

Propagation Model Modernization and Validation

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Spectrum Sharing/Coexistence Studies

- TN 101, Volume II, Section V, Begins:

“As a general rule, adequate service over a radio path requires protection against noise when propagation conditions are poor, and requires protection against interference from co-channel or adjacent channel signals when propagation conditions are good. Optimum use of the radio spectrum requires systems so designed that the reception of wanted signals is protected to the greatest degree practicable from interference by unwanted radio signals and by noise.”

poor propagation conditions = fading side of the distribution ($p > 0.5$)

good propagation conditions = enhancement side of the distribution ($1-p < 0.5$)

Spectrum Sharing/Coexistence Studies

- Hufford et al., NTIA Report 82-100, § 6 (“*A Guide to the Use of the ITS Irregular Terrain Model in Area Prediction Mode*,” April, 1982):

“..., it seems undeniable that received signal levels are subject to a wide variety of random variations and that proper engineering must take these variations into account.”

The propagation channel ought to be treated as random:

Means/medians and variances are functions of distance due to different mechanisms dominating over different distance ranges

Spectrum Sharing/Coexistence Studies

- One-on-One versus Many-on-One
 - Cumulative distribution function comparison of individual unwanted and wanted sources versus the cumulative distribution function of many unwanted sources compared to the cumulative distribution function of the wanted source
 - In both instances, the interfering (unwanted) sources' deployments (e.g., locations, transmitter powers, heights above ground) may also be random

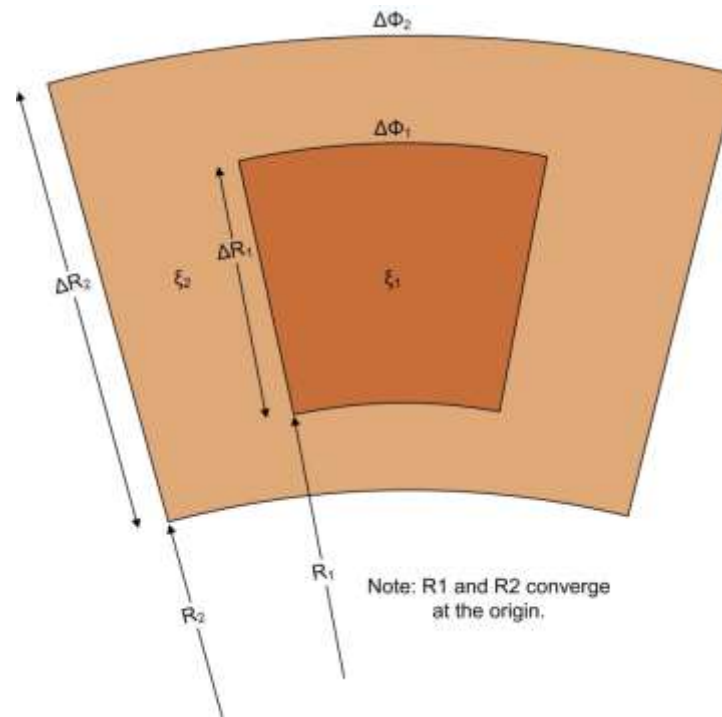
Propagation Models in Spectrum Sharing/Coexistence Studies

- Site-General versus Site-Specific Models
 - Site-General assumes that mean/median propagation loss increases monotonically with distance for given terminal heights and frequency of operation (e.g., Rec. ITU-R P.1546*, ITM (Area Mode), SEM**, etc.)
 - Exclusion/protection zones are defined by a single distance given the interference protection criterion
 - “Simple” source deployment with victim at (or above) the origin (i.e., urban sector surrounded by a suburban sector, both surrounded by a rural sector)

* This model only has the enhancement side of the time variability distribution currently included

** Variabilities must be added to median prediction

Propagation Models in Spectrum Sharing/Coexistence Studies

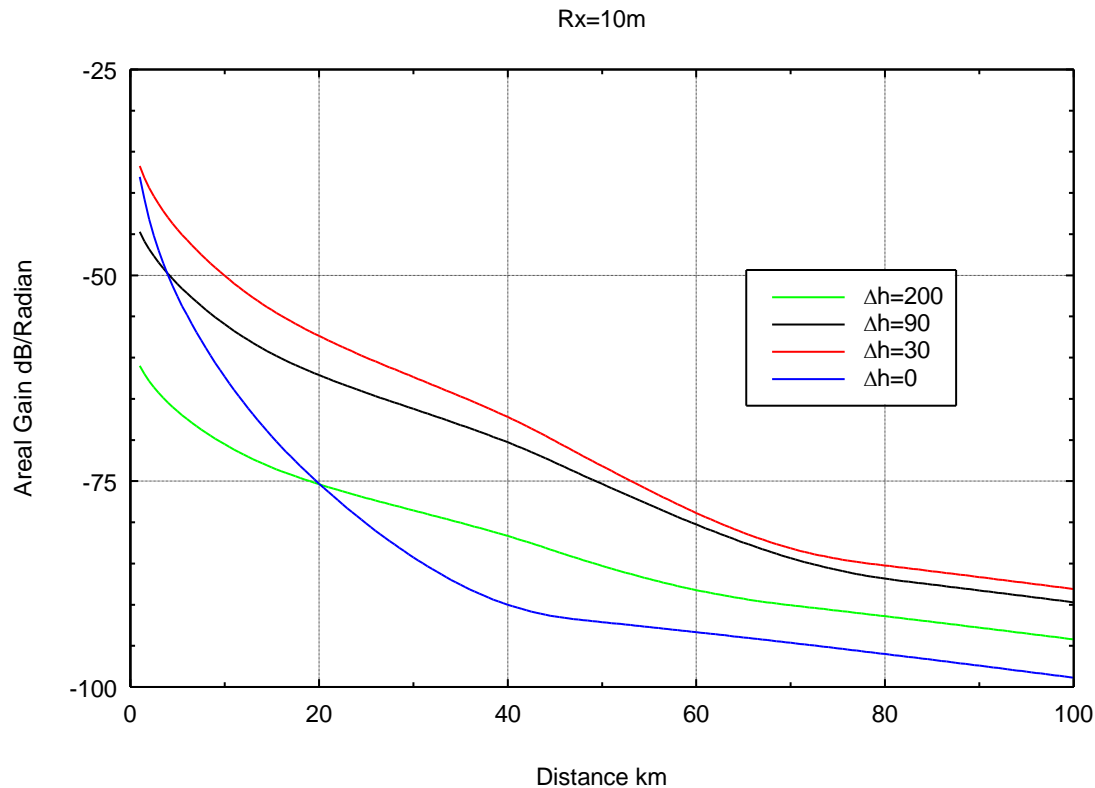


Propagation Models in Spectrum Sharing/Coexistence Studies

- Site-General Models (continued)
 - Power Sum is related to the Integration of transmission gains over the source region (assuming uplink power is an iid RV in that region)
 - Mean and Variance of the Aggregate Power from the Central Limit Theorem
 - Advantage: sensitivity analysis of the aggregate interference based on general deployment characteristics/parameters
 - Disadvantage: neglects deployment details in specific markets

Propagation Models in Spectrum Sharing/Coexistence Studies

- $\Gamma = 10 \log \left(\int_R^{R+\Delta R} \overline{g_{b_{ITM}}}(\rho) \rho d\rho \right)$



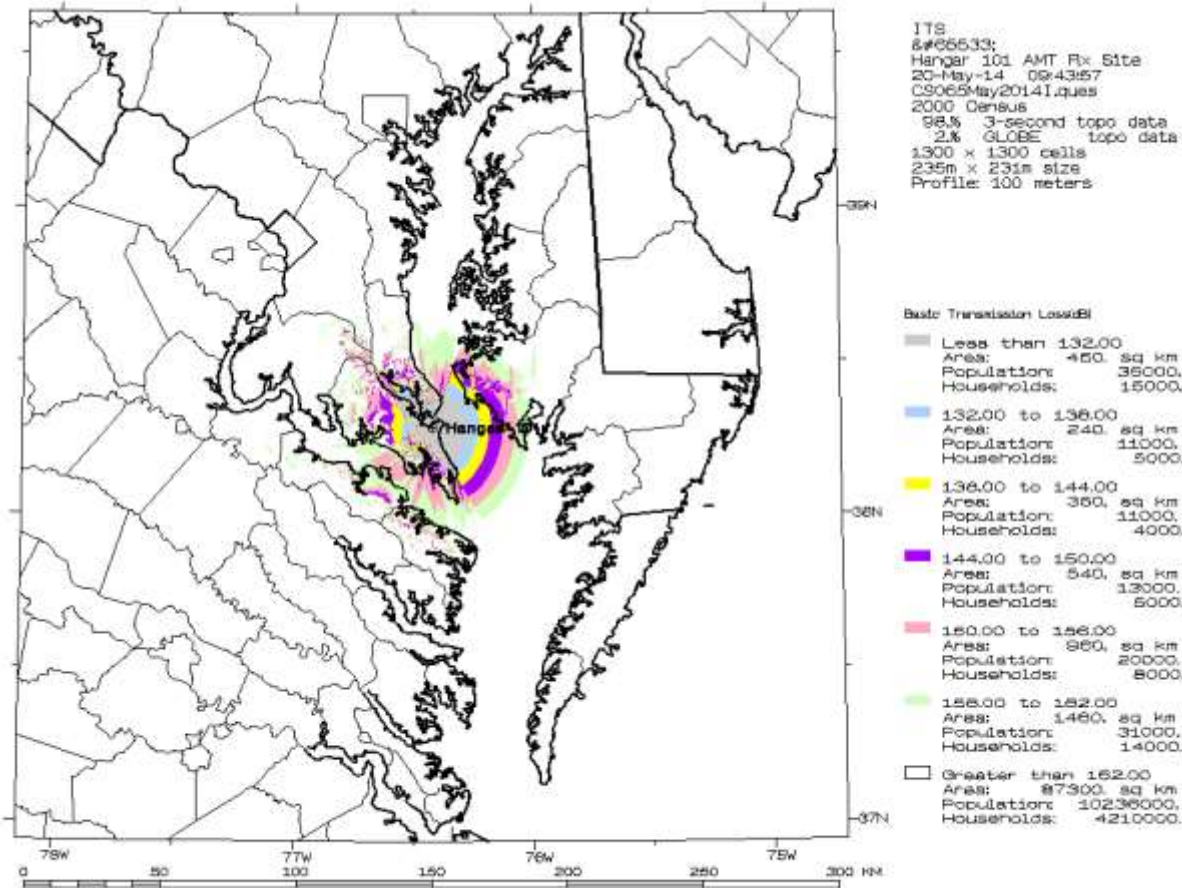
Propagation Models in Spectrum Sharing/Coexistence Studies

- Site-Specific Models
 - Individual sources' path losses may not be monotonically increasing with distance to the victim (e.g., Rec.'s ITU-R P.452*, P.1812*, P.2001, ITM (point-to-point mode), TIREM**, etc.)
 - Cumulative Distribution Function of the Power Sum by Monte Carlo Techniques Treating the Basic Transmission Loss as a Random Variable
 - Clutter, terrain and individual sources' deployment details give rise to location (as opposed to simple distance) dependent interference effects
 - In the following examples, the ITM's median basic transmission losses (without additional clutter losses) are shown as functions of location for $h_{tx} = 1.5 \text{ m}$, $h_{rx} = 20.3 \text{ m}$ (heights above ground level), $f = 1767.5 \text{ MHz}$

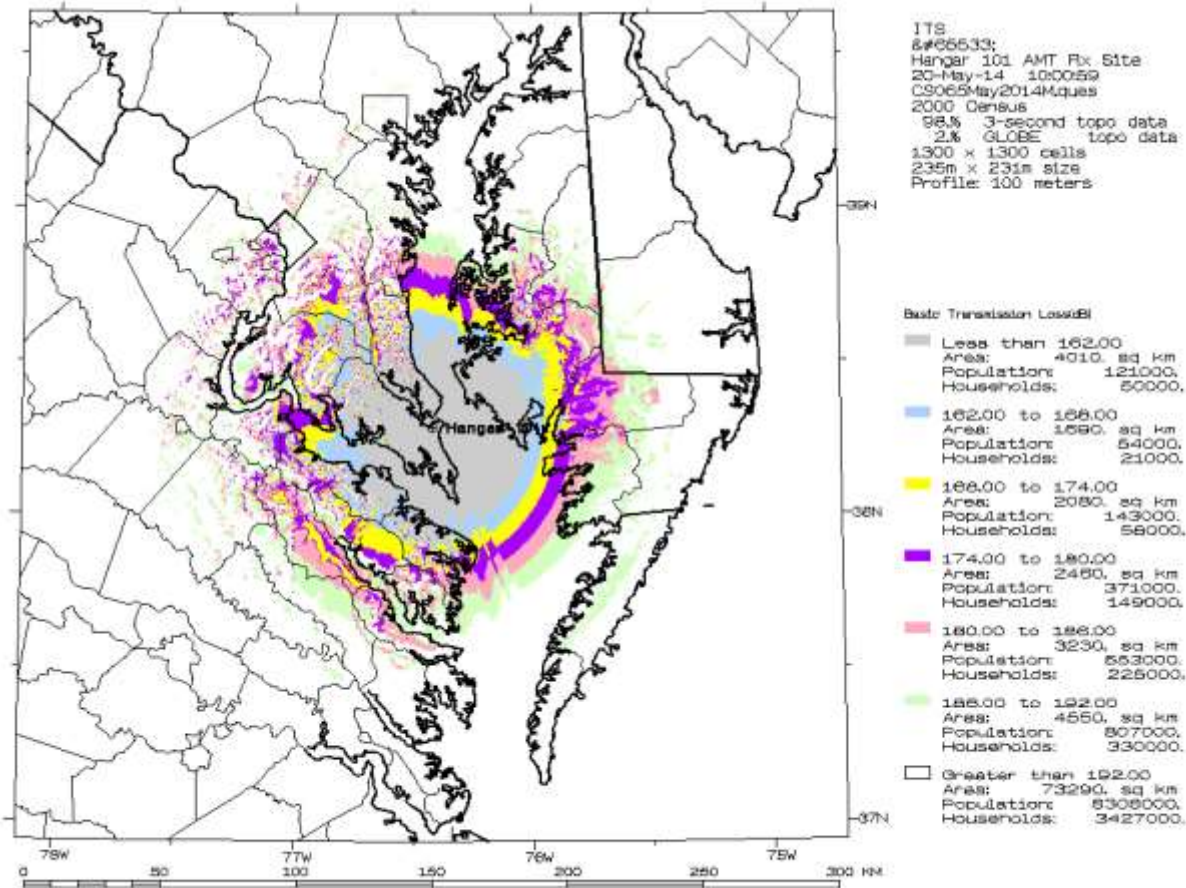
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Propagation Models in Spectrum Sharing/Coexistence Studies



Propagation Models in Spectrum Sharing/Coexistence Studies



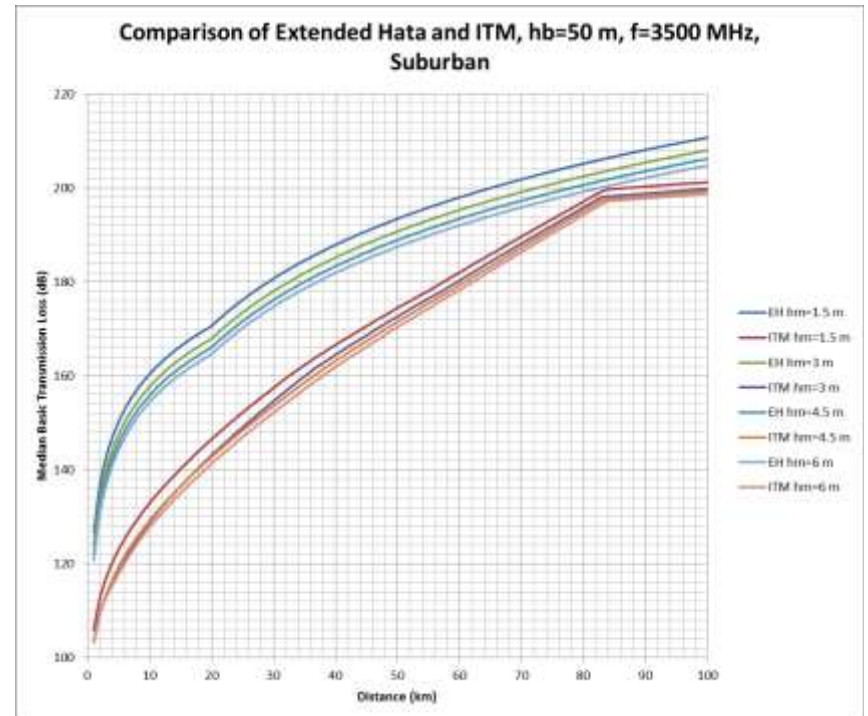
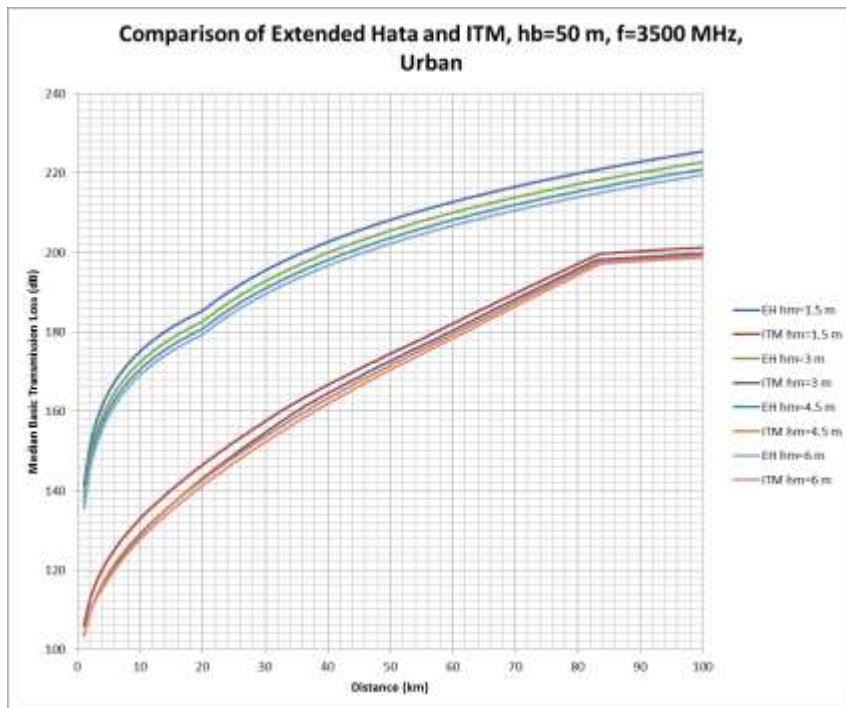
Improvement/Modernization of Propagation Models for Spectrum Sharing/Coexistence Studies

- The propagation models listed above will, at best, only provide for additional clutter losses through an “endpoint” correction (except for Rec. ITU-R P.1812)
- A. Longley (“*Radio Propagation in Urban Areas*,” OT 78-144) showed that ITM’s median attenuation (in Area Mode, $\Delta h = 45\text{ m}$) underestimated Okumura et al.’s Basic Median Attenuation for quasi-smooth terrain by as much as 38 dB at 3,000 MHz and at short ranges (the difference is frequency and distance dependent)
- Thus substantial reductions in estimates of protection zone distances might be anticipated if the propagation models were to better account for clutter
 - See, e.g., NTIA letter to the FCC on the 3.5 GHz band proceeding

Comparison of Extended Hata and ITM (Area Prediction Mode, $\Delta h = 45 \text{ m}$)

Difference between the Blue-Green and Red-Orange Curves Would Be Longley's Urban Factor for these Antenna Heights

Difference between the Blue-Green and Red-Orange Curves Would Be the Corresponding Suburban Factor for these Antenna Heights



Improvement/Modernization of Propagation Models for Spectrum Sharing/Coexistence Studies

1755-1780 MHz

- Agreed upon end correction of 10-20 dB for urban/suburban, 0-10 dB for rural, both ranges assumed uniformly distributed

3.5 GHz

- All urban and suburban areas assumed to mimic Japan in the 1960's
- Accounts for distance dependence but lacks empirical validation; domestic wireless carriers calibrate their datasets
- Studies require extended range (> 20 km) data

Improvement/Modernization of Propagation Models for Spectrum Sharing/Coexistence Studies

- One Possible Approach Going Forward: Integrated Terrain + Clutter Model
 - Treat Local Clutter As Multiple Knife Edge Diffraction (Vogler, Bertoni et al., Torricco et al.) with Edges due to Terrain (Horizons Determined by Last Local Edge for Each Terminal) + Smooth Sphere Diffraction (Vogler Three-Radius Method, Effective Terminal Heights from Last Local Edge)
 - “Free Space” vs. Reflection vs. Diffraction Dominated Over Roof Propagation for a Terminal Whose Height is Above the Clutter Height
 - Convex Hull vs. Terrain “Clutter” Factor
 - Full UTD Formulation for Oblique Incidence
 - Edge Heights and Separations Will Be Representative (Tuned for Environments from Measurements)
 - Piecewise Continuous Losses in “Line-of-Sight”, Diffraction and Troposcatter Ranges
 - Troposcatter: Should Last Edge Effective Height Determine the Common Volume Height or Should the Closest Edge
 - Location vs. Clutter Variability
 - Time Variability for Longer Paths
 - Model Validation Will Require Extensive Measurement Effort