Data Analytics for Novel Evaporation Duct Height Inversion Technique

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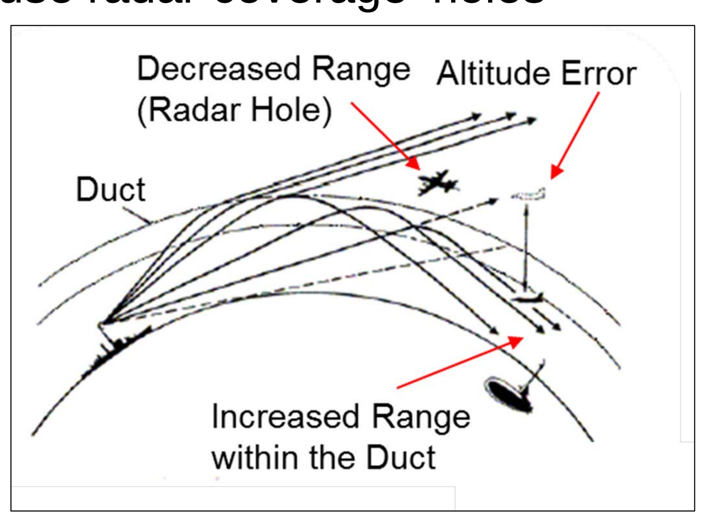
Introduction

Radiowave propagation in the marine atmospheric boundary layer (MABL) remains a subject of research interest given the potential utility of the ducting propagation mechanism. Ducting propagation is highly dependent on atmospheric conditions; experiments that combine propagation measurements with detailed atmospheric characterization can offer opportunities for improved modeling of the MABL effects on propagation in the future.

Background

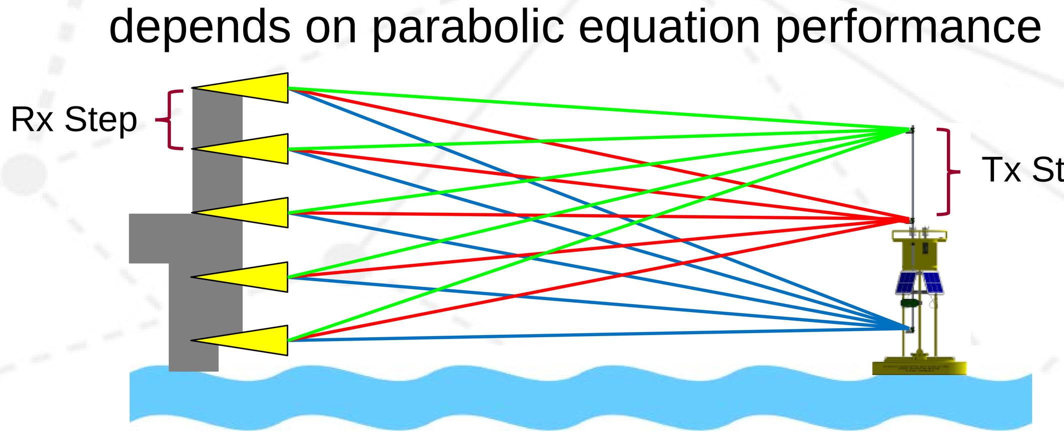
- Non-standard radio wave propagation in the marine atmospheric boundary layer (MABL) has a significant impact on ship-based communications and sensing systems
- Can extend coverage for radar or communication systems
  - Or cause greater interference from other sources
  - Can cause radar coverage 'holes'



- Highly dependent on local meteorological conditions
  - Remains difficult to predict effect deterministically (and therefore to exploit this propagation mechanism) despite years of research
  - Extensive recent research in developing systems to characterize the local propagation environment

Aims

- X-Band Beacon Receive Array (XBBR)
  - Fits a vertically sampled, normalized, array of one-way transmission loss measurements with parabolic equation models
  - Advantages:
    - Near real-time EDH estimation, use of TOI
  - Disadvantages:
    - Assumes constant EDH for entire range, depends on parabolic equation performance



System Design

Transmit Subsystem

Omnidirectional monopole antennas driven by phase-locked coaxial resonator oscillator at 14.0 dBm

Separated slightly in frequency to distinguish in post-processing

11 GHz + 45.5, 47.9, and 48.7 MHz

Power Consumption = 2W

Transmitters controlled via SATCOMMS

Transmitting 10 minutes of every hour

Investigating the use of 4-18 GHz phase-locked loop tunable frequency synthesizer for future campaigns

Receive Subsystem

20 dB gain X-band Horn Antennas

Amplified and Mixed with 11-GHz

Local oscillators for each channel are phase locked

Filters to reduce out of band interference

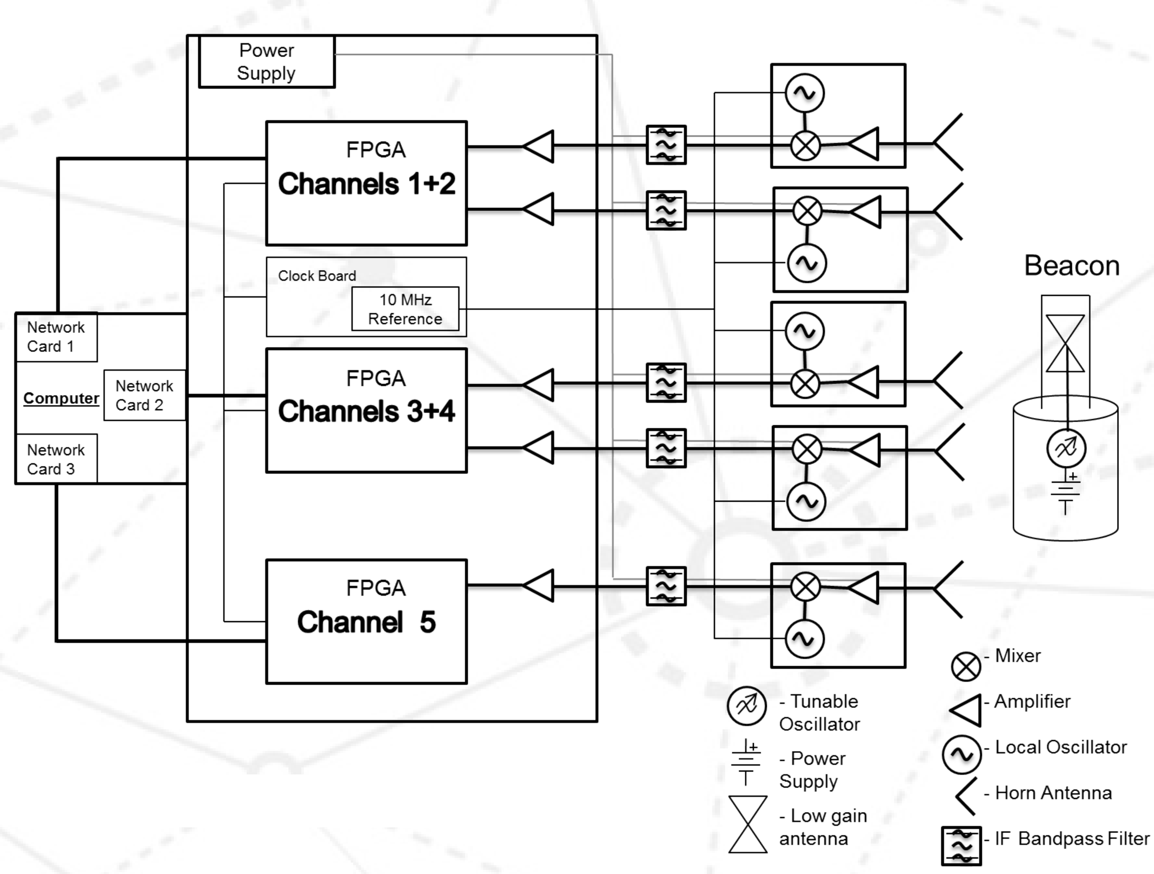
Five 16-bit ADC's sampling at 80 MSPS

40 MHz bandwidth spans range of 3 transmit beacons

Raw ADC data recorded at one million samples (12.5 ms) per capture

Retriggered every 10 seconds

Receiver Noise Figure 3 dB

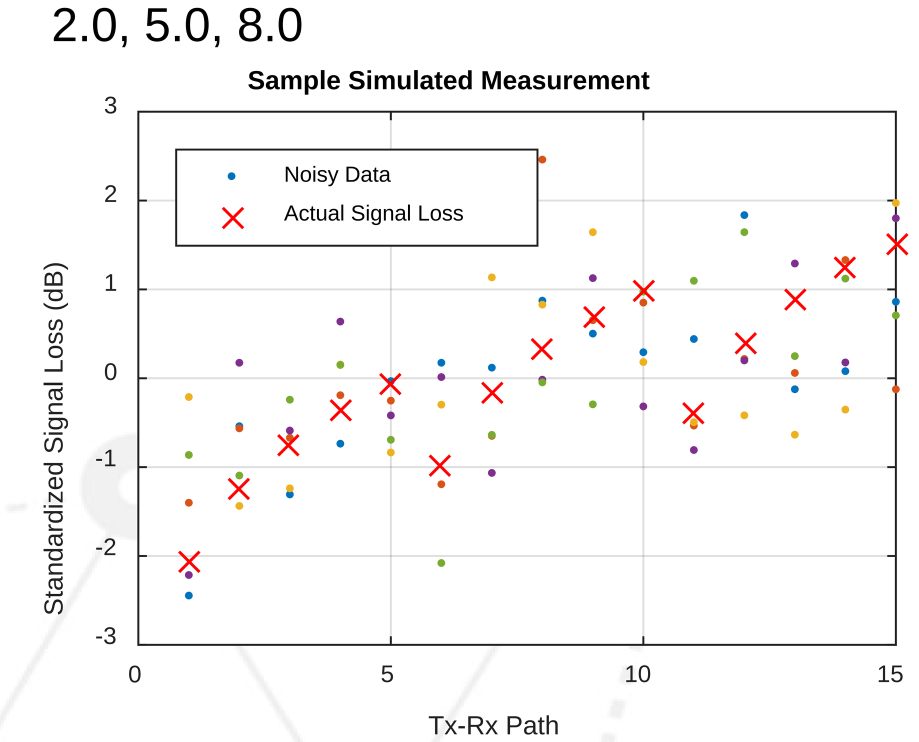


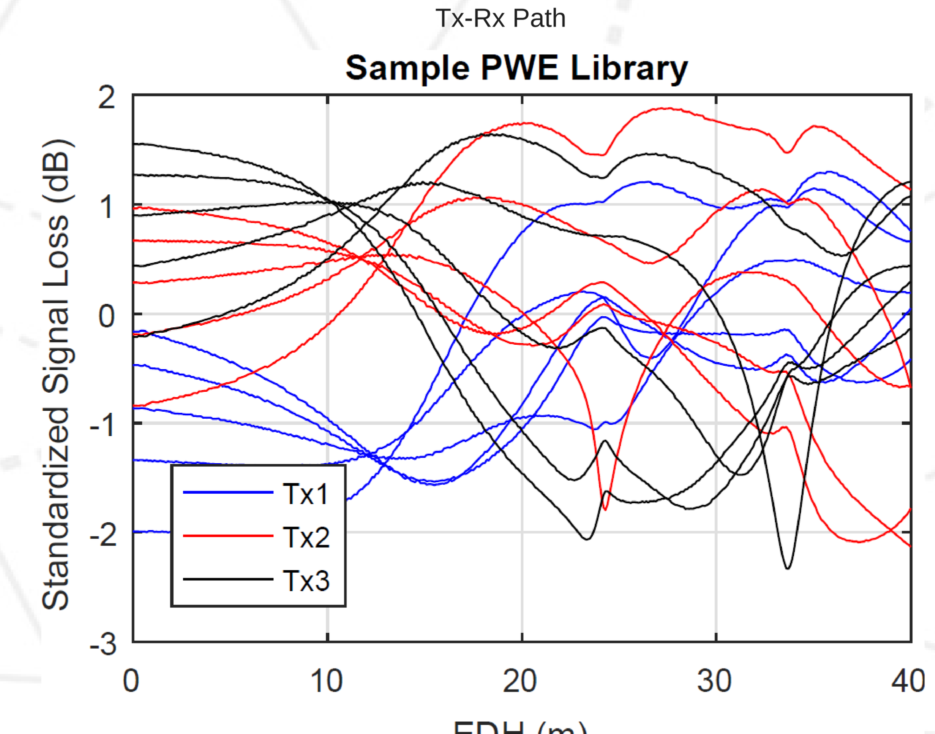
Methods

- Parabolic Wave Equation (PWE)
  - Input: Meaurement Parameters
  - Output: Signal Loss
- EDH Inversion applies Objective Function:

$$\Phi(EDH) = \sum_{i=1}^{N_R} \sum_{j=1}^{N_t} \left| L_{n,(i,j)}^{obs} - L_{n,(i,j)}^{sim}(EDH) \right|^2$$

  - $L_n^{sim}(EDH)$: Simulated Signal Loss values
  - L_n^{obs}: Measured/Simulated Received Power values between arrays of Transmitters and Receivers
- Parameter Optimization Variables:
  - Monte Carlo Iterations = 500
  - Noise = 5 dB (independent of each channel)
  - Range = 15 km
  - Transmit (Tx) Array Center: 20 m
  - Receive (Rx) Array Center: 20 m
  - Frequency Center: 11GHz
  - Possible Distances Between:
    - Tx Step Size (m) = 0.5, 1.0, 2.5, 5.0, 7.5
    - Rx Step Size (m) = 0.5, 1.0, 2.5, 5.0, 7.5
    - Freq Step Size (GHz) = 0.005, 0.1, 0.5, 1.0, 2.0, 5.0, 8.0





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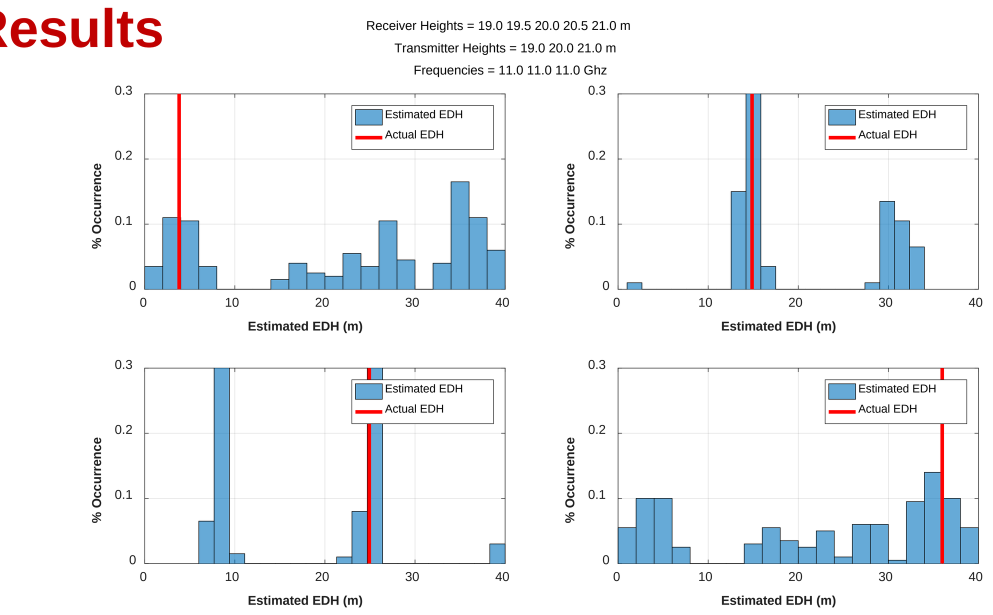
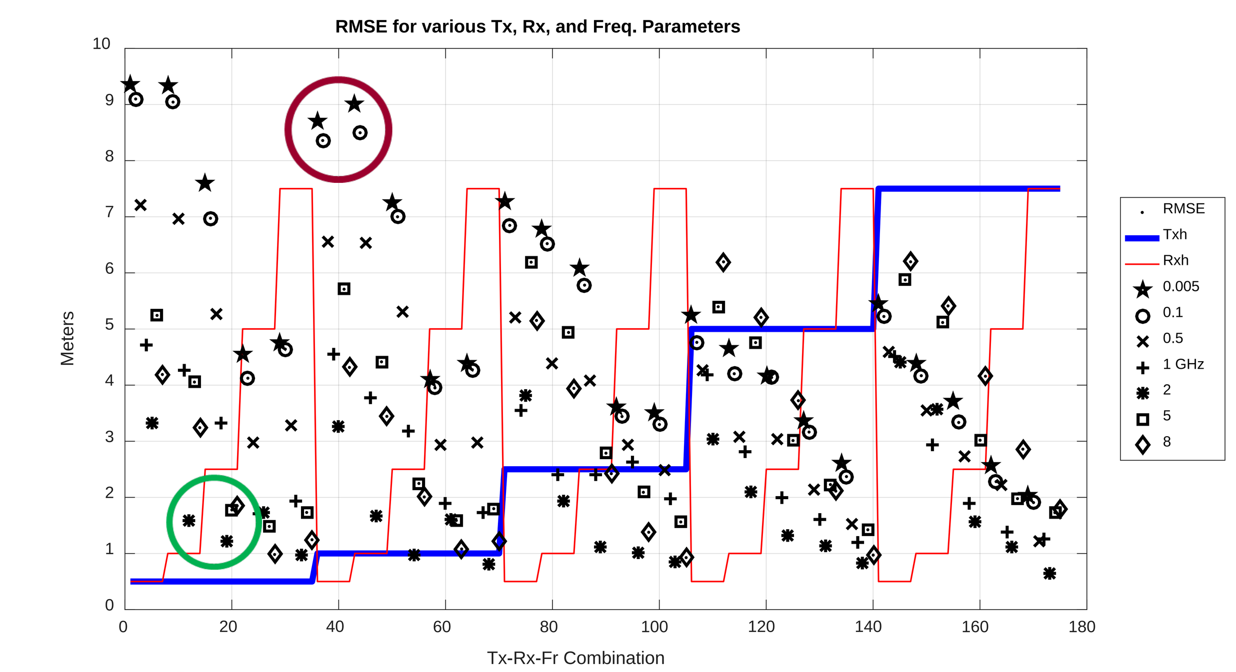
[1] Patterson, Wayne L. "Advanced refractive effects prediction system (AREPS)." *Radar Conference, 2007 IEEE*. IEEE, 2007.

[2] Barrios, Amalia E. "A terrain parabolic equation model for propagation in the troposphere." *Antennas and Propagation, IEEE Transactions on* 42.1 (1994): 90-98.

Results



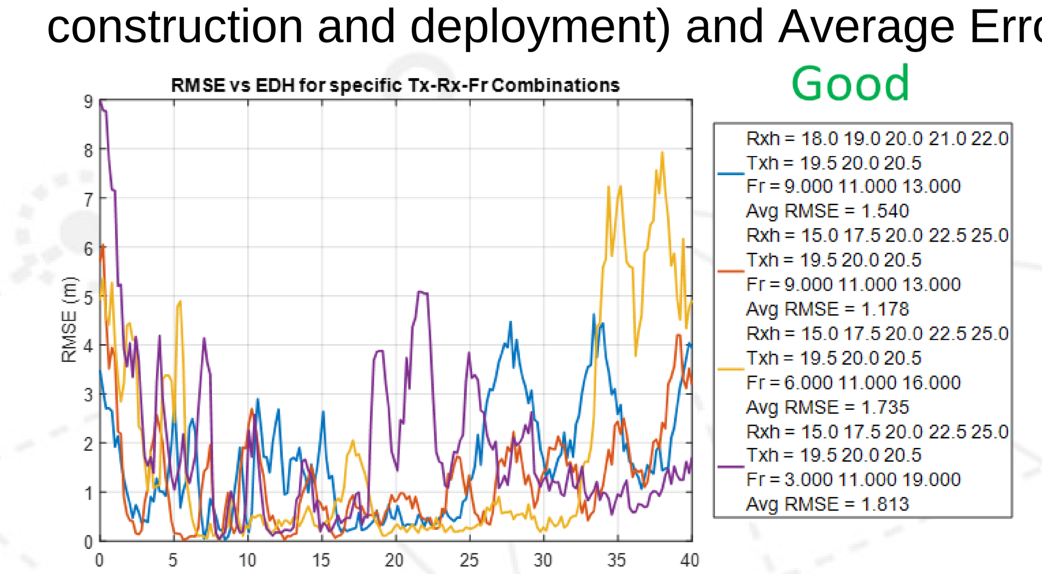


Conclusions

Ambiguities exist. More error exists for parameters that lead to VTRPE libraries with similar relative values for Different EDH heights

Need to find balance between Step Size (ease of construction and deployment) and Average Errors

Good



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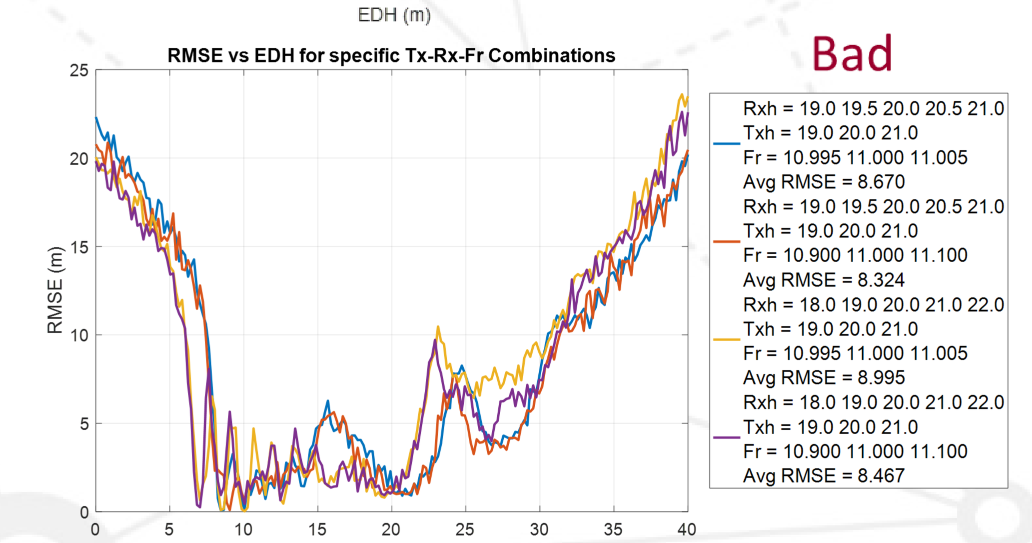

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