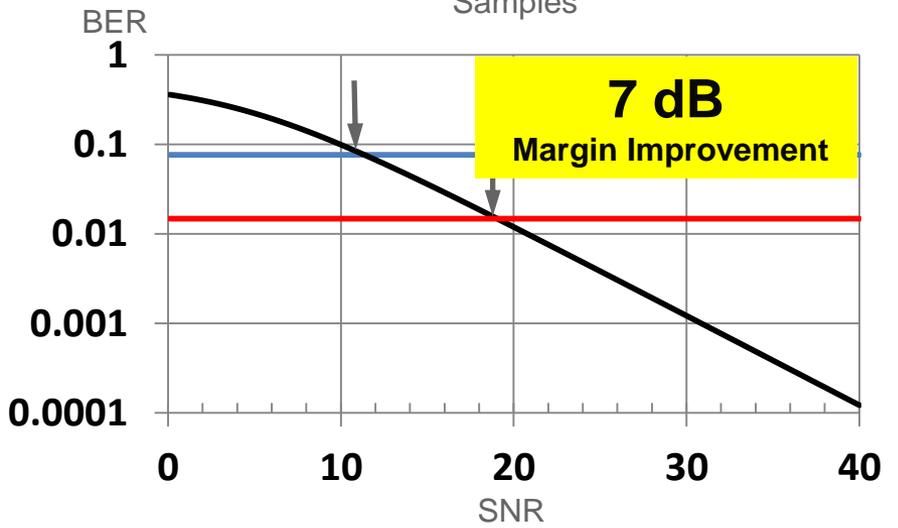
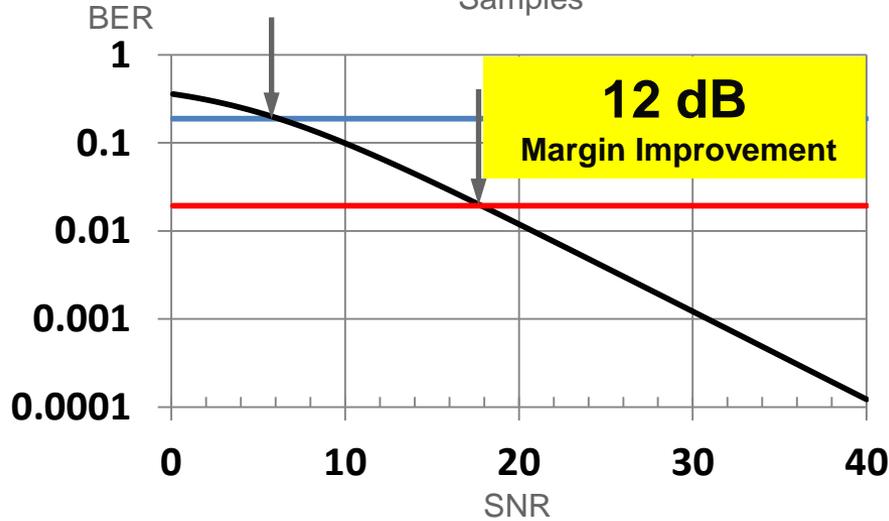
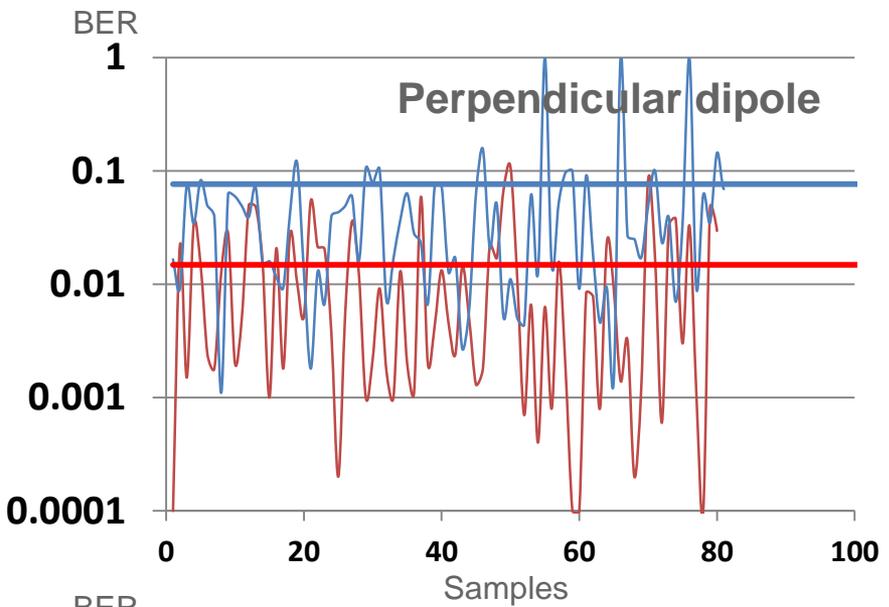
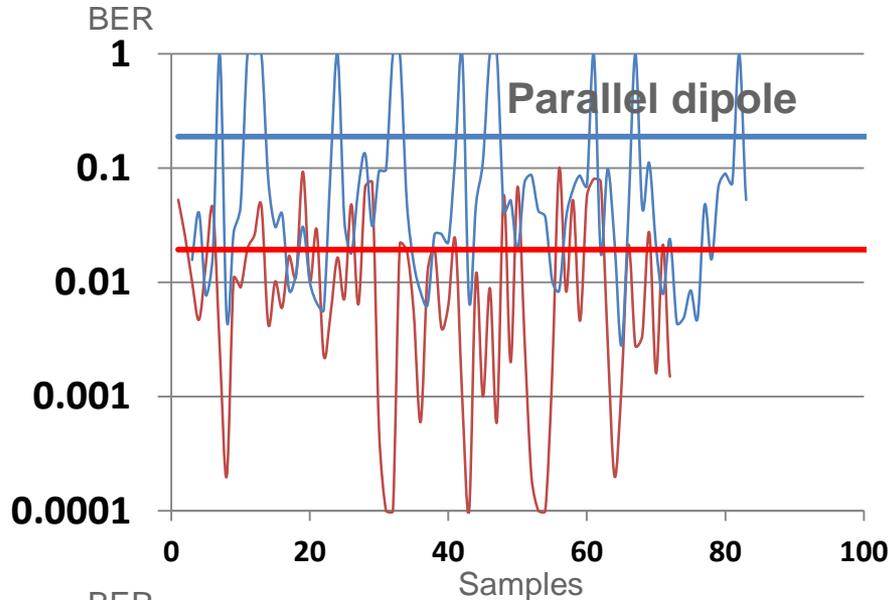




Indoor Test 2

Description – Indoor office complex
Distance – 14.4 miles
Note – Heavy small scale fading





Indoor Tests Summary and Observations

Average Margin Improvement of CPOL

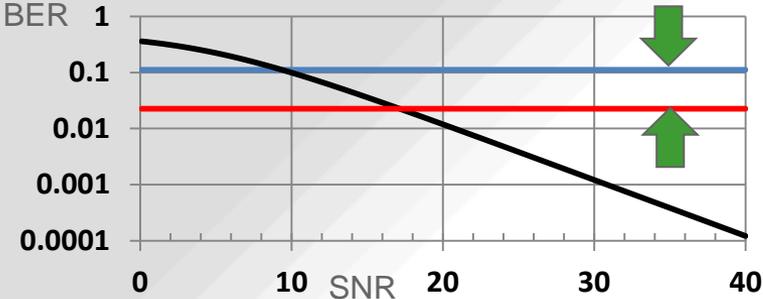
Parallel
6.8 dB

Perpendicular
8.3 dB

Observations

- Both outdoor and indoor measurements produced similar results for both parallel and perpendicular CPOL tests. On average, CPOL provided 7.5 dB of margin improvement. Why are indoor and outdoor measurements similar on average?

CPOL helps mitigate the effects of small scale fading which is present both indoors and outdoors. The only difference is large scale fading which tends to only shift the mean signal strength.



As the mean signal strength decreases, the BER increases, but the margin improvement gap remains the same.



- The benefits of circular polarization hold true for both indoor and outdoor service.

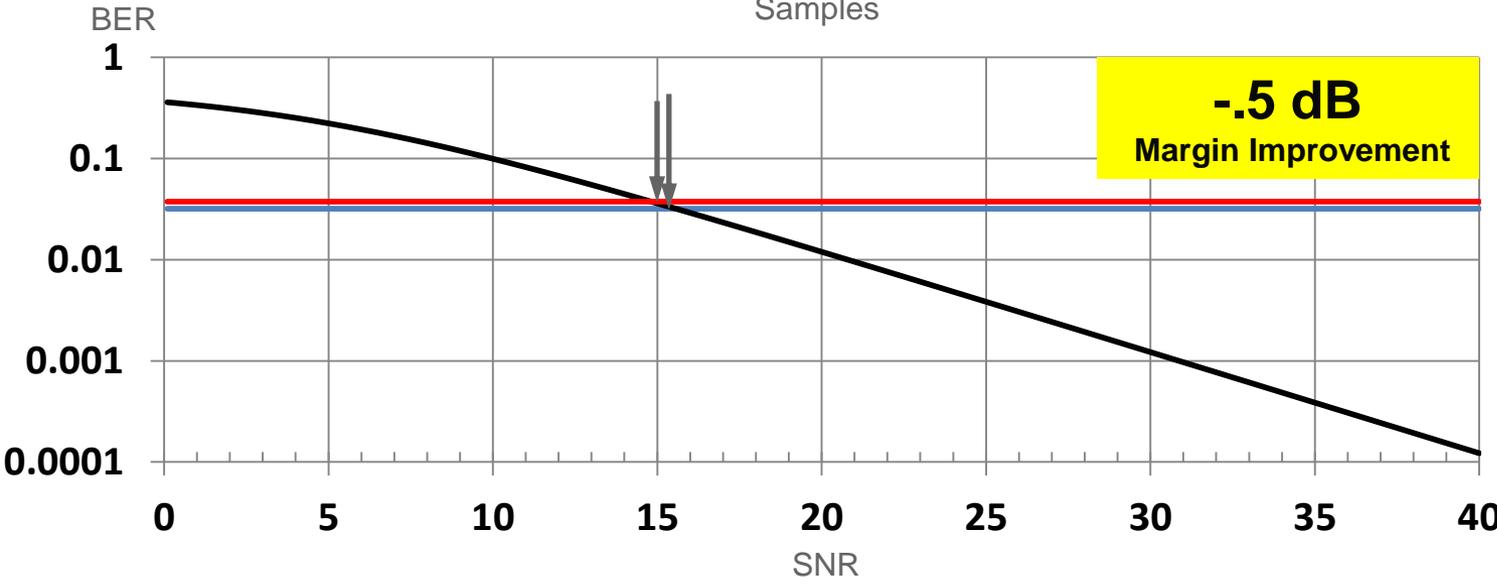
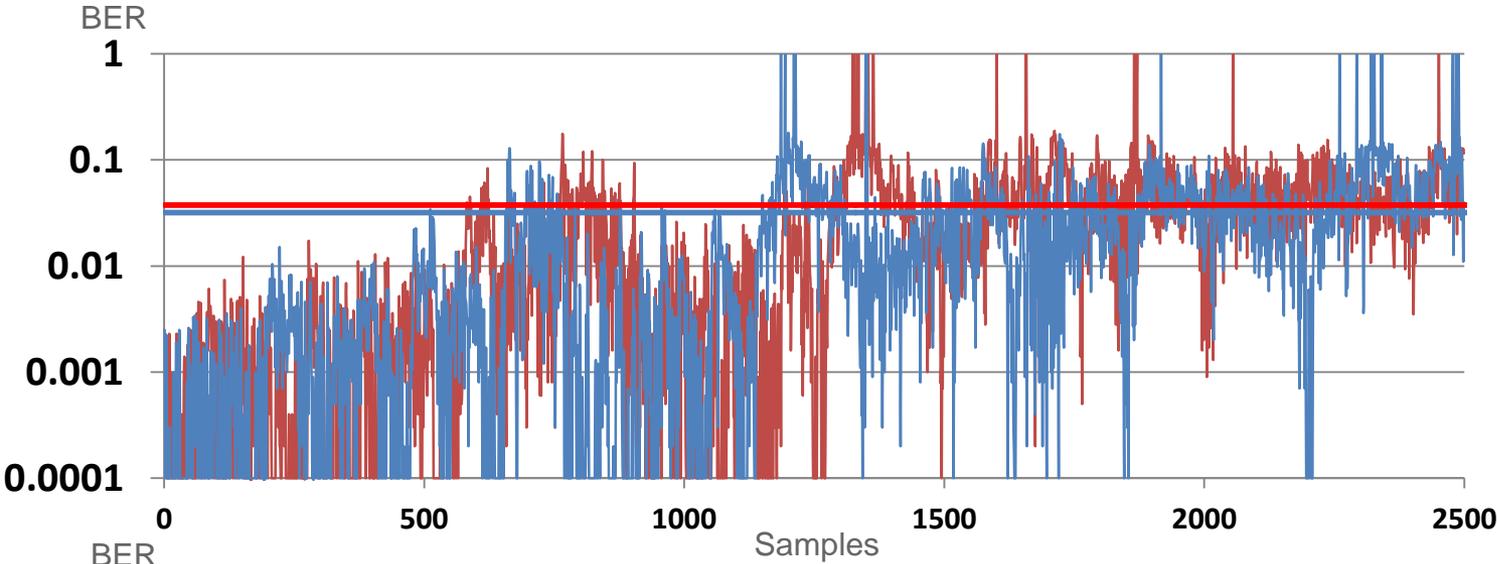
Drive Test 1

Rotating dipole inside car - 60 mile drive.



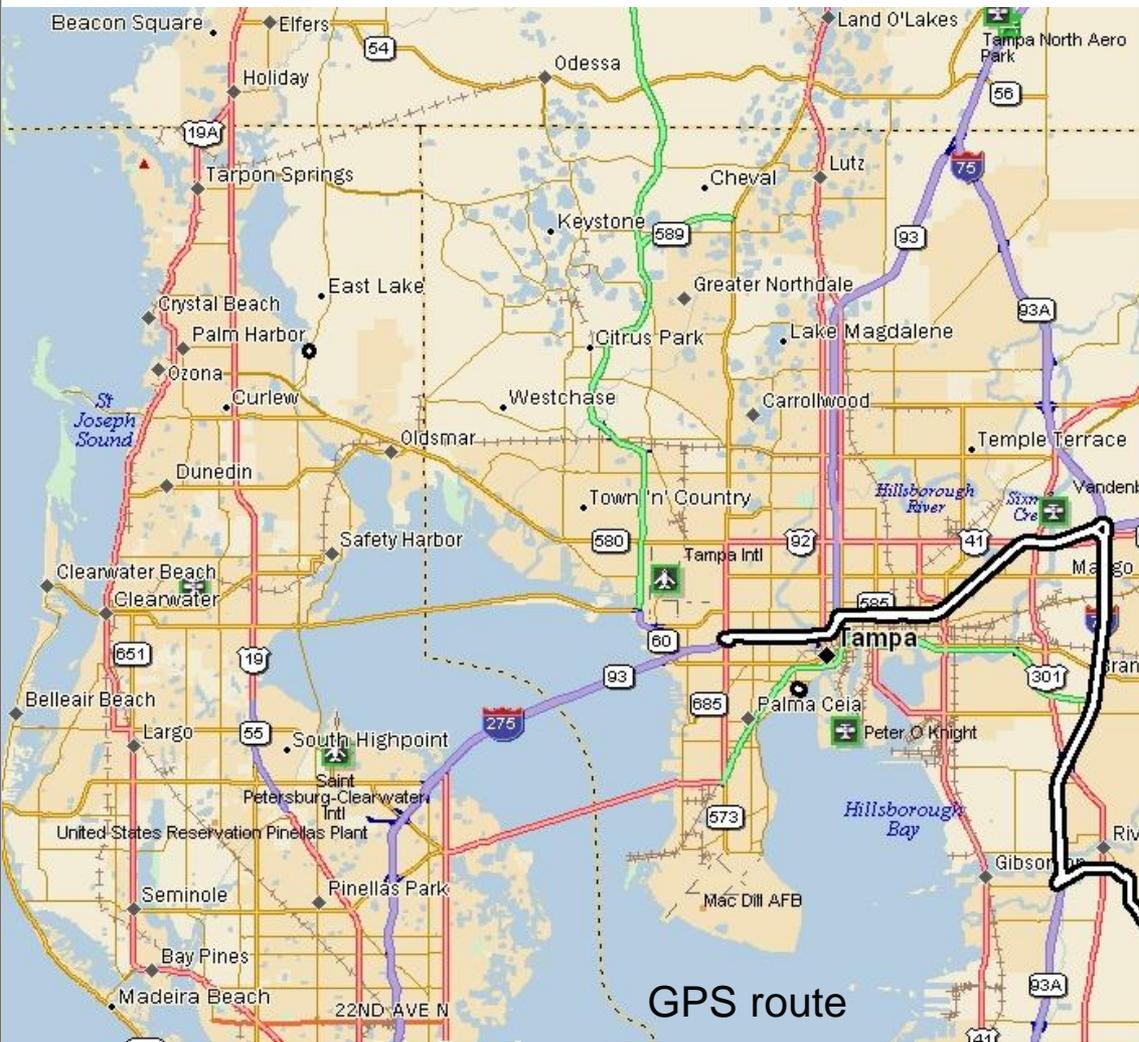
Mobile antenna unit

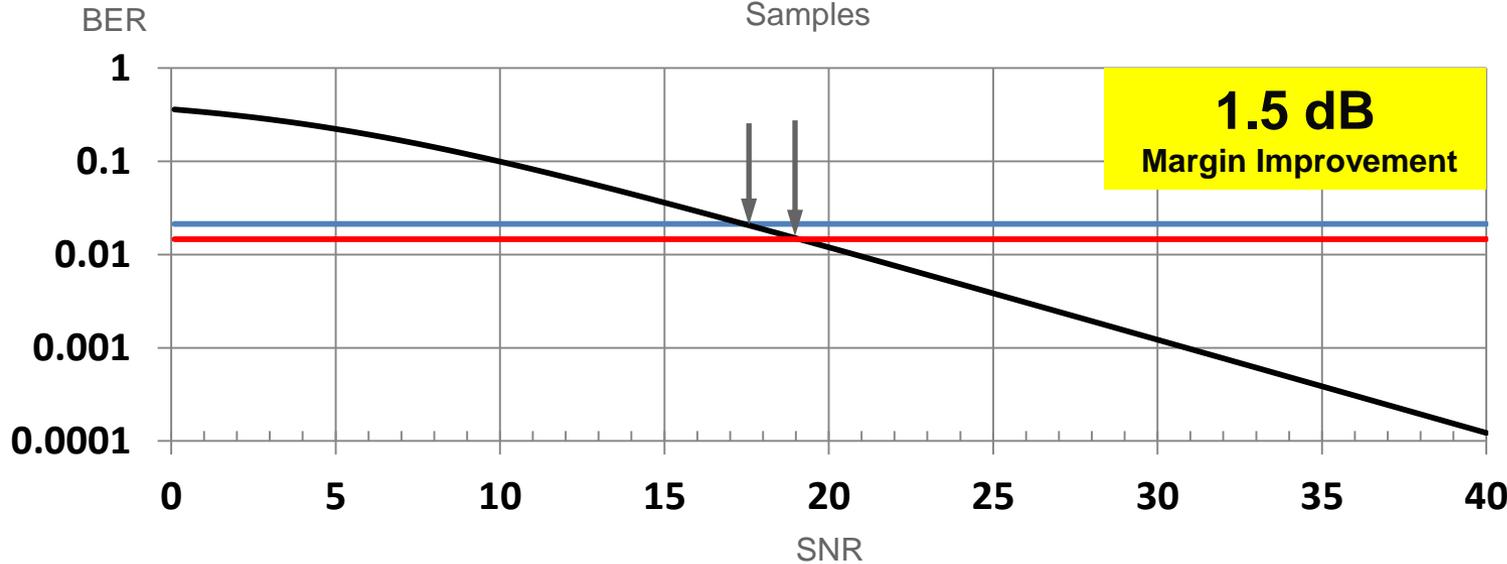
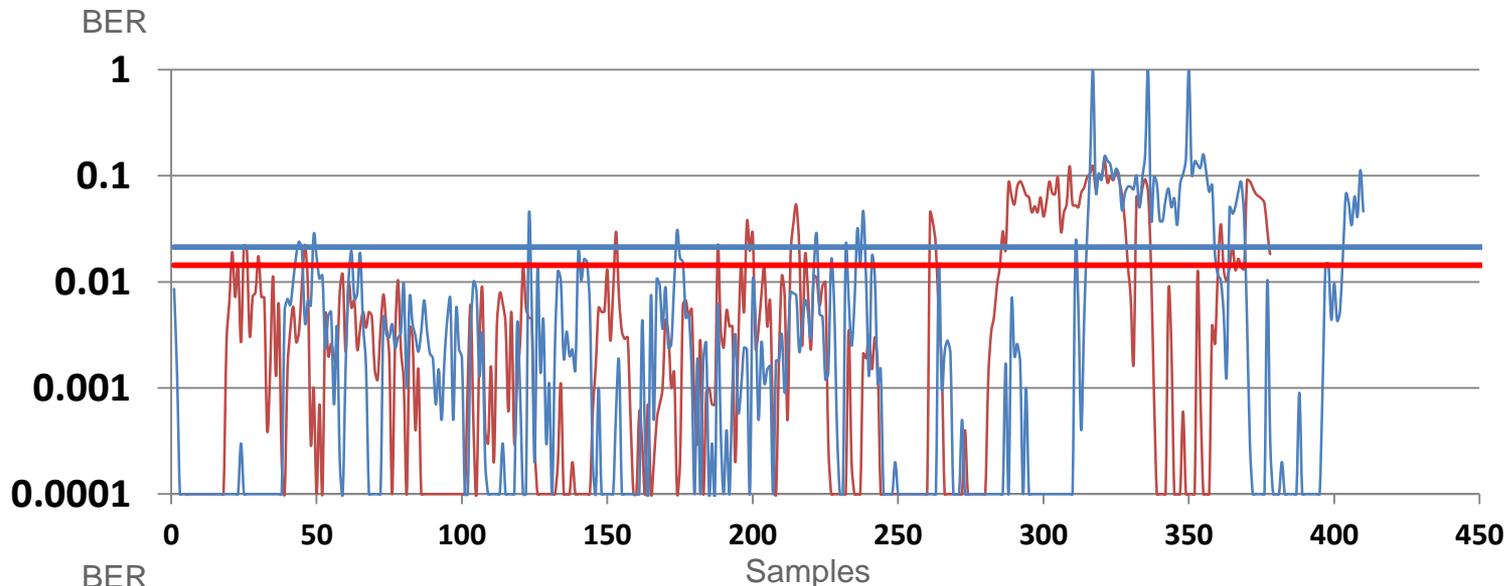




Drive Test 2

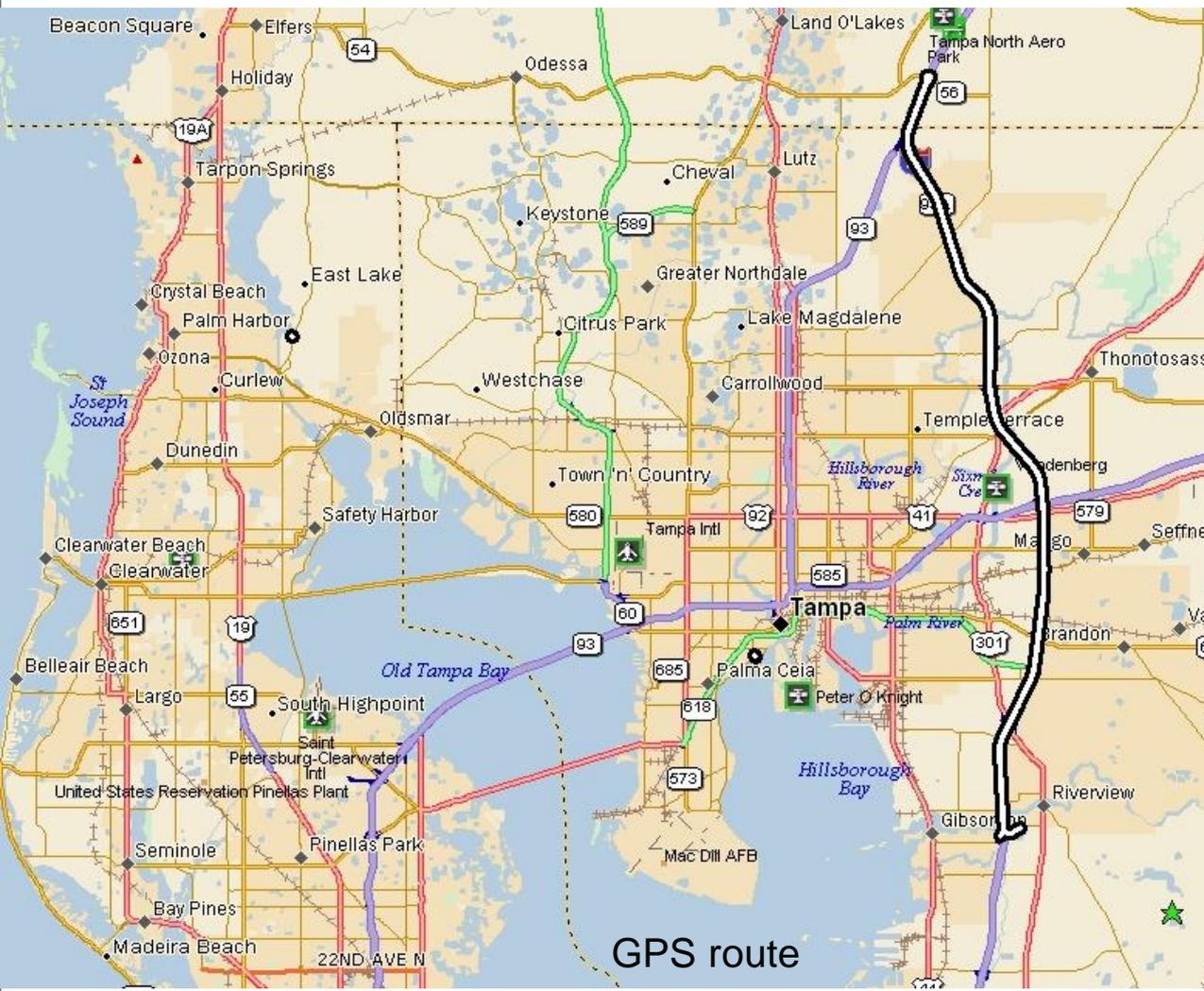
Small monopole on top of car - 25 mile drive.





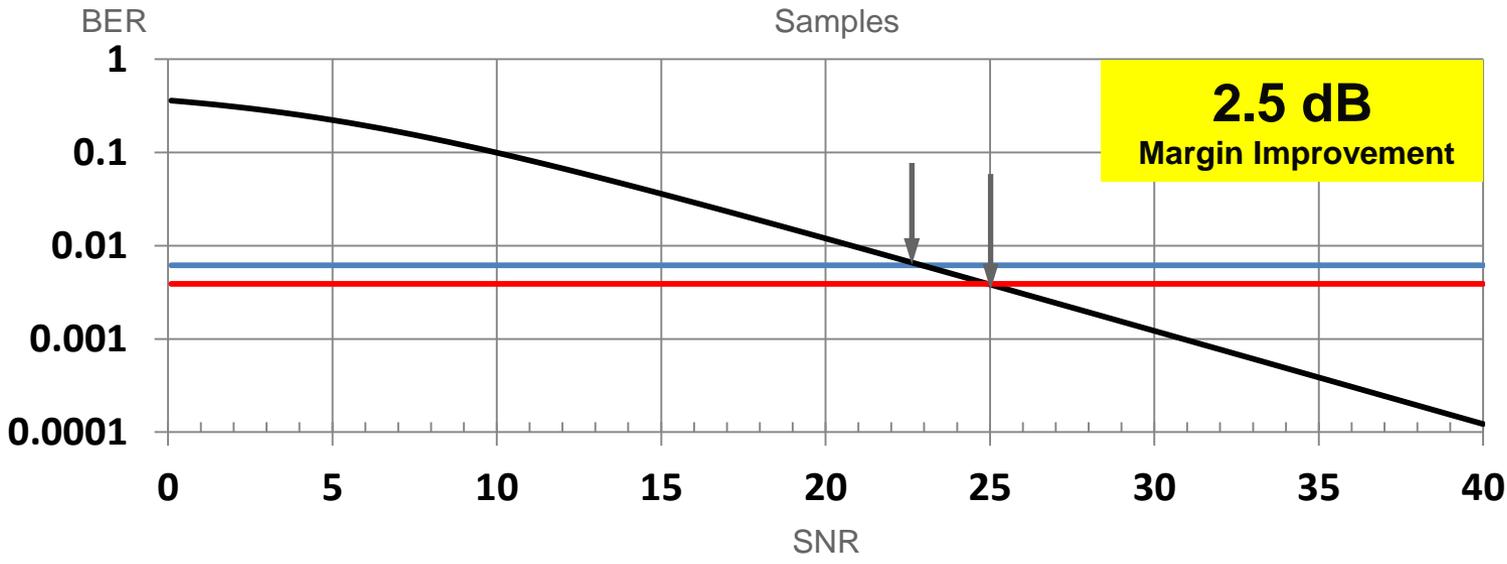
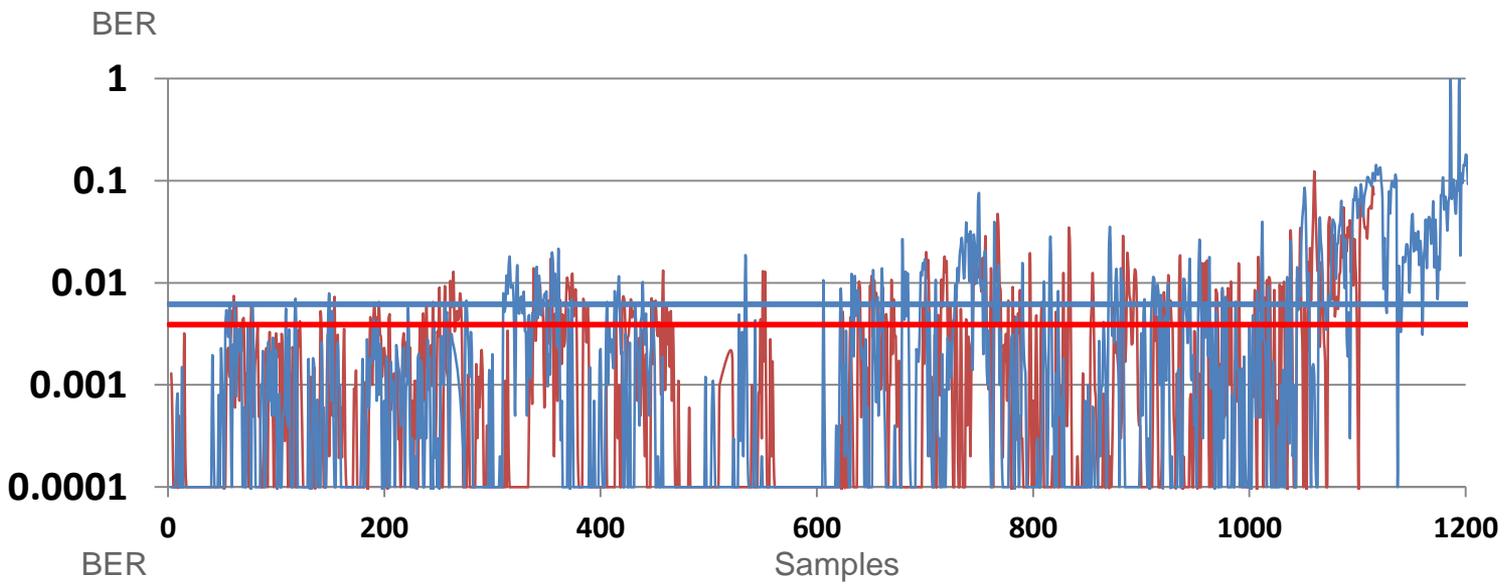
Drive Test 3

Large monopole on top of car - 30 mile drive.



Mobile antenna





Drive Tests Summary and Observations

Average Margin Improvement of CPOL	Inside car	Small monopole top of car	Large monopole top of car
	-0.5 dB	1.5 dB	2.5 dB

Observations

- ❑ CPOL provides no advantage inside the vehicle. As the antenna is raised above the car, CPOL begins to show margin gains. Why?

A boundary condition used to solve Maxwell's equations states, "The E-Field tangent to a ground plane is 0".



James Maxwell

Conclusions

- ❑ In situations where the receiver is not directly above or below a ground plane, circular polarization provides a significant advantage over linear polarization for mobile applications.



- ❑ Circular polarization provides margin improvement for both indoor and outdoor service.



- ❑ BER testing confirms that circular polarization provides 5 to 7 dB of margin improvement over linear polarization.

Bottom Line...

Circular polarization will be necessary to maintain reliable mobile connectivity.



Questions