Polarization Measurements and Antenna Orientation Optimization in Multipath Channels

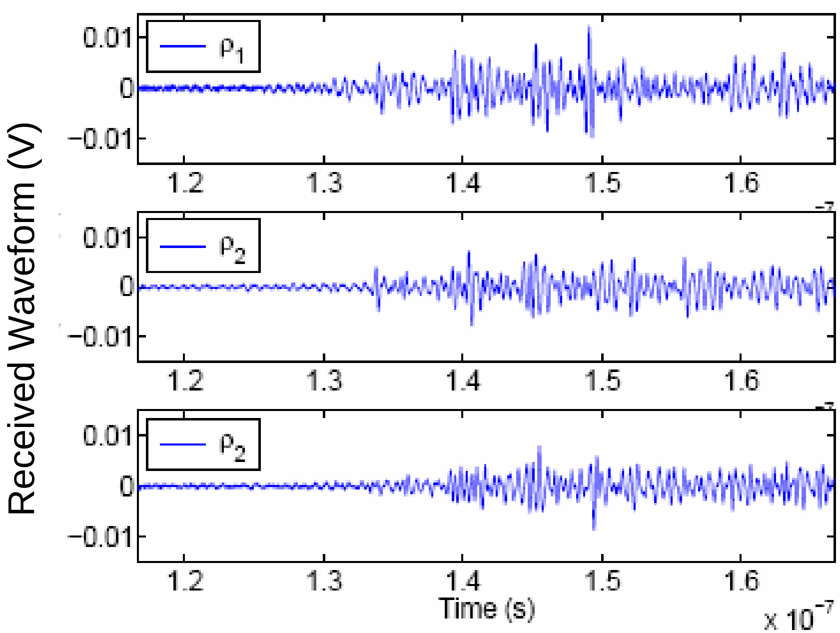
SangHyun Chang

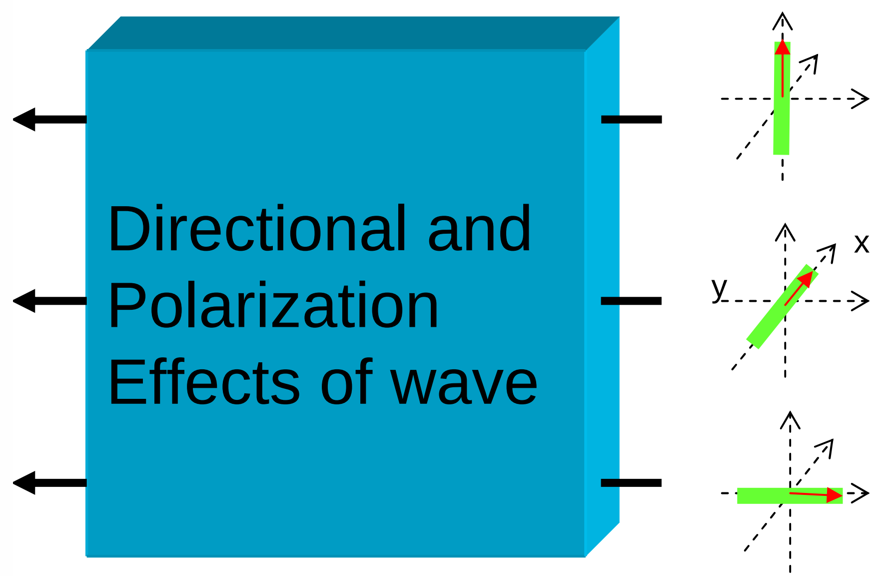
UltRa Lab
Communication Sciences Institute and Electrical Engineering-Systems
University of Southern California

Motivation

When a transmitted signal propagates,
especially with penetration and/or reflection by an object,
the transmitted signal polarization of each frequency component
may vary individually over a frequency band.

How to *characterize* wave-polarization
for non-narrowband signals?





Contribution of this Research

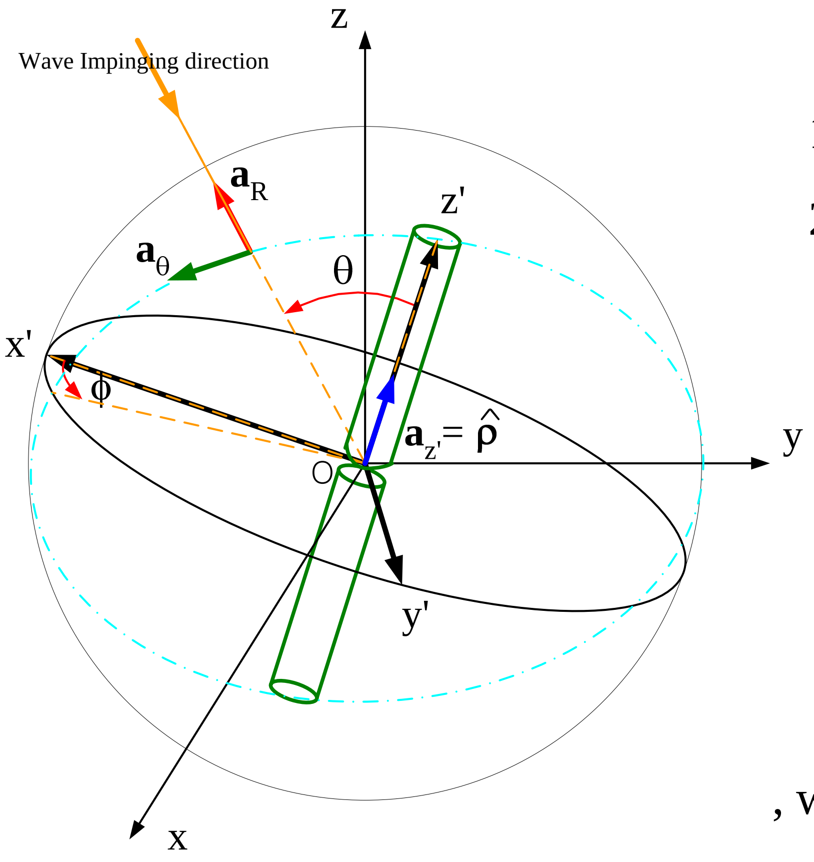
- What is the optimal antenna orientation?
  - <u>criteria</u>: Deterministic vs. Statistical,
    Maximum energy capture, Ranging accuracy, …

- Link Budget Calculations

- Polarization Diversity
  - QoS for the mobile comm. system user
  - MIMO

Multipath Channel Model

$$V_L(f) = \sum_n \left[\overline{\mathbf{E}}_n(f,\theta_n,\phi_n) \cdot \overline{\mathbf{h}}(f,\theta_n,\phi_n) \frac{Z_L(f)}{Z_L(f)+Z_R(f)} \right] + N(f)$$



1. Antenna matches with the load over all f.
2. Hertzian dipole antenna approximation:

$$\overline{\mathbf{h}}(f,\theta,\phi) \simeq -\mathbf{a}_\theta C_0 \sin\theta$$

$$\boxed{V_L(f) \simeq \left[\overline{\mathbf{E}}(f) \cdot C\hat{\rho} \right] + N(f)}$$

, where $C = \frac{Z_L}{Z_L+Z_R} C_0$, and $\overline{\mathbf{E}}(f) = \sum_n \overline{\mathbf{E}}_n(f)$.

Processing on Measured Data

Three orthogonal antenna orientation measurements:

$$v_k(t) = s_k(t) + n_k(t) = [\mathbf{e}(t) \cdot C\hat{\rho}_k] + n_k(t) \qquad k = 1, 2, \text{ or } 3$$

$$\mathbf{v} = \mathbf{s} + \mathbf{n} = C\mathbf{R}^T\mathbf{e} + \mathbf{n}$$ (Equivalent vector representation)

<u>Electric-Field Estimate</u>

$$\widetilde{\mathbf{e}} = (C\mathbf{R}^T)^{-1}W(\mathbf{v})$$, where W(*) is Wiener Filter operator.

<u>Received Signal Estimate</u>

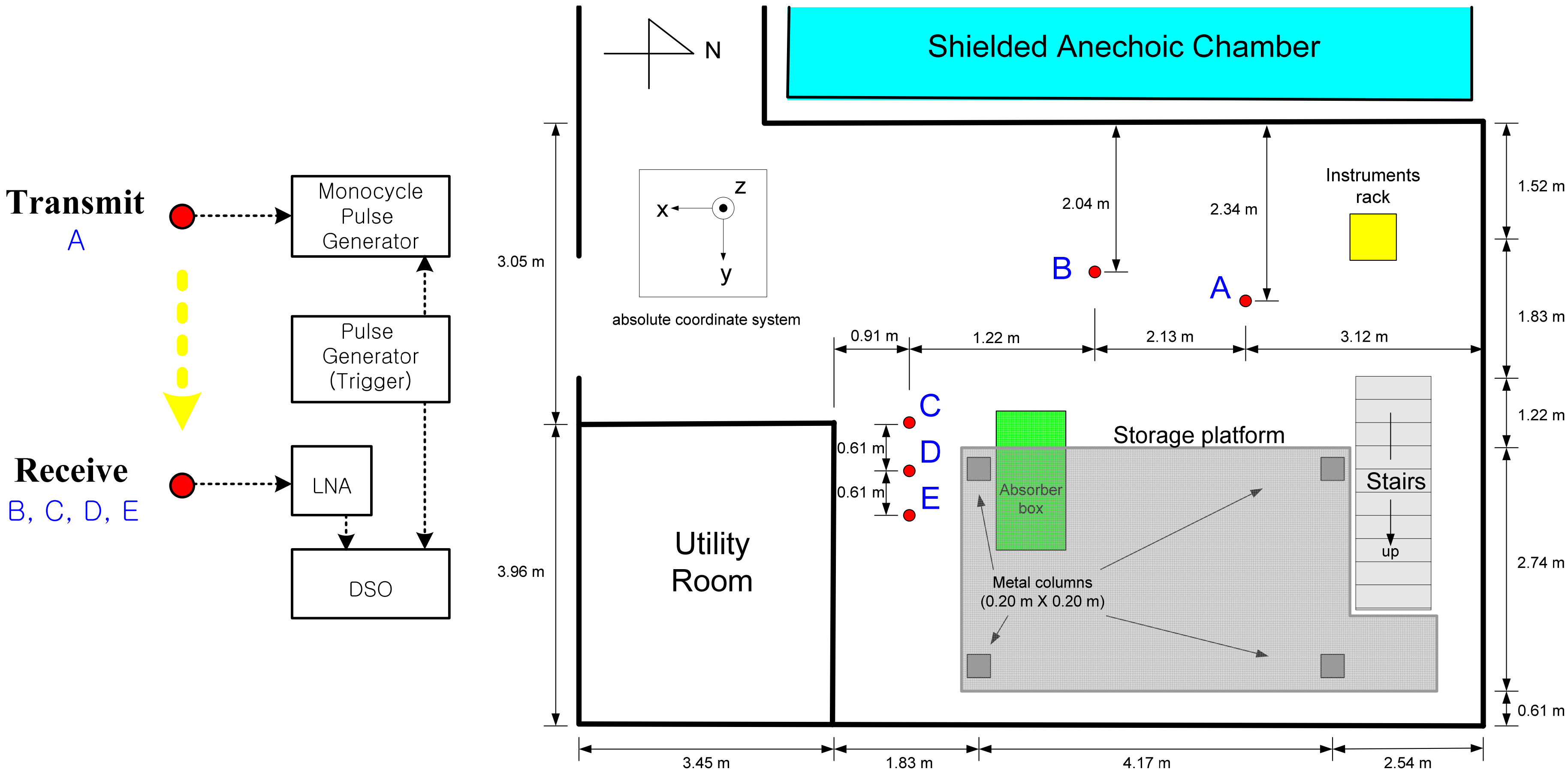
$$\widetilde{r}(t) = \widetilde{\mathbf{e}}(t) \cdot C\hat{\rho}.$$

<u>Received Signal Energy upper and lower Bounds Calculation</u>

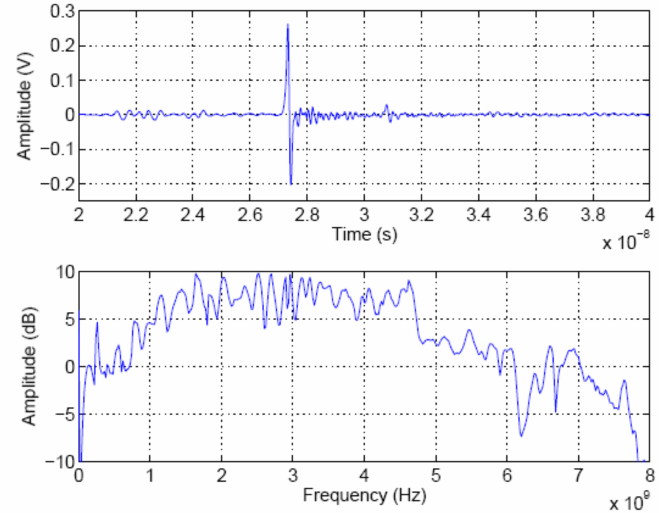
$$E(\hat{\rho}) = \frac{1}{50}\sum_{i=1}^{4000}\widetilde{r}^2(t_i)\Delta t = \frac{1}{50}\sum_{i=1}^{4000}\|\widetilde{\mathbf{e}}(t_i) \cdot C\hat{\rho}\|^2\Delta t = \frac{1}{50}\left\|C\widetilde{\mathbf{e}}^T\hat{\rho}\right\|^2\Delta t = C'\hat{\rho}^T(\widetilde{\mathbf{e}}\widetilde{\mathbf{e}}^T)\hat{\rho}$$

$$C'\lambda_{min} = C'\min_i \lambda_i \le E(\hat{\rho}) \le C'\max_i \lambda_i = C'\lambda_{max}$$

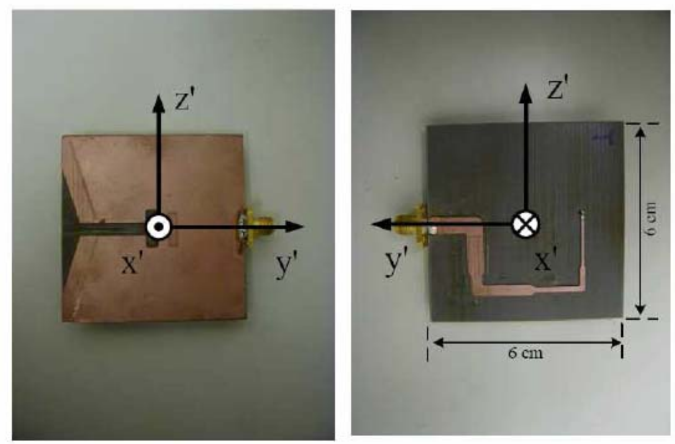
Experimental Setup (1/2)



Experimental Setup (2/2)



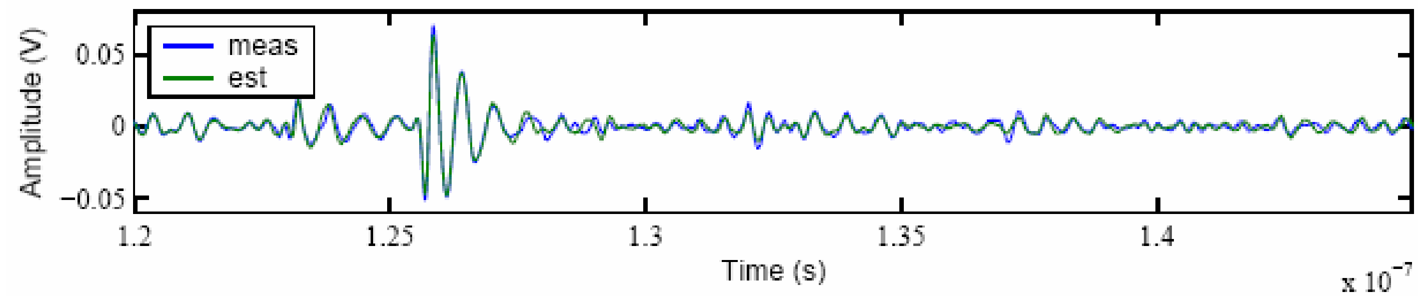
F
P



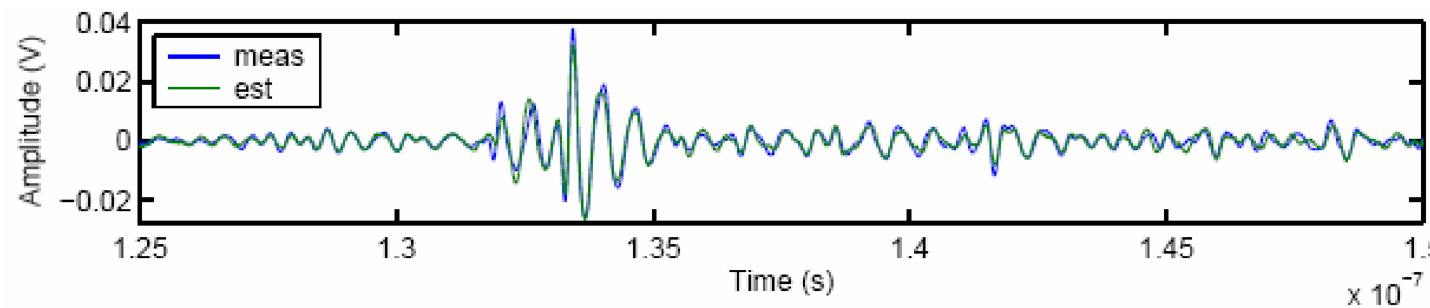
J.M. Yang and A. Prata, Jr., ``Broadband printed circuit board folded dipole antenna,'' in *IEEE Antennas and Prop. Society Symposium*, vol. 1, pp. 771–774, Montery, CA, Jun. 2004.

Received Waveform Estimation

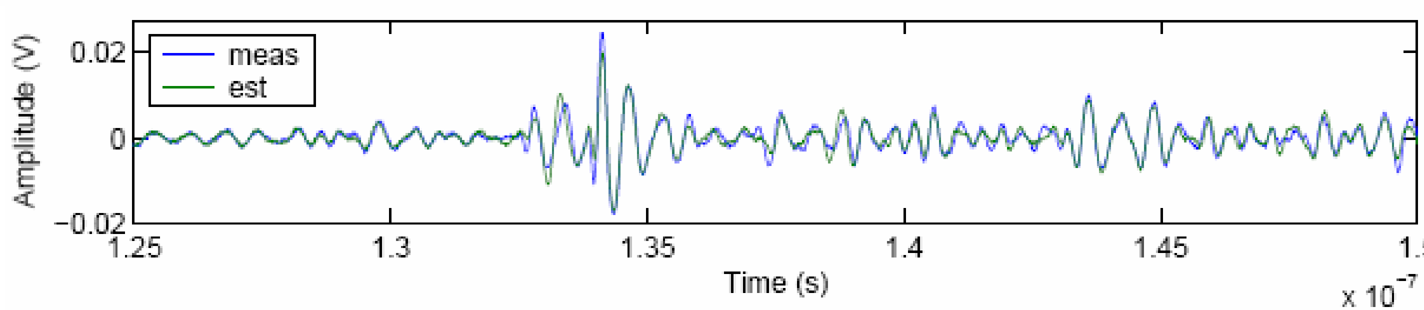
B



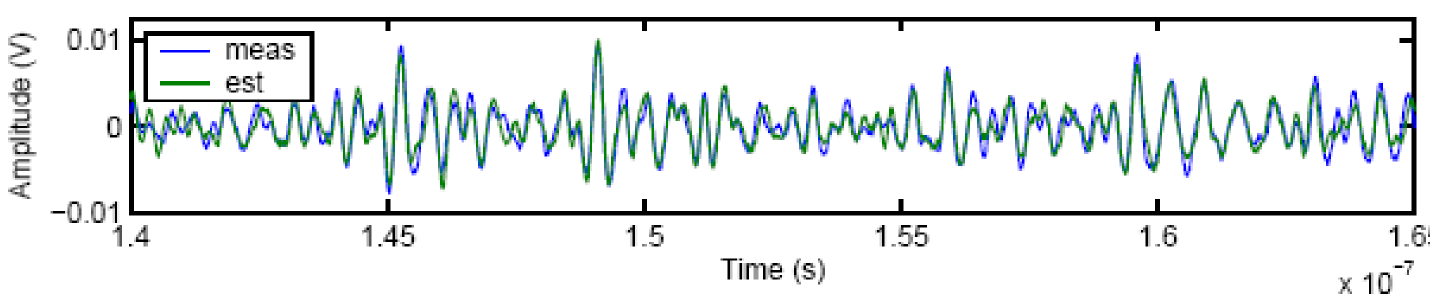
C



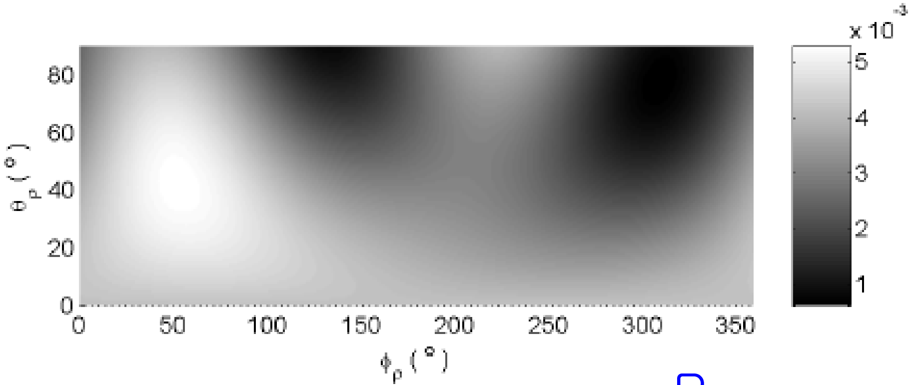
D



E



Energy Density Function w.r.t. antenna orientations



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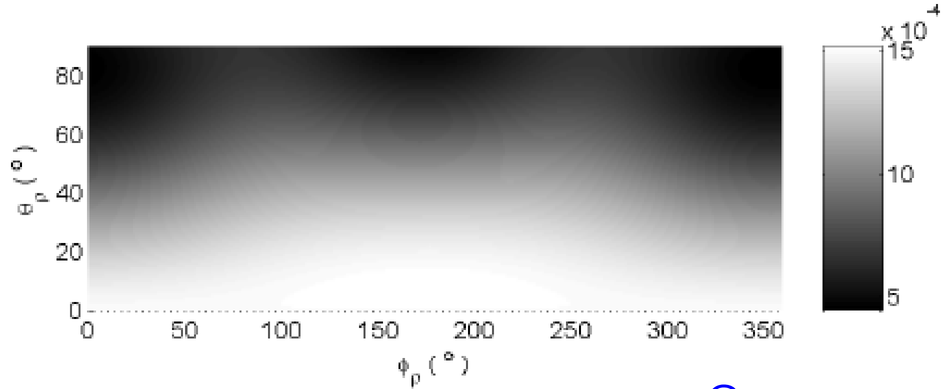

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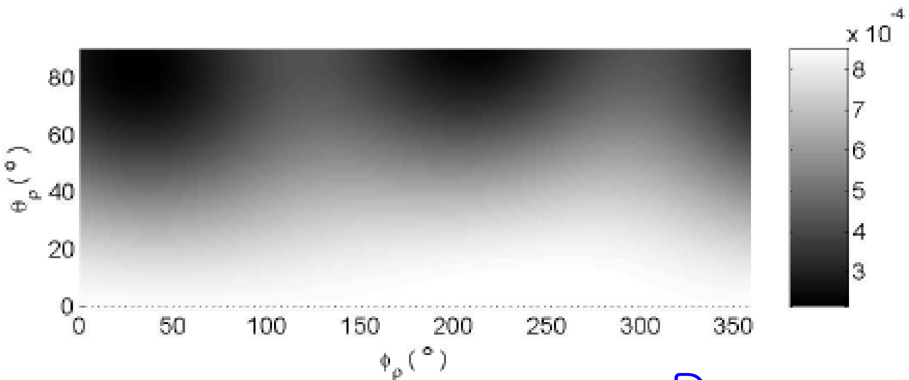

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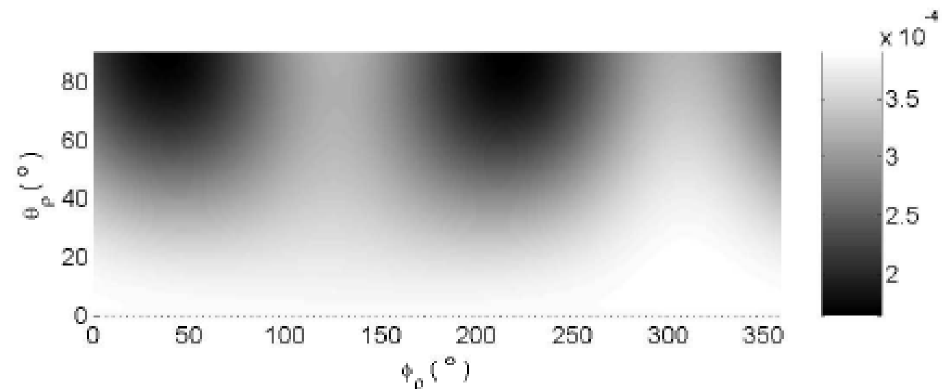

E

Conclusion and Future Work

- The polarization estimation process for multipath channels has low calculation complexity and requires only three propagation measurements.
- The estimation process is applicable to any type of narrowband/wideband/UWB signals.
- Receiving antenna orientation can have a considerable effect on the performance of an indoor UWB radio receiver.
- By reciprocity theorem, the optimal receiving antenna orientation in receiving mode can be equal to the optimal transmitting antenna orientation in transmitting mode.

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