Hybrid Propagation Models for Broadcast Coverage Predictions and Spectrum Management

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Outline for Part 1

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Introduction

- ITU-R Working Party 3K and its Sub-Group 3K-1 have been working for many years to identify a suitable path-specific propagation prediction method and to develop a Preliminary Draft New ITU-R Recommendation (PDNR) on the method;
- A Correspondence Group has been formed to collect test data and to evaluate several candidate methods;
- Present work is part of this effort.
Introduction

- It has been proposed that a modular framework be adopted for the new model, for ease of collaborative development and incremental modification and extension. A structure similar to that of Recommendation ITU-R P.452 may, initially, be appropriate.

- A possible breakdown of model elements might be:
  - Diffraction – is the only element of concern here
  - Lower-troposphere variability (e.g. ducting)
  - Troposscatter
  - Combination of processes.
Objective

- To test the prediction capability of several methods for the estimation of the excess path loss due to irregular terrain using the ITU-R Correspondence Group 3K-1 (EBU, HTI) and ITS data banks of VHF/UHF measurements;
- Display difficulties with variants of conventional prediction methods and propose partial solutions.
Experimental Data: HTI

- HTI measurements have been performed using the OFCOM measurement car, equipped with a height-adjustable telescopic mast (up to 11 m in height) that support a Yagi antenna, being able to automatically measure the field strength versus height or azimuth;

- Hardware features and transmitter data (frequency, coordinates, antenna radiation pattern, radiated power, etc.) are stored by the measurement computer, allowing exact conversion of the received signal into field strength;
The measurement sites have been selected to avoid effects that are not considered in prediction models, such as attenuation due to vegetation, or short and near obstacles. For obtaining only a dominant reflection, which produces a clear height function, sites with flat terrain near the receiver in direction of the transmitter have been chosen.

Path profiles have been determined from the Digital Elevation Model for Switzerland, with resolution of 50 m.
Experimental Data: HTI

Profile from S. Chrischona (Tx) to Frienisberg (Rx), showing 2 obstacles

Height function measured at Frienisberg
Experimental Data: HTI

Average values of errors (HTI implementation)

Standard deviations of errors (HTI implementation)
Experimental Data: HTI

Average values of errors
(L&S Telcom implementation)

Standard deviations of errors
(L&S Telcom implementation)
Experimental Data: CG 3K-1 and ITS

- VHF/UHF field strength measurements will be treated as if they were performed at a single height;
- Combined with corresponding information (ERP, frequency, terrain profile, etc.), they have been incorporated into the ITU-R Correspondence Group 3K-1 and ITS data bases relating to terrestrial broadcasting.
- 9628 VHF and UHF links in different countries in Europe (EBU, HTI) and in the USA (ITS phases 1 and 2) have been selected for our tests.
Experimental Data – CG 3K-1 and ITS
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Experimental Data – CG 3K-1 and ITS
The following prediction methods have been applied to the CG 3K-1/ITS:

- Conventional methods (Bullington, Deygout, Epstein-Peterson) – the present versions assume knife-edge main obstacles and corrections for their longitudinal extents and for sub-path structures;

- Multiple knife-edge method of Recommendation ITU-R P.526-9;

- Longley-Rice method (ITM/ITS – downloaded from http://www.its.bldrdoc.gov/software and incorporated with only a few i/o changes).
Prediction Methods: sub-path models

- Knife-edge obstacle if obstructed fraction of Fresnel ellipsoid for the sub-path is small;
- Plane Earth if obstructed fraction of Fresnel ellipsoid for the sub-path is large;
- Linear interpolation between the two predicted values otherwise.
Prediction Methods: sub-path models

- Knife-edge
- Obstacle
- Equivalent Plane Earth
Prediction Methods: sub-path models
Prediction Methods: sub-path models

\[ y = -8.9330 \times 10^{-3} x^2 - 2.3691 \times 10^{-1} x + 8.0918 \times 10^0 \]

\[ R^2 = 4.4654 \times 10^{-1} \]
Prediction Methods: sub-path models

- Additional polynomial corrections are applied to classes of links characterized by the number of main obstacles (zero to 5 and more than five) and by the presence (or absence) of sub-path structures within the Fresnel ellipsoids for the sub-paths;
- Correction for errors due to the sub-path model and to the longitudinal extents of main obstacles.
Prediction Methods: sub-path models

![Graph showing sub-path correction by model (dB)]

The graph depicts the error in dB against sub-path correction by model in dB. The equation is:

\[ y = -1.0560 \times 10^{-6}x^2 + 1.5225 \times 10^{-3}x - 8.3700 \times 10^{-2} \]

The coefficient of determination, \( R^2 \), is calculated as:

\[ R^2 = 4.1258 \times 10^{-6} \]
Results from the CG 3K-1/ITS links – all links

Average Error [dB]

Number of Obstacles
Results from the CG 3K-1/ITS links – all links

<table>
<thead>
<tr>
<th>Number of Obstacles</th>
<th>Multiple Knife-Edge</th>
<th>Epstein-Peterson</th>
<th>Deygout</th>
<th>Bullington</th>
<th>Longley-Rice</th>
<th>Deygout C</th>
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# Results from the CG 3K-1/ITS links – results from different data bases

<table>
<thead>
<tr>
<th>Data Base</th>
<th>Number</th>
<th>Average (dB)</th>
<th>Standard Deviation (dB)</th>
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<tbody>
<tr>
<td>ALL</td>
<td>9628</td>
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<td>EBU</td>
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<td>HTI</td>
<td>435</td>
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Conclusion

- Present implementations of several methods with corrections for sub-path effects yielded average values for the received field intensity that were 2 dB to 8 dB stronger than the corresponding measurements and with standard deviations from 12 dB to 15 dB.

- Additional polynomial corrections applied to the Deygout and Bullington models eliminated the average error and decreased the standard deviations to 10 dB.

- **Standard deviations of errors are still large!**
Experimental Data: HTI

CDF of errors by different models implemented by HTI using profiles with 2 obstacles

CDF of errors by different models implemented by L&S Telcom using profiles with 2 obstacles
Experimental Data: HTI

- Small errors in the terrain profile could lead to large errors in field strength predictions;
- Different implementations of the same model could lead to different prediction results;
- For this particular data set, the Bullington and the L&S Telcom models give the best results in terms of mean values and standard deviations.
Results from the CG 3K-1/ITS links – links without sub-path structures

Average Error [dB] vs. Number of Obstacles

- Multiple Knife-Edge
- Epstein-Peterson
- Bullington
- Longley-Rice
- Deygout
- Deygout C

Number of Obstacles: 0, 1, 2, 3, 4, 5

Errors range from -25 to 15 dB.
Results from the CG 3K-1/ITS links – links without sub-path structures

![Graph showing standard deviation in dB for different models under various number of obstacles.](image-url)
Results from the CG 3K-1/ITS links – links with sub-path structures

![Average Error vs Number of Obstacles]
Results from the CG 3K-1/ITS links – links with sub-path structures

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