ALION
SCIENCE AND TECHNOLOGY

Aligned with your needs.

Advances in TIREM:

Preparing for a New Round of Model Building and Validation

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Site-Specific Propagation Models

- Crowded, Contested, Expensive Spectrum...
  - Most useful bands occupied
  - Often by more that one user
- Spatial Diversity – Exclusion Zones...
  - Find region around a military base or port excluding civilian radios
  - Small enough not to exclude too much useful civilian area
  - Large enough to ensure security and QoS of military comms
- Accurate, Site-specific, Environment-specific Propagation Models are a must…
  - ITM, TIREM, ITU models, …
  - Must evolve with new data, new models, new ideas

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TIREM and TIREM Evolution

- The **T**errain **I**ntegrated **R**ough **E**arth **M**odel
  - Models radio frequency propagation loss over irregular terrain and sea water for ground-based and airborne transmitters and receivers
  - A central part of RF analysis and planning tools (AGI STK, OPNET, GATE, NPT, ...)
  - Accurate and Fast
  - Portable (Linux, Windows, 32/64-bit)
  - Well-known and tested algorithms: diffraction, reflection, refraction, ...
- TIREM is evolving to meet new demands
  - Models for diffraction, troposcatter, losses due to rain, fog, have advanced over the years
  - The demands for accuracy and speed are driven by spectrum crowding and co-location

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Integrated Physics Models

- Spherical Earth Model
  - Propagation over terrain at 2 MHz or less, or smooth terrain (water, parking lot)
  - Always in TIREM – Expose API for HF and smooth Earth problems
  - Invertible: range as a function of loss – exclusion radius or coverage radius
- Terrain Diffraction
  - Knife-edge Diffraction (ITU-R P.526)
  - Augmented by round hill diffraction
- Liebe Millimeter Wave Model (MMWProp)
  - Atmospheric absorption O2, H2O > 10GHz
  - TIREM/SEM has always had this baked in for Std US Atmosphere
  - Extend LOS propagation to 350 GHz (New version in TIREM - ITU-R P.767-9 - goes up to 1000 GHz!)

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New Integrated Physics Models Cont'd

- Scintillation Model
  - Propagate through F-layer of the ionosphere
  - Frequency < 10 GHz; 225 km < h < 400 km - Satellites
- Rayleigh Dust Model
  - Very fine dust and smog
  - Auxiliary tool to convert visibility to particle density
  - Sandstorms, rotor wash, smog
- Flexible Atmosphere modeling
  - Accurate refractivity gradient (eventually including ducting)
  - Accurate absorption (with MMWave model above)

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New Integrated Physics Models Cont'd

- Flexible Terrain Profile Data Structures
  - Allow overlay of clutter, buildings, vegetation
  - Allow exploration and comparison of Knife Edge identification algorithms
  - Allow variable surface permittivity and conductivity
- Expansive Analysis Output Data Structures
  - Loss contributions from all internal algorithms
  - Ancillary geometrical parameters effecting propagation losses
  - Helps measure the impact of constituent model changes and parameter changes

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New Integrated Physics Models Cont'd

- Hata Urban Model
  - Empirical urban propagation model
  - Provide link geometry, level of urbanization
  - COST-231 Hata enhancements added
- Slab forest model
  - Slab of lossy-dielectric
  - Direct, Internally reflected, refracted waves
- Long Term Fading
  - TN 101 curves – fits to measured deviations from mean loss
  - Should be revisited by the RF propagation community (ITU-R P617)
  - Or... Run TIREM with varied realistically terrain, atmospheric, and electrical parameters – Monte Carlo simulations

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Testing and Validation

- Continual regression and unit tests
  - Part of build process
  - Make sure no surprises happen
- Recover/Build a validation and model comparison framework
  - Old NOAA measurement campaigns: Gunbarrel Hill, ...
  - Old Danish terrain profiles at 5 m delta – Ravenstru,
  - Measured propagation losses from HF up through about 20 GHz
- Waiting on / looking for new measured data
  - NOAA anomalous propagation from White Sands
  - ASMO - White Sands Missile Range large exercise – 225, 1370, 1840

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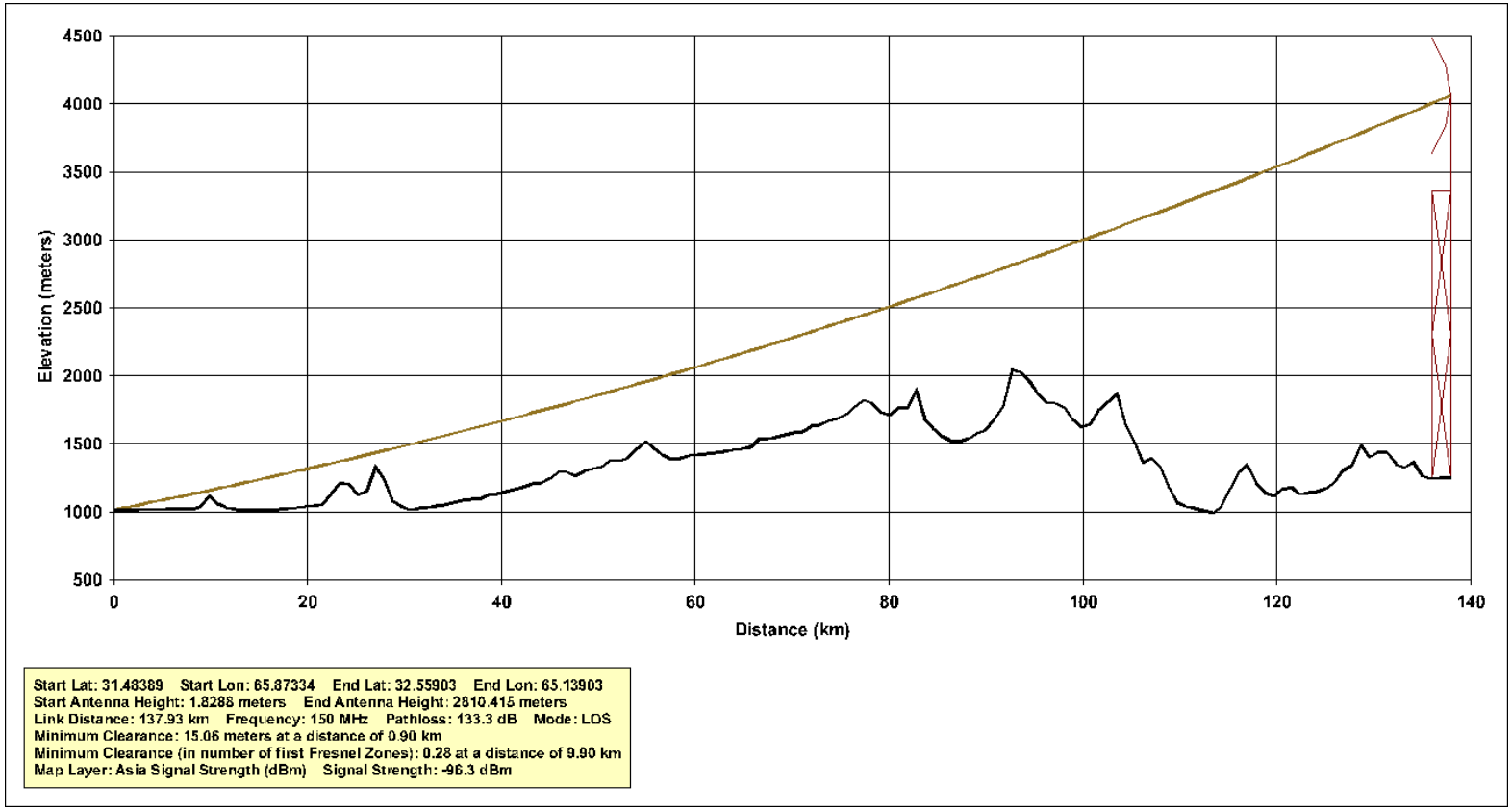
Multipath Fading – A Recent Challenge



Multi-Path Deep Fading "Surprises"

- In 11/2010 Alion staff noticed some puzzling features in radar coverage plots
  - Deep notches in smoothly changing loss plots
  - Sensitive to small changes in geometry
- Traced to terrain intrusion into antenna – antenna horizon path segments
  - Near cancellation of direct and reflected waves
  - Multi-path fading **is** a real phenomenon. Really, it is.
  - Point of confusion and difficulty for years (TIREM-SEM Handbook)
  - Abrupt large changes in loss even for small terrain features
  - TIREM uses an admittedly *ad-hoc* modeling of rough-surface reflection; Cuts off when Fresnel clearance is 0.56 (first Fresnel zone).

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Multi-Path Deep Fading Solutions

- Mean Multi-path solution still required
  - We could average interference extrema
  - We can do better though
- Consider an elevated Tx. As you move Rx away over a knife edge:
  - The path begins as a simple LOS path.
  - As the Rx goes over the knife edge we have a BLOS path treated as a knife-edge diffraction
  - As you move the Rx to an opposite hill (LOS again) the “knife edge” is now a “smooth plain”?!? This is inconsistent
  - Effectively assumes long uninterrupted visible reflection region

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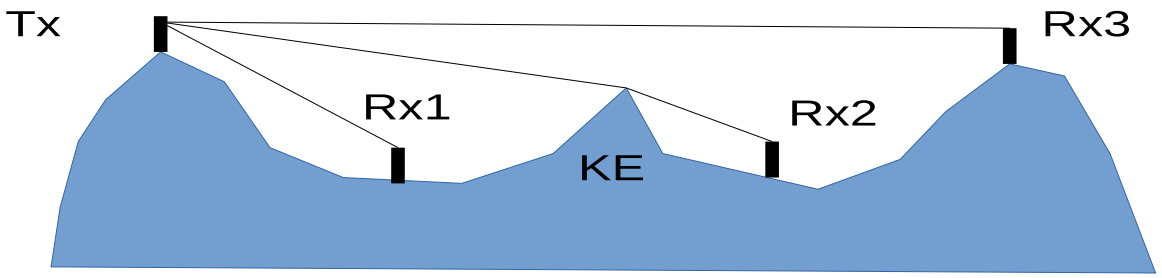
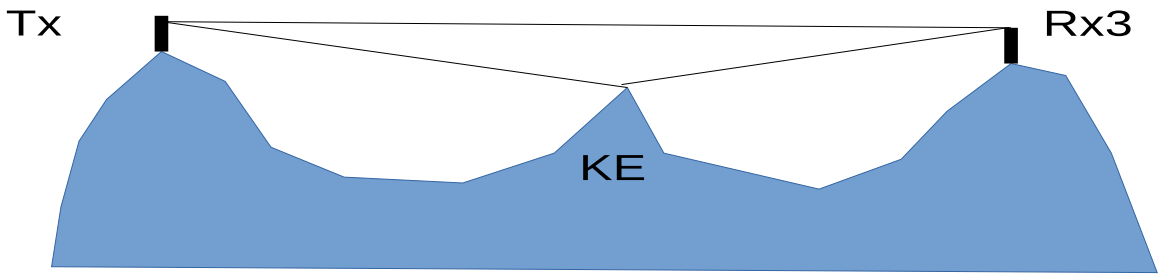
Picture of Previous Slide



KE is a knife edge for Rx2



KE should also be a knife edge for Rx3

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Multi-path Deep Fading - Solutions

- Offer Lit-region knife-edge diffraction
  - The loss deltas are in the low teens instead of mid twenties or higher – we soften, realistically, the near-null multi-path fading
  - There is a logical consistency to the algorithm – everything is a knife edge (except over the ocean) – no extra magic parameters, continuation of known knife edge physics
  - We are still honest about multi-path fading by providing an estimate of fading variability
- Leave the old model in as an option
  - It's pessimistic but familiar
  - Three guesses which users select…
  - Deprecate (but keep) access the old multi-path algorithm in new TIREM

The Future (What keeps us up at night)

- TIREM Evolution
  - TIREM (or something) must evolve to solve the current and emerging spectrum issues
  - Real urban propagation: data gathering, integration (handoff) to terrain propagation
  - What happens when (not if) someone shows us 10 cm terrain data (preprocessing, feature interpretation, problem size)
  - More atmospheric components and pollutants (CO2, aerosols)
  - Wedge diffraction option instead of knife-edge diffraction
  - Anomalous propagation - ducting

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The Future (What keeps us up at night)

- TIREM Evolution continued
  - Re-examine TIREM models and free parameters (Is current TIREM an 'overfit'?)
  - Multipath fading is a large source of variability – geometrical problem
  - Troposcatter is the largest source of long term variability – meteorological problem
  - Clutter, man made terrain, mobile terrain
  - Inter-knife-edge multipath
  - **Expand testing and validation with more data – we need a framework for comparing models, curating measured data, machine learning, ...**

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