Interference Mitigation Using Adaptive Polarization

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Introduction

- Focus:

Mission and Life Critical Communications

  - Major deployments ongoing
  - Long standards cycle = Outdated at deployment
    - SISO, Narrow Band, Lack coding, Limited spectrum
  - Limited budgets = long service life
  - Underperforming and Failing systems
    - Growing interference (self and adjacent band)
    - Missed coverage expectations (expensive mitigation)

Physical Layer Solution Space

- WINNF:

Top Ten Most Wanted Wireless Innovations

#3 FCC receiver performance specifications

#4 Wide Spectral Range, Multi-band

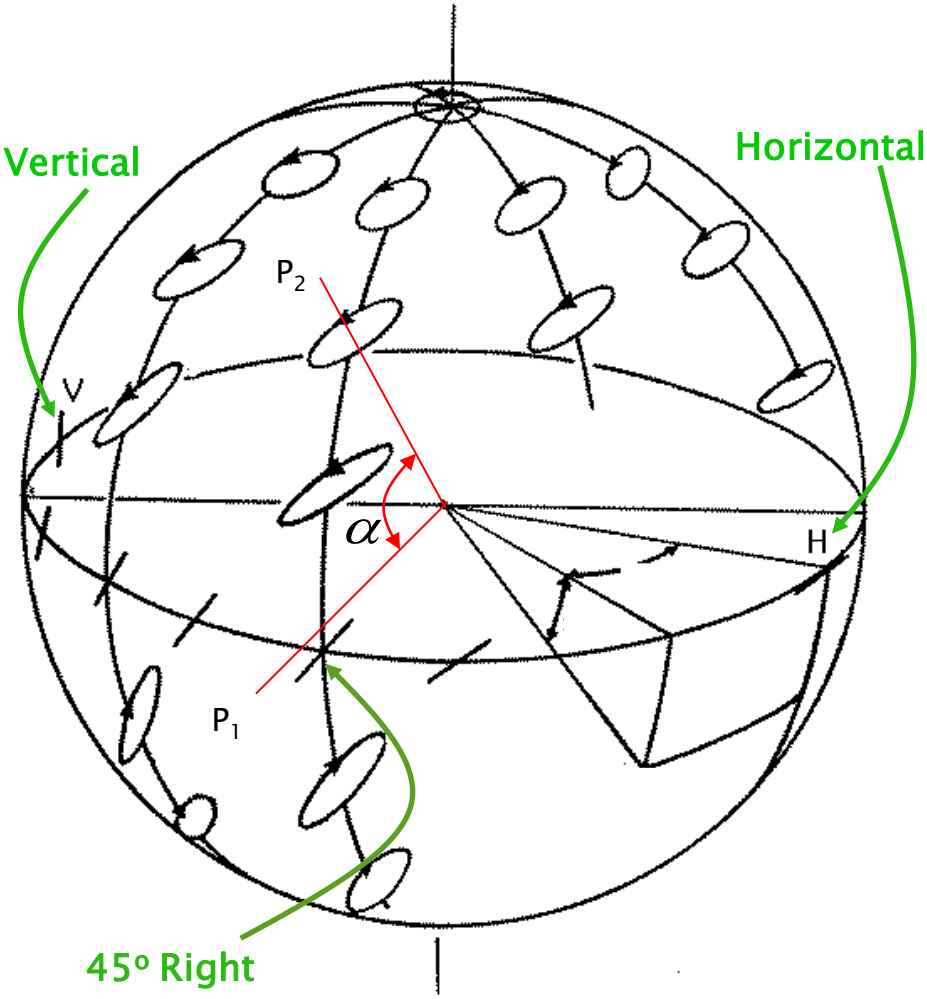
#5 New Rx and Tx components

#8 Interference Mitigation

- Adaptive filtering
- Adaptive beam forming
- Adaptive polarization

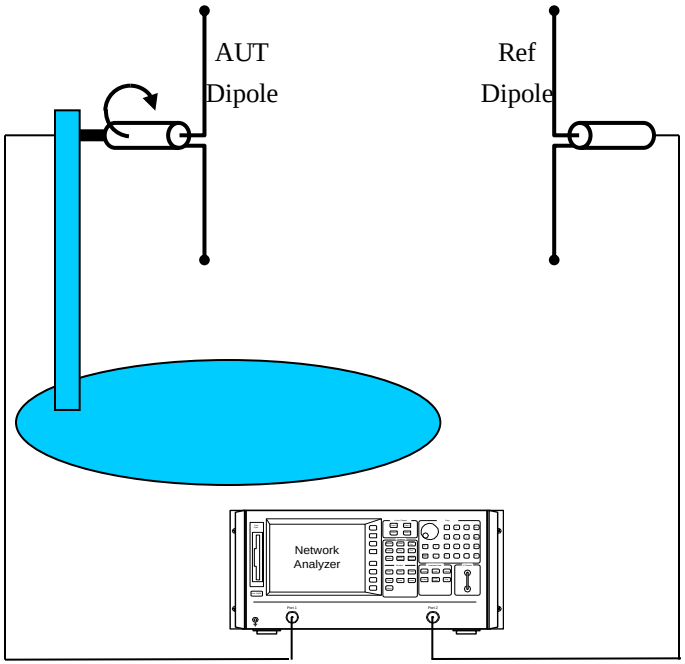
Polarization

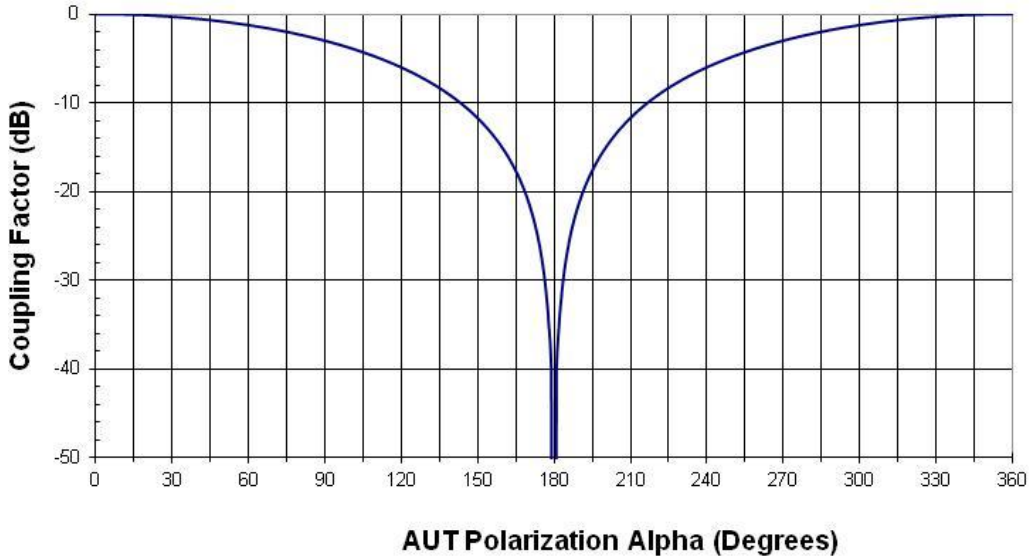
- Poincaré Sphere
  - Linear polarizations on equator
  - Left Hand Circular Polarization (LHCP) and RHCP are special cases of elliptical polarization
  - Angle between any two polarizations, P_1& P_2 given by α
  - Directly opposite polarizations (α=180^o) are orthogonal



Polarization Dependent Loss (PDL)

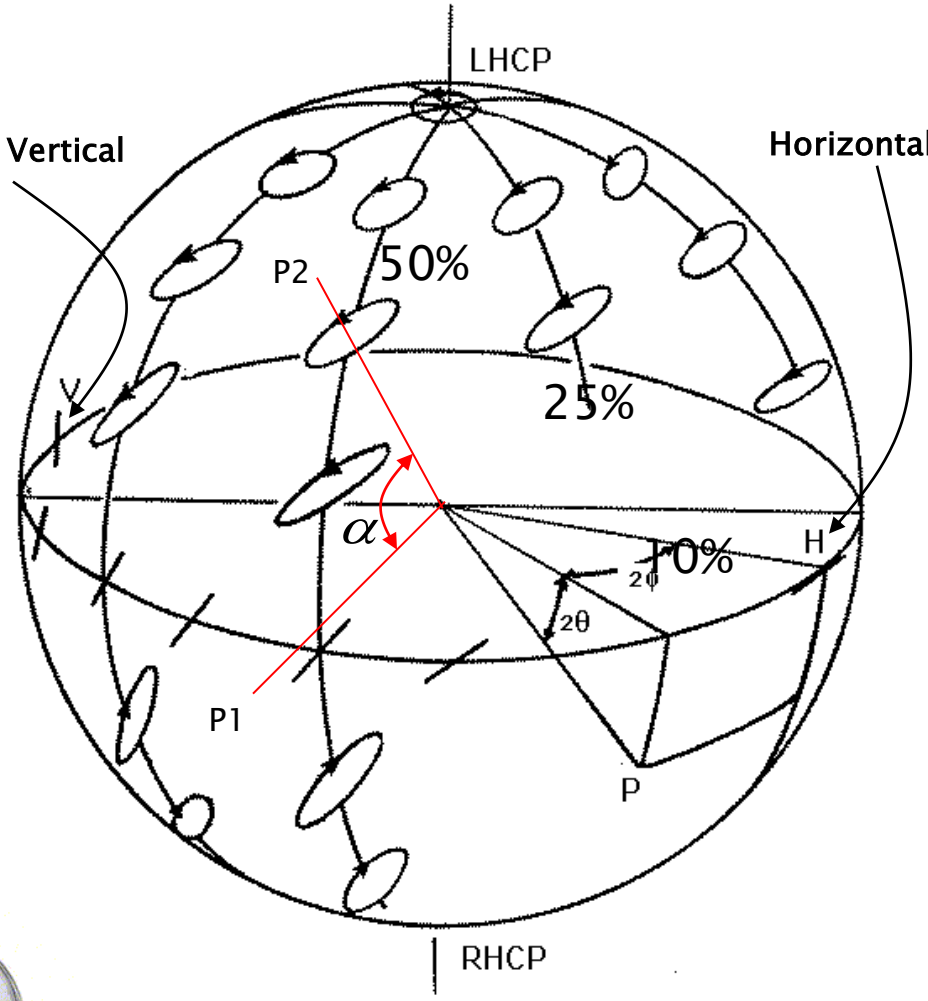
$$PC_{P_1P_2} = 10\log_{10}\cos^2\left(\frac{\alpha}{2}\right)$$





Scattering

?



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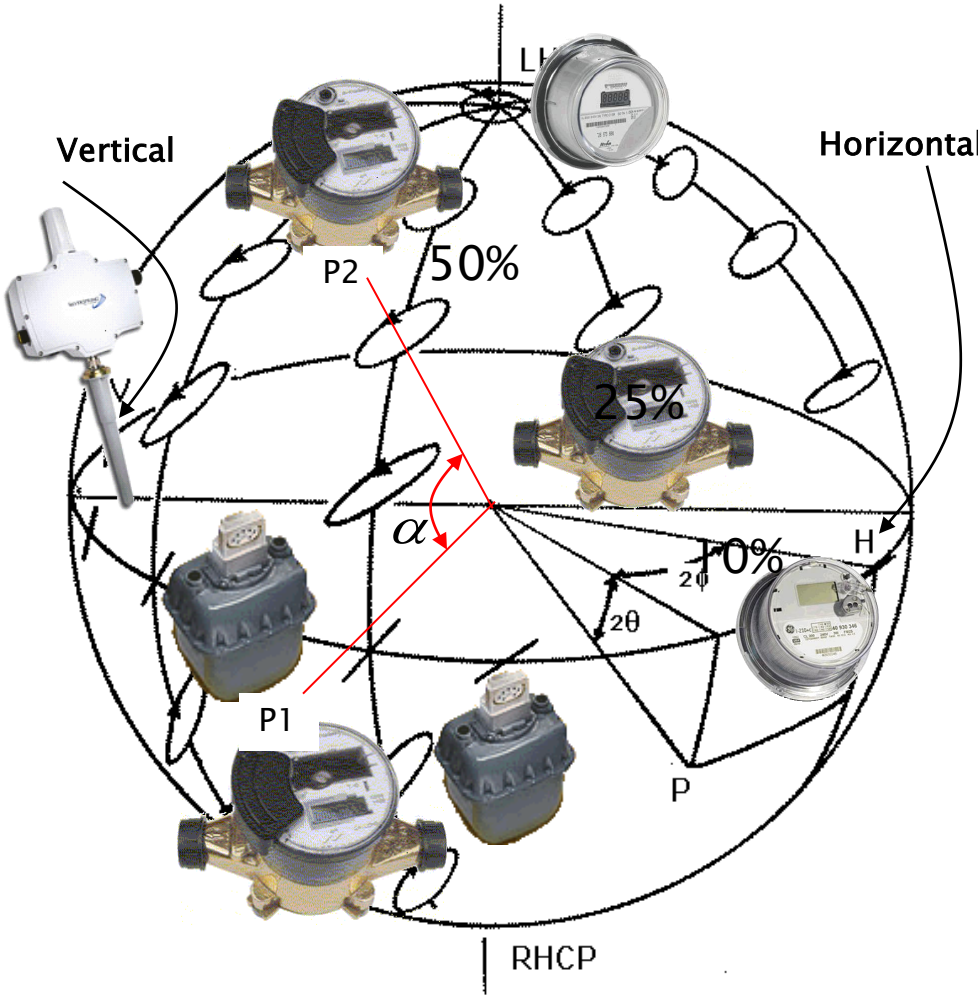
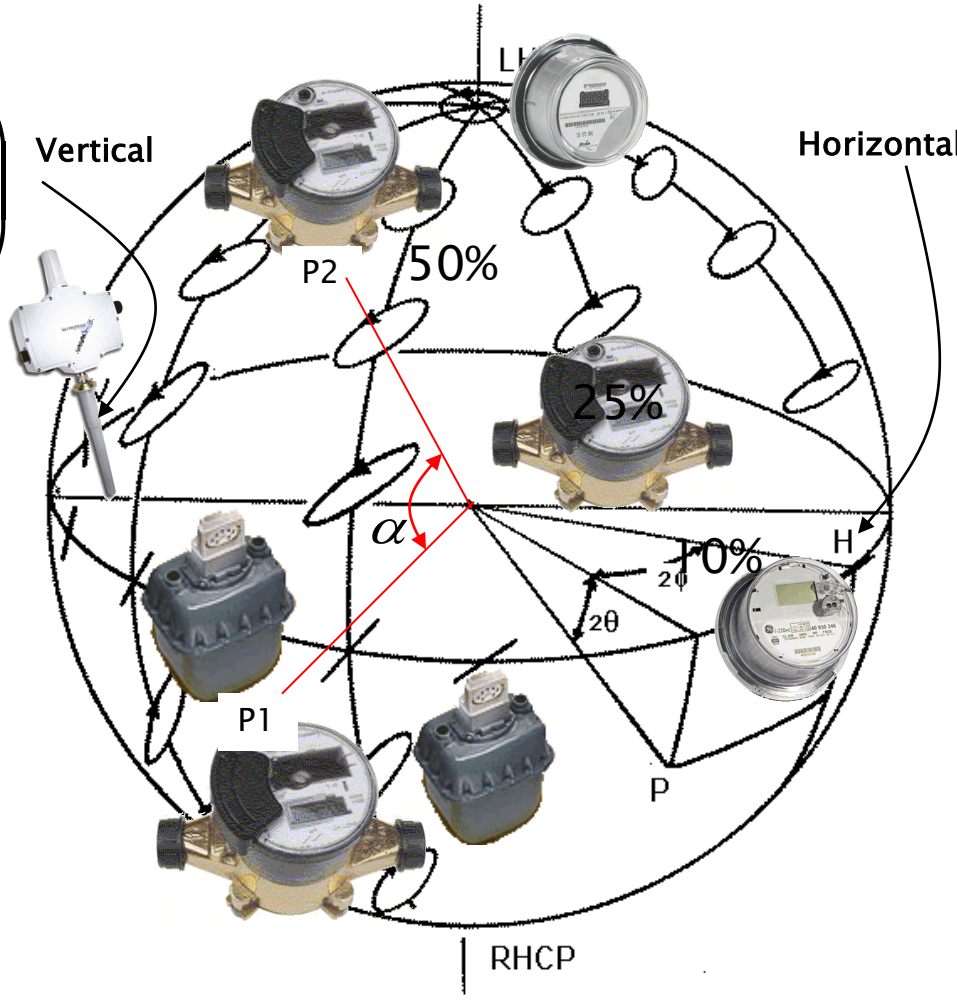


Scattering

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

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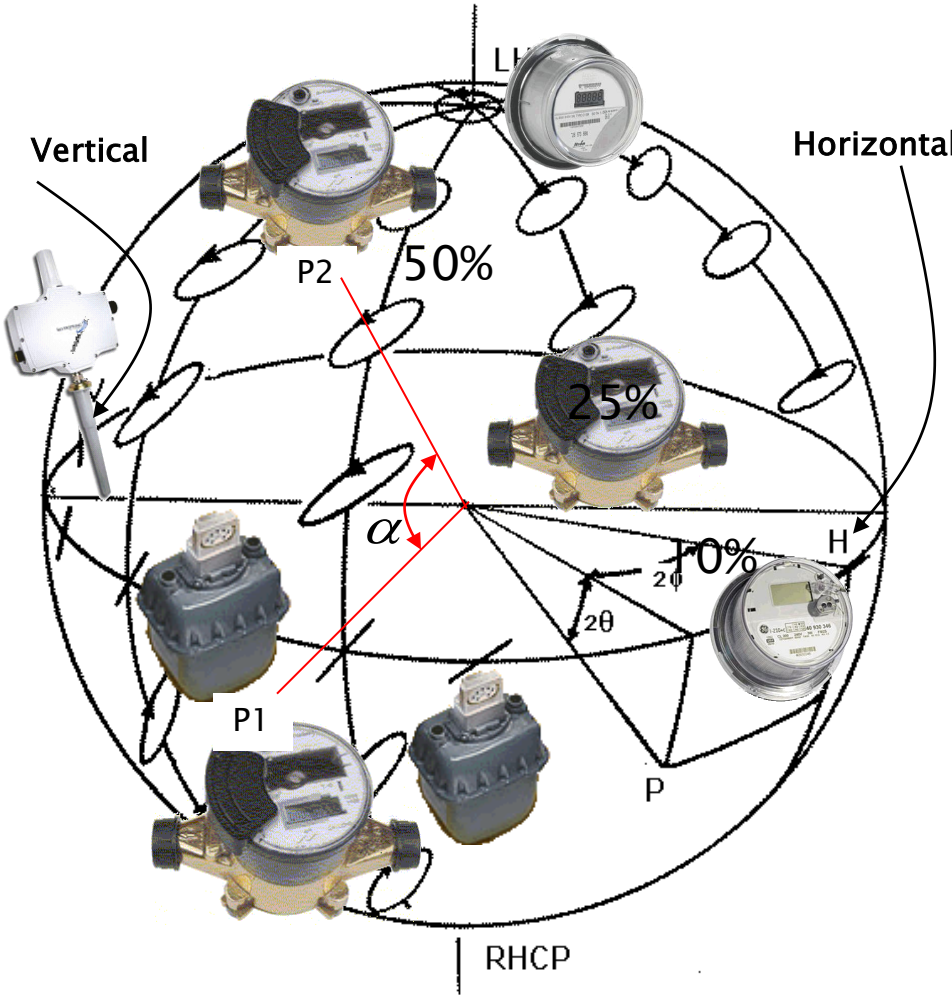
Angle α	% Population	Min CPL dB
90	50	-3
120	25	-6
143	10	-10
154	5	-13
168.5	1	-20
172	0.5	-23
174.3	0.25	-26
176	0.125	-29
180	0	-infinity



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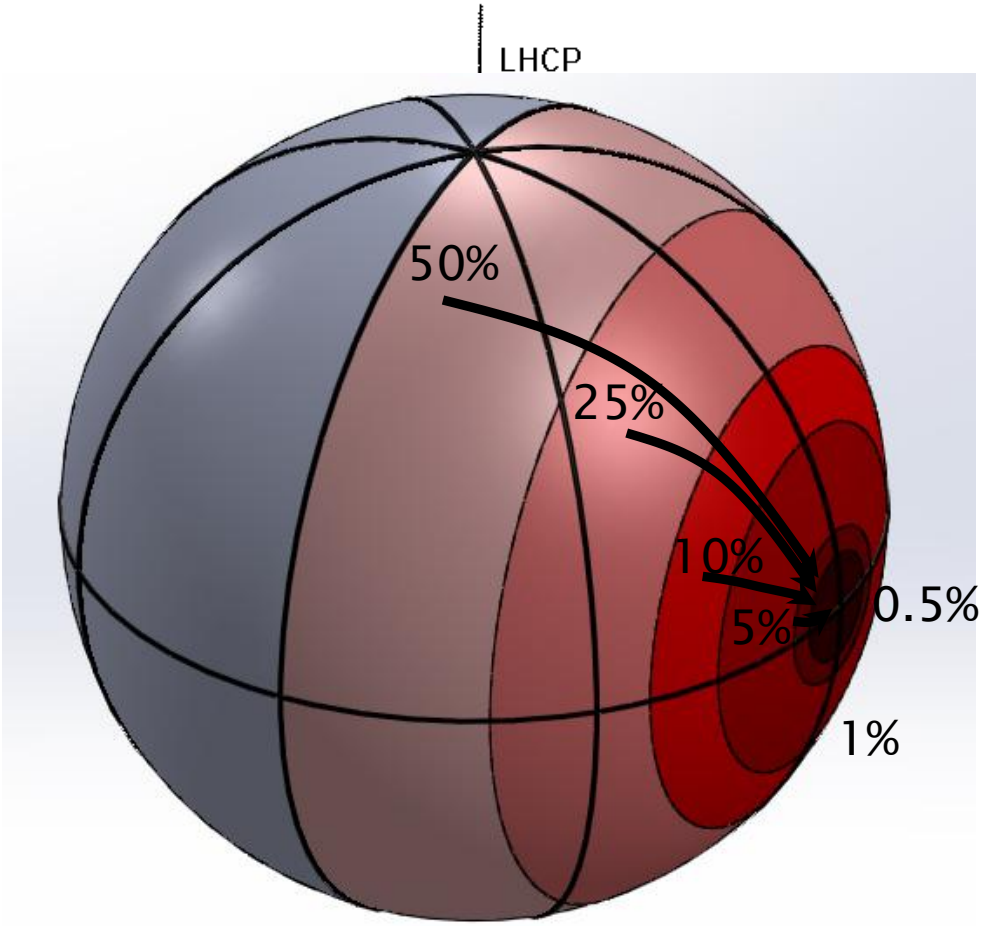
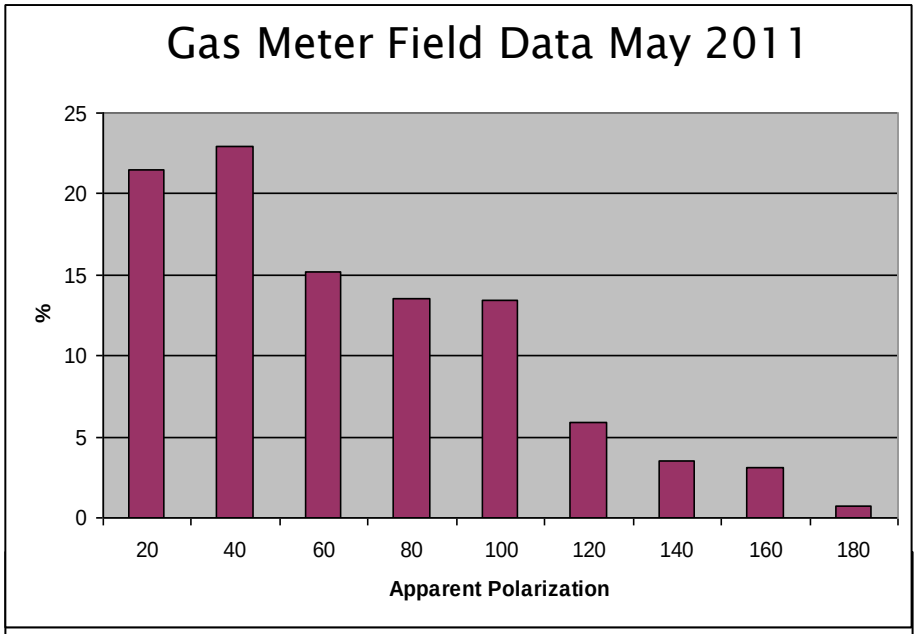
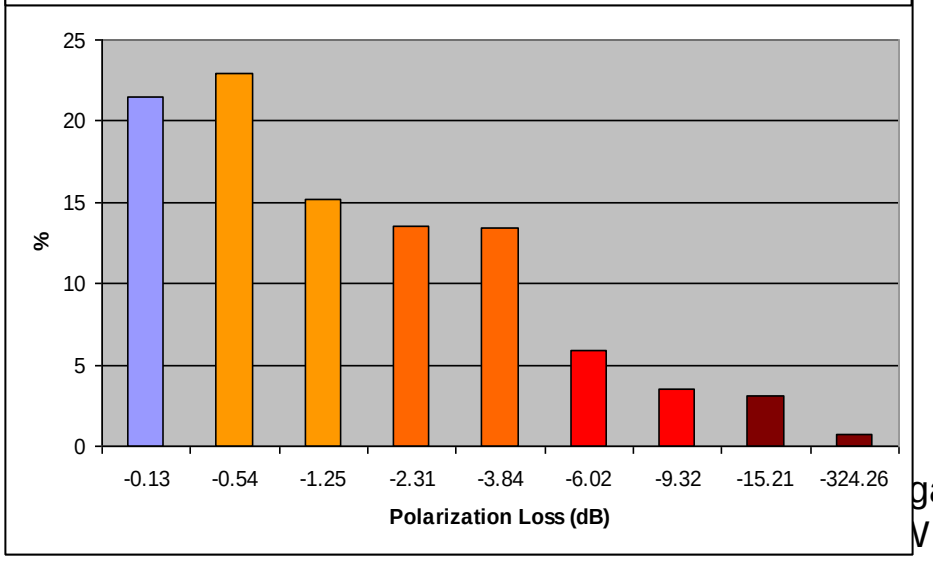
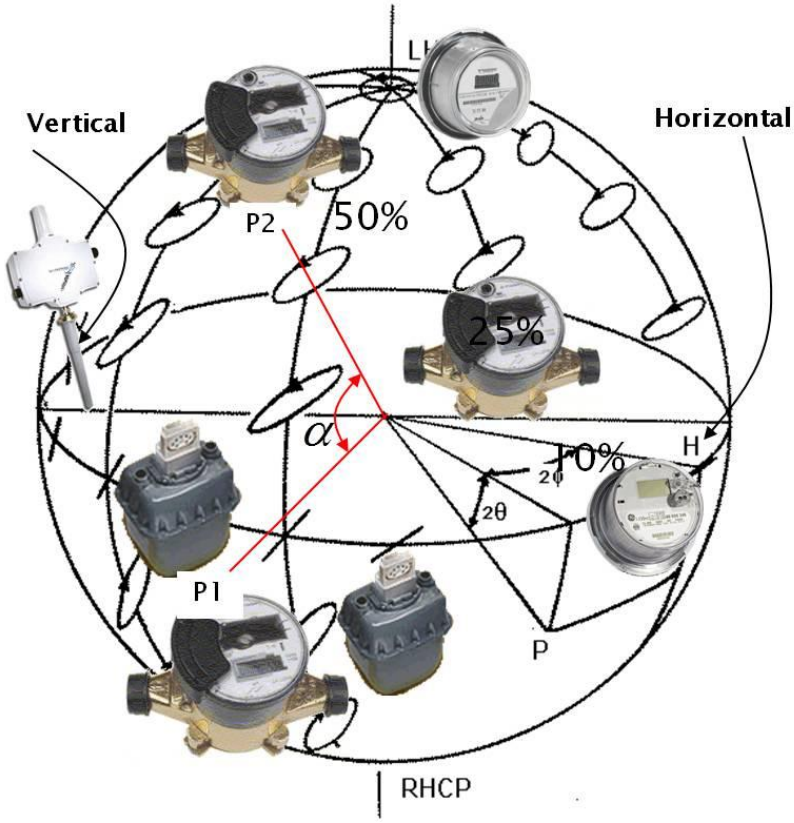


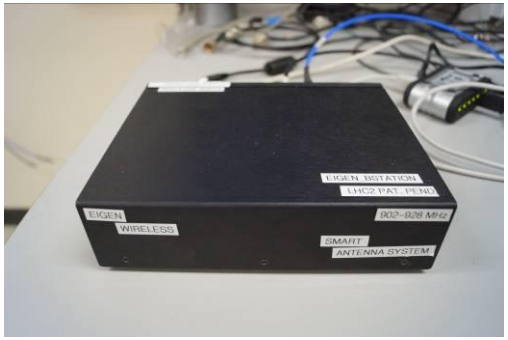
Scattering


Gas Meter Field Data May 2011
%
25
20
15
10
5
0
20
40
60
80
100
120
140
160
180
Apparent Polarization

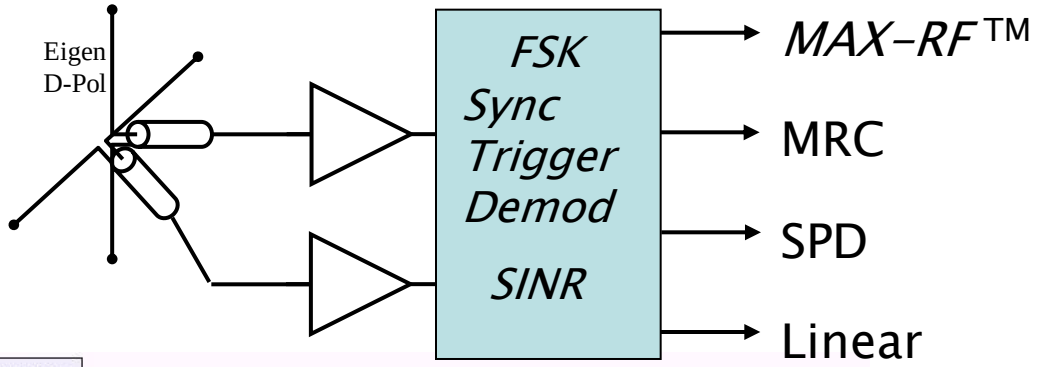

%
25
20
15
10
5
0
-0.13
-0.54
-1.25
-2.31
-3.84
-6.02
-9.32
-15.21
-324.26
Polarization Loss (dB)

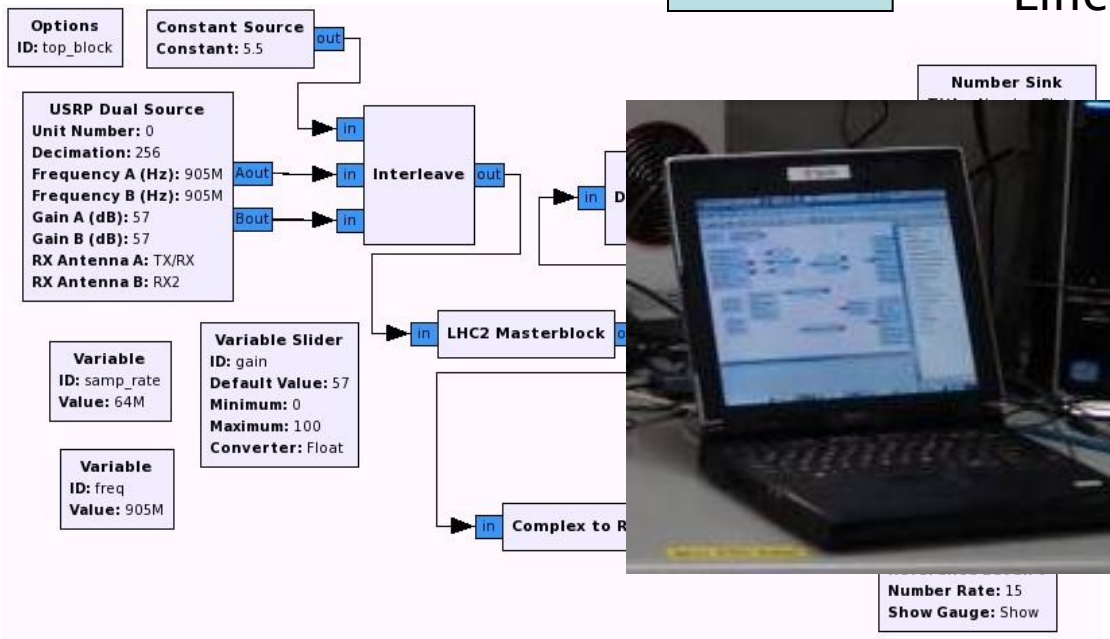

Vertical
Horizontal
P2
50%
25%
α
P1
P
RHCP
2θ

SDR Architecture

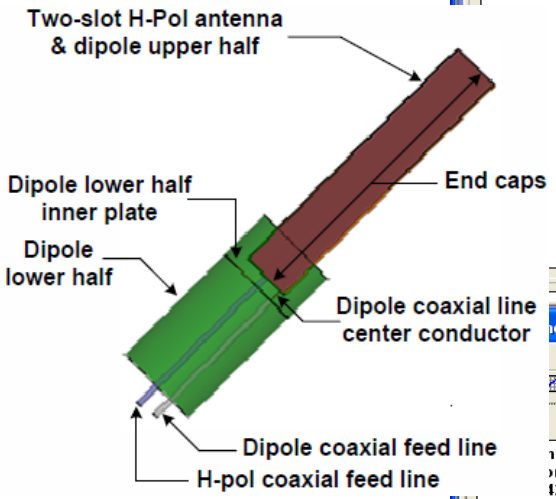


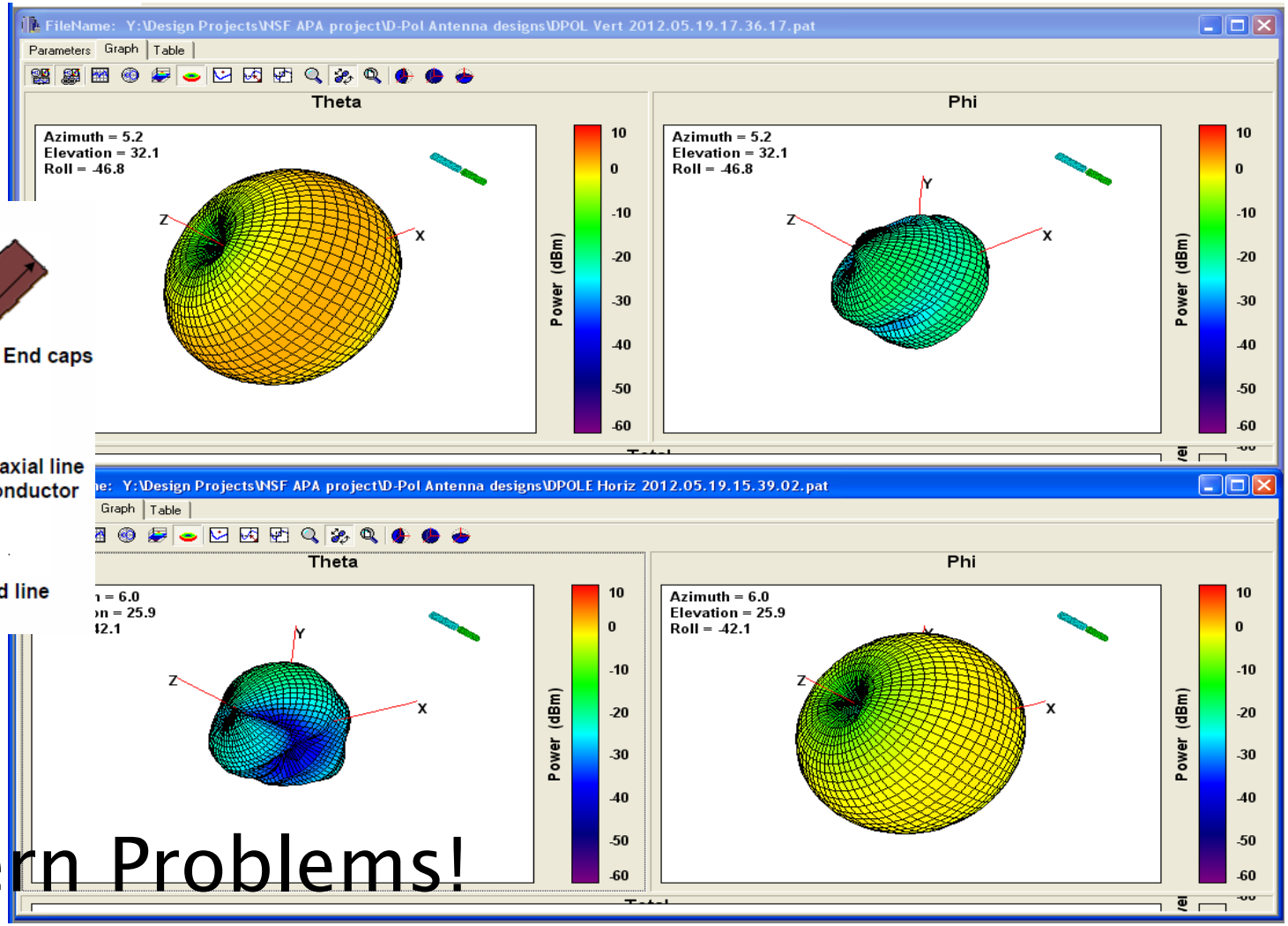
MAX-RF™ Antenna & USRP Receiver





Antennas

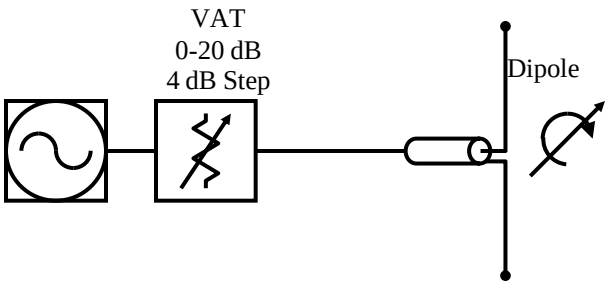




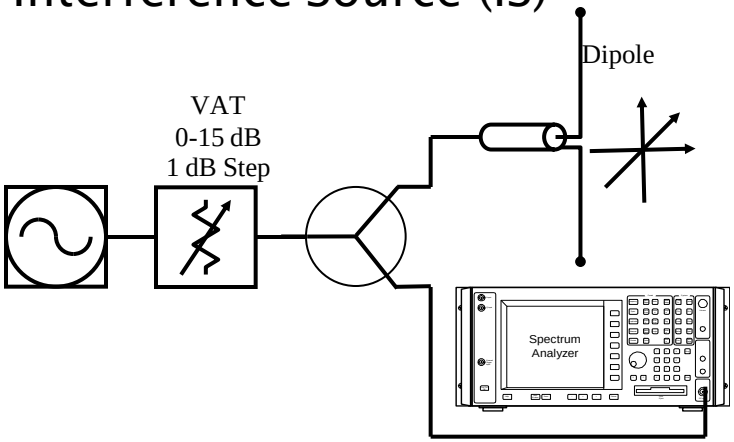
No pattern Problems!

Lab/Field Setup

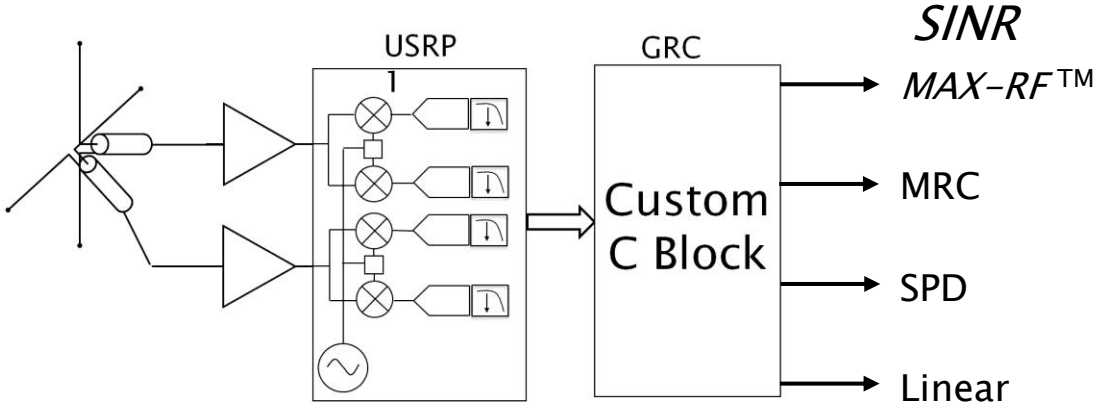
Signal of Interest (SOI)



Interference Source (IS)



MAX-RF™ Antenna & Receiver

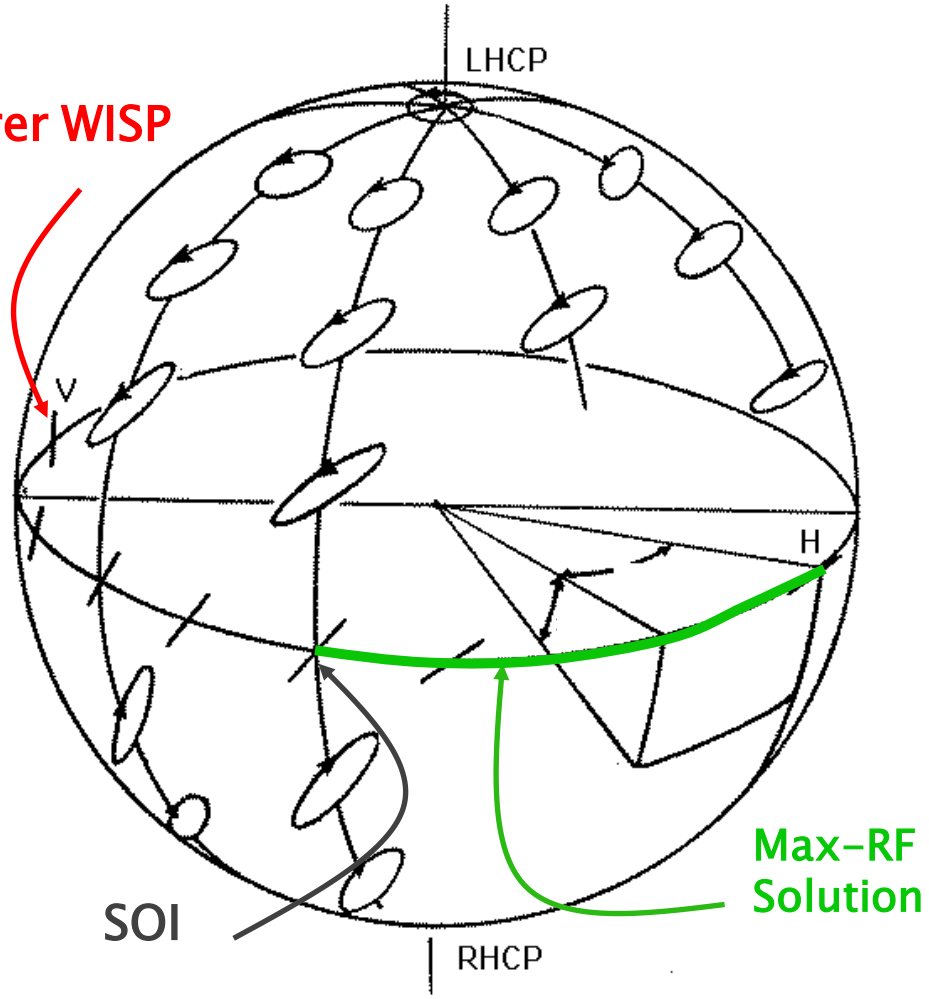


APA Rx Algorithms

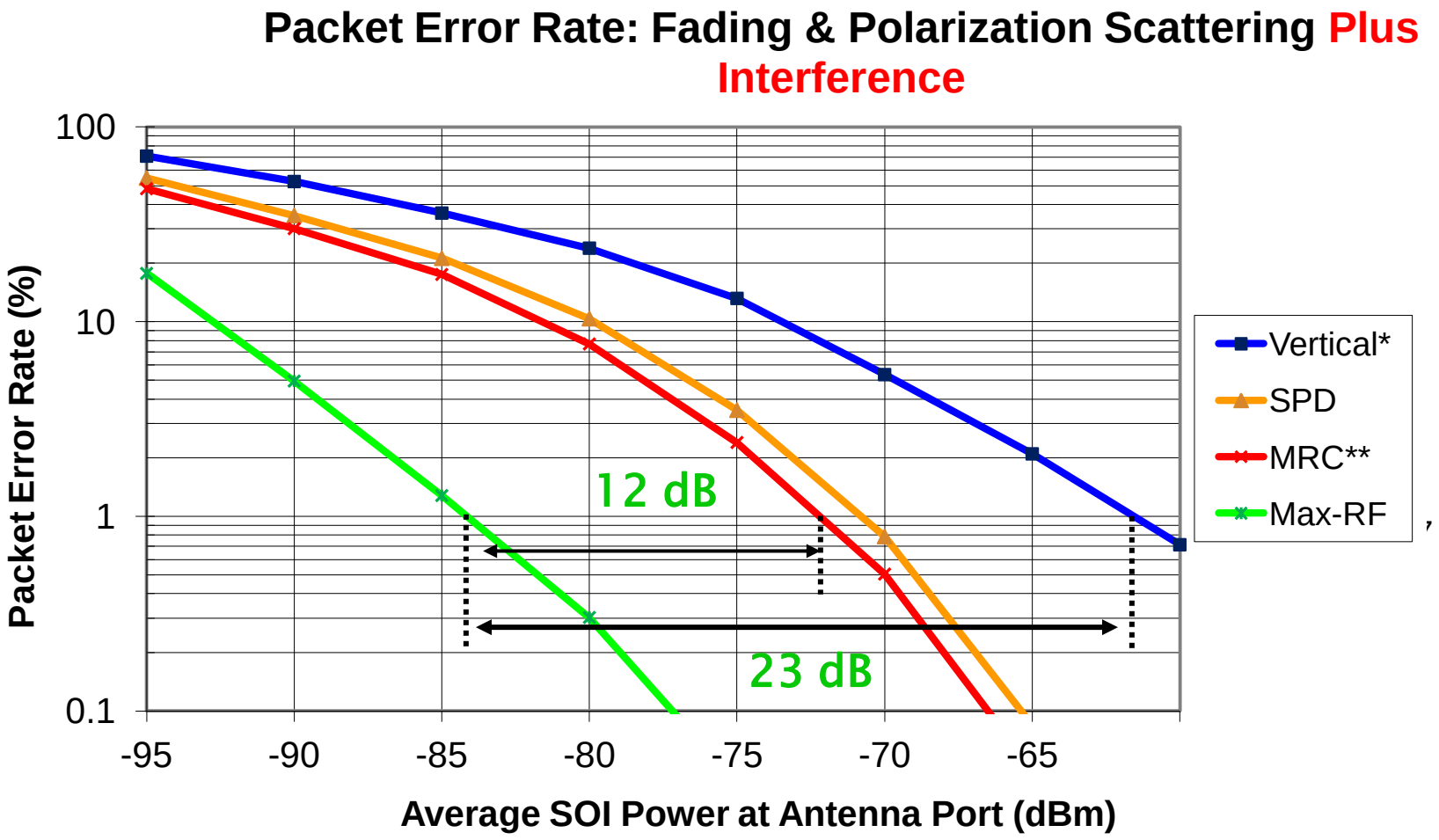
- APA algorithms (MMSE, Zero Forcing, Kalman Filter, etc.) assume benefit of:
  - Coherent detection, carrier recovery (e.g. PSK, QAM)
  - Channel coding, Pilot tones etc.
- Our method (*Max-RF*^{TM})
  - Carrier Recovery not required
  - Backward compatible for P-25, TETRA, others

Optimal SINR

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



Performance Results



Novel APA_{RX}

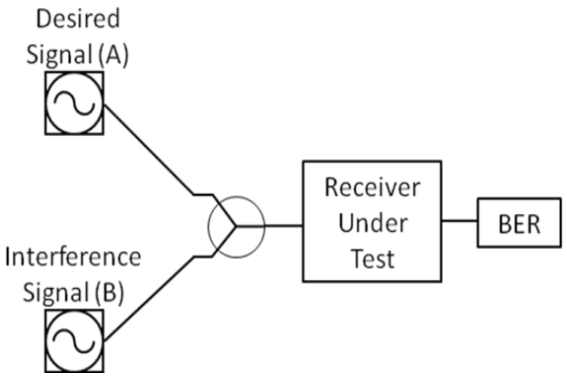
- SINR estimator
  - Not well behaved, not monotonic over polarization domain, local maxima
- SINR proxy was developed
  - Well behaved, monotonic over polarization domain, single global maximum
  - Exact Proxy: Optimal polarization state determined by the SINR proxy is exactly the optimal polarization state for SINR estimator

APA_{Rx} Benefits

- Closed-form per-packet optimal solution
- No carrier recovery
  - Obvious application to non-coherent systems
  - Deep negative SINR synchronization, triggering (-5 or -20dB), followed by carrier recovery and demodulation for coherent systems
  - Improves receiver IP2, IP3 and reciprocal mixing

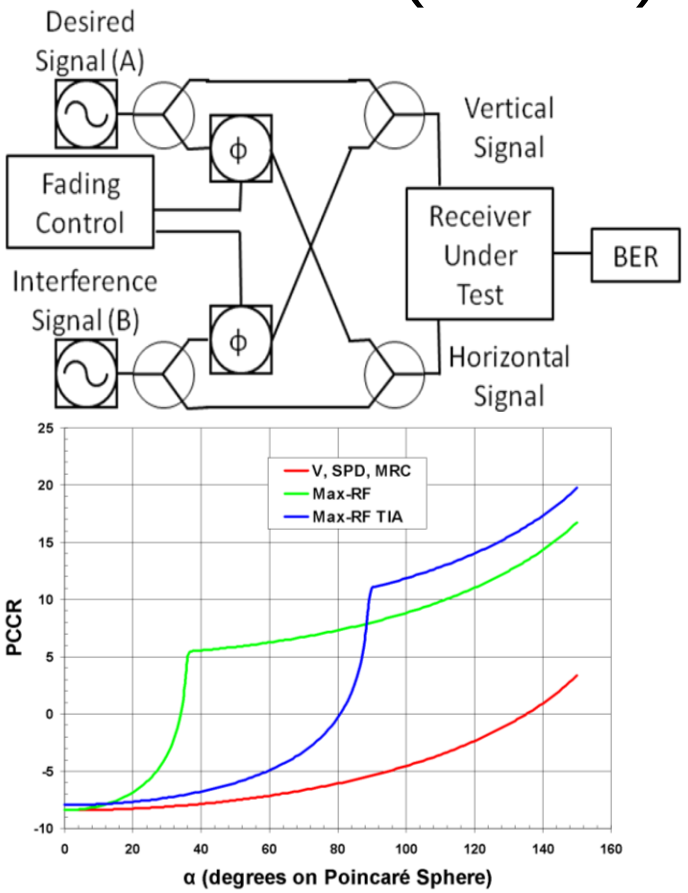
Test Challenges

- Co-Channel Rejection (CCR)



- TIA-102 P-25
  9dB

- Polar CCR (PCCR)



Summary

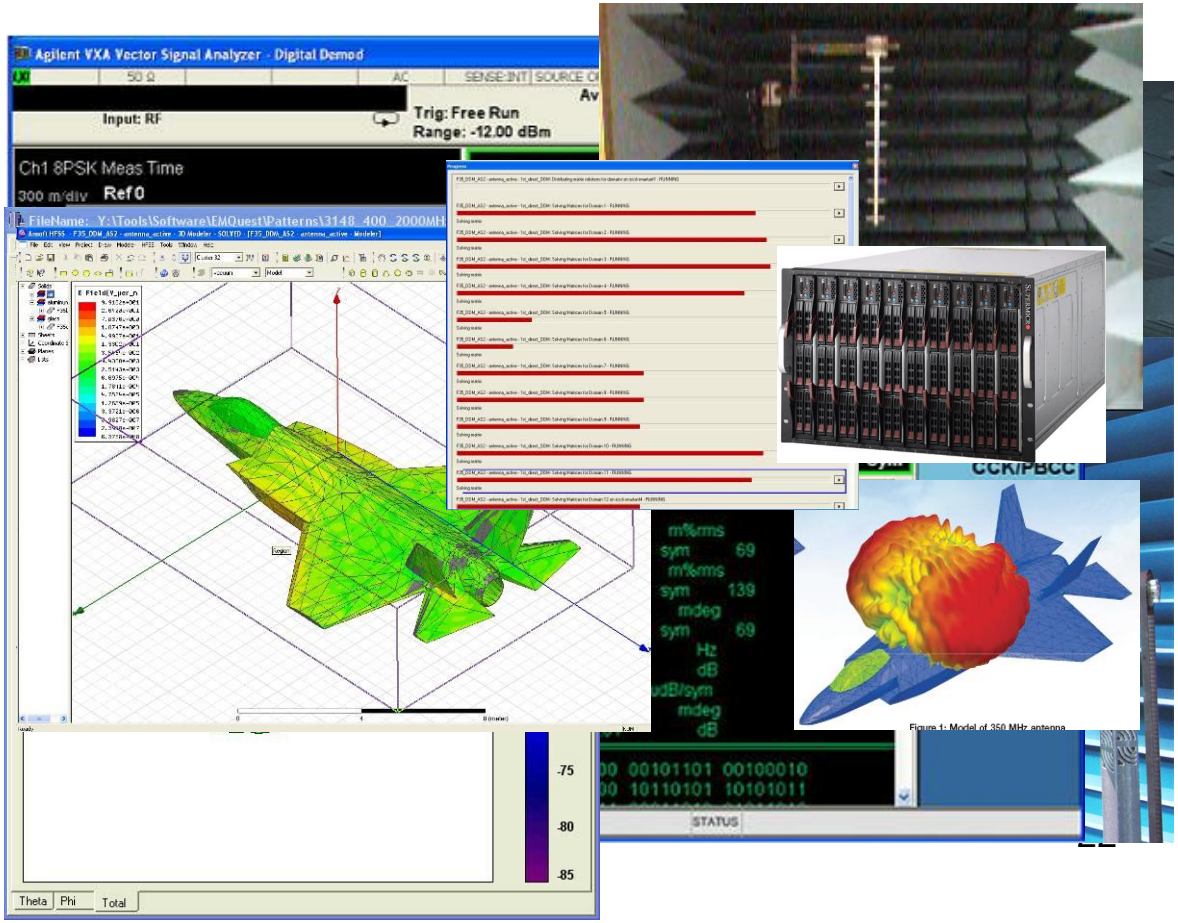
- 4 of WINNF Top 10 addressed
- Eliminates PDL and suppresses interference
  - 99.9% coverage can only be achieved through APA (1% of population 20dB link loss)
  - No Carrier Recovery: Negative SINR non-coherent and coherent system Sync and Trigger
  - Future proof for growing interference
- Lower Tx and Rx filter costs
- Product differentiation
  - Standards independent and backward compatible

GU Smart Antenna & Radio Lab (SARL)

Eigen Wireless

Mission: Create jobs through industry/university cooperative technology research and product development.

- 2 shielded anechoic chambers, automated 3D radiation pattern capture
- 40 GHz VNA w/ time domain, 40 GHz 80 MHz BW VSA.
- Software Defined Radios
- 3D Electromagnetic Simulation (HFSS) w/ cluster computing



Thank You. Questions?

- **Demonstration Today:**

  Workshop 5B

  "Real World Implementations"

  (Door 60 small auditorium)

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  – Dr. Steven Schennum
    - schennum@gonzaga.edu

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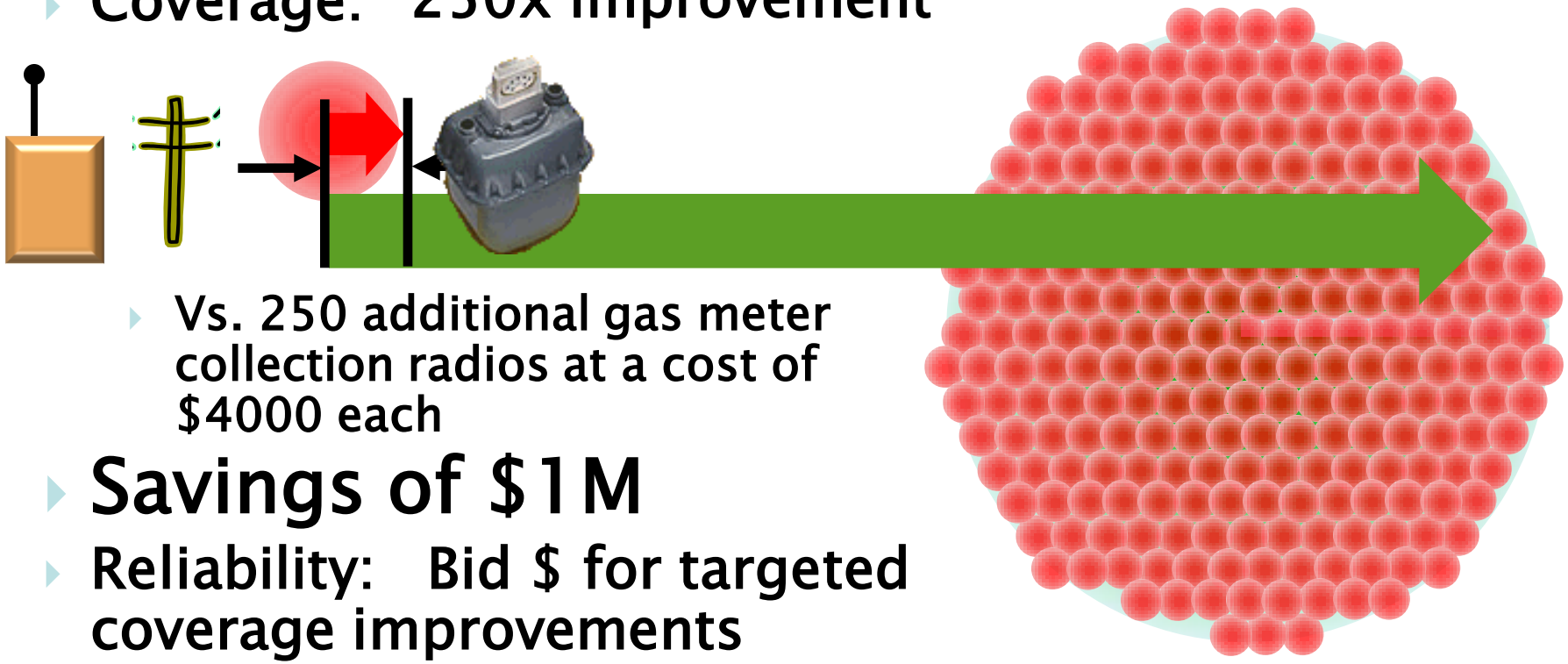
Backup Slides

23dB Improvement

Deliver breakthrough performance for Public Safety and Smart Utility Wireless Networking systems.

- 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