SFU ENGAGING THE WORLD

Software-Based Design and Evaluation of Multiple Antenna Systems

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WIRELESS WORLD RESEARCH FORUM

Outline

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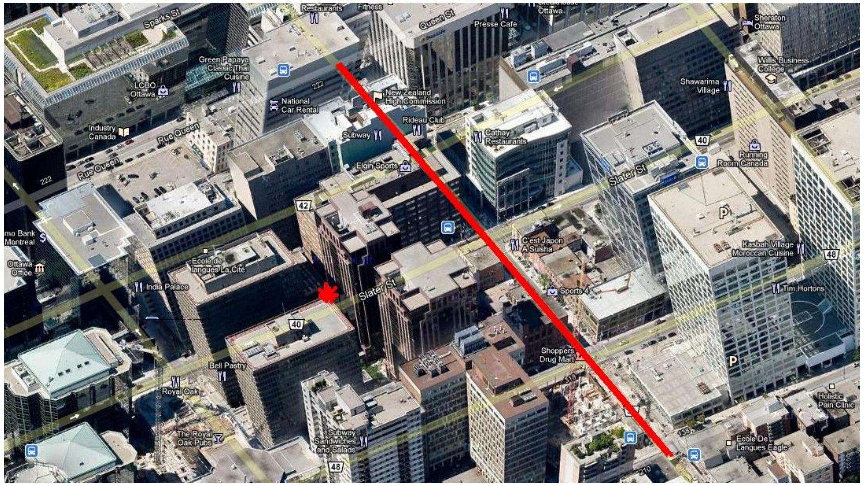
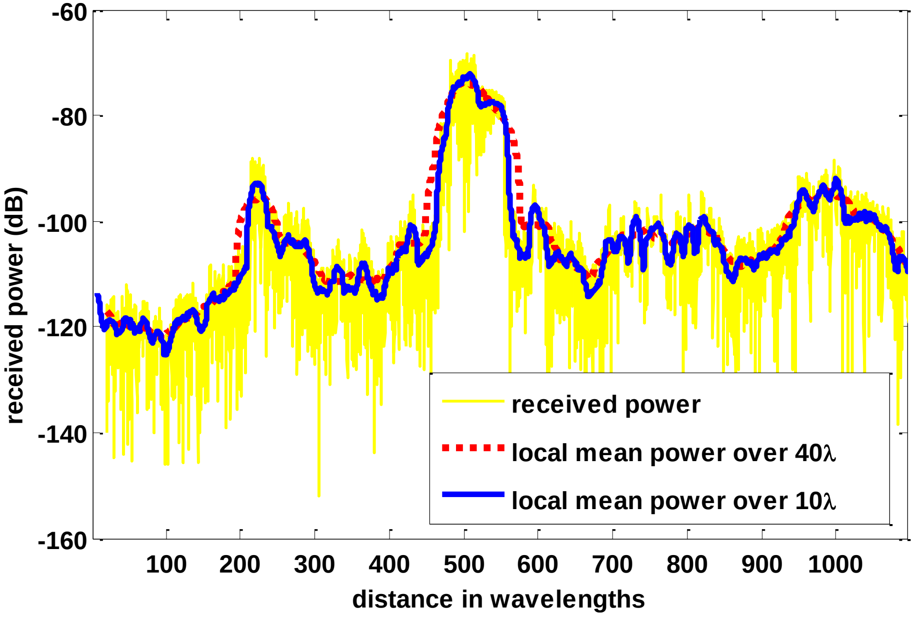




Driver: Demand for Spectrum

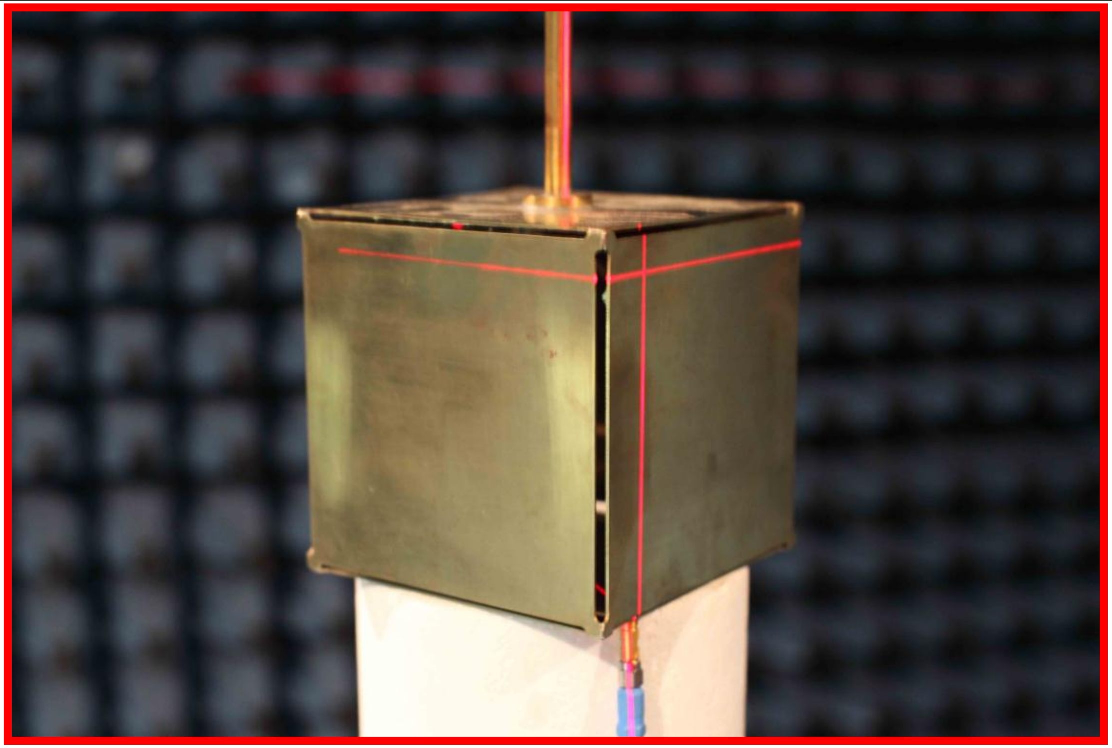
Larger traffic

Greater number of users

- Smaller cells
- MIMO: offers the most potential
- Challenging research for MIMO:
  - designing for large scale
  - developing the antennas and their deployment
  - developing the communications technologies

Research Needed Now!

- Antenna Evaluation
- Compactness
- Spatial efficiency
- Radiation efficiency
- Embedded patterns
- Communications limits



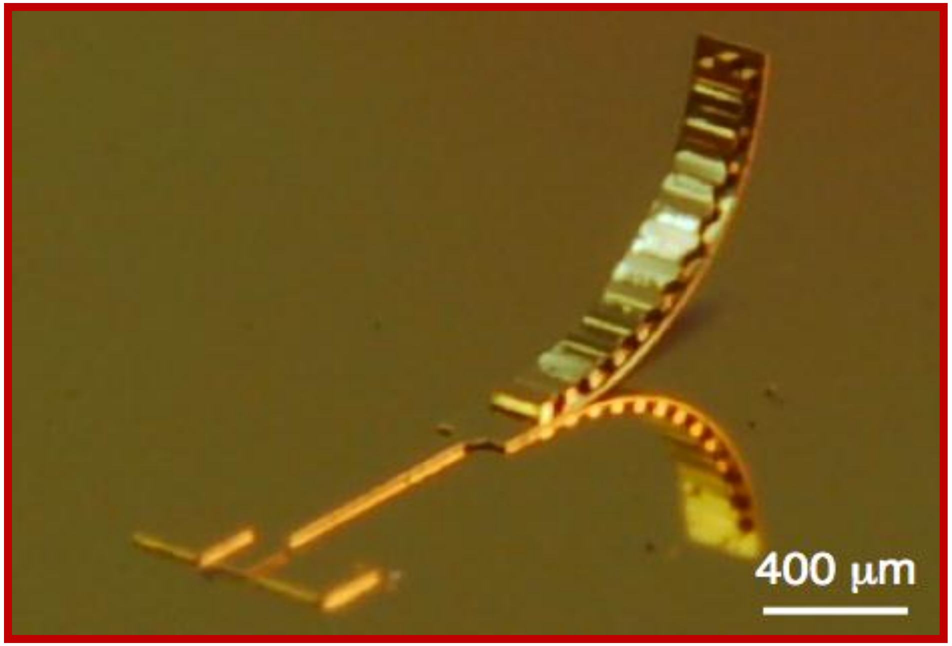
Compact 12-port MIMO antenna
Designed, simulated,
software performance-evaluated,
built and physically measured
at the Sierra Wireless lab
at SFU

Motivation for More Compact, Big-MIMO

- Design of MIMO antennas at higher frequencies
- Propagation environment is critical
- Physical antenna configuration
- MIMO antenna efficiency
  - Cost of the network
  - Efficiency of the network

- Channel knowledge
- Adaptation of weights
- Communications design

60 GHz high efficiency
CMOS-compatible, on-chip antenna
[Microelectronic s lab, SFU]

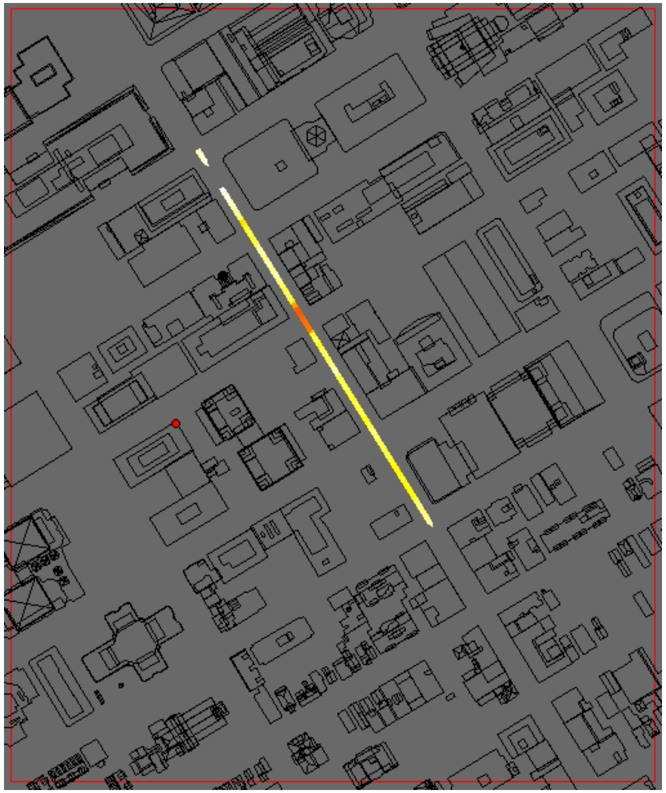


Contributions

Direction forward for

- Evaluation
- Planning

Large scale MIMO



Computer simulation

MIMO antenna parameters

Geographical/in-building data bases

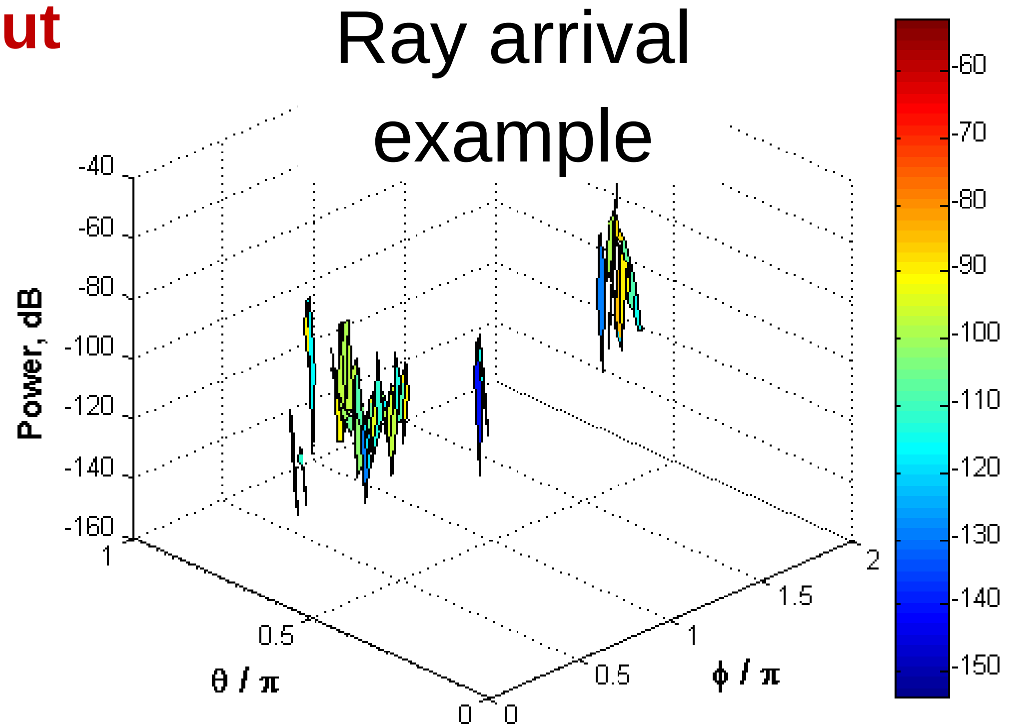
Problem Definition

Digital Communications

- Goal: **high throughput**

Single Antenna:

- **Fluctuations tens to hundreds of dB**



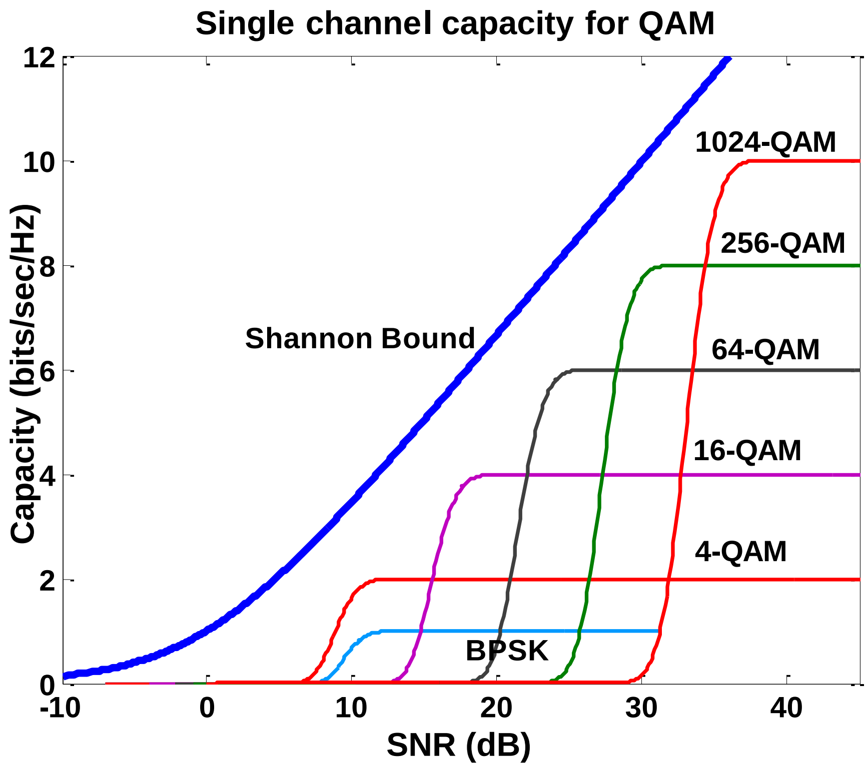
Single Modulation?

- Cannot provide spectral efficiency

Problem Definition

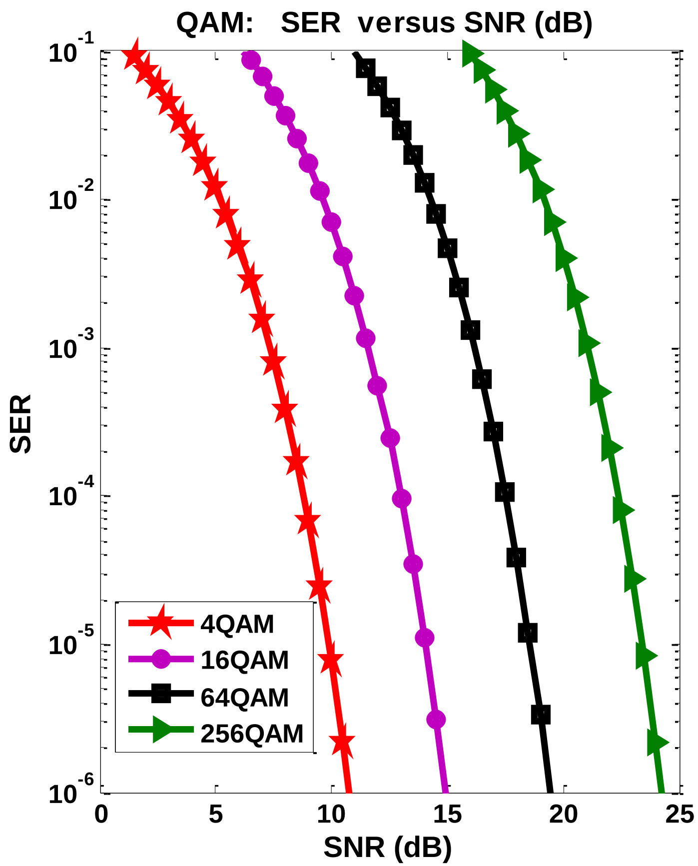
Metrics for digital communications

Information-theoretic capacity



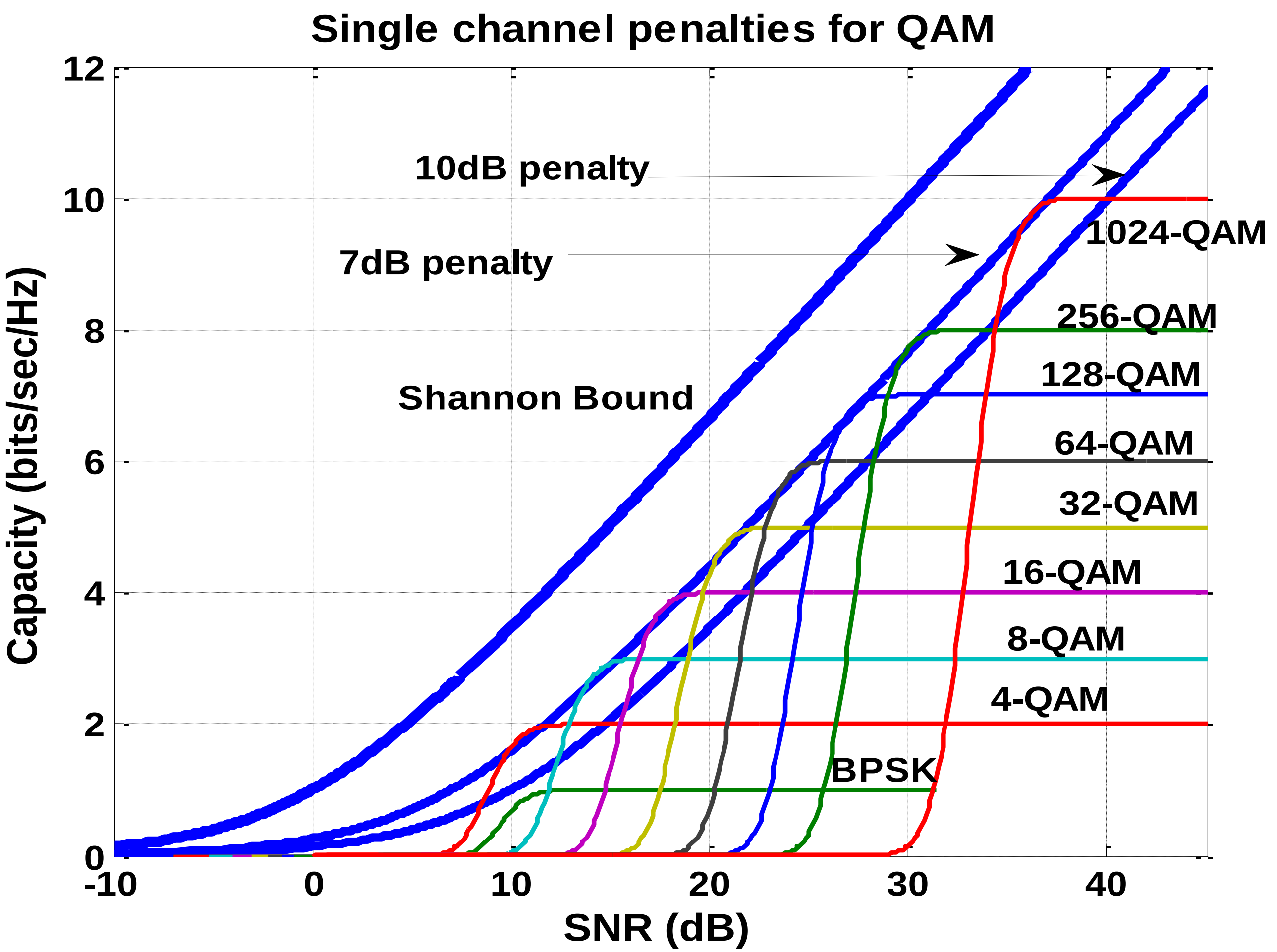
Practicable capacities?

Error rates



Problem Definition

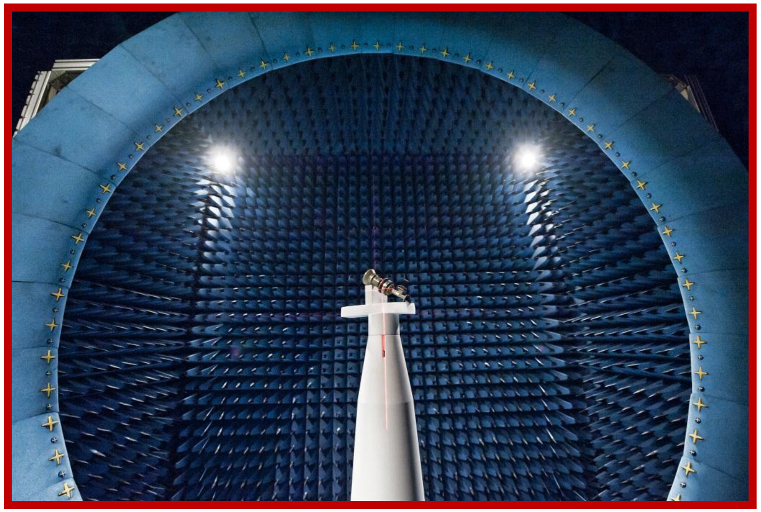
The Analogue Path to Digital Communications

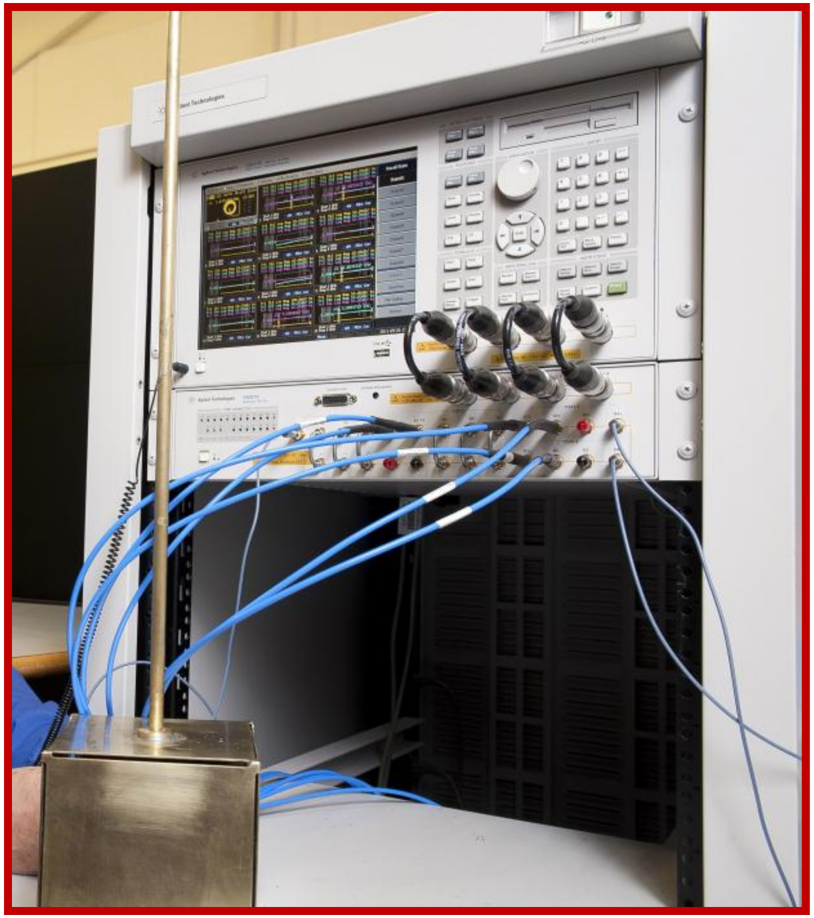


Getting closer to the Shannon Bound: adaptive modulation and coding

Channel Evaluation Techniques

- Physical Measurement





- Statistical Modeling
- Physical Modeling

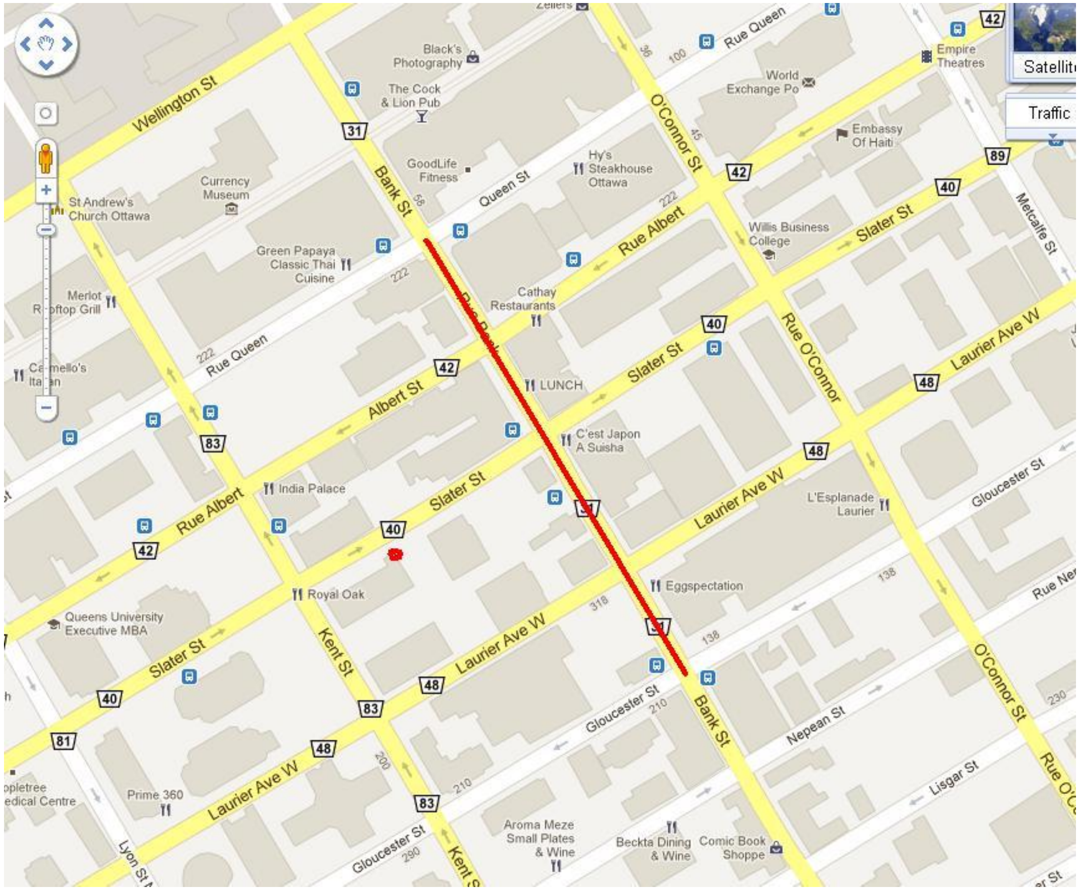
Channel Modeling: Ray-Tracing

- Providing a quasi-realistic channel
- Different ray-tracers, different calculations and criteria

	A	B	C	D	E	G	H
1	Delay (mus)	Azimuth-of-De	Elevation-of-De	Azimuth-of-A	Elevation-of-A	Amplitude (dB)	Phase (deg)
2	0.945	-20	-14.6	-114.5	14.6	-118.2	115.6
3	0.881	18.1	-3	134.8	49	-130.7	-91.7
4	0.957	-20	-14.4	-139.7	14.4	-121.3	133.7
5	0.987	-20	-14	-91.8	14	-127.8	4.2
6	1.157	38.9	-11.9	154.6	11.9	-128.2	55.8
7	1.057	-17.1	-13	-129.2	13	-138.3	91.1
8	1.176	38.9	-11.7	126.1	11.7	-132	-15.1
9	0.898	19	-3	177.6	43.8	-135.1	85.8
10	1.616	49.6	-8.5	152.4	8.5	-132.9	83.9

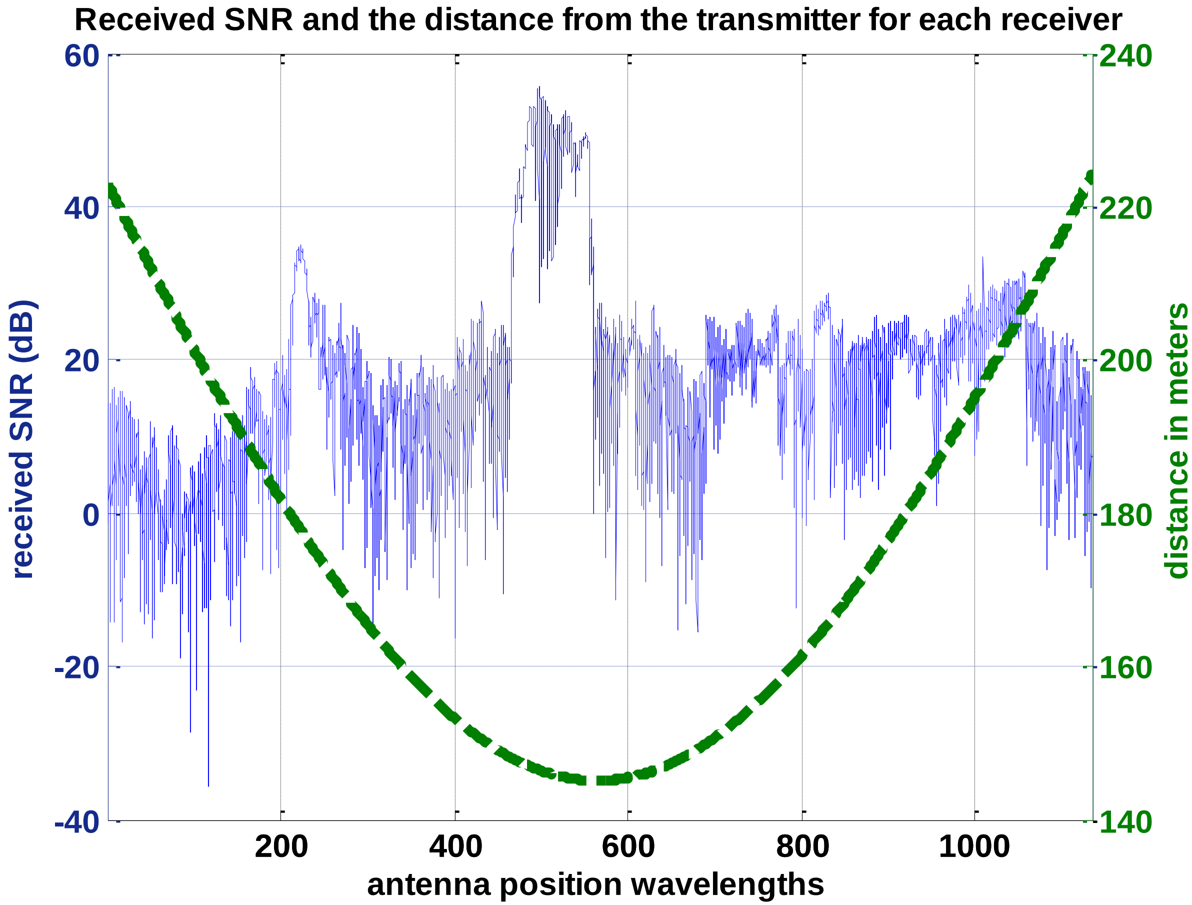
Sample of ray-traced file,
i.e., a file of incident signals at the receiver point

Example: Scenario



Receiver trajectory and transmitter location using Google maps

Summed Field Strength



- The SNR is much higher for the line-of-sight part of the trajectory
- Frequency=1 GHz

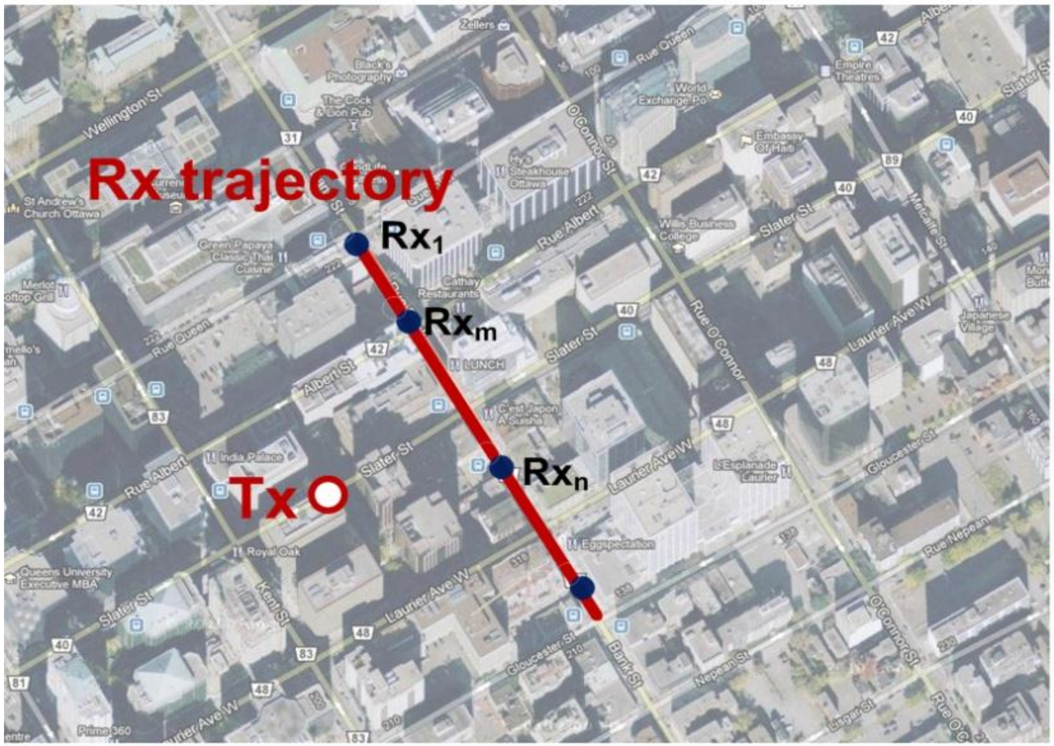
Diversity Analysis

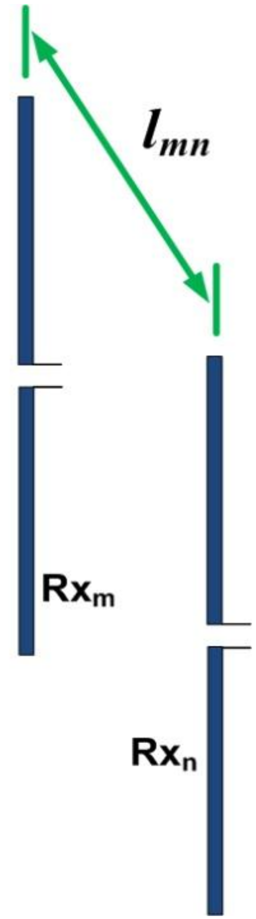
- Metric for diversity performance:
  diversity gain
- Two dipoles or monopoles mounted on the ground plane
- Spacing of antennas = $\boldsymbol{l}_{\mathbf{mn}}$

Diversity Gain:

- statistical improvement of SNR, from applying diversity

Diversity Analysis

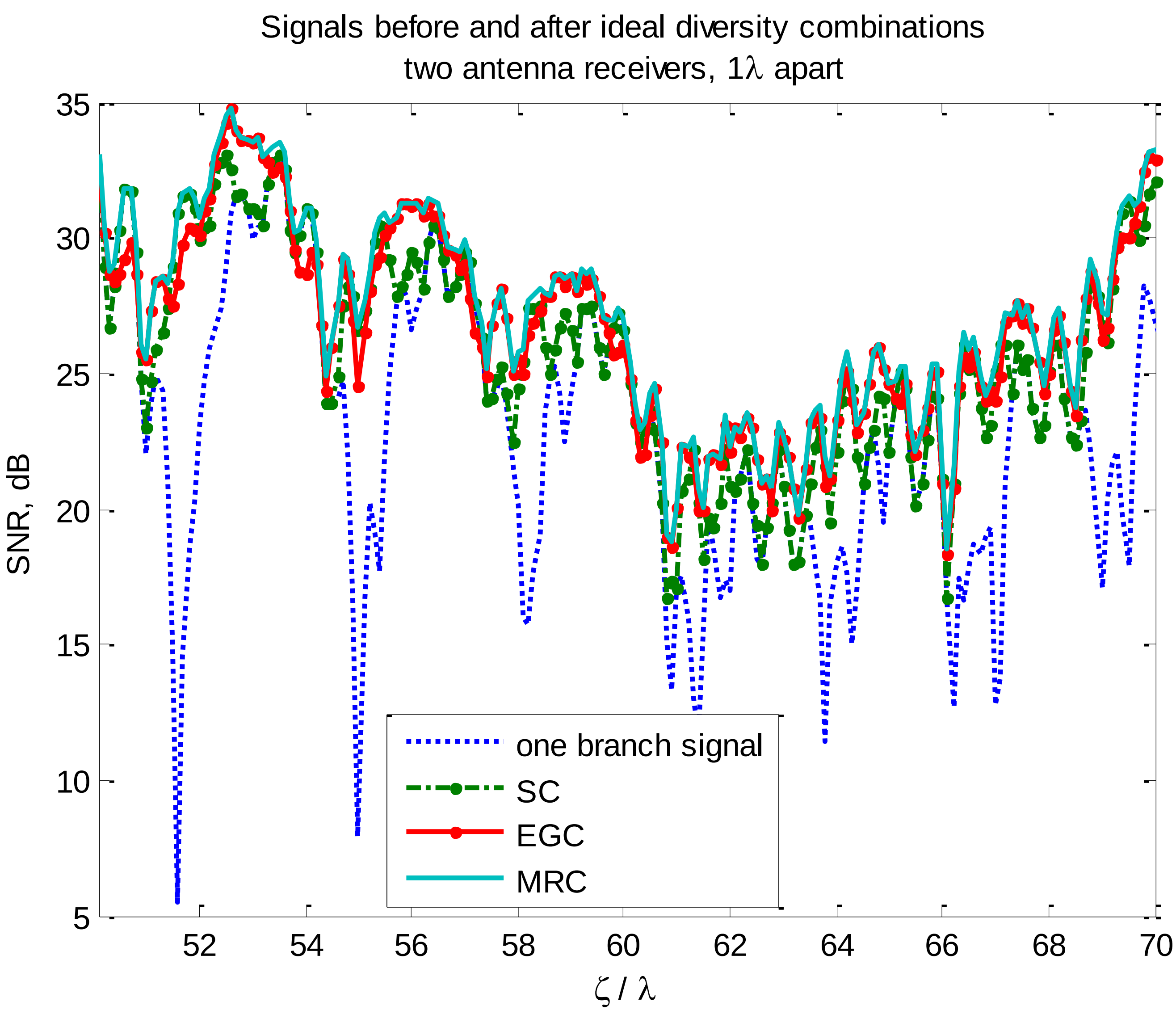




Benchmark combining techniques:

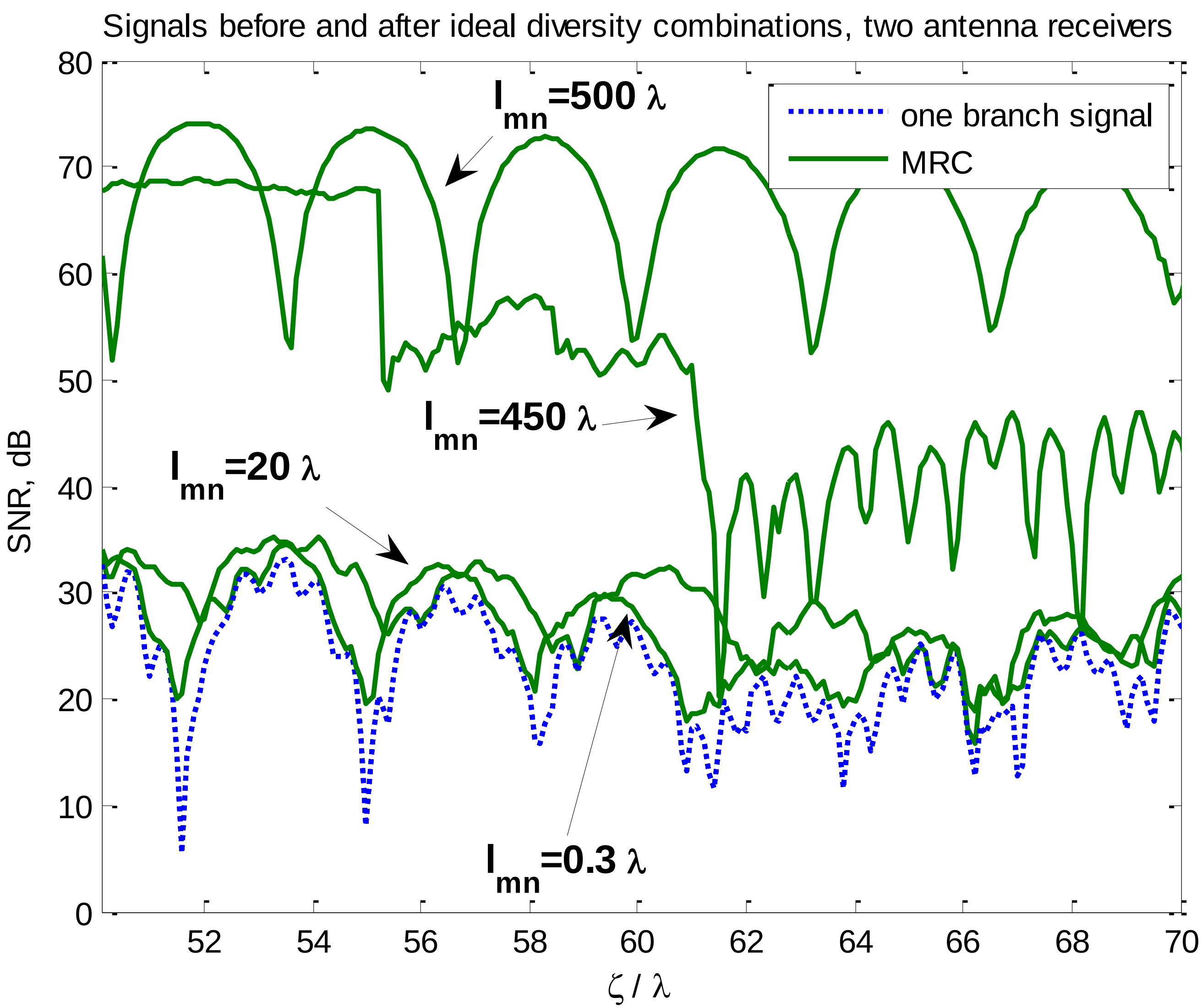
- Selection combining (SC)
- Equal gain combining (EGC)
- Maximum ratio combining (MRC)

Diversity Gain: Results



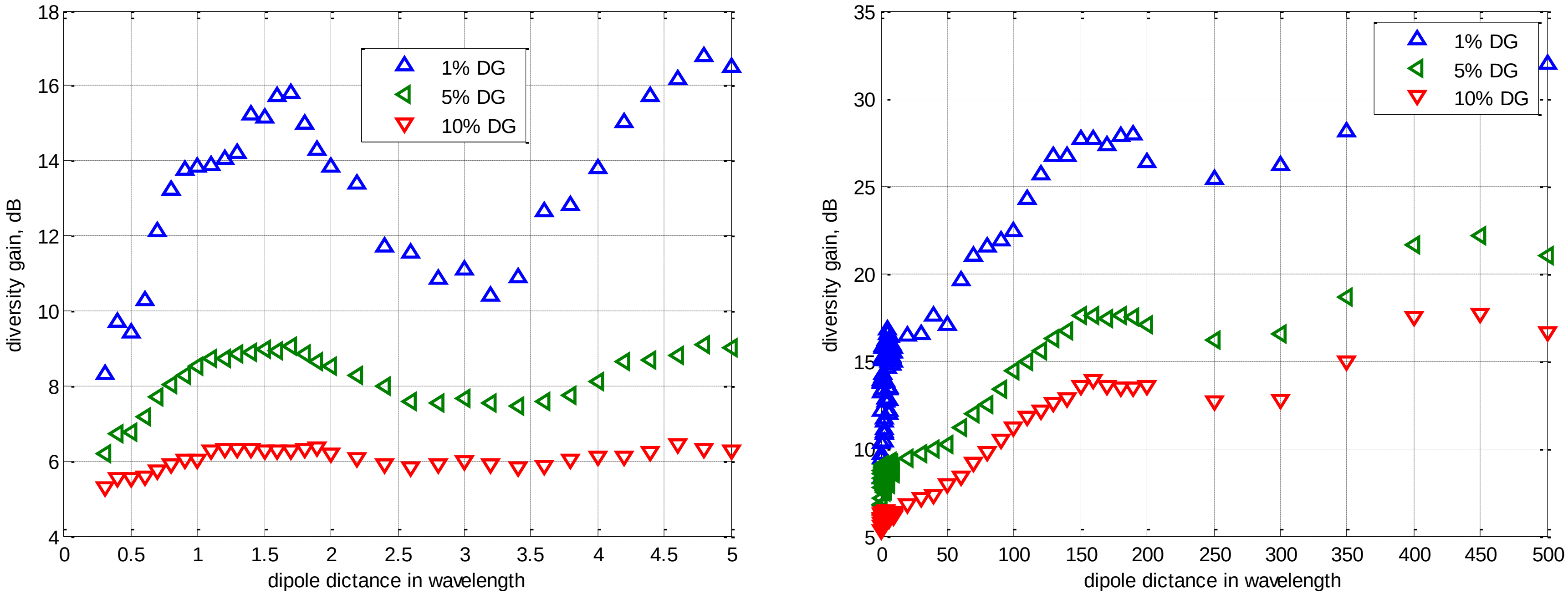
- Benchmark spacing
- l_{mn}= 1λ
- Optimum benchmark MRC

Diversity Gain: Results



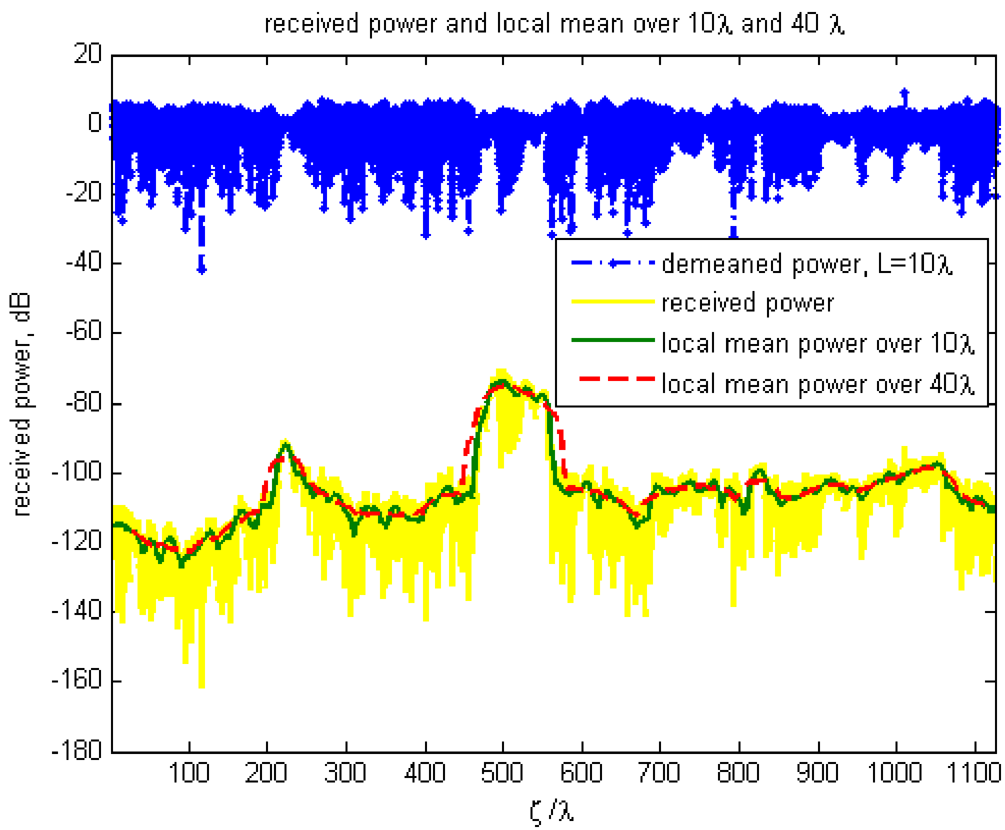
- Different spacings (l_{mn}).
- Even two branches provide tens of dB improvement for diversity gain

Diversity Gain: Results



- Variation of diversity gain for different probabilities
- Vary high diversity gain is achieved by only two antennas

Summary: Simple Example of Channel



signal type	10% DG	5% DG	1% DG
raw fading	6.36dB	8.78dB	15.78dB
fast fading	6.61dB	8.26dB	13.40dB

Summary

- There is no standard for MIMO (or any multiport) antenna evaluation.
- There are very few proposed methods to evaluate the performance of multiport antennas.
- Several metrics are widely used to describe digital communications performance, all indirect (not accurate for a practical situation).
- **Physical modeling can be applied to evaluate the antennas performance**
- No standard exists for ray-tracing codes.
- **Lots to do! - The directions forward and the required research is laid out in the written paper.**