Propagation Model Development & Comparisons

Outputs

- Comparison of algorithms in ITM and TIREM models.
- Comparison of ITM and TIREM models to various measurement datasets.
- Support of the U.S. Army in propagation model comparisons.

Propagation model development in FY 2003 focused on intercomparison and harmonization of the two radio frequency electromagnetic wave propagation models employed by the U.S. Government, the Irregular Terrain Model (ITM) and the Terrain Integrated Rough Earth Model (TIREM). This work was sponsored by NTIA's Office of Spectrum Management (OSM) and by ITS. In addition, the U.S. Army at Ft. Huachuca, Arizona, sponsored model comparisons against measured data for several propagation models in use by the U.S. Army Information Systems Engineering Command (USAISEC). Progress in each area for FY 2003 is described below.

ITM & TIREM Intercomparison

ITM was developed by ITS, and TIREM by OSM/IITRI. Since both models were based on NBS Technical Note 101,* their propagation prediction algorithms were very similar thirty years ago. ITM has remained virtually unchanged since the mid eighties, but TIREM has undergone many significant changes during the same time period.

In FY 2001, ITS began a project to describe and compare the algorithms used in ITM and TIREM. This work continued in FY 2003. The algorithms for the line-of-sight (LOS), diffraction, and troposcatter regions are being examined, as well as how each model utilizes an effective antenna height for these calculations. The final report will provide a better understanding of these algorithms, propose explanations for why ITM and TIREM produce different answers, and suggest methods for obtaining the same answers with each model which also agree more closely with measured data.

*P.L. Rice, A.G. Longley, K.A. Norton, and A.P. Barsis, "Transmission loss predictions for tropospheric communication circuits," NBS Technical Note 101, vols. 1 & 2, May 1965 (rev. May 1966 and Jan. 1967).

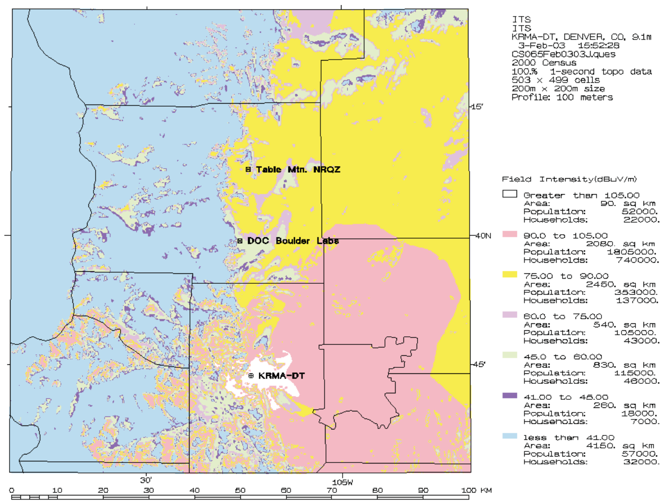
ITM & TIREM Harmonization

The goals of this work are to improve the predictive accuracies of ITM and TIREM, and to reduce or eliminate, where possible, differences between the models' predictions for circuits with equivalent input values, while preserving the increased predictive accuracies. This study was originally begun in FY 2001 to compare ITM v1.2.2 and TIREM v3.14 predictions to several measured radio propagation datasets. The set of measured data consists of over a dozen datasets containing more than 41,000 measurements, which range from 20 to 10,000 MHz. Many types of terrain (plains, hills, mountains, etc.) are included, and a wide variety of antenna heights and polarizations for the transmitter and receiver antennas were used for the measurements. If the data used to develop the empirical model cover all possible propagation situations, then the model should apply as a tool to perform radio-wave propagation predictions along any path. However, there are propagation scenarios not contained in this database.

Difficulties arose when the results of two previous comparison studies were examined. The two studies considered data from datasets with substantial commonality and found comparable mean and variance statistics for the models' prediction errors. Furthermore, there was evidence that the measurements and predictions, and, hence, the prediction errors, were subject to significant correlation. Computation of meaningful statistics in the presence of correlated data was a major problem encountered in this study.

Initial results from the study demonstrate that there is substantial correlation in the data and the statistics are significantly affected by it. This correlation is due to many of the measurements having been made at multiple frequencies and antenna heights on the same path. When propagation conditions for the measurements and hence predictions were found to be good or bad for a particular path, they were good or bad for all frequencies and heights along the path. Univariate statistical analysis of the data relies on data samples in which the individual measurements have been randomly drawn from a large universe of radio-wave propagation measurements. These samples should be independent and have identical frequency distribution. When the data samples are correlated, this independence assumption is violated.

ITS has proposed and tested a mechanism for dealing with this data correlation. The measurements on one path are considered independent of those taken on another path. The excess loss relative to free space predicted by ITM is compared to the measured data, and the difference is used as the statistical random variable. By segregating the data so that it is taken from different paths, a multivariate statistical analysis can proceed. This enables testing the significance of the distribution of the means, medians, and standard deviations of the difference between model loss predictions and measured data.



ITM prediction (using USGS 1 arcsec terrain data) of field strength for proposed digital TV broadcast antenna on Lookout Mountain near Golden, CO.

Effective Antenna Height Study

Transmitter and receiver effective antenna heights above the dominant reflecting plane are computed by an algorithm within ITM. The effective antenna heights along the propagation path are determined from the terrain contour, structural antenna heights above ground level, and distance to horizon from each antenna. ITM uses effective antenna heights except when computing horizon elevation angles, distances to horizons, and Fresnel zone clearances, while TIREM uses structural heights exclusively. This difference has a significant impact on propagation loss predictions. Thus, the correct value of reference attenuation depends on the values of effective antenna height. Effective antenna height changes the predicted propagation loss by as much as 45 dB relative to predictions using only a structural height.

An investigation was performed to determine the behavior and dependency of ITM propagation loss predictions as a function of effective antenna heights. ITM was used to make propagation loss predictions for most propagation paths in the measured data. In one case, the ITM effective antenna height algorithm was used to select the effective antenna height. In a second case, the effective antenna height was fixed at the structural height. The predicted and measured values of propagation loss were compared for both cases. The loss deviation is the predicted value of attenuation from the model minus the measured value of attenuation.

The comparison of ITM predictions to measured data has generated several different behavior characteristics related to this internal computation of effective antenna height. This information will provide guidance in selecting an improved effective antenna height computation. In some cases, ITM computes a large effective antenna height that differs substantially from the structural height, resulting in a large deviation between the value of predicted and measured transmission loss. There are cases where, if the effective antenna height were made equal to the structural height, then the deviation could be reduced. However, in many cases, the deviation resulting from measured paths using the structural height is much larger than the deviation for the measured paths using the effective height. There are also many measured paths where the optimum value of effective antenna height is somewhere between the ITM-determined effective antenna height and the actual structural antenna height. The effective antenna height is always greater than or equal to the structural height. Further study of the behavior of ITM in different scenarios will provide information for the development of a new effective antenna height algorithm that minimizes the deviation between predicted and measured propagation loss.

Recent Publication

N. DeMinco and P. M. McKenna, "Evaluation and comparative analysis of radio-wave propagation model predictions and measurements," *Applied Computational Electromagnetics Society Symposium Digest*, vol. X, Mar. 2003.

For more information, contact:
Paul M. McKenna
(303) 497-3474
e-mail pmckenna@its.bldrdoc.gov