Introduction to Clutter Modeling Tutorial

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Outline

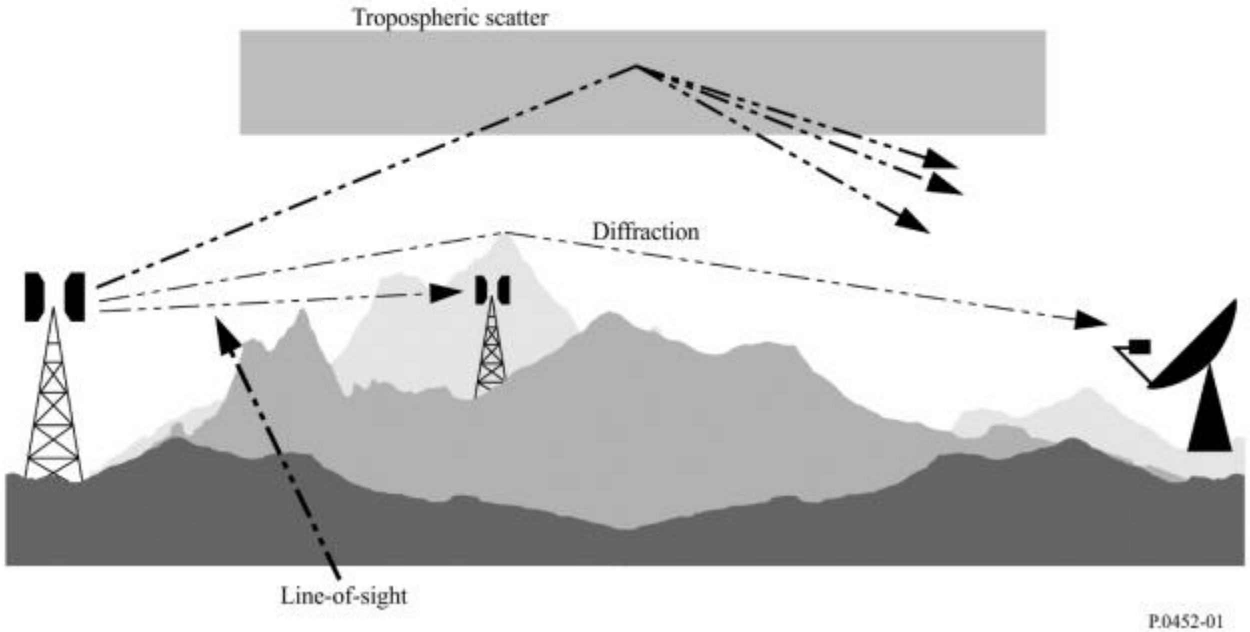
- Introduction to Clutter
- Software Tooling
- Environmental Data
- Modeling Overview
- Measurement Datasets

Overview

- Present short overview on clutter, models, data, and software tools
- Familiarize the user with basic concepts
- Background information on tutorial activities

Radio wave Propagation

- Radio waves travel, or *propagate*, through the environment from a transmitting source
- To prevent harmful interference, need to develop methods to predict signal strength at an arbitrary location for a given transmitter configuration
- Propagation losses are caused by:
  - Free space loss
  - Ionosphere
  - Terrain (diffraction theory)
  - Rain (hydrometeor scatter)
  - Atmospherics (troposcatter)
  - Clutter…



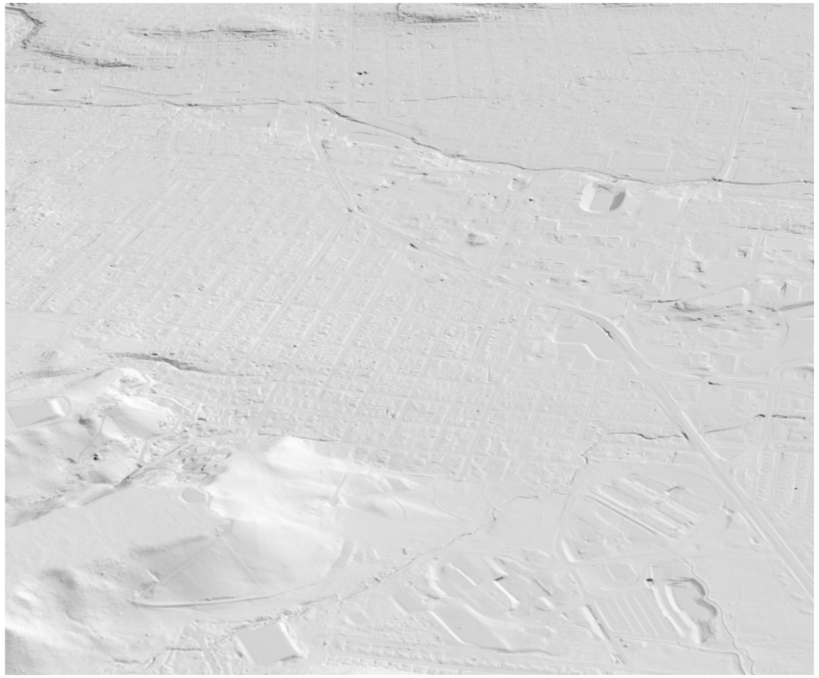
Cite: *Recommendation ITU-R P.452*

Defining Clutter

- What is clutter?

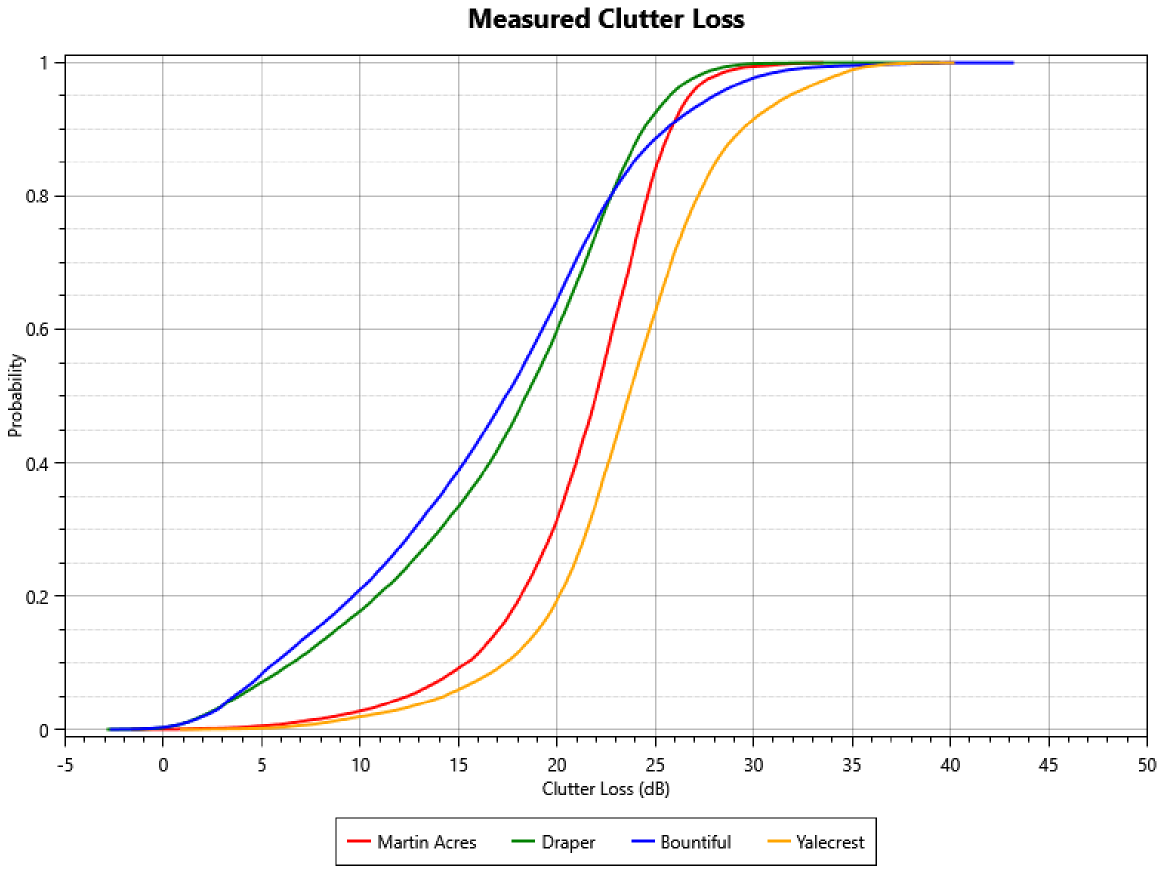
Clutter refers to objects, such as buildings or vegetation, which are on the surface of the Earth but not actually terrain.

- Recommendation ITU-R P.2108



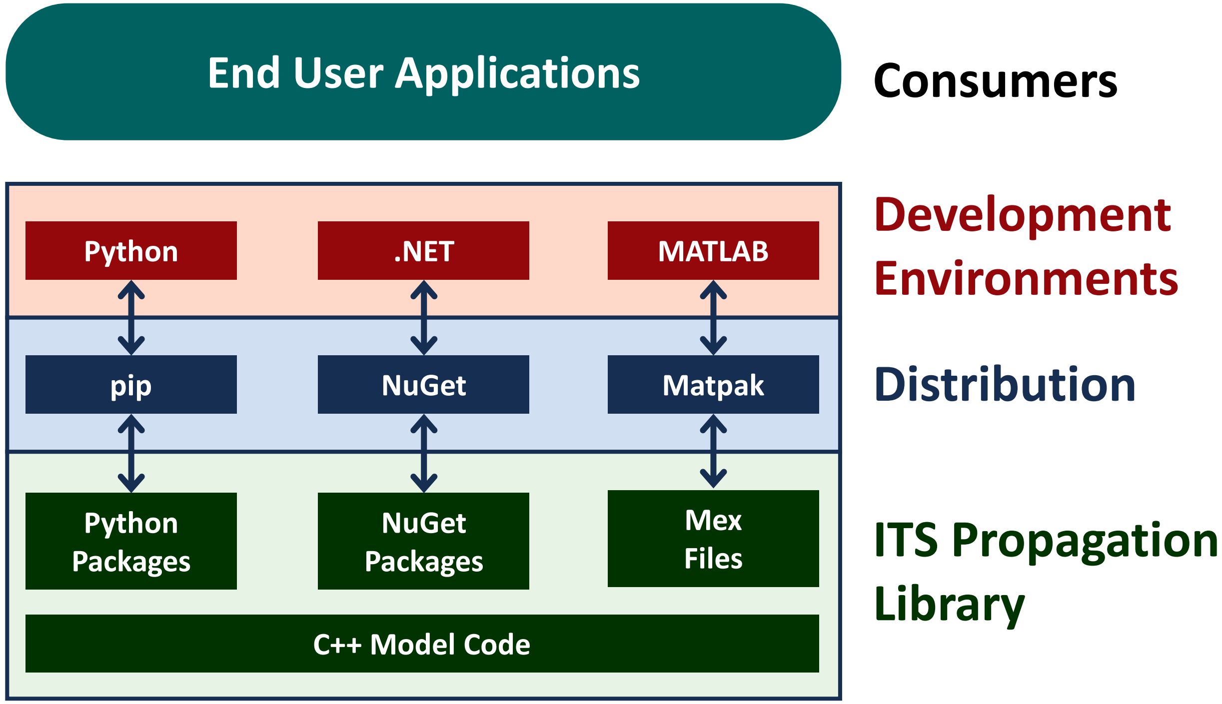
Impact of Clutter

- Clutter can have a significant impact on radio wave propagation
- Losses depend on
  - Structure makeup
  - Vegetation
  - Frequency
  - Elevation
- Sharing analysis results between new commercial cellular systems and incumbent government radars can be strongly influenced by clutter models used



ITS Propagation Library

- Software implementations are a requirement of modern model development
- Open source, cross-platform, and multi-language support
  - Democratization of capabilities
  - Authoritative and trusted source
- Public development with beta releases
- ITS has defined an architectural structure, with a software maturity pipeline
- Will soon start publishing to PyPi and NuGet

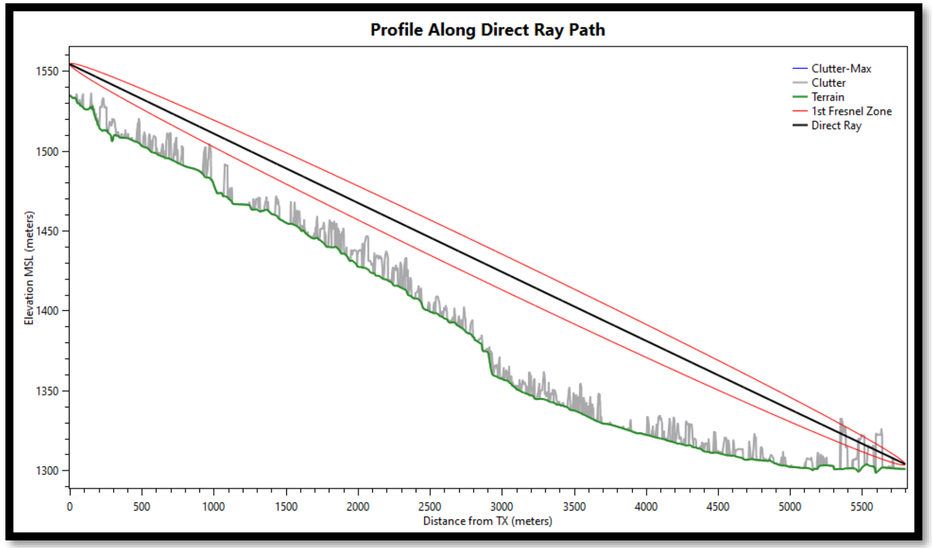


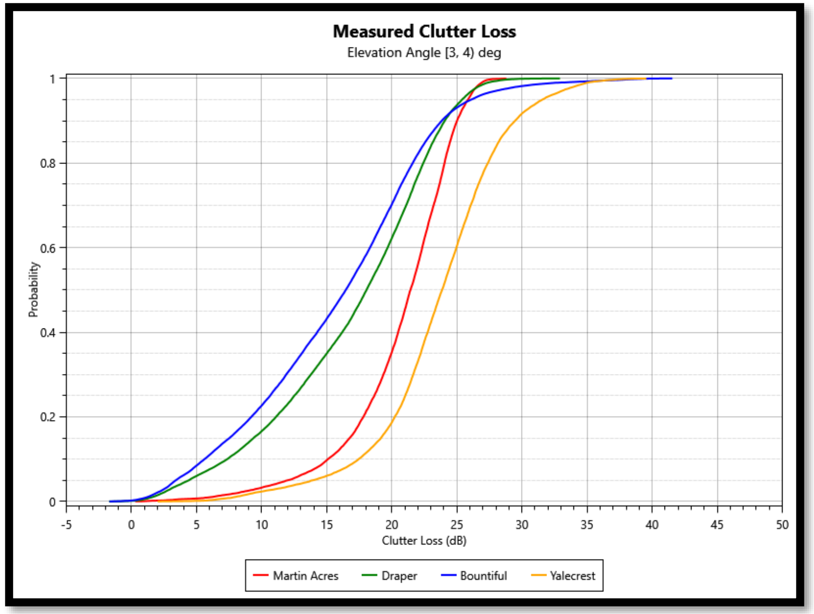
Environmental Data

- Multiple data sources used in clutter models
- Bare earth terrain data
  - Seamless coverage of contiguous U.S. at 1/3 arc-second (~10 meter)
- Land cover / land use
  - Approximately 30 meter resolution
  - Classifies pixels into categories of land use
- Building models
  - Provide 3D geometries of building structures
  - Vector-based data
- Lidar
  - 3D information on structural and vegetative environment
  - Can be post-processed into high resolution raster data (1 meter)

Clutter Modeling

- Variety of ways to construct a clutter model
- Point-to-point (site-specific) methods
  - Use of location specific information (lidar, etc.)
  - Generally, computationally more expensive
- Point-to-area (site-general) methods
  - Statistical prediction results, suitable for Monte Carlo simulations
  - Use clutter categories or statistics
- Examples of clutter models
  - Okumura-Hata
  - Recommendation ITU-R P.2108
  - ITS EuCAP paper





Okumura-Hata Model

- Set of curves for median loss
- Designed for a base station / mobile link
- Corrections for terrain effects
- Classifies environment into three environments: Urban, Suburban, Open (Rural)
- Empirical data from 1960 Tokyo and environs
- Used to predict basic transmission loss

Ref: Okumura, Y., et al, "Field Strength and Its Variability in VHF and UHF Land-Mobile Radio Services," Review of the Electrical Communication Laboratory, Vol 16, No 9-10, Sep-Oct 1968

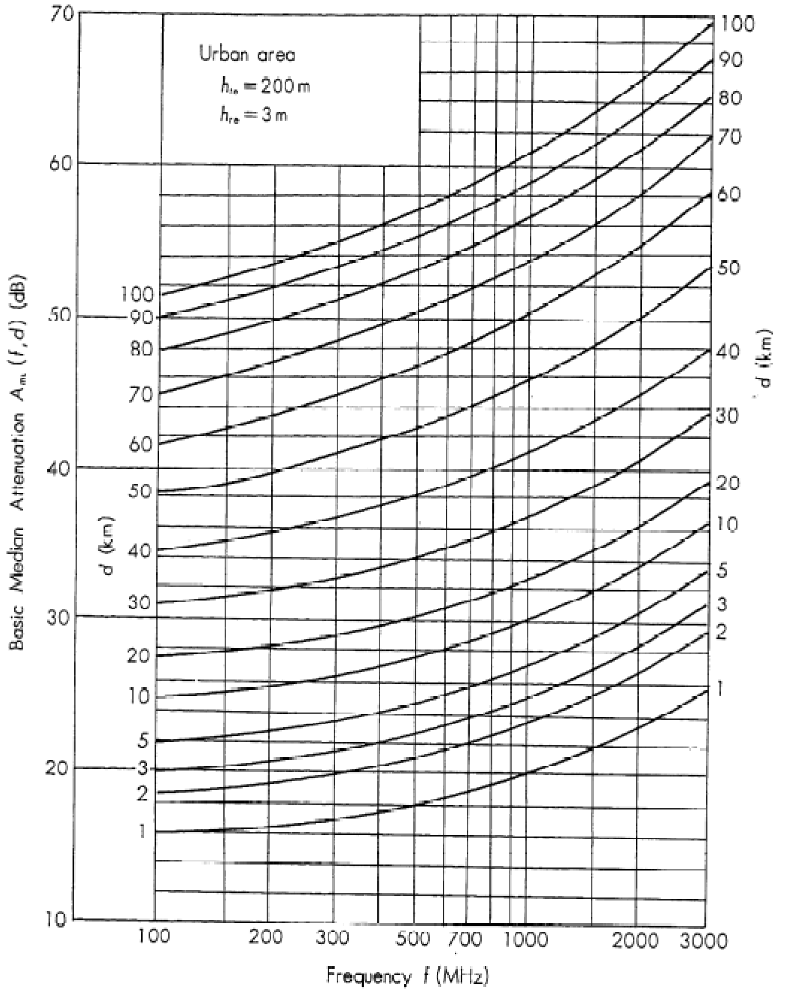


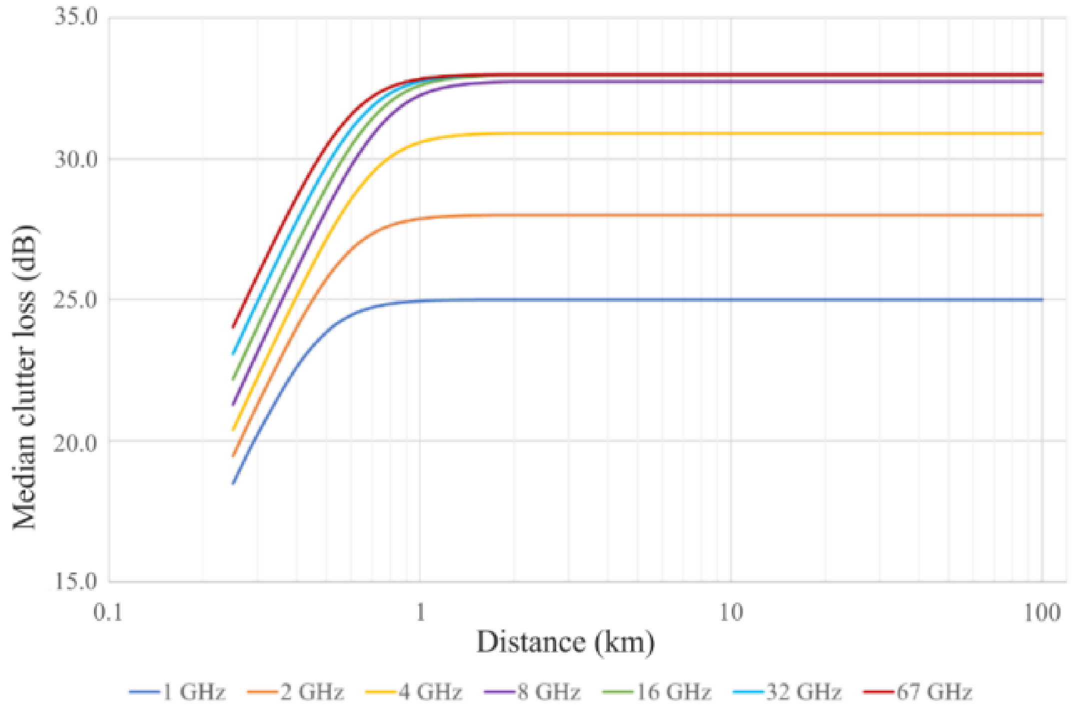
Fig. 15—Prediction curve for basic median attenuation relative to free space in urban area over quasi-smooth terrain, referred to $h_{te} = 200$ m, $h_{re} = 3$ m.

Recommendation ITU-R P.2108, §3.2

- Terrestrial statistical model
- Predicts clutter loss only
- Valid for both ends of a link (min distance)
- No clutter categories — valid for urban and suburban environments
- Assumptions
  - Terminals are well below the clutter
  - Path geometry is approximately horizontal

FIGURE 1

Median clutter loss for terrestrial paths



P.2108-01

Ref: Recommendation ITU-R P.2108, https://www.itu.int/rec/R-REC-P.2108-1-202109-I/en

ITS EuCAP Model

- Models clutter as a slab on top of terrain
- Empirical data from Boulder, CO
  - Suburban neighborhood
  - Two different transmitter heights
- Based on 3D clutter distance, which incorporates elevation angle
- Optimized regression analysis to determine representative height of clutter
- Detailed investigation on following slides …

Ref: Kozma, W, et al, "A Proposed Mid-band Statistical Clutter Propagation Model Utilizing Lidar Data," 17th European Conference on Antennas and Propagation (EuCAP), 2023, https://its.ntia.gov/publications/3367.aspx

ITS EuCAP Model: Formulation

- Clutter loss modeled as,

$$L_c = L_{c,m} + Y_L(p)$$

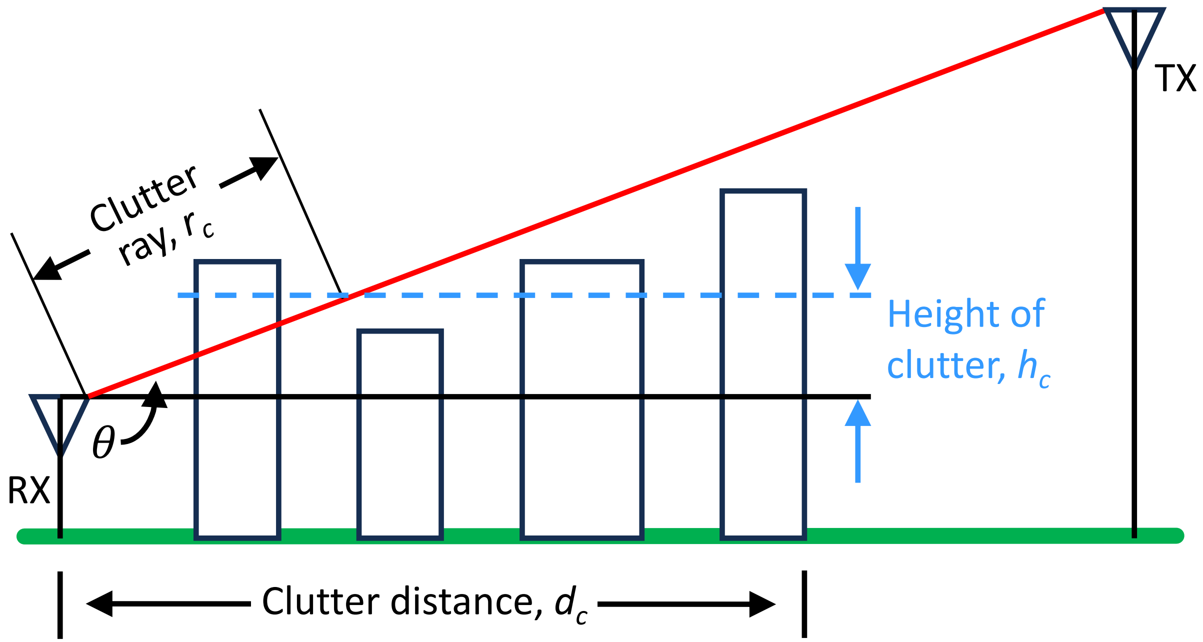
- Median clutter loss, $L_{c,m}$, modeled as,

$$L_{c,m} = a \log_{10} r_c + b$$

with

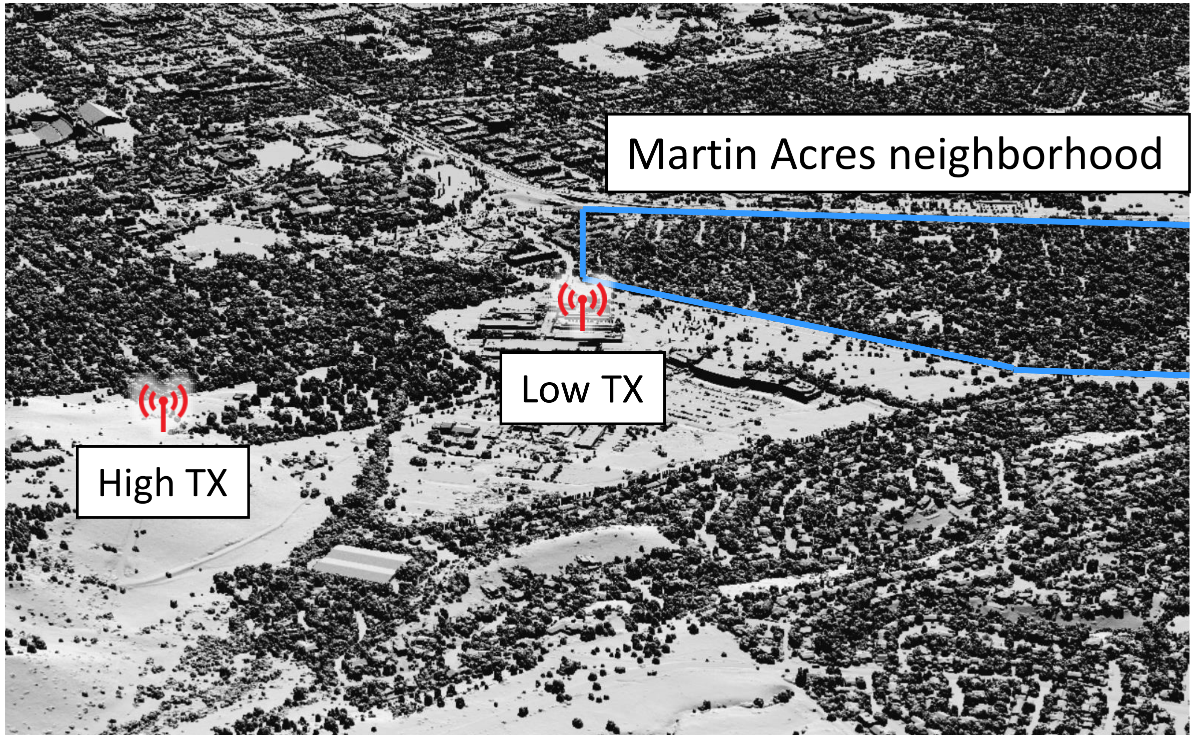
$$r_c = MIN\left(d_c, \frac{h_c}{\sin\theta}\right)$$

- Location variability, $Y_L(p)$, modeled as normal distribution, in dB

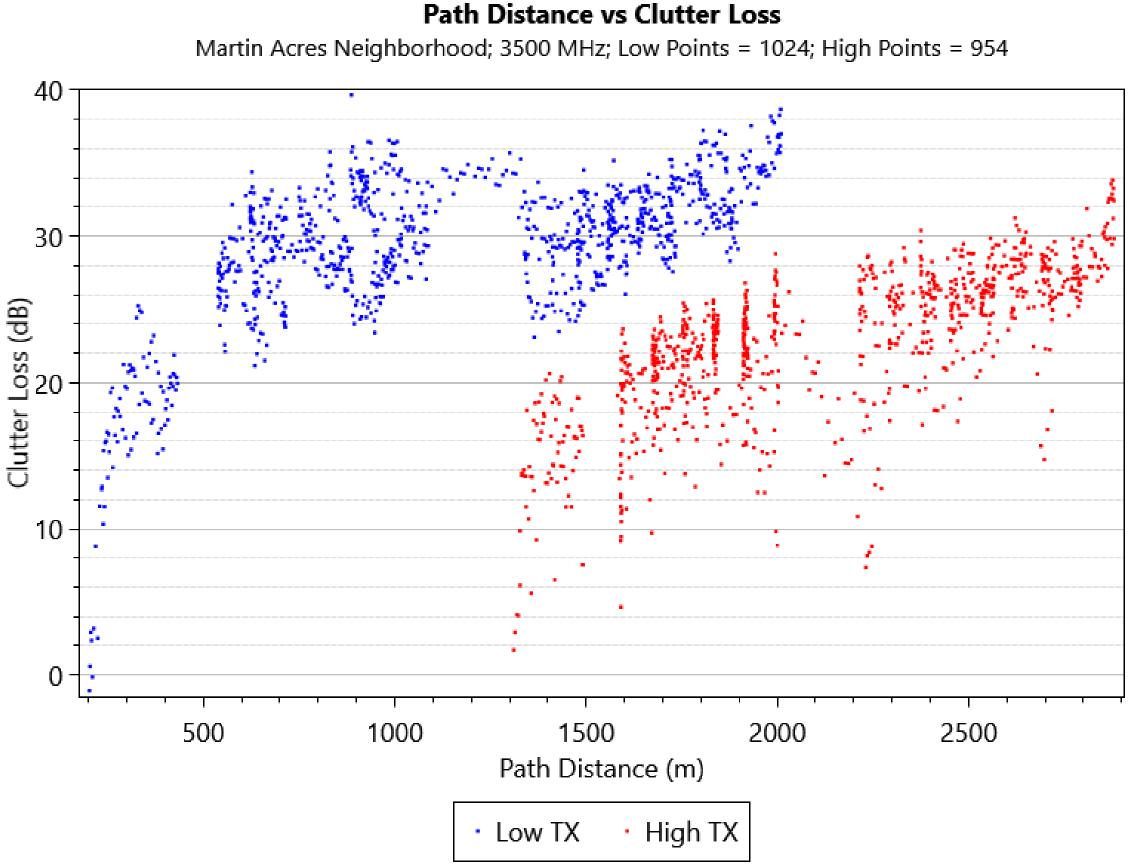


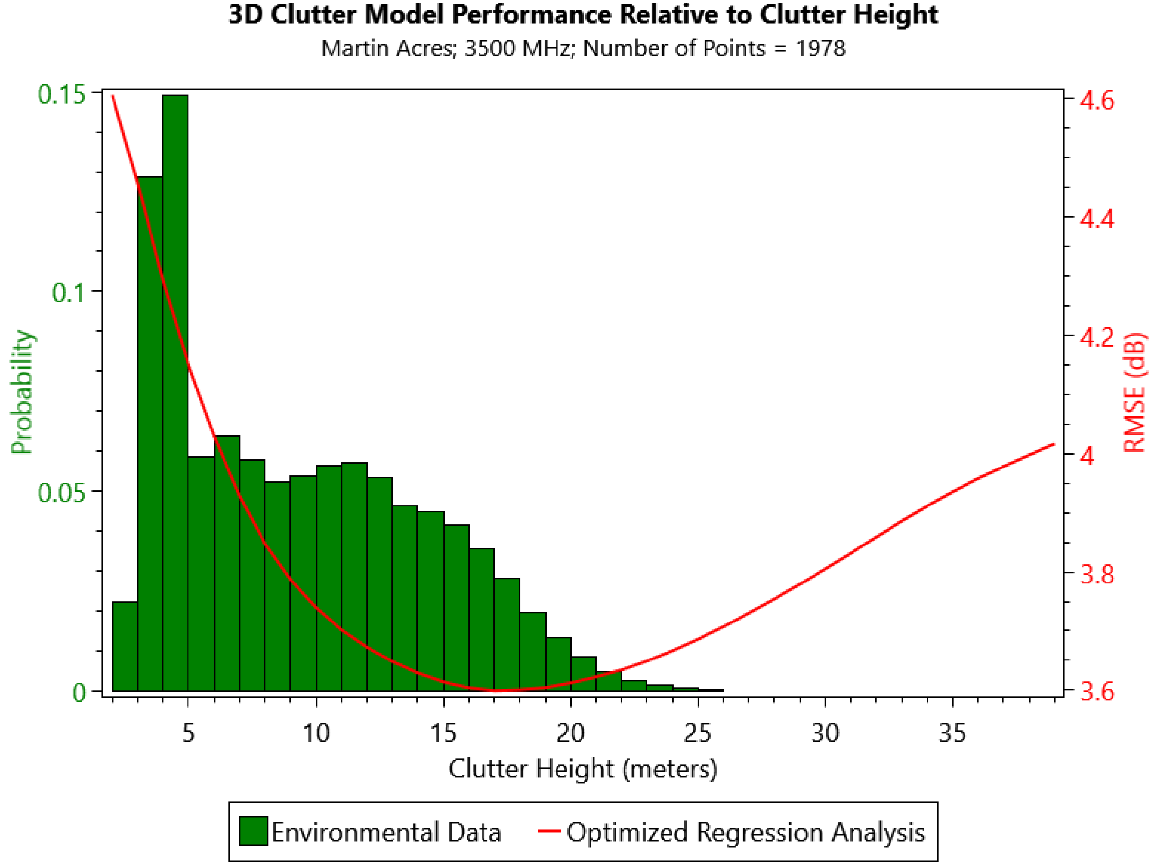
ITS EuCAP Model: Experimental Setup

- Two transmitter locations
  - Low TX: roof of Building 1 Wing 4
  - High TX: atop mesa behind Building 1
- Vertical difference between TXs is ≈140 m
- Receiver was mobile measurement van with roof mounted antenna
- Transmitted CW signal at 3.5 GHz
- Omni-direction antennas
- Clutter environment bounded by Broadway
  - East: clutter
  - West: free space



ITS EuCAP Model: Data Analysis





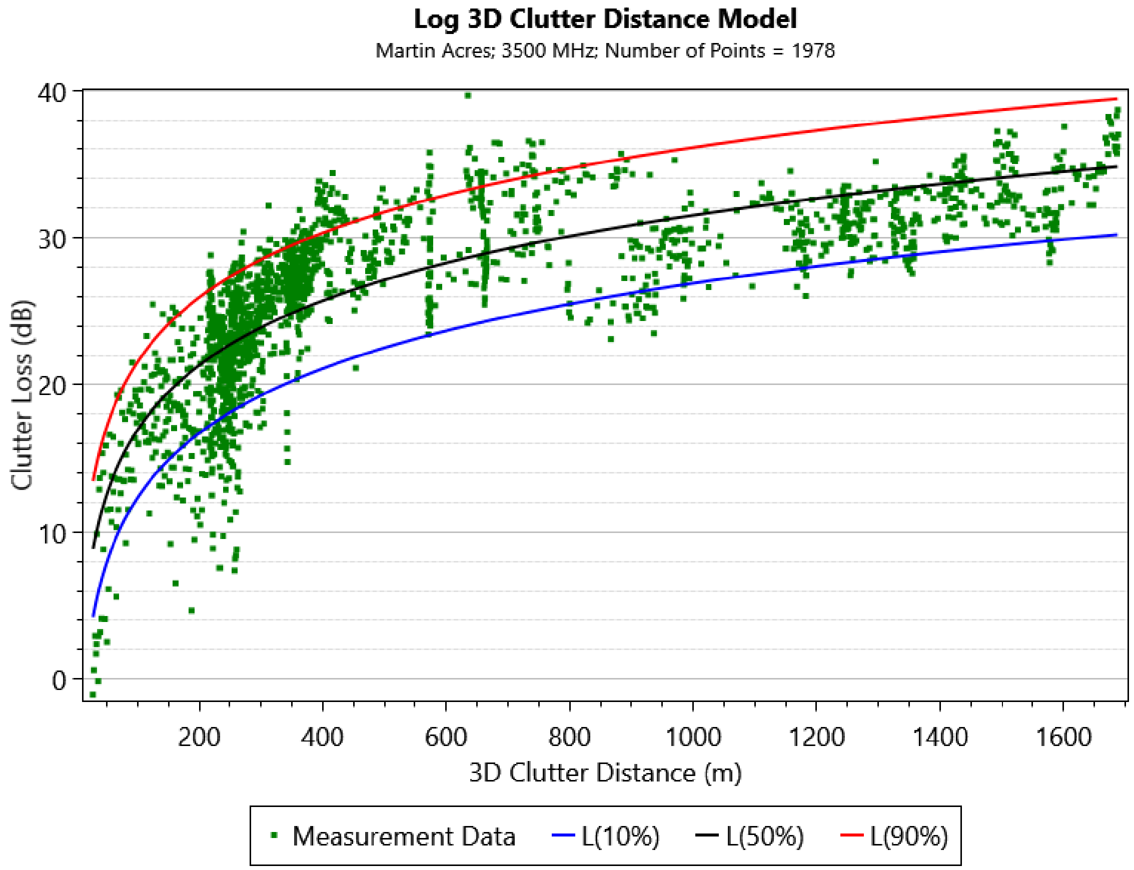
ITS EuCAP Model: Results

- Regression analysis based on 3D clutter distances results in singular point cloud
- Height of clutter $h_c \approx \mu_c + 2\sigma_c$
- Logarithmic fit for median clutter loss

$$L_{c,m} = 14.6 \log_{10} r_c - 12.289$$

- Location variability

$$Y_L(p) = \mathcal{N}(\mu = 0, \sigma = 3.6)$$



Measurement Datasets

- Standardized JSON format
- Basic transmission loss values, along with supporting properties
- Available on GitHub
  - Markdown descriptions of each dataset
  - Downloads via releases
  - Coming soon: https://github.com/NTIA/mid-band-clutter
- Upcoming data releases
  - Summer 2024: 3.1-4.2 GHz
  - Fall 2024: 1.7 GHz
  - Spring 2025: 7-8 GHz


```
{
  "metadata": {
    "SchemaVersion": 1,
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      "RX was Green Van"
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Questions?