






# Propagation Modeling for Statistical Interference Analysis

**Dr. Jeffrey Boksiner**

Chief Engineer, Radio-Frequency Communications Division

Space & Terrestrial Communications Directorate (S&TCD)

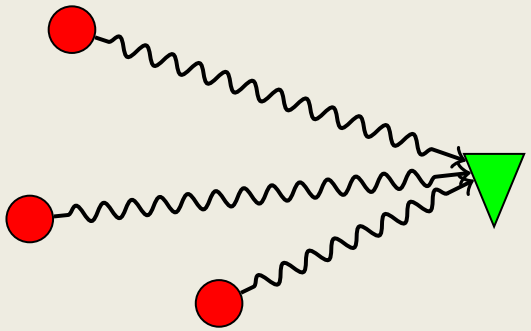
**13 May 2015**

APPROVED FOR PUBLIC RELEASE

# Key Applications for Propagation Modeling

## Interference Analysis

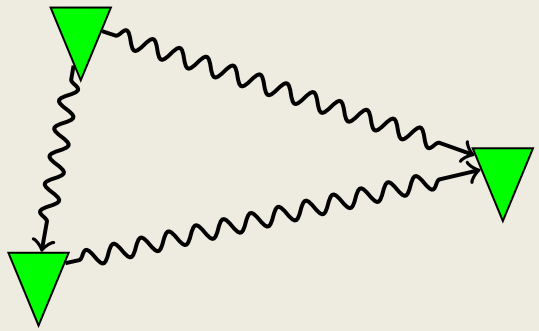
- Compute interfering signal
- Compare to Interference Protection Criteria (IPC)
- Evaluate probability of exceeding IPC with respect to system availability objectives
- Aggregate multiple interferers
  - Potentially wide range of distances and powers



$$p_I = g_r \sum l_i g_i p_i$$

## Network Planning

- Meet range and availability objectives
  - Compute received signal level
  - Determine fading statistics
- Evaluate site-specific receiver performance
  - Predict channel conditions
  - Predict spatial channel model for MIMO

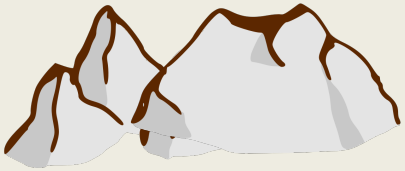


*Focus on computationally-efficient models for ground-ground mobile networks*

# Commonly Used Propagation Models

## Models that predict mean path loss

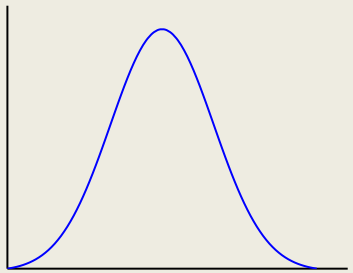
- Rural rough-earth models such as TIREM or ITM
  - Treat sparse diffractions and reflections
  - Do not take into account built structures organically
  - Different models produce diverse results due to differences in approach



- Urban models (e.g. Hata type models)
  - Empirical provenance, not site specific
  - Can be derived by considering regular uniform diffractions
  - Do not take terrain into account organically

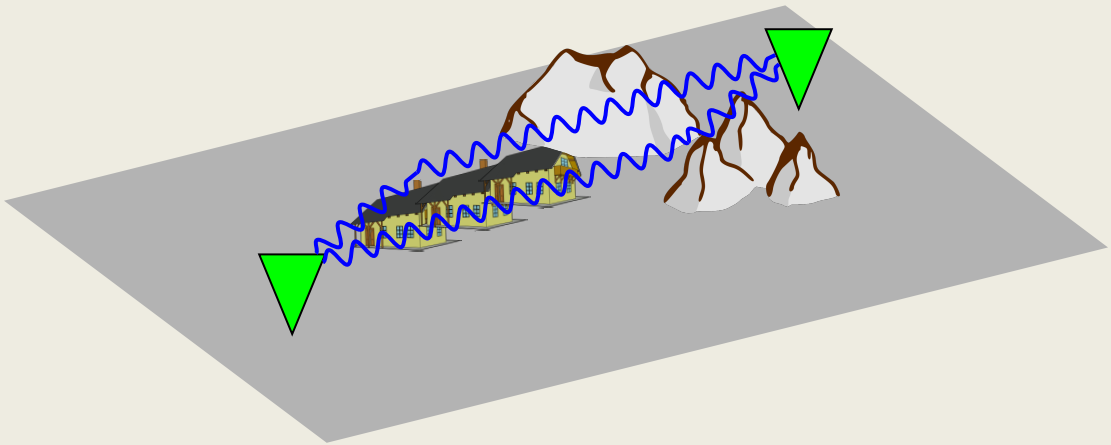
## Fading distributions and channel models

- Mostly reference models based on measured data
- Model selection based on the classification of the environment
- Certain site-specific models provide reliability calculations



# Goal: Integrated Path Loss Model

- Treat terrain features, structures, and land cover organically
- Predict appropriate path loss distribution function based on density of structures
- Predict power delay profile based on available propagation paths
- Consider lateral reflections and scattering

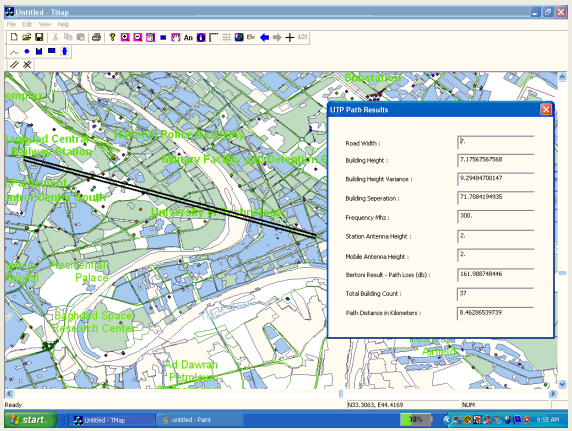


*Recent CERDEC research in propagation modeling provides the basis for development of an integrated model*

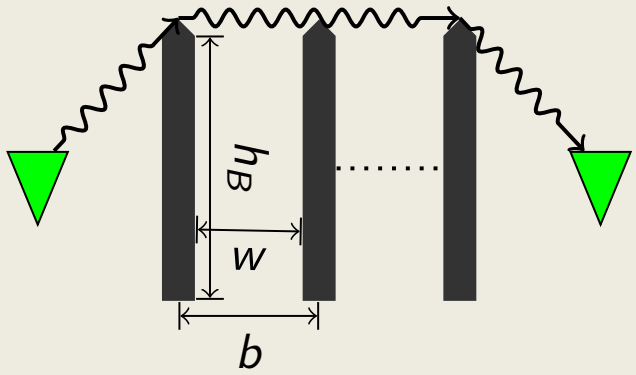
- CERDEC collaborations: NYU Polytechnic, international partners, NTIA ITS

# The Urban Propagation Model (UPM)

- Site-specific urban model
  - A long-range model that predicts the path gain for the vertical plane (VP)
  - A short-range model ($< 1$km) that predicts the path gain for the horizontal plane (HP)
- Characteristics of the urban environment extract from GIS data
  - Average building height, average building separation, average road width and path distance
  - VP contribution dominates for buildings $< 4$ stories
- VP path loss over rooftops
  - Multiple diffractions of passed rows of buildings
  - Diffraction from rooftop fields to ground level

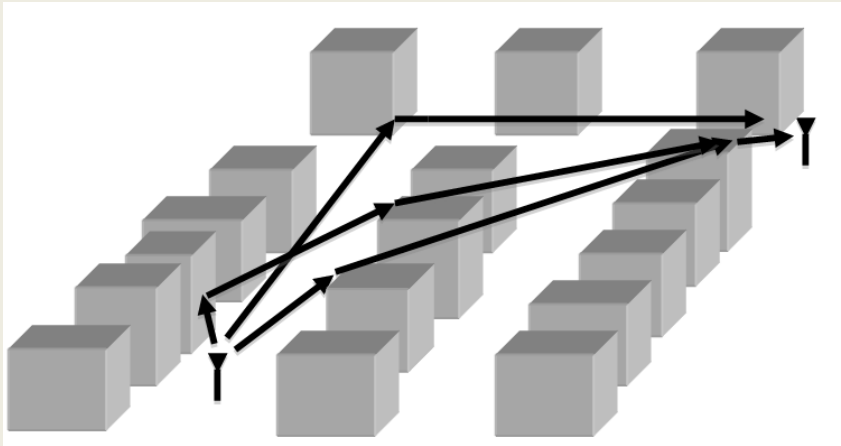



Extract



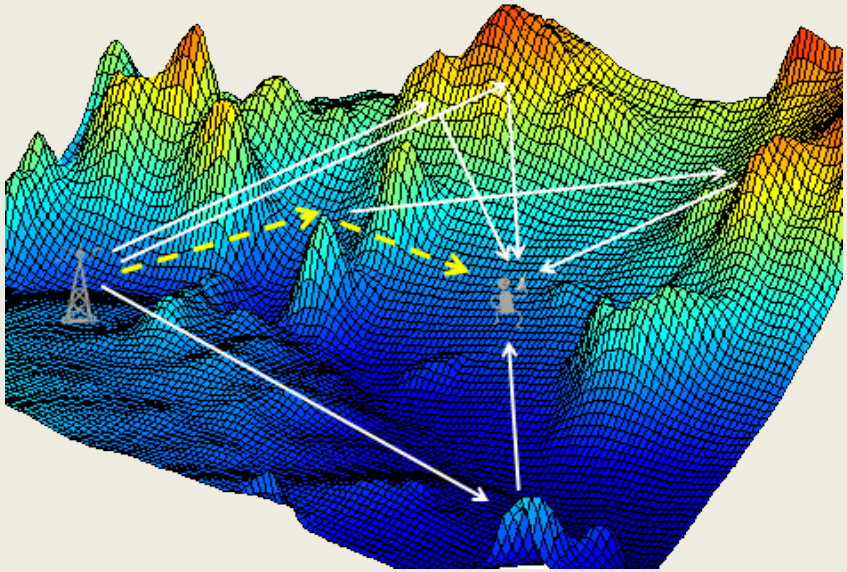
# Urban 3D Model

- Site-specific urban model taking into account multipath
- Propagation approximately divided into
  - Vertical Plane (VP)
  - Horizontal Plane (HP)
- LOS links for mobiles on same street
- For mobiles on different streets – Non-LOS links
  - Observed that HP contribution dominates for buildings $> 5$ stories
  - Observed that VP contribution dominates for buildings $< 4$ stories
- VP and HP each have primary and several types of secondary multipath contributions
- Characteristics of the urban environment extract from GIS data



# Rural 3D Model

- Site-specific rough-earth model taking into account multipath from lateral reflections
- Predicts mean path loss and the power delay profile
- Uses TIREM to compute the contribution in the vertical plane
- Non-specular scattering from terrain elements using
  - Bistatic scattering formula
  - Laberts Law for scattering coefficient
  - Precomputes to identify visible facets
  - Computational time for a single radio link is on the order of milliseconds



# Path to Integrated Model

- Taken initial steps to addresses terrain effects, e.g. hills and inclines, in urban environments
- Consider impact of
  - Earth curvature and surface along the terrain profile
  - Elevations along a terrain profile
  - Angle of incidents
  - Diffraction losses due to edges such as hills
- Needs further validation
- Challenges
  - Fully integrated model will require development of an efficient numerical approach to join sparse and regular diffraction integrals
  - prediction of shadow fading distribution will depend on modeling node positions
  - More measurements are needed for validation

*Development of a fully integrated model is feasible though challenging*

*In the long run, need to make greater use of direct channel estimation*