Real Word Implementations

SDR-WInnComm 2014

Interference Mitigation

Bob Conley & Steve Schennum

Agenda

- Technology Overview and Background
- Interference
- Antennas
- Optimal Adaptive Algorithms
- Demonstration Setup OTA vs. Channel Emulation
- Detailed Demonstration
- Q&A

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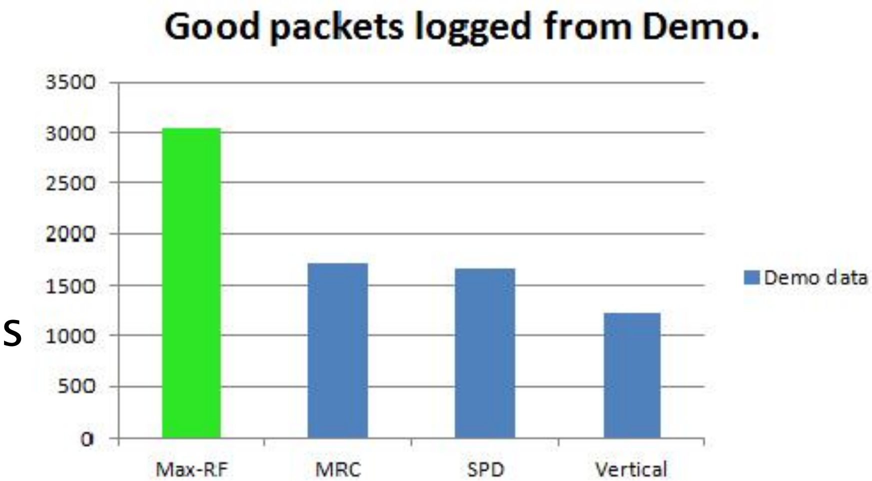
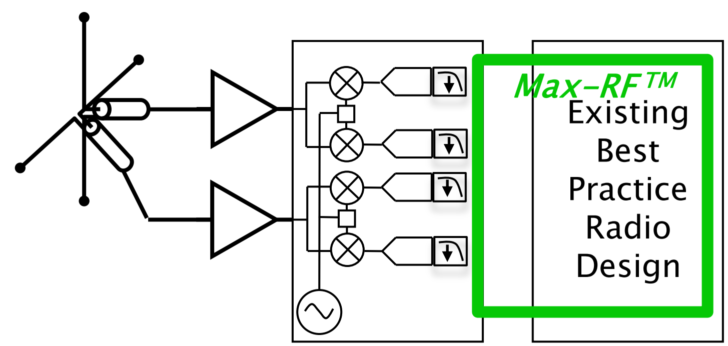
What are we demonstrating?

- Smart Antenna
  - Antenna+Algorithms
- Initial Targets:
  - Mission Critical Communications
  - P-25, TETRA, SUN
- Lower deployment costs
- Lower component costs
- Performance Multiplier
- **True Differentiator**
  - **Overlays on any standard**





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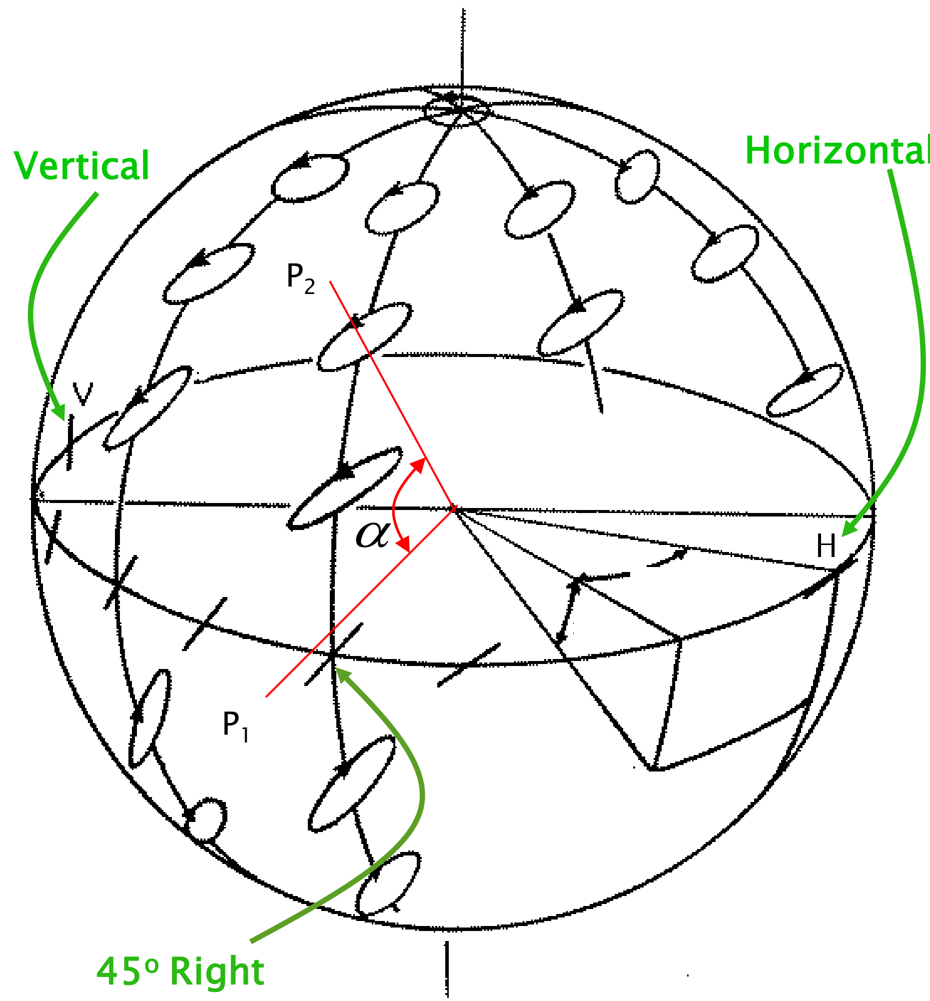
Polarization States

- Poincaré Sphere
  - Linear polarizations on equator
  - Left Hand Circular Polarization (LHCP) and RHCP are special cases of elliptical polarization
  - Angle between any two polarizations, P_1 & P_2 given by α
  - Directly opposite polarizations (α=180°) are orthogonal



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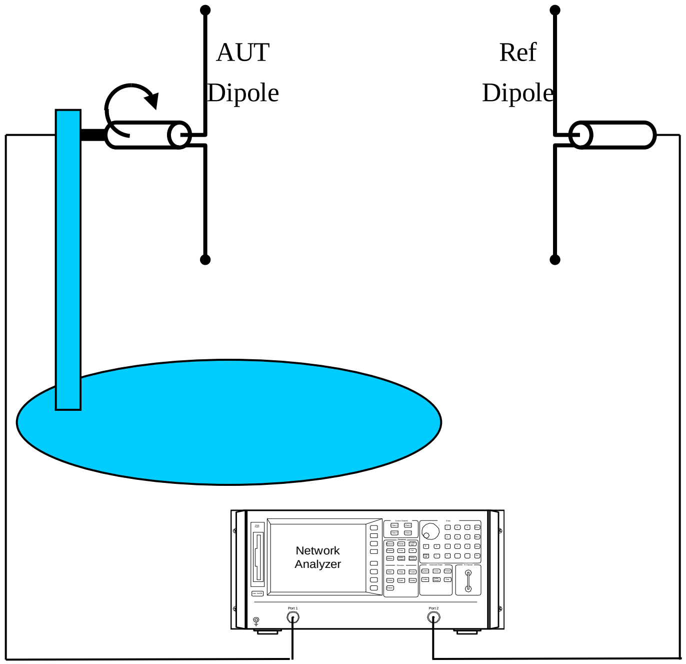
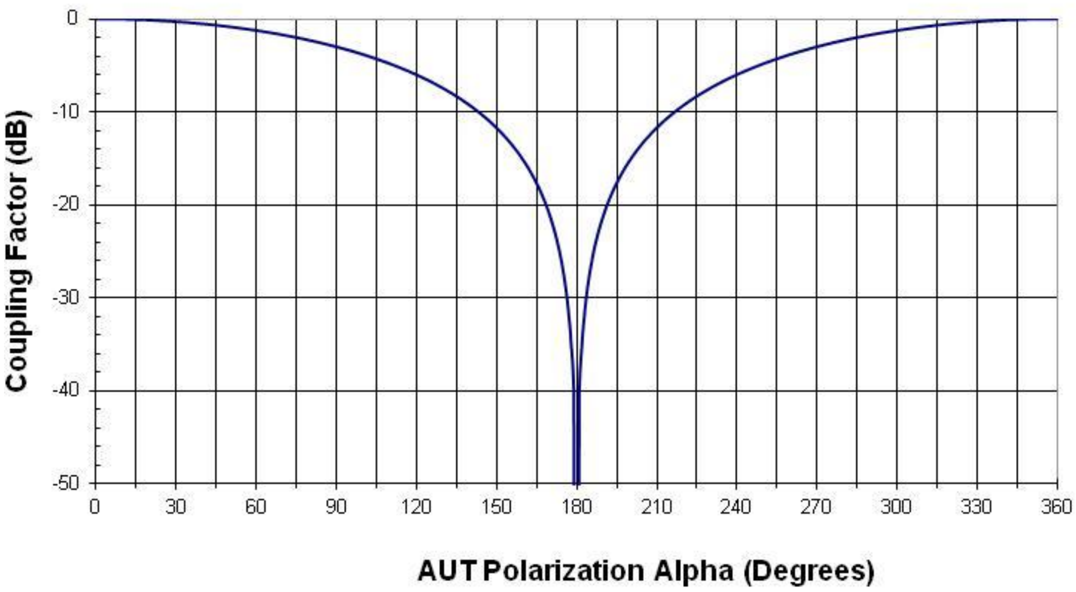
Polarization Coupling

$$PC_{P_1P_2} = 10\log_{10}\cos^2\left(\frac{\alpha}{2}\right)$$





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Interference Sources

- In Network (Self) Interference
  - Same: modulation types & packet structure
  - Close proximity
    - adjacent and alternate channel
  - Co-Channel

- Non-Network interference
  - Unlicensed Bands
  - Co-site out of band
  - Intermods
  - IP2 (e.g. LTE & others with high AM)
  - Reciprocal Mixing
  - High Power LOS emitters
  - Passive Intermods (PIM)

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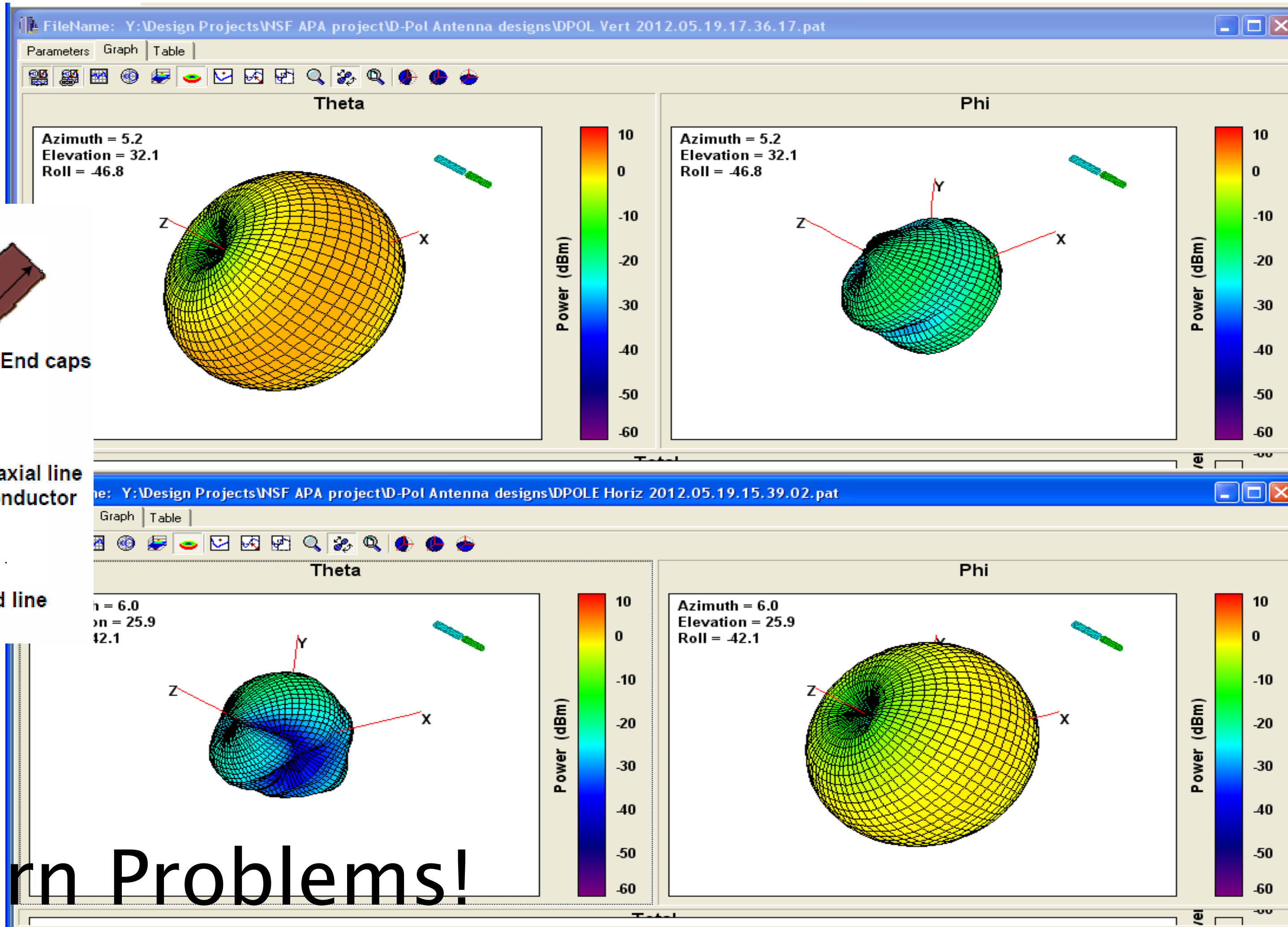
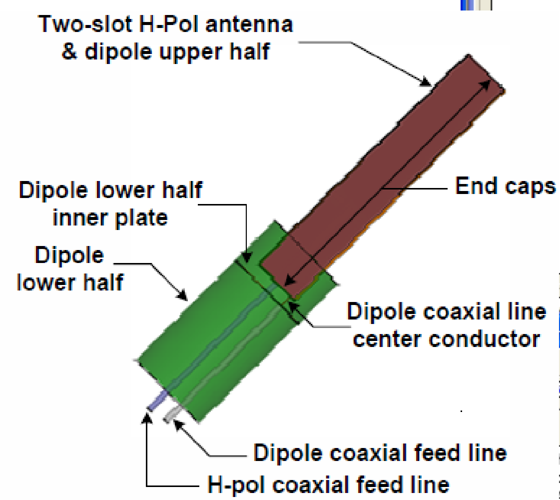
Max-RF™ D-Pol Omni Antennas





No pattern Problems!

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APA_{Rx} Algorithms

- *Max-RF*™ Rx
  - Per-packet Blind Adaptive Polarization
  - APA w/o carrier recovery
    - Initial targets were Non-Coherent Systems
  - As a result of no carrier recovery:
  - Coherent systems enjoy
    - Basic Sync and Trigger (-5dB SINR)
    - Deep Sync and Trigger (-20dB SINR)

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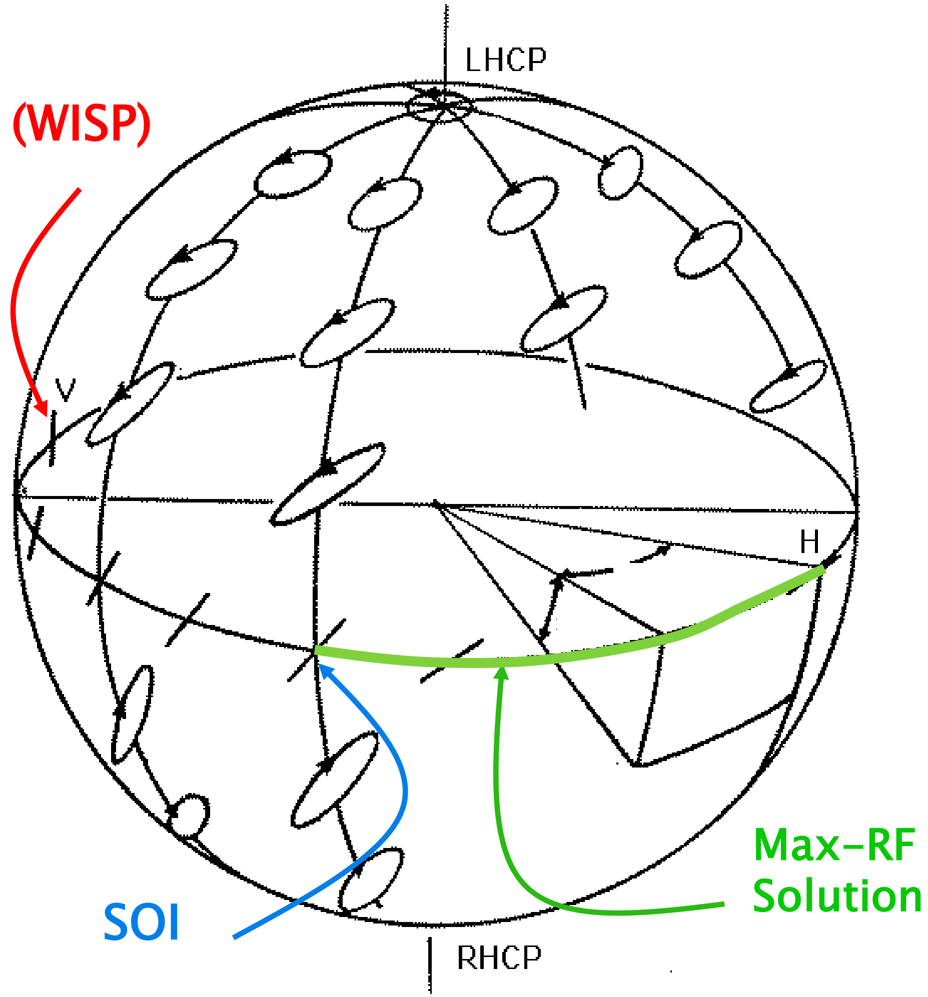
Max-RF™ Optimal Solution

- Strong Vertical Interferer
- Signal of Interest (SOI) at 45°
- *Max-RF*™ optimal solution along arc from 45° to horizontal



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Demonstration Setup and Parameters

- Simulations based on synthetic network architecture
  - Single Signal Of Interest (SOI) and single Interference Source (IS) each with variable parameters synthesizing respective populations
- General parameter specifications
  - Signal of Interest (SOI)
    - FSK modulation
      - 50 kbps
      - 160 bits w/ 32 Preamble bits and 32 CRC bits
  - Channel
    - Interference: Calibrated AWGN
  - Receiver
    - Receiver Noise = -111 dBm

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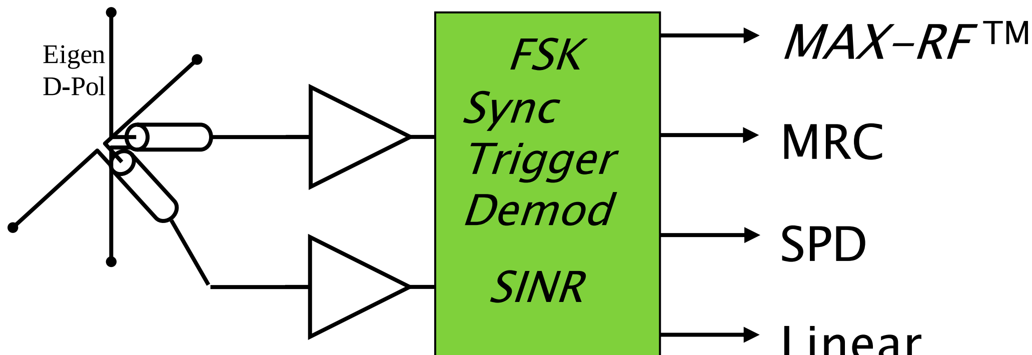
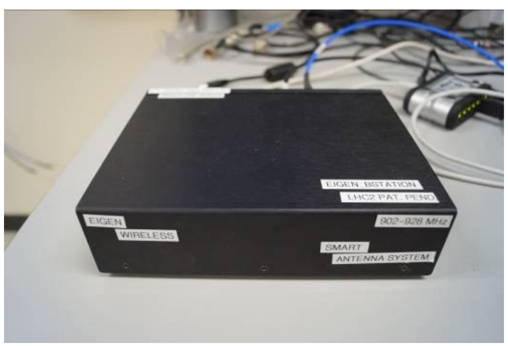
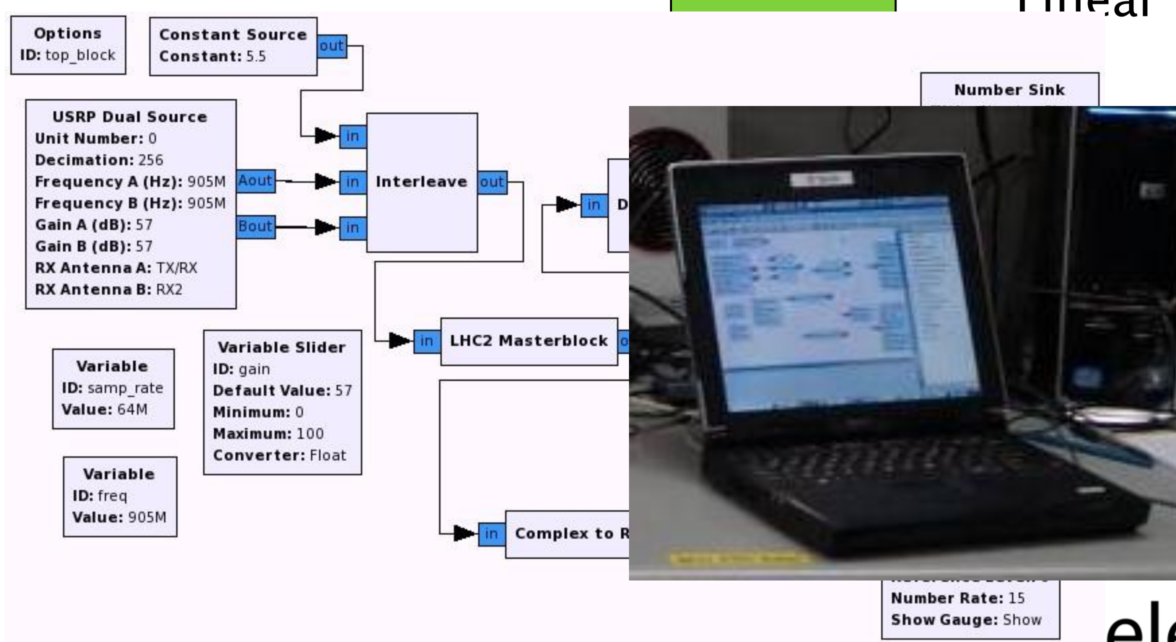
Live Demo OTA *Max-RF*™ Block Diagram

MAX-RF™ Antenna & USRP Receiver

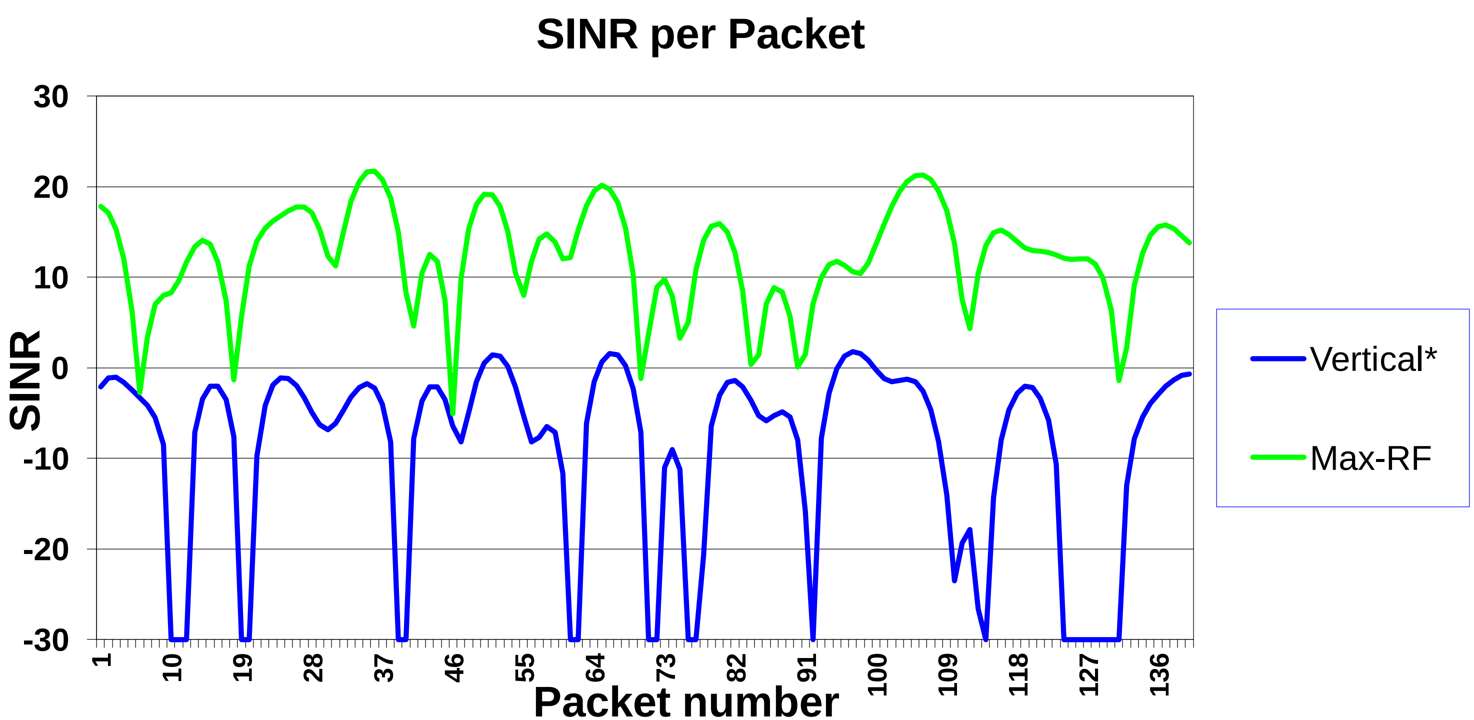






Laboratory Demo and Results

- Live demonstration requires quick results
  - Unlike PER and BER which take a long time to generate statistics



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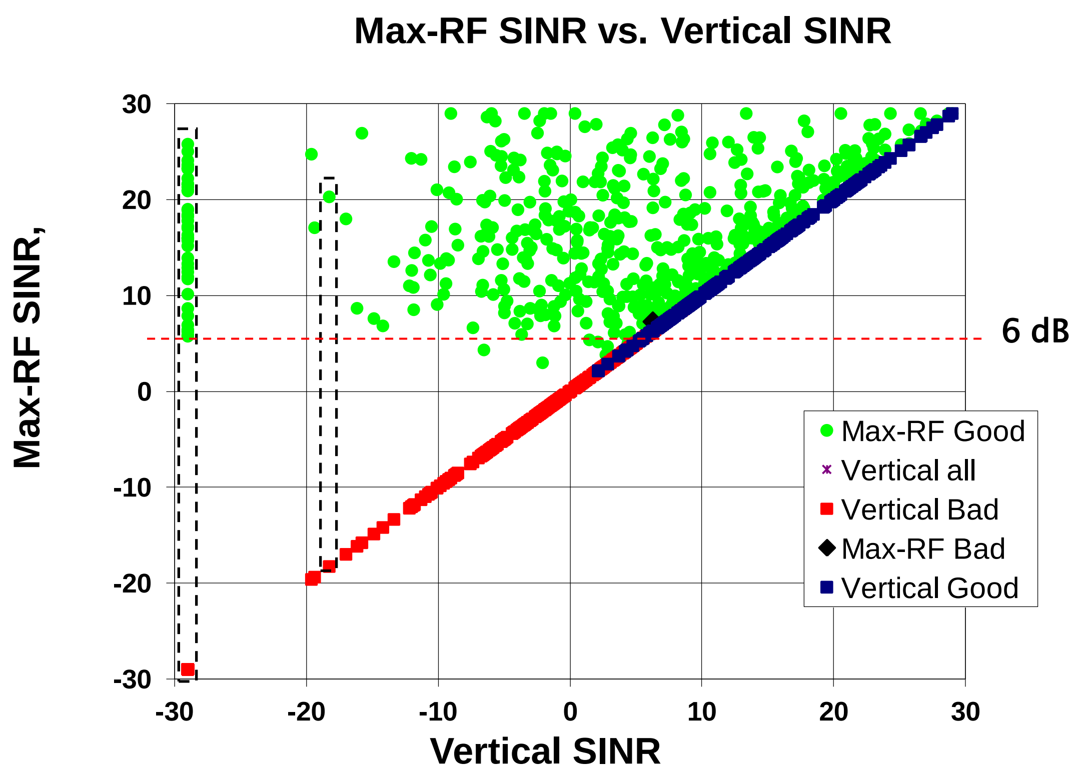

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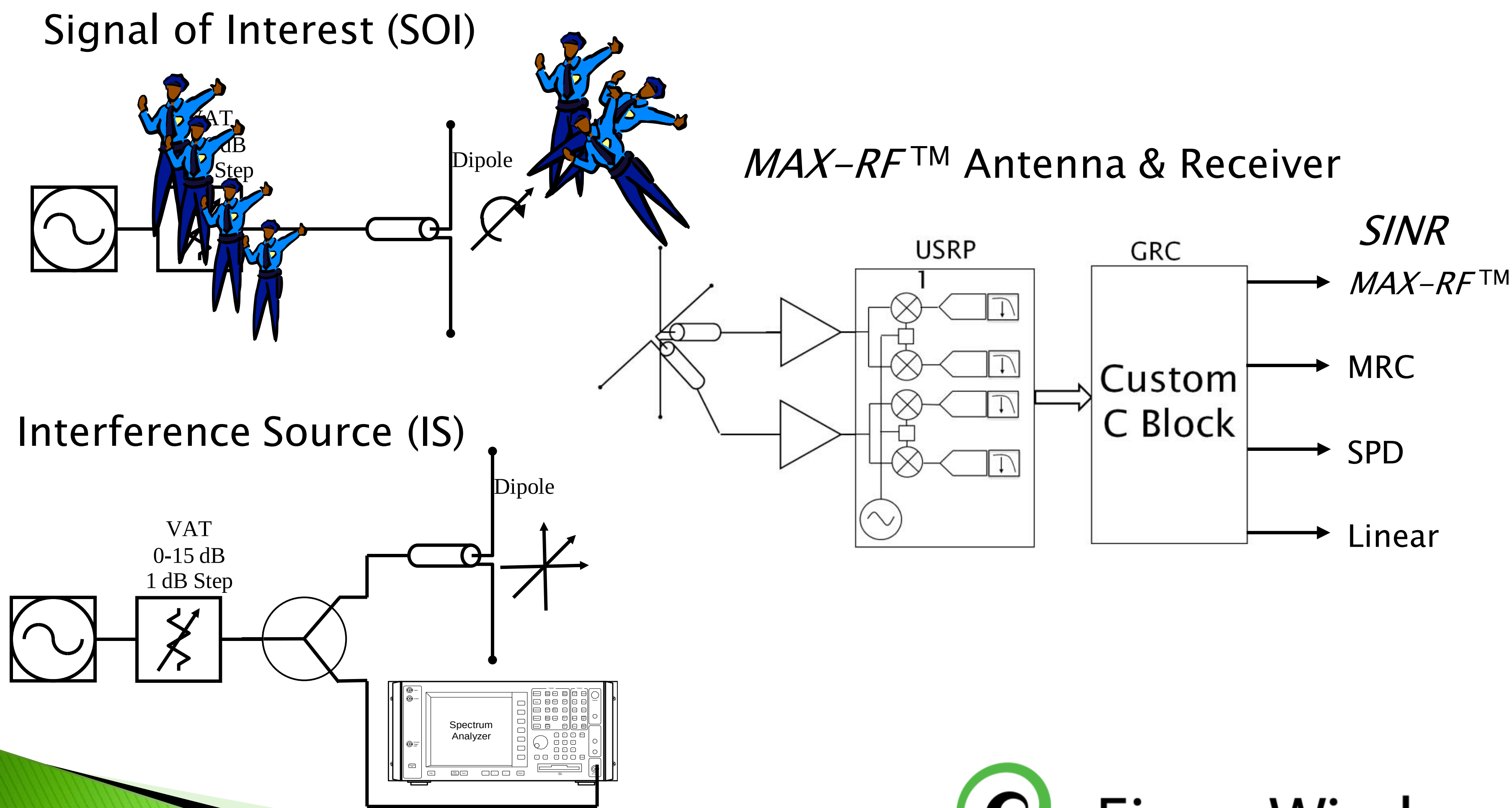
Live Demo OTA *Max-RF*™ Block Diagram



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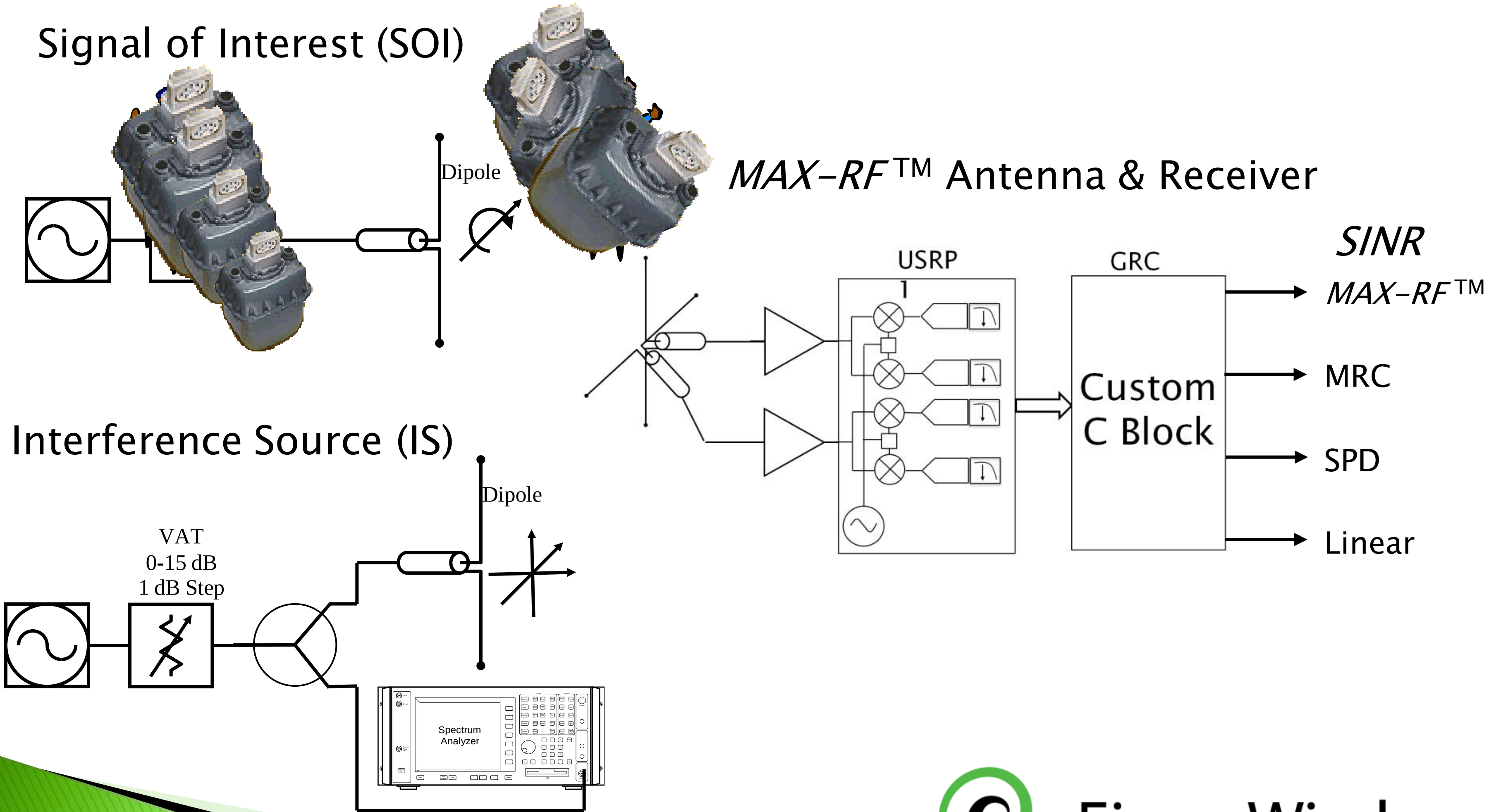
Live Demo OTA *Max-RF*™ Block Diagram



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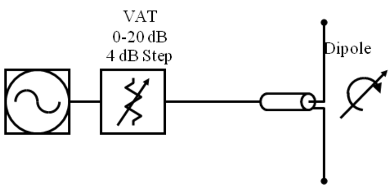
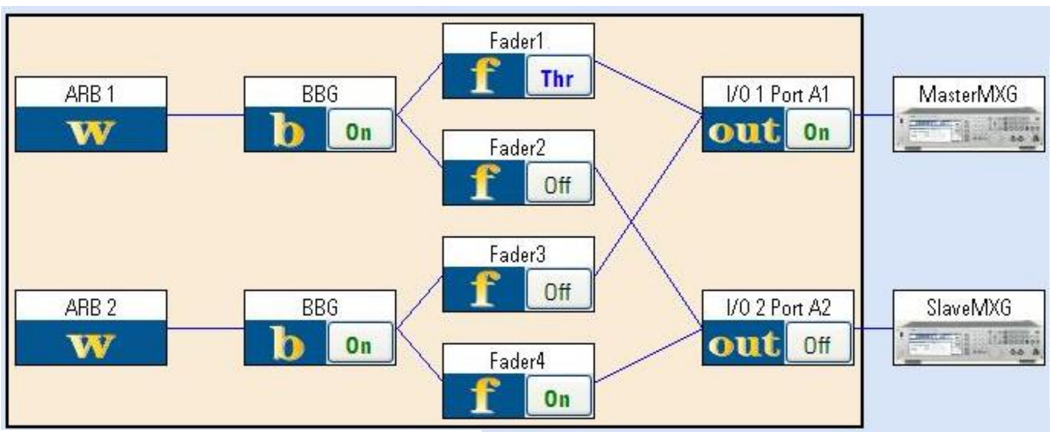
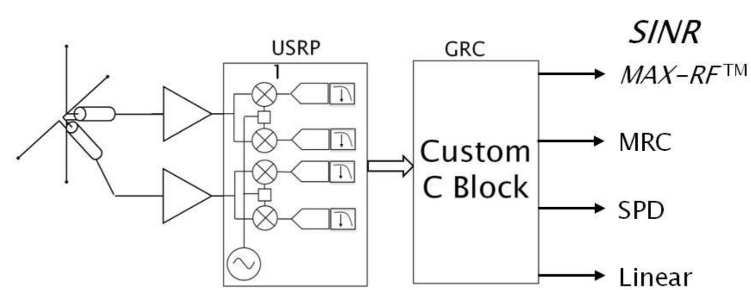
Live Demo Cabled System Block Diagram

Signal of Interest (SOI)

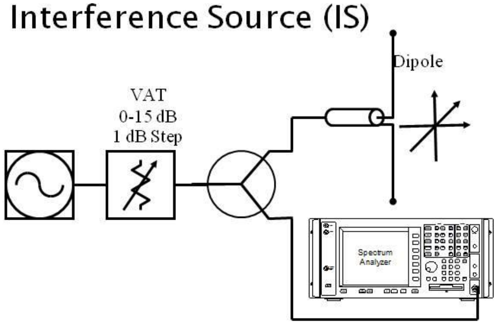




MAX-RF™ Antenna & Receiver



Interference Source (IS)



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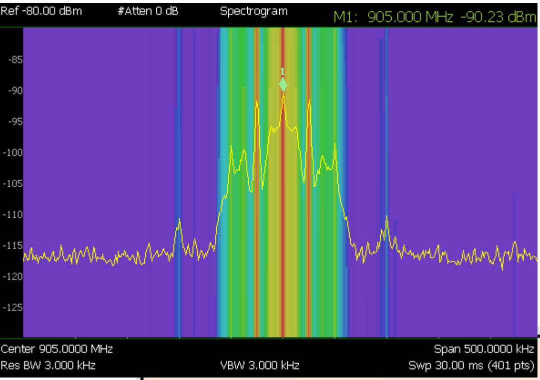
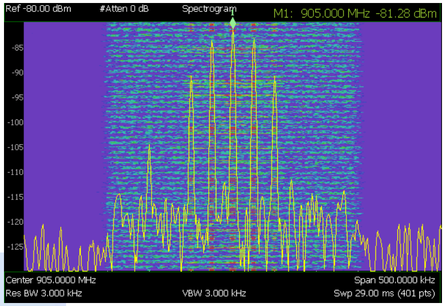
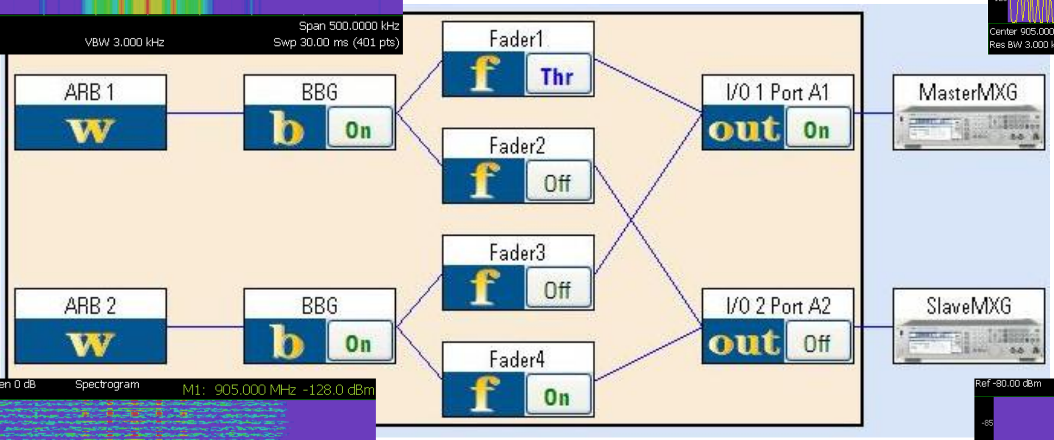
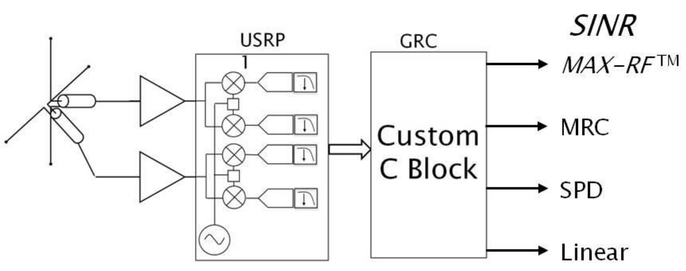
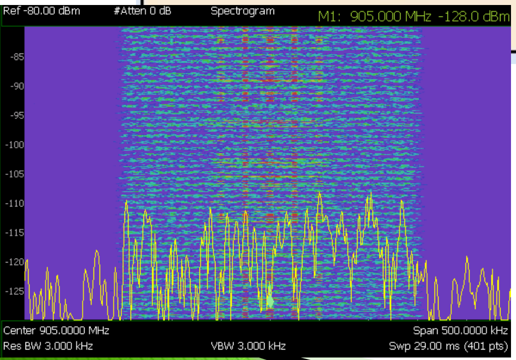


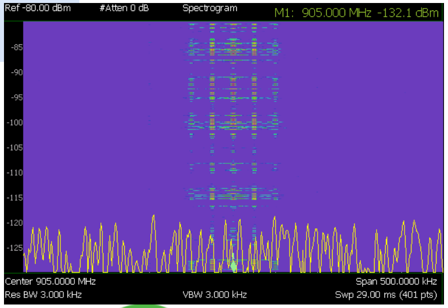




MAX-RF™ Antenna & Receiver







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Live Demonstration Case Flow

	Signals of Interest		Interference Sources	
Case	Power	Polar	Power	Polar
1	High	Vert	–	–
2a	High	Variable	–	–
2b	Step 0–20dB	Variable	–	–
3	Step 0–20dB	Variable	0–20dB	Left 45°
4	Rayleigh	Rayleigh	Rayleigh	Rayleigh
5	Fixed	Step Variable	–	–

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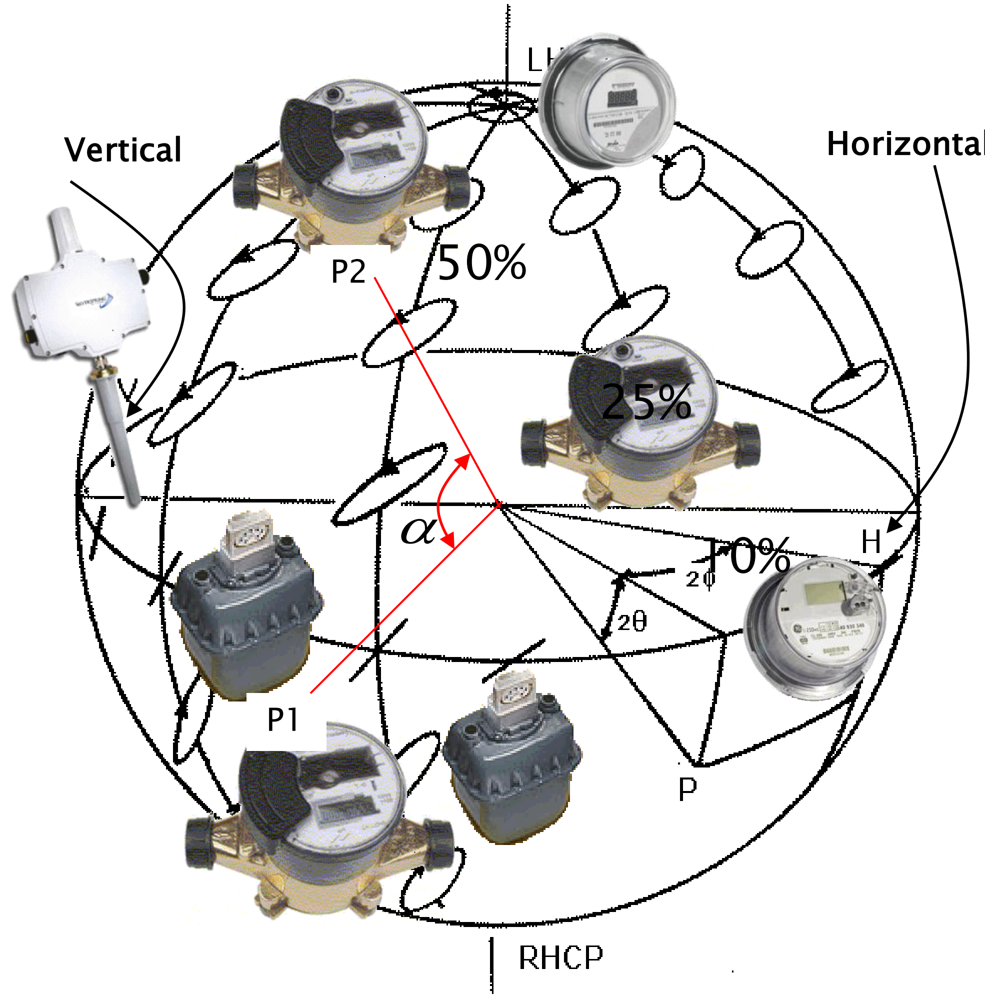
Signal Loss (sINR)

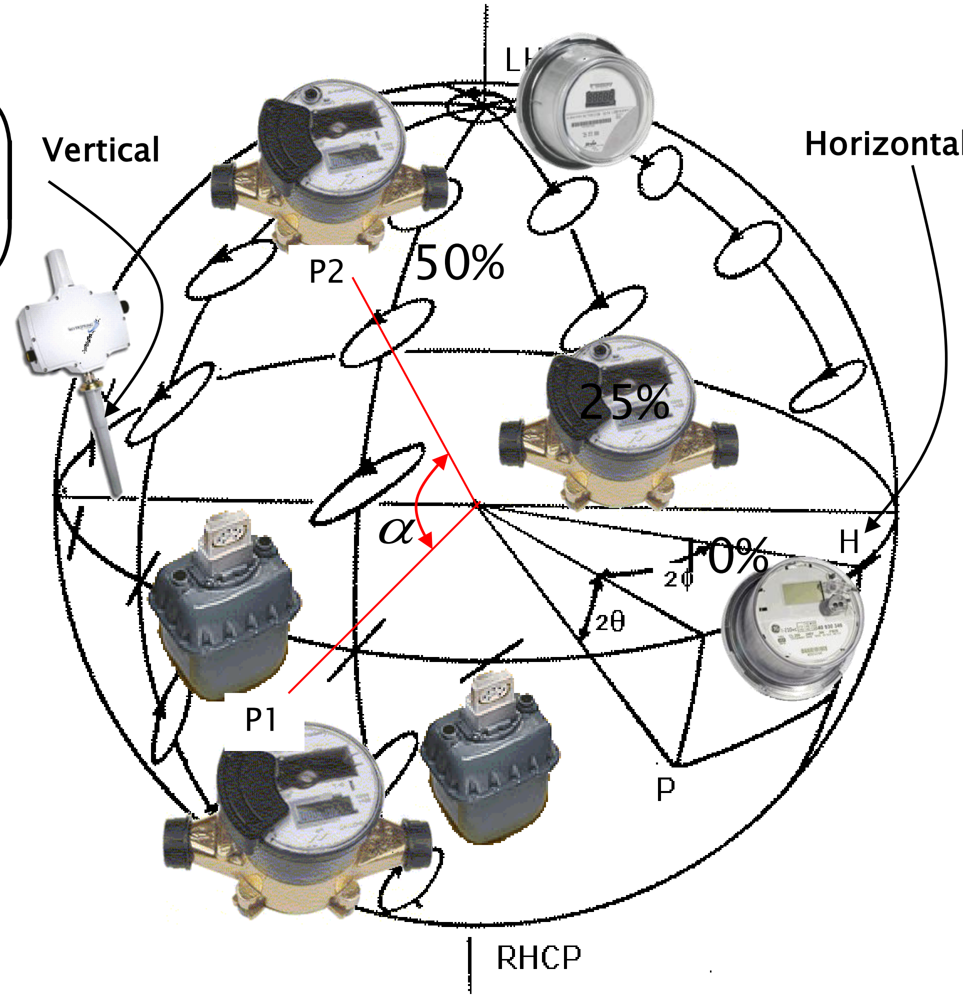
?



Signal Loss (sINR)

$$CPL_{P_1P_2} = 10\log_{10}\cos^2\left(\frac{\alpha}{2}\right)$$

Angle α	% Population	Min CPL dB
90	50	-3
120	25	-6
138	13	-9
151	6.3	-12
159.5	3.2	-15
165.6	1.8	-18
169.8	0.8	-21
180	0	-infinity



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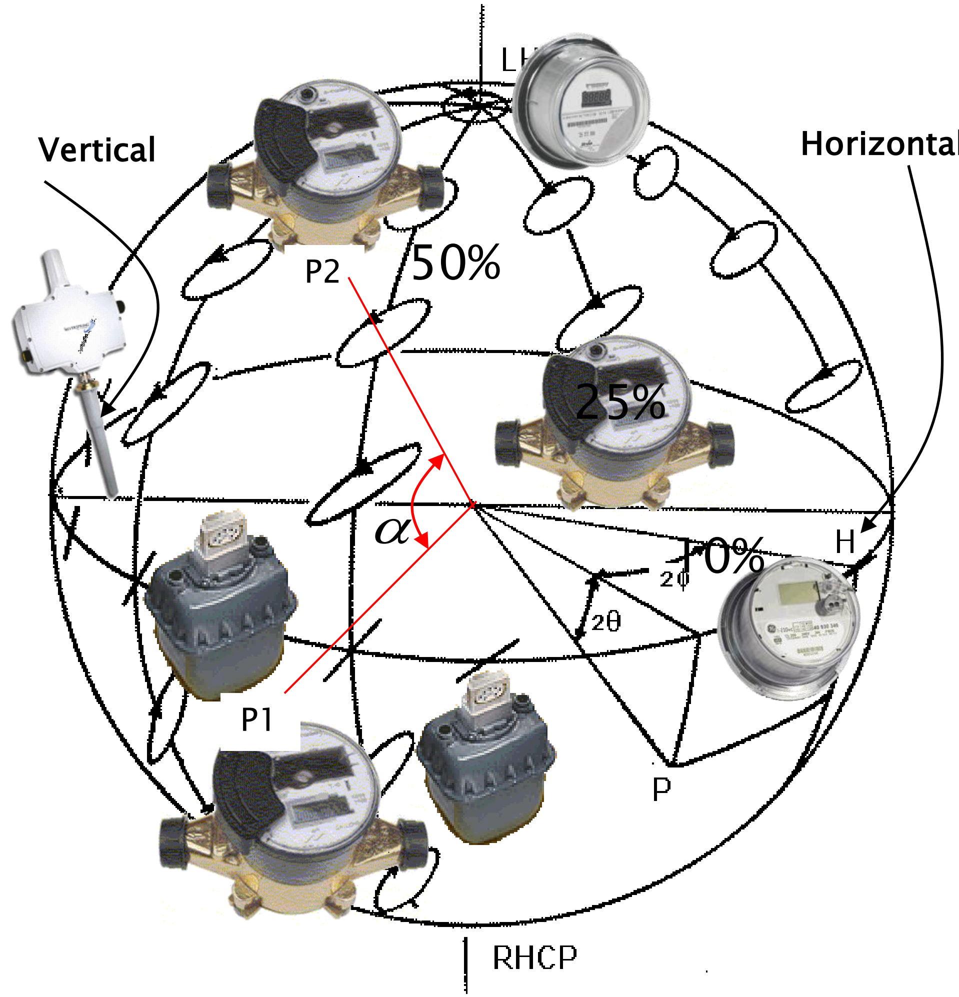
Signal Loss (sINR)

Angle α	% Population	Min CPL dB
90	50	-3
120	25	-6
143	10	-10
154	5	-13
168.5	1	-20
172	0.5	-23
174.3	0.25	-26
176	0.125	-29
180	0	-infinity



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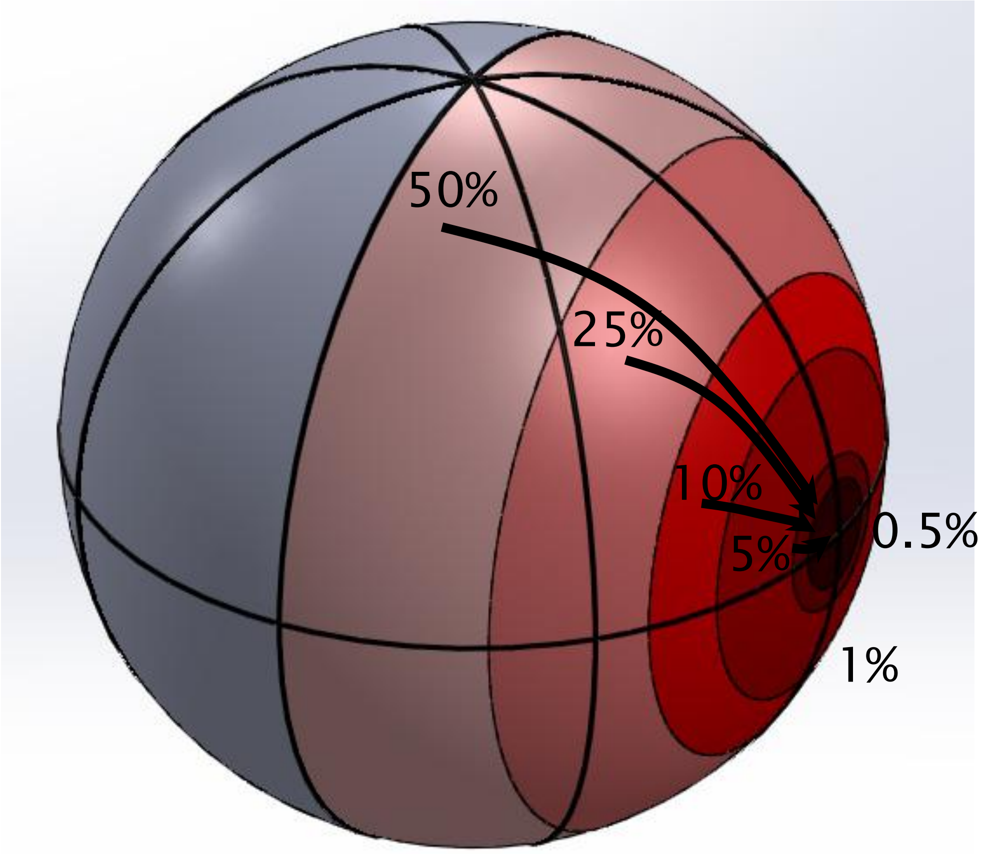

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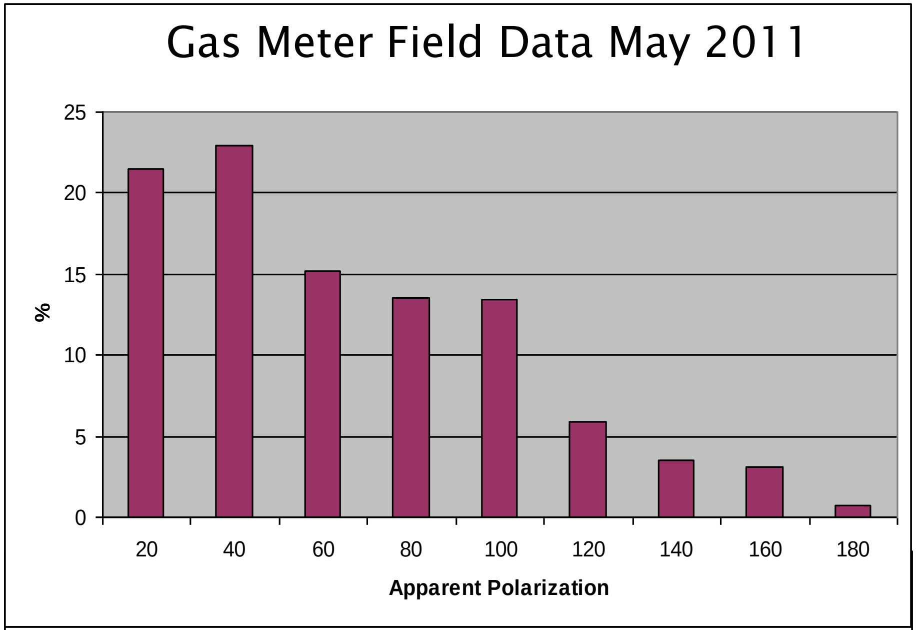
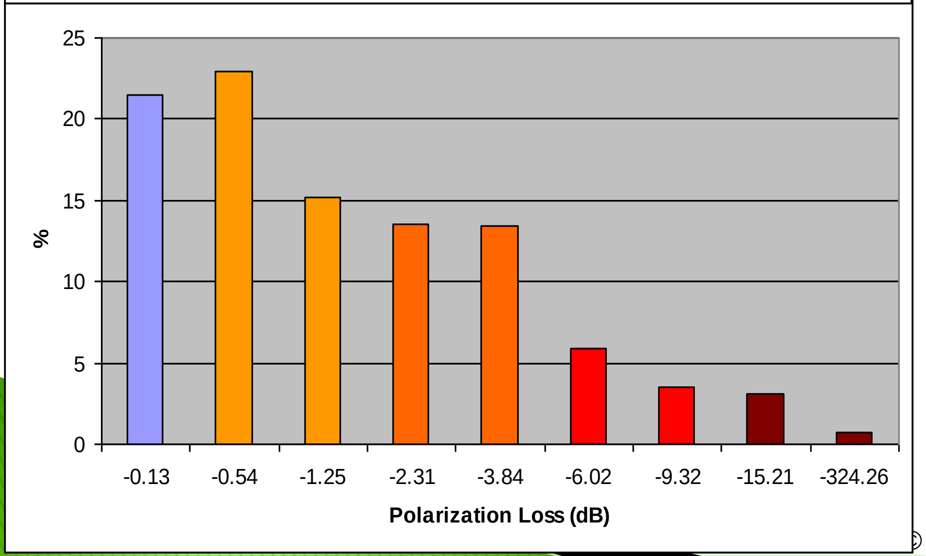
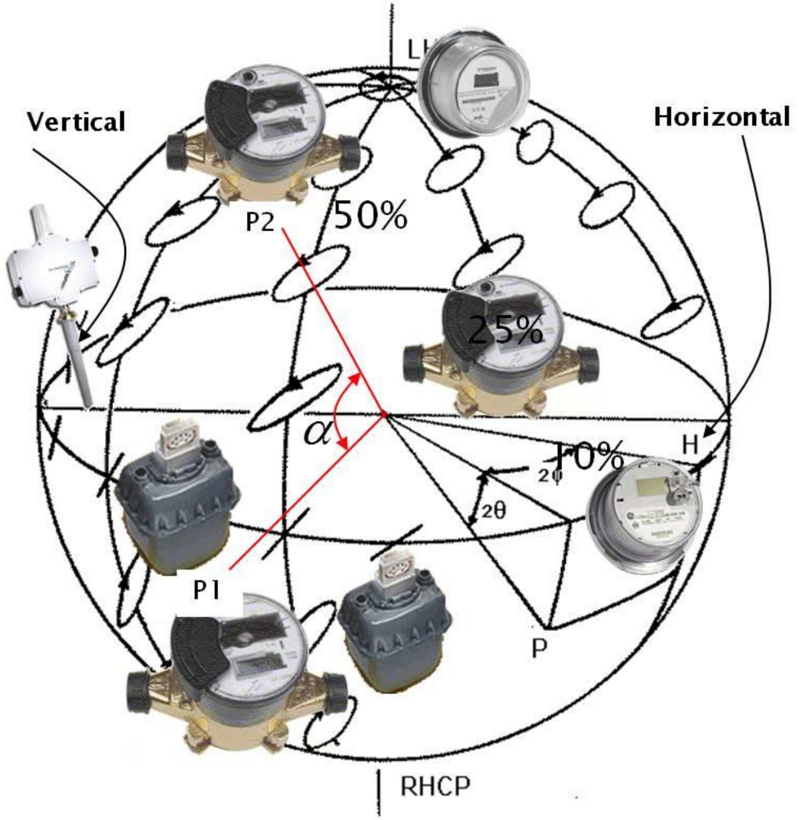
Signal Loss (sINR)







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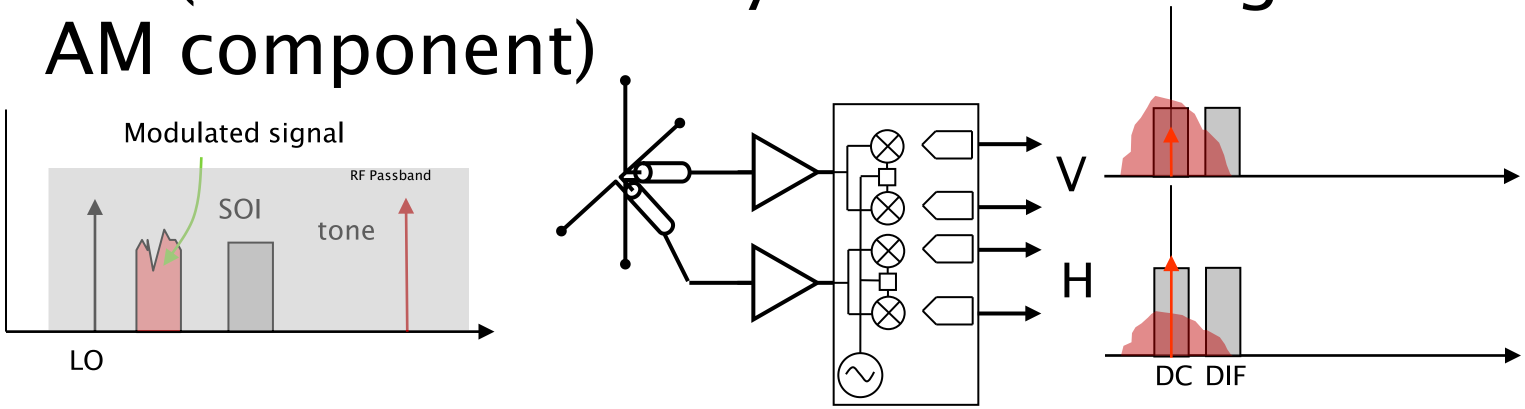
Max-RF™ A Solution To IP2

- IP2 (LTE and other systems with significant AM component)



- Interferer's AM and receiver's IP2 results in energy around DC (Zero IF) and potentially in Digital IF
- Polarization phase of interferer is modified Polarization is preserved for the SOI
- *Max-RF*™ Solves for optimal rejection of IP2 energy

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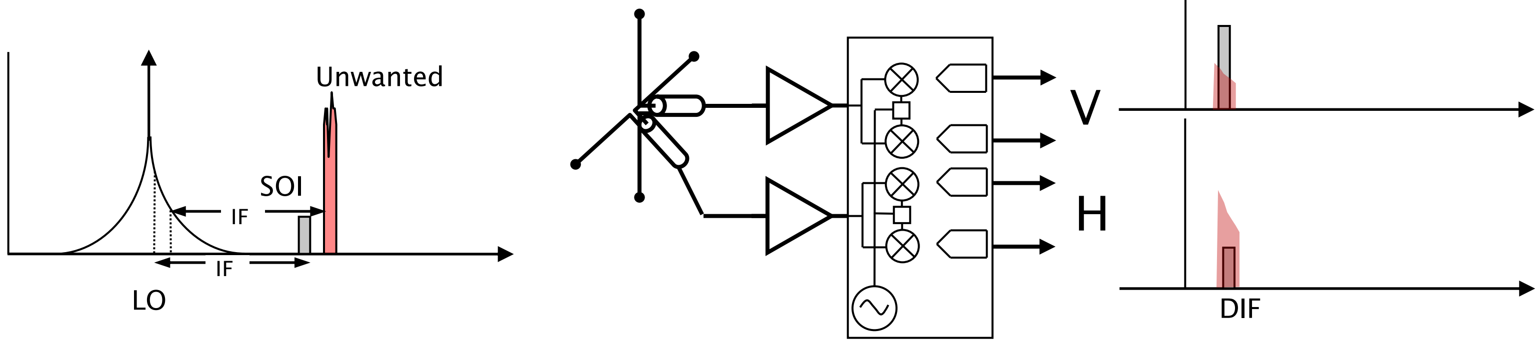
Max-RF™ A Solution To Reciprocal Mixing

- LO phase noise can mix closely spaced unwanted signals into the IF



- The common LO noise preserves the polarization of the unwanted signal
- *Max-RF*™ solves for optimal SINR, rejecting the unwanted signal as if it were originally co-channel

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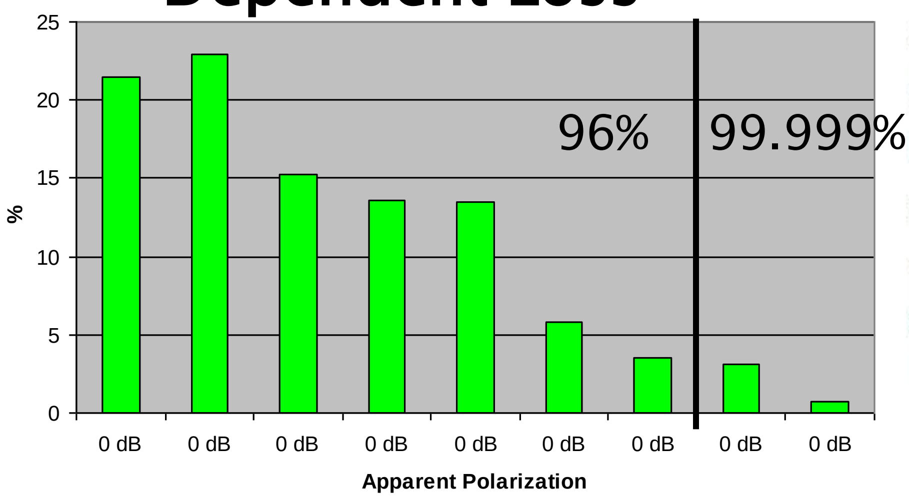
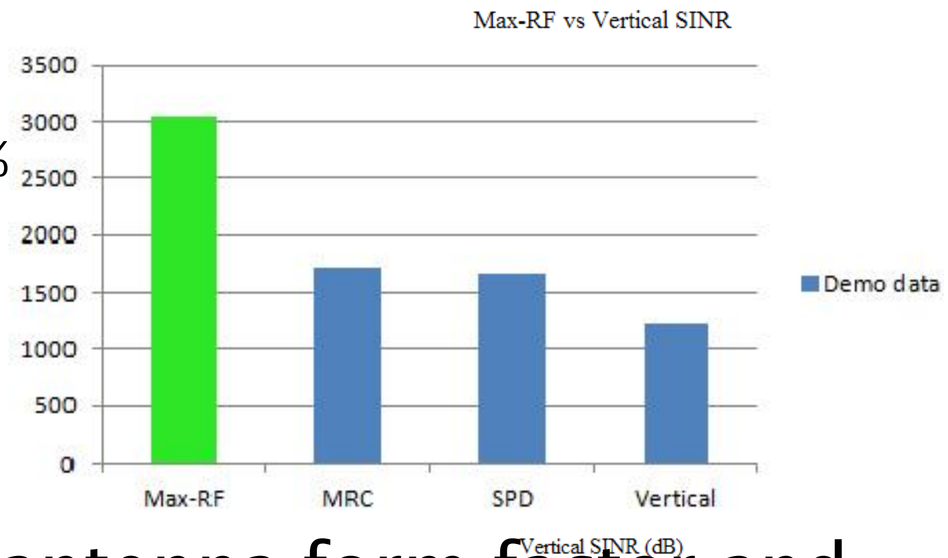
Max-RF™ = Unique Antenna + Algorithms

- *Max-RF*™ optimally eliminates **Polarization Dependent Loss**



- *Max-RF*™ optimally mitigates **Interference**



- While maintaining the antenna form factor and deployment method of current equipment
- **Standard** and **Radio** format **Agnostic**

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Live Demonstration Questions

	Signals of Interest		Interference Sources	
Case	Power	Polar	Power	Polar
1	High	Vert	–	–
2a	High	Variable	–	–
2b	0-20dB	Variable	–	–
3	0-20dB	Variable	0-20dB	Left 45^{o}
4	Rayleigh	Rayleigh	Rayleigh	Rayleigh
5	Fixed	Step Variable	–	–

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Thank you, Questions?

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- bconley@eigenwireless.com

- Dr Steven Schennum
- schennum@gonzaga.edu

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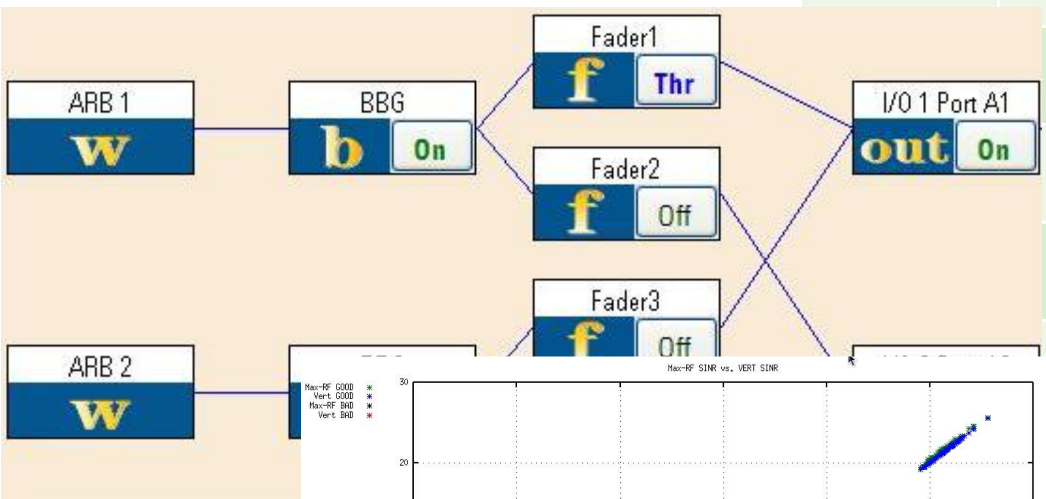
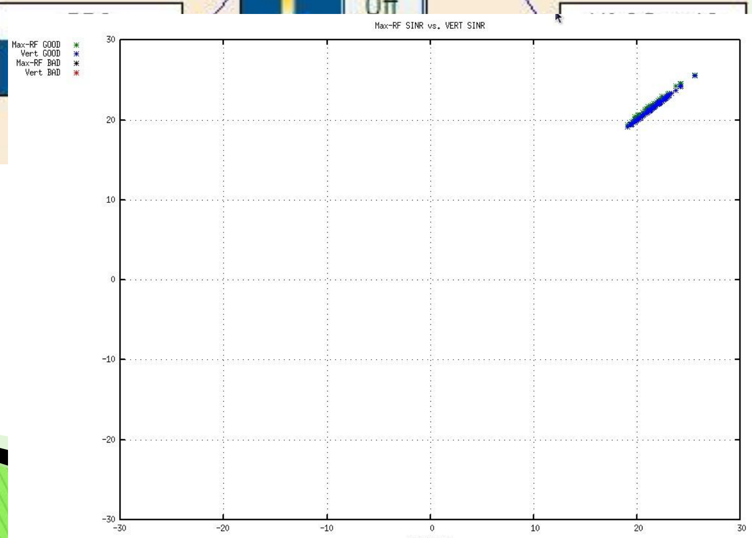
Backup Slides

Live Demonstration Case 1

	Signals of Interest		Interference Sources	
Case	Power	Polar	Power	Polar
1	High	Vert	–	–
	High	Variable	–	–
	0-20dB	Variable	–	–
	0-20dB	Variable	0-20dB	Left 45º
	Rayleigh	Rayleigh	Rayleigh	Rayleigh
	Fixed	Step Variable	–	–





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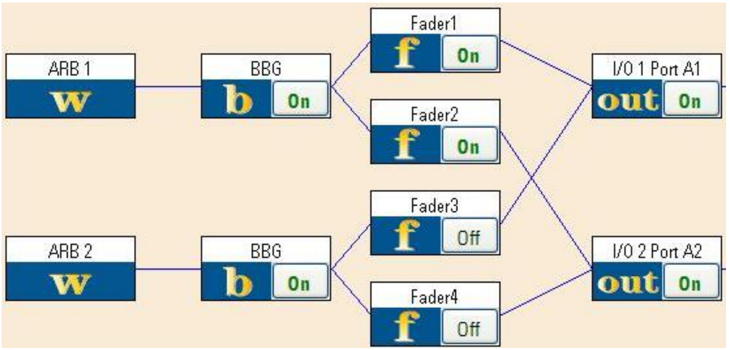
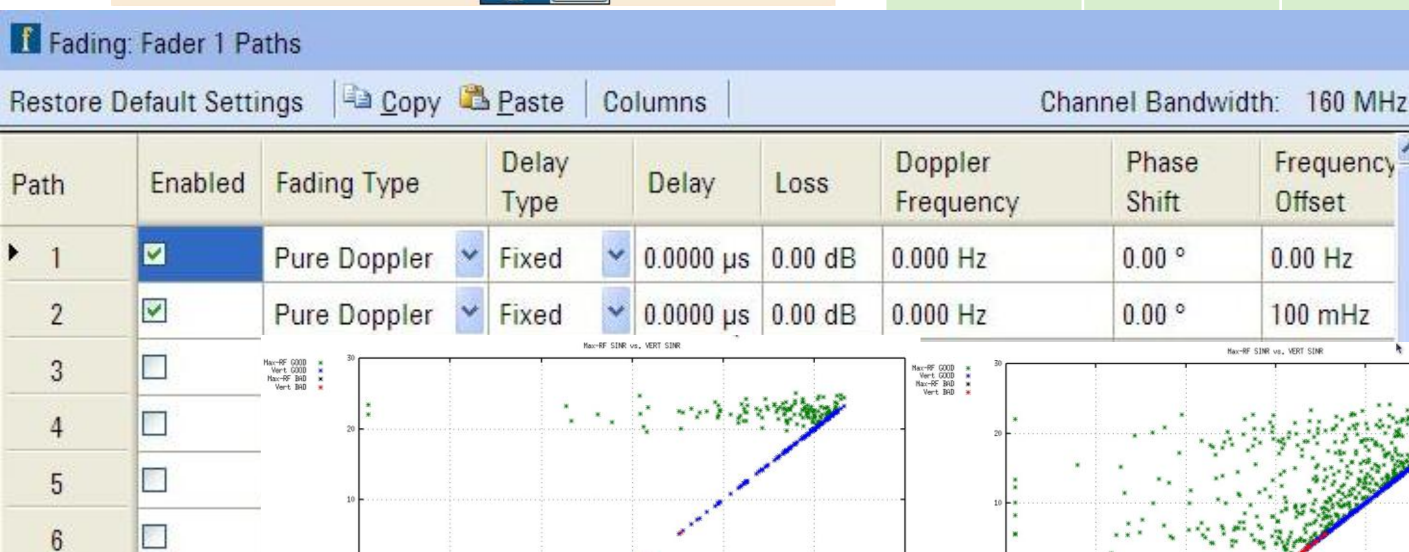
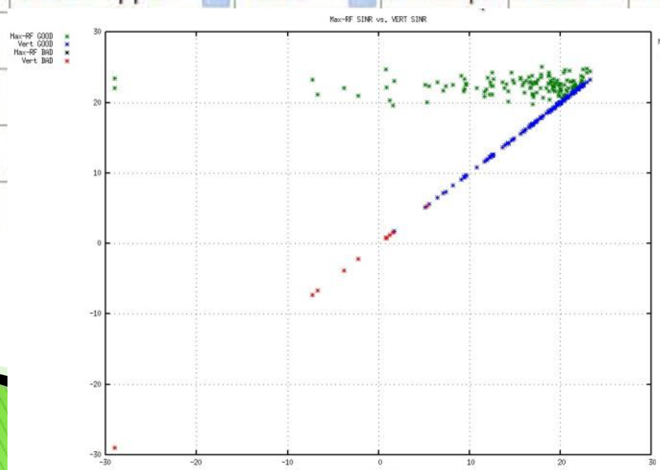
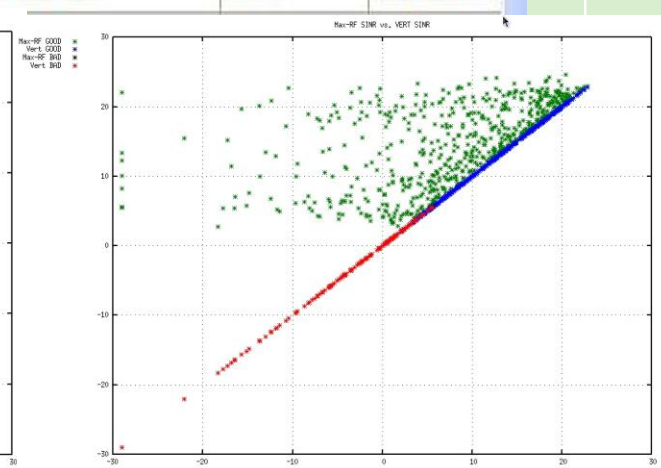
Live Demonstration Case 2a, 2b



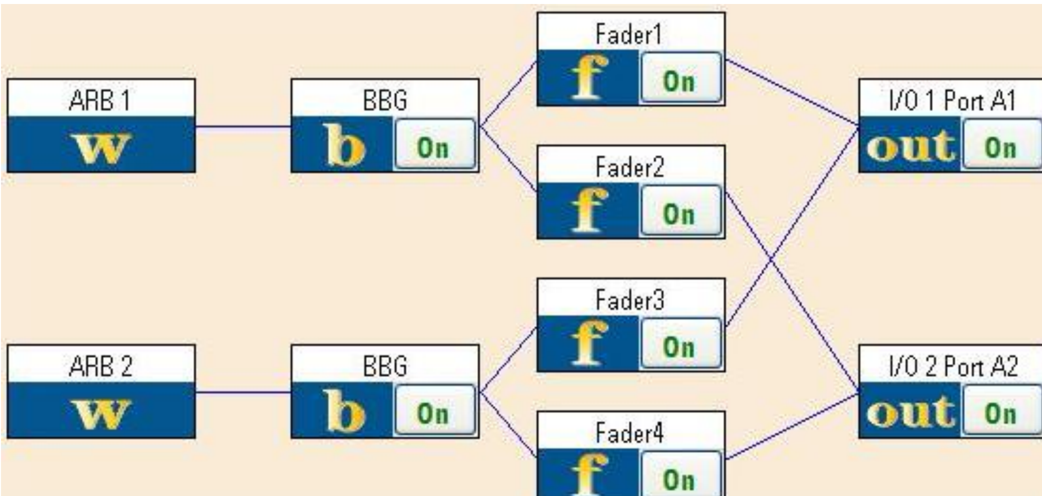
	Signals of Interest		Interference Sources	
Case	Power	Polar	Power	Polar
1	High	Vert	–	–
2a	High	Variable	–	–
		ble	–	–
		ble	0-20dB	Left 45°
		gh	Rayleigh	Rayleigh
			–	–

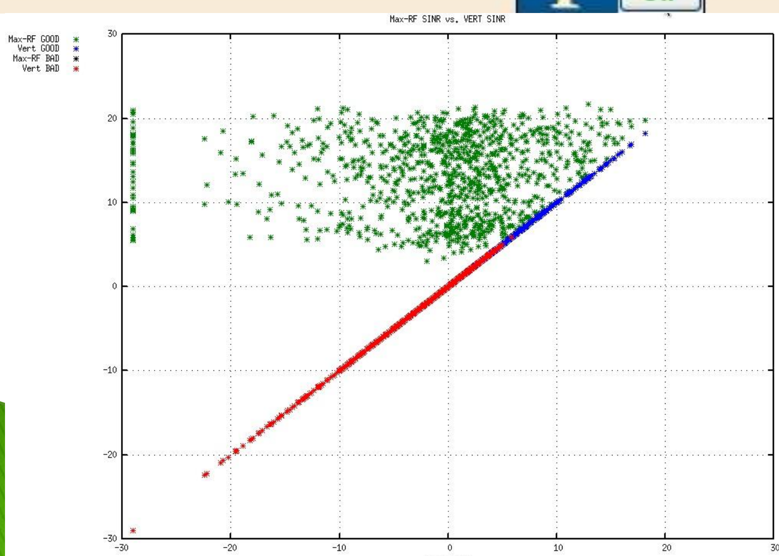






Live Demonstration Case 3





	Signals of Interest		Interference Sources	
	Power	Polar	Power	Polar
	High	Vert	–	–
	High	Variable	–	–
2b	0-20dB	Variable	–	–
3	0-20dB	Variable	0-20dB	Left 45º
4	Rayleigh	Rayleigh	Rayleigh	Rayleigh
5	Fixed	Step Variable	–	–

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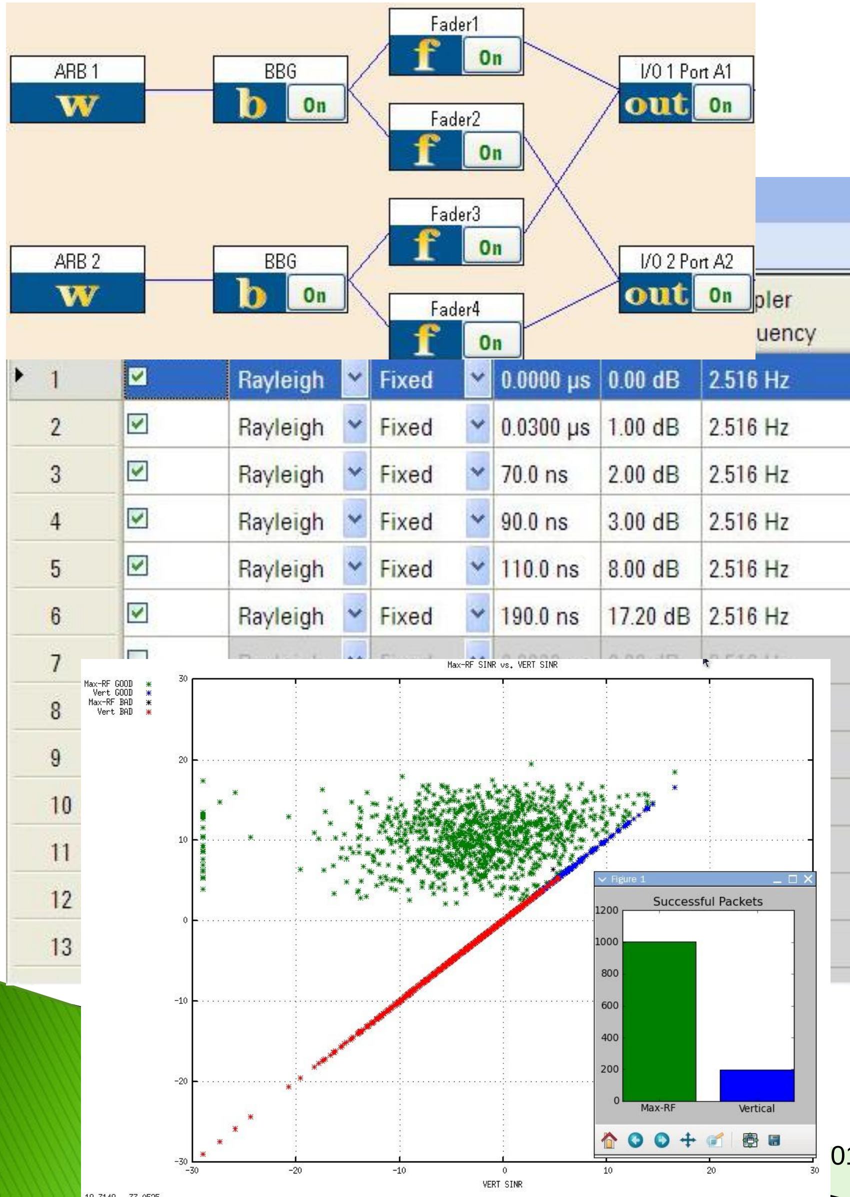
Live Demonstration Case 4



	Signals of Interest		Interference Sources	
Case	Power	Polar	Power	Polar
1	High	Vert	–	–
2a	High	Variable	–	–
2b	0-20dB	Variable	–	–
3	0-20dB	Variable	0-20dB	Left 45°
4	Rayleigh	Rayleigh	Rayleigh	Rayleigh
5	Fixed	Step Variable	–	–

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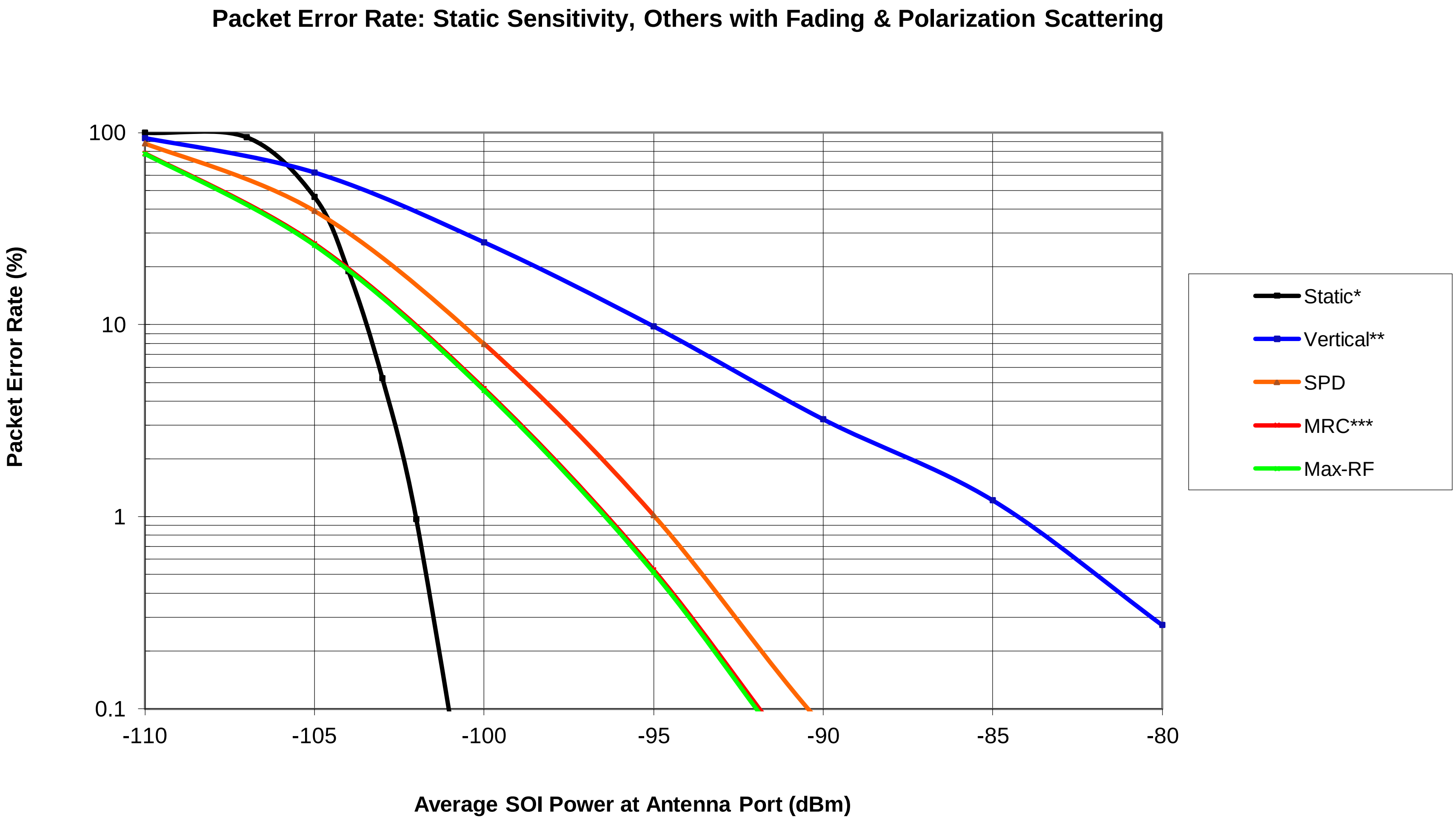
Simulated PER w/ No Interference



* Noise Limited Static Sensitivity for any polarization w/o fading
** Any Linear Polarization
*** **MRC with Eigen D-Pol & Ideal Carrier Recovery**
(See speaker's notes)

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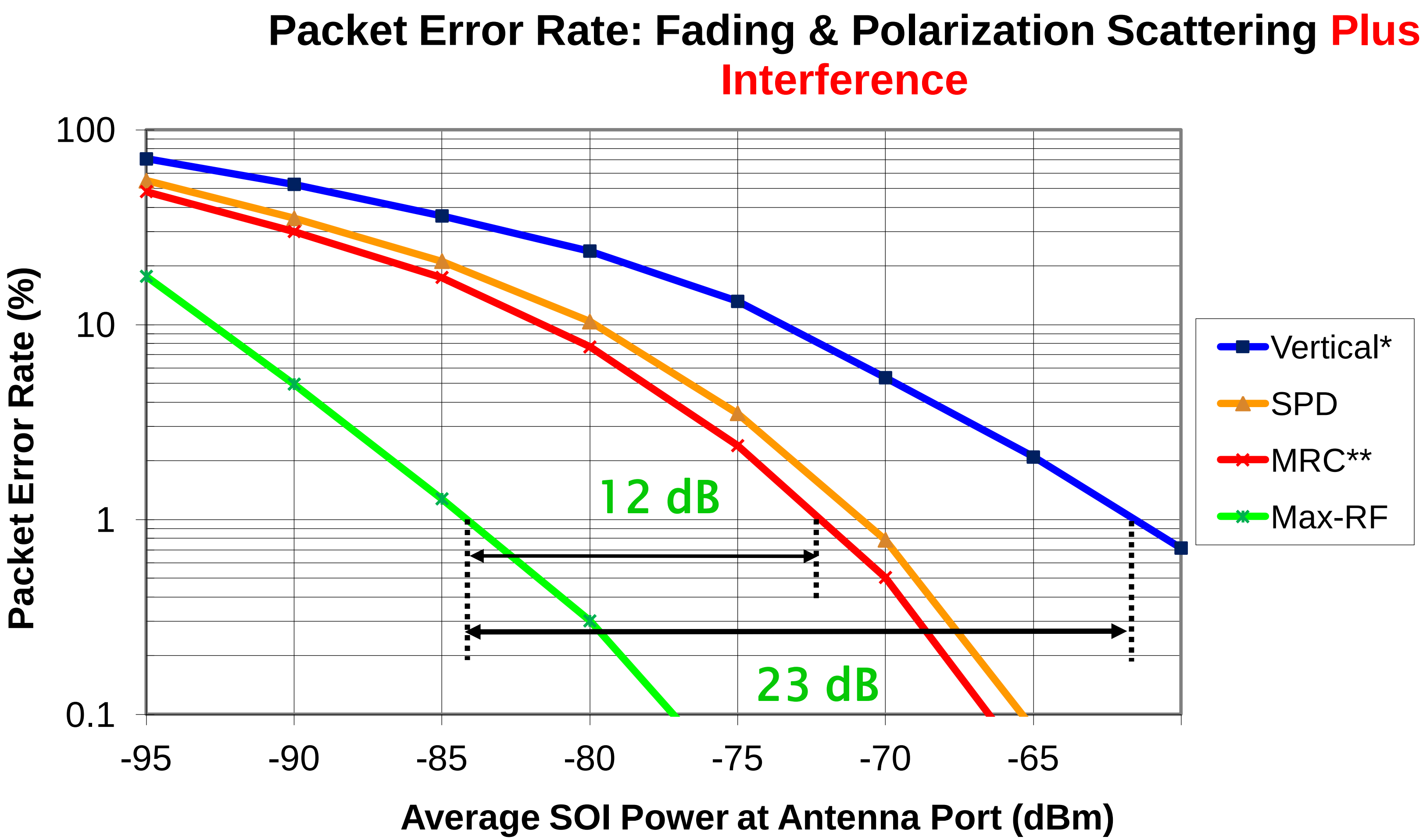
Simulated PER w/ Interference



*Any Linear Polarization
**MRC with Eigen D-Pol & Ideal Carrier Recovery
(See speaker's notes)

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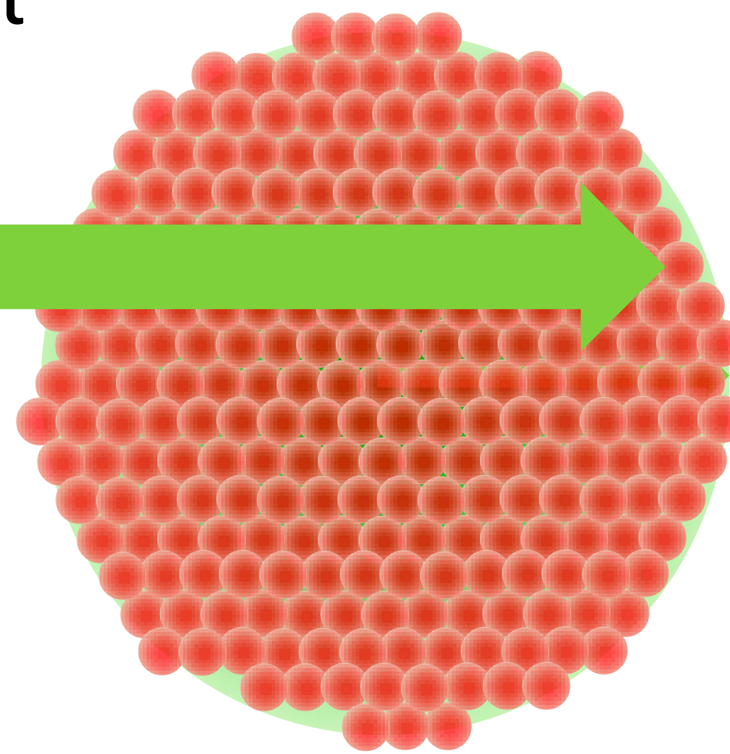
23dB Improvement

- Range: Up to 14x improvement
- Coverage: 250x improvement



  - Vs. 250 additional gas meter collection radios at a cost of $4000 each
- **Savings of $1M**
- Reliability: Bid $ for targeted coverage improvements

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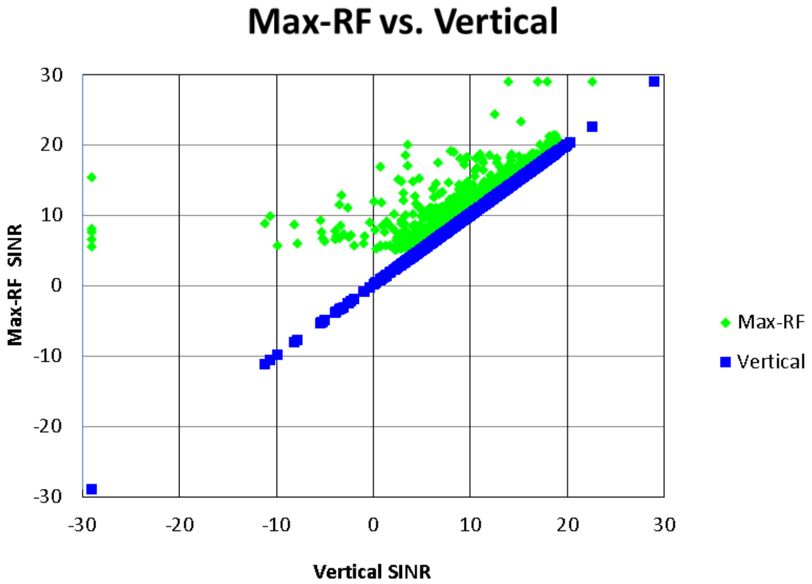
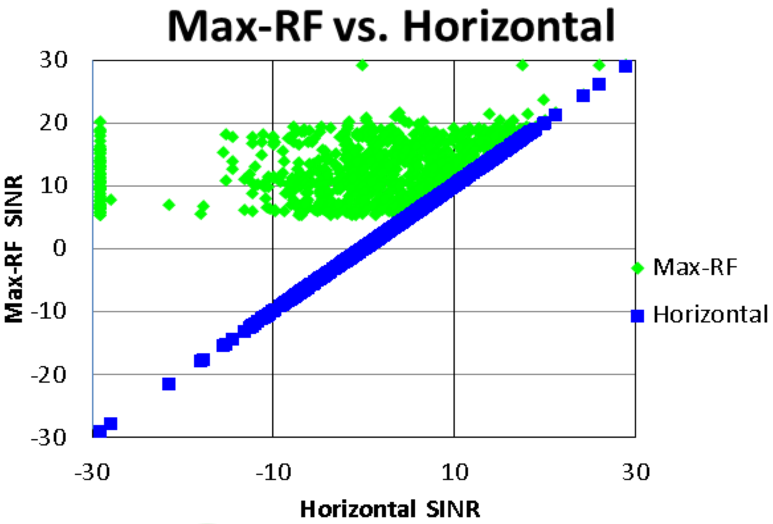
Field Results

- Gas AMR in a Low Interference Environment





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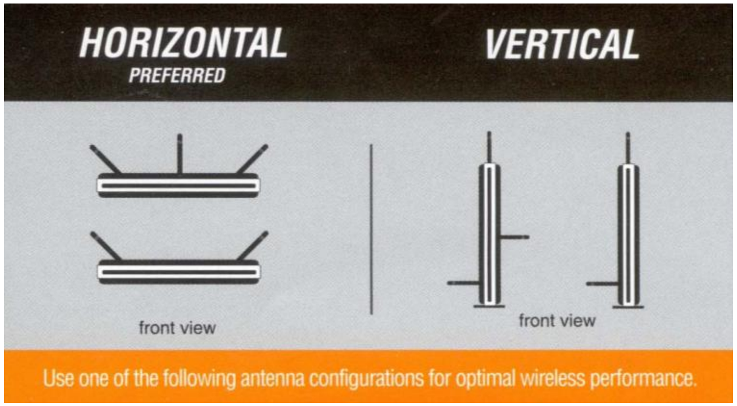
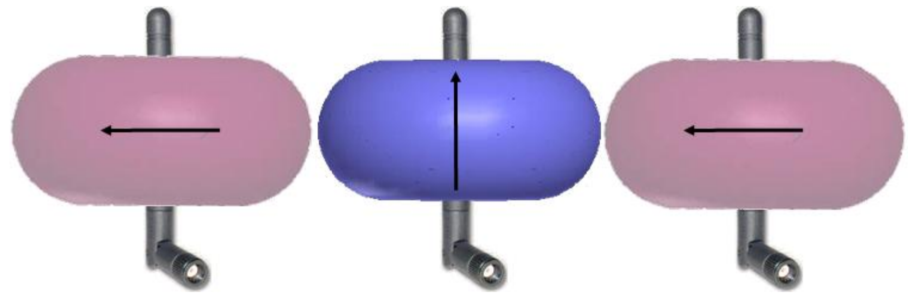
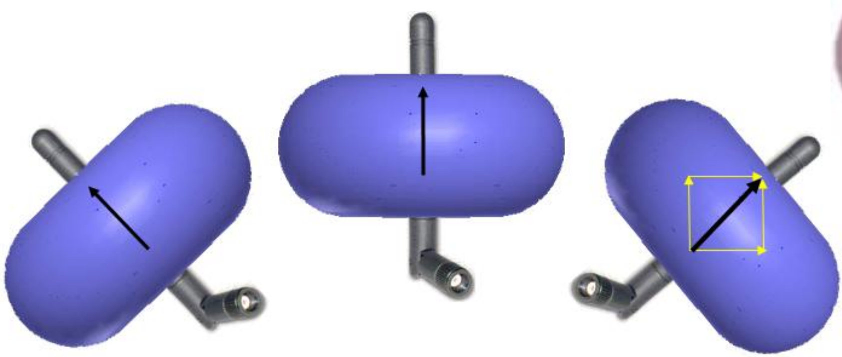
Max-RF™ D-Pols =No Pattern Problems







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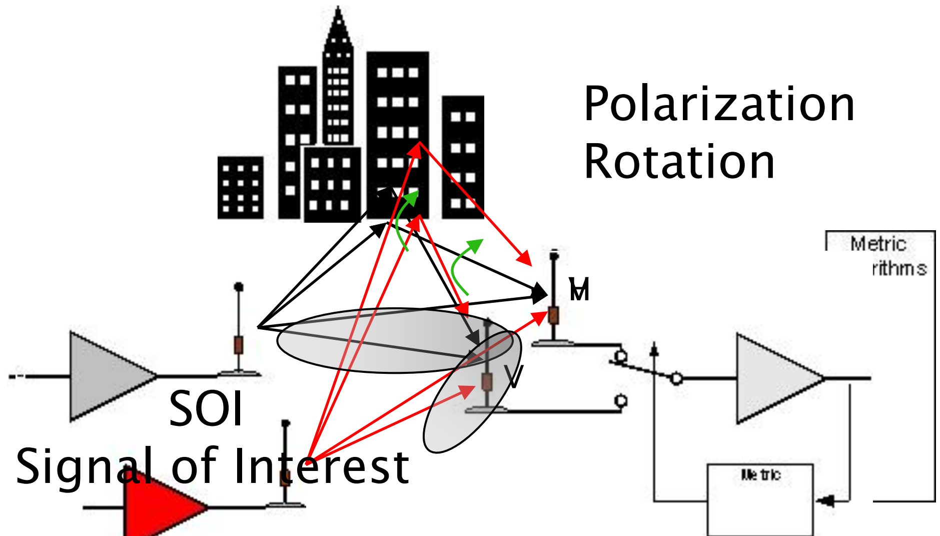
Max-RF™ Rx Per Packet Computation Overhead: Similar to MRC

- Optimal Solution
  - Complex multiplies: 3*N + 12
  - Real multiples: 3*N
  - Complex adds: 6*N
  - Complex divides: 1
  - Real Square root: 1
    - where N = # of "preamble" bits.
- The signal combining is additional
  - Complex multiplies: 2*M
  - Complex adds: M
    - where M = # payload + CRC bits.
- Memory Requirements
  - 4*N complex samples

Eigen Wireless

Alternative Antenna Techniques

- Switched (or Selection) Diversity (SD)
  - Lower probability of a multipath fade on both antenna
  - Based on signal quality metrics
- Switched Polarization Diversity (SPD)
  - Superior to SD
    - Recovers many polarization fades
- Combining Diversity
  - Equal power combining
  - Maximal Ratio Combining (MRC)
    - Can recover polarization fades if No Interference
- Spatial Filtering
  - Beam forming (switched or active)
  - Null steering
    - Can null interferer(s) but not on Line of Sight (LOS) of SOI



SISO SIMO
Signal Input Single Output Multiple Output

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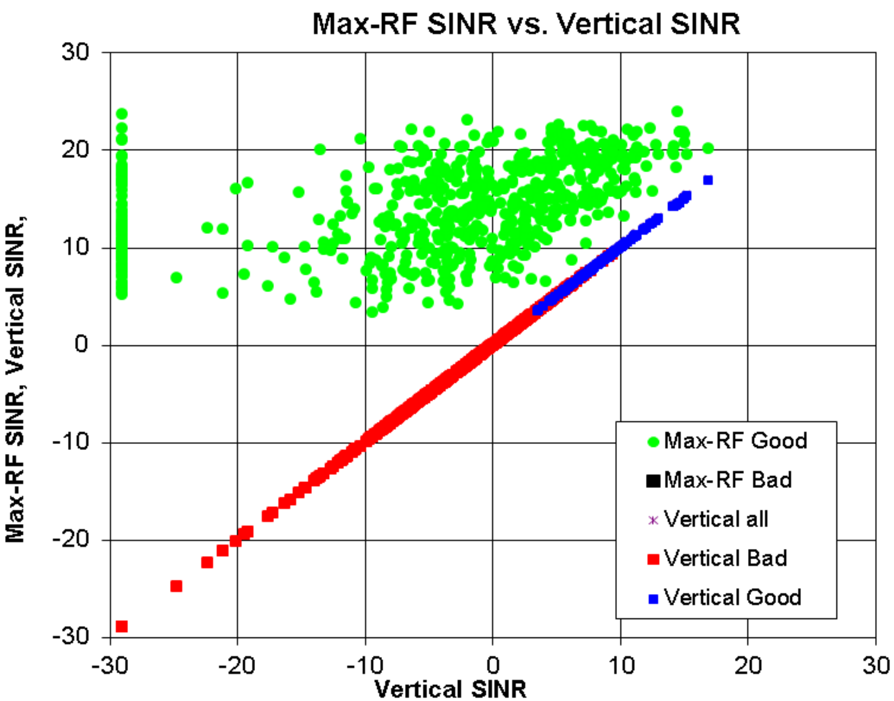
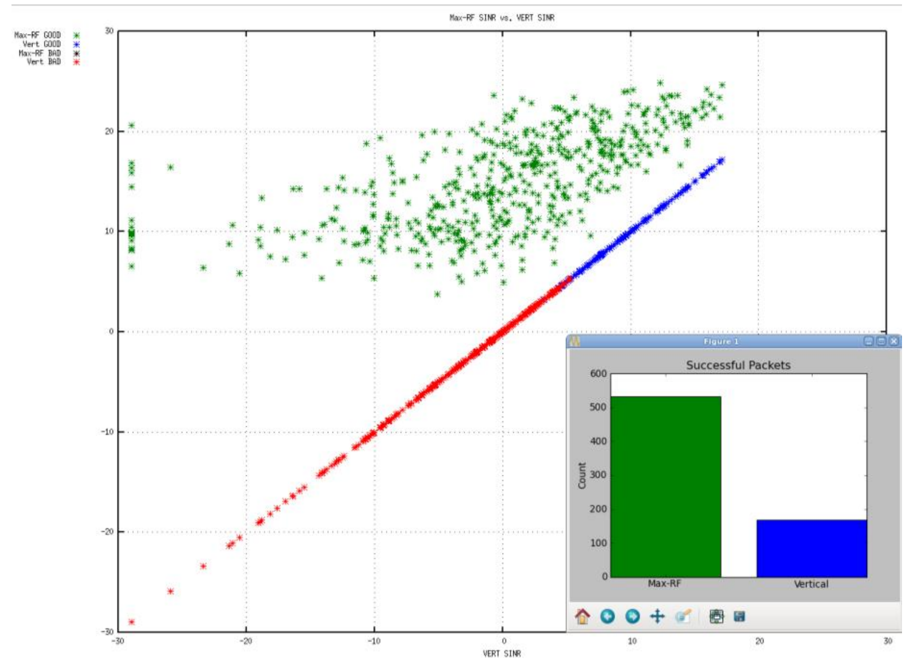
Simulation Experimentation





Excellent agreement between simulation, experimentation and the field

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Max-RF™ Tx Patent Pending

- APA Precoded Downlink Transmission
- For semi stationary TDD systems where reciprocity holds
- Based on analysis of *Max-RF*™ Rx results for associated/registered devices