Hybrid Propagation Models for Broadcast Coverage Predictions and Spectrum Management

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Outline for Part 1

○ Introduction

○ Objective

○ Experimental Data

    ○ HTI

    ○ CG 3K-1 and ITS

○ Prediction Methods

○ Results

○ Conclusion

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)
  ◦ Troposcatter
  ◦ 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.
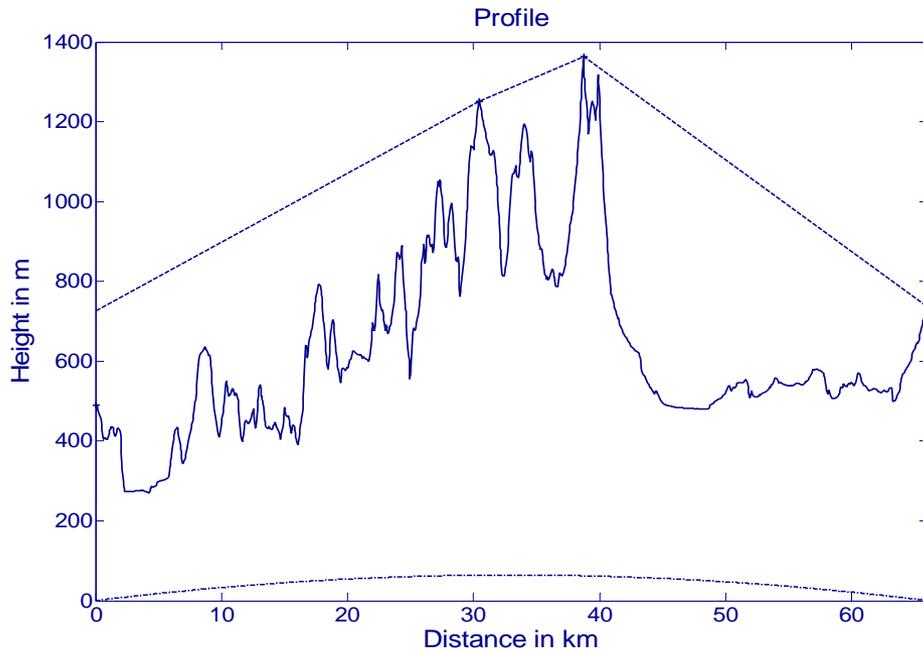
Experimental Data: HTI

◦ 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;

Experimental Data: HTI

◯ 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
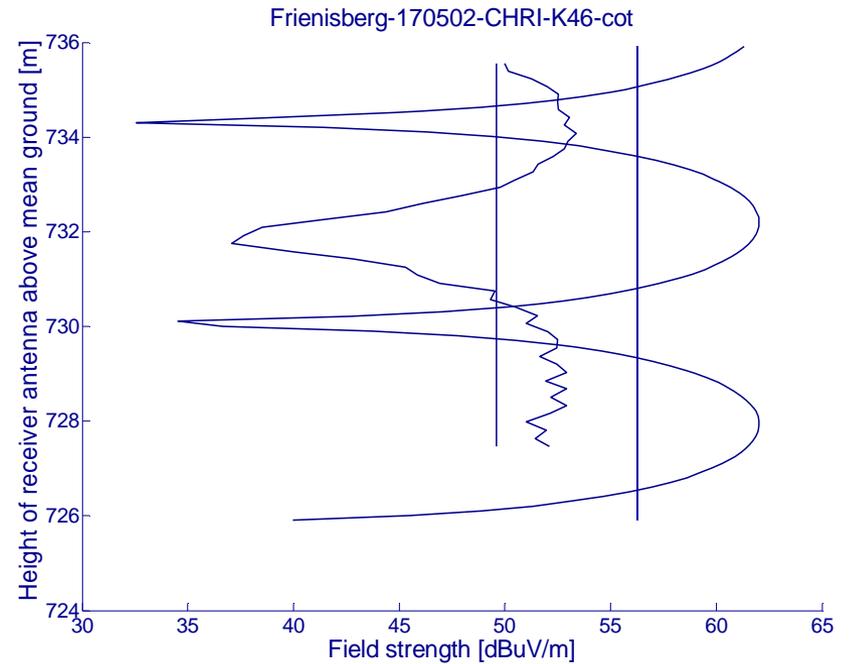
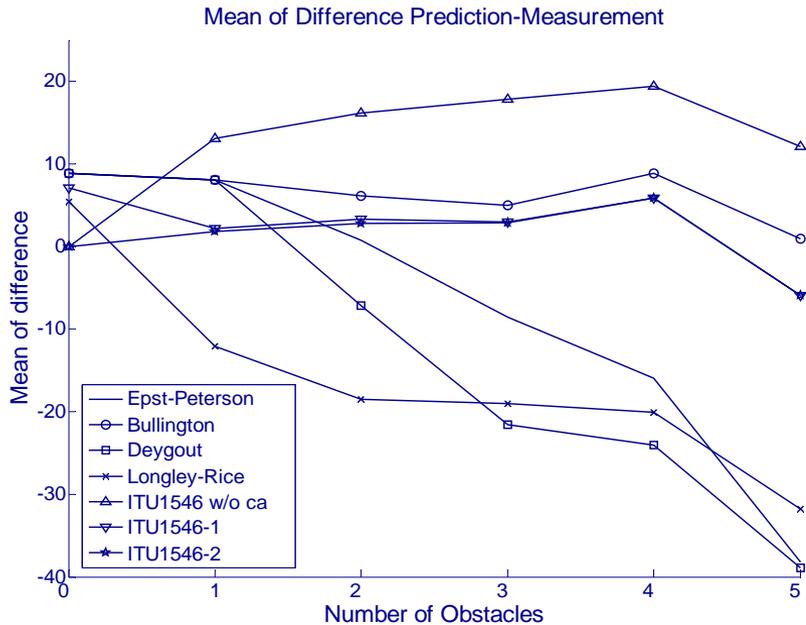
Height function measured at Frienisberg
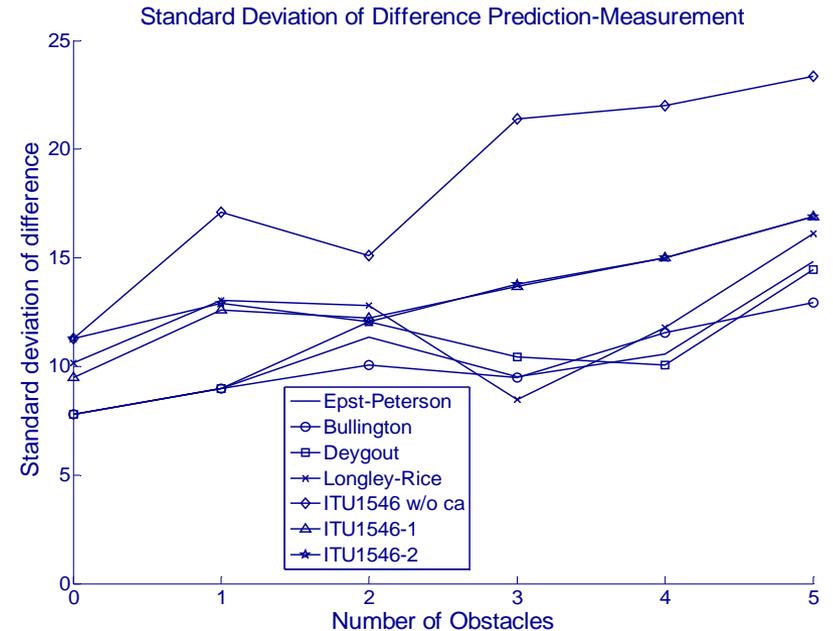
Experimental Data: HTI

Chart showing CDF vs Gradient [dB/m]. The x-axis "Gradient [dB/m]" ranges from 0 to 60. The y-axis "CDF" ranges from 0.0 to 1.0.
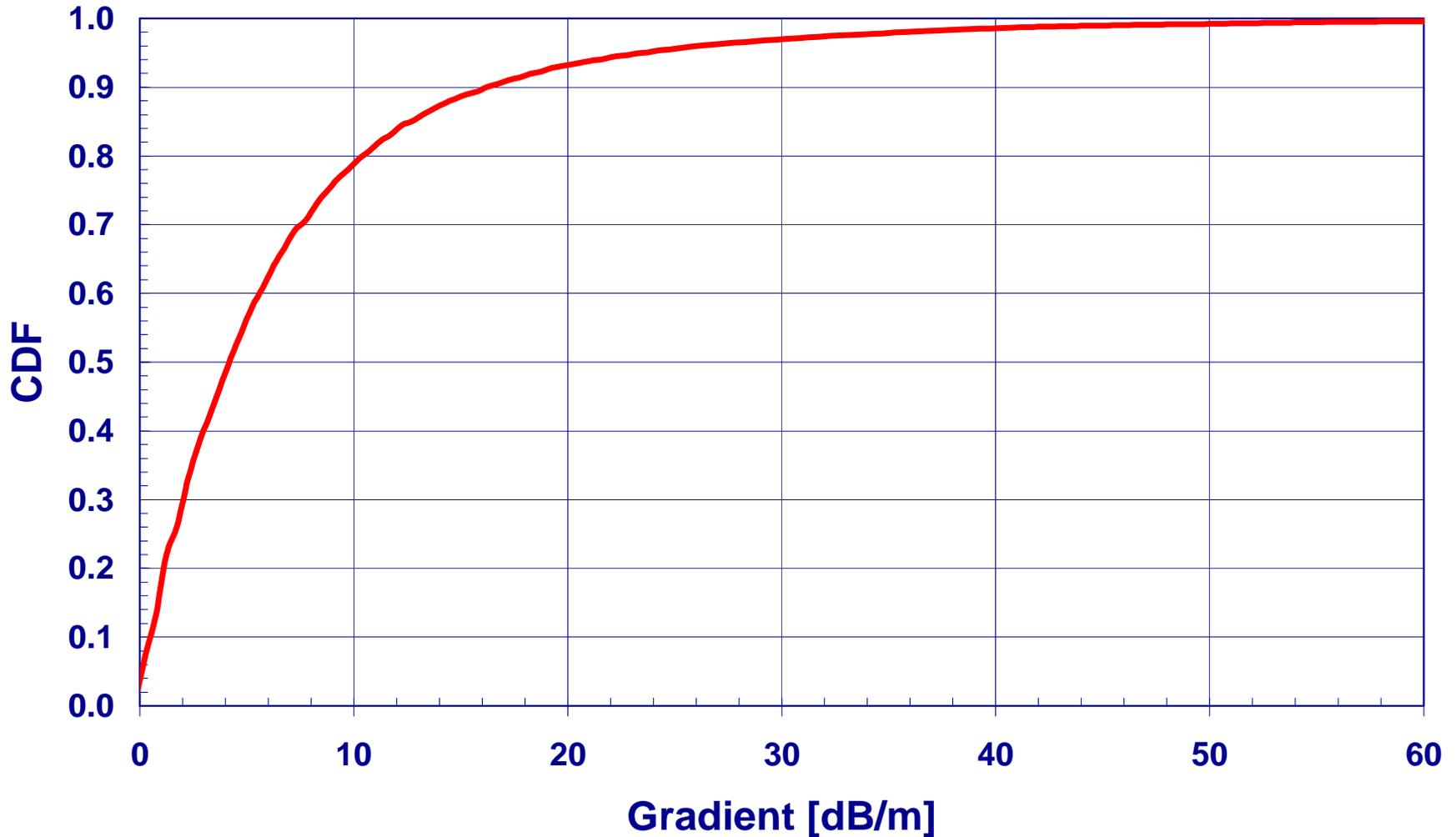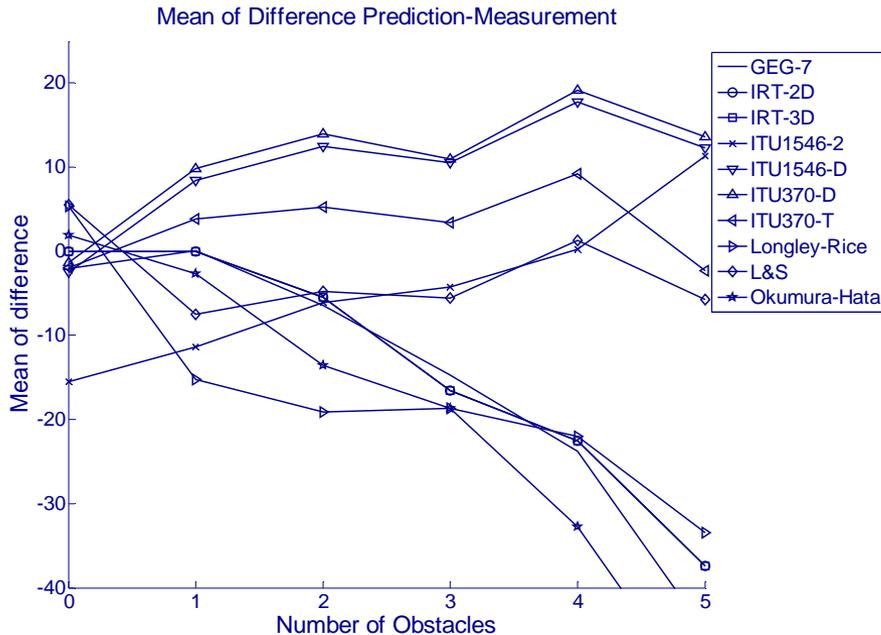
Experimental Data: HTI

Average values of errors
(HTI implementation)

Standard deviations of errors
(HTI implementation)

Experimental Data: HTI

Mean of Difference Prediction-Measurement

Average values of errors
(L&S Telcom implementation)
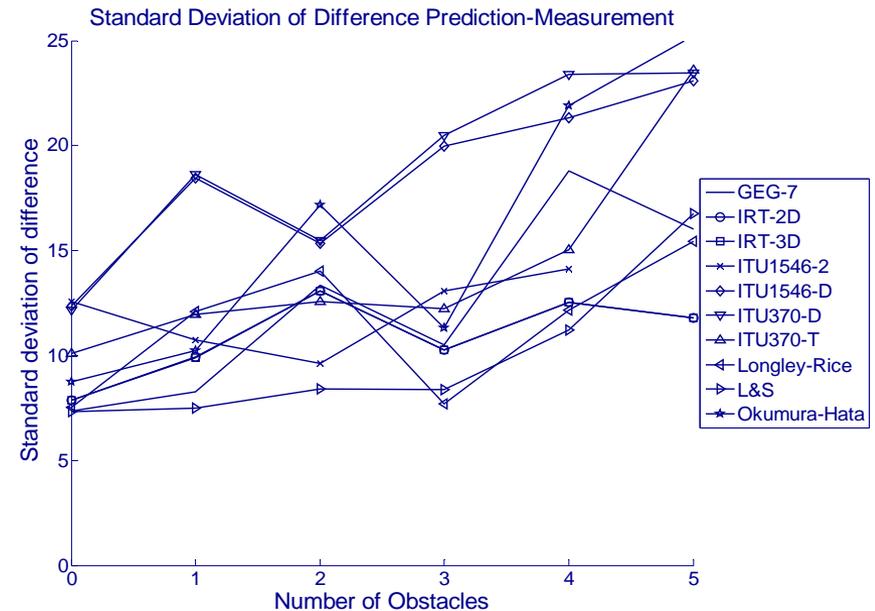
Standard deviations of errors
(L&S Telcom implementation)

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.
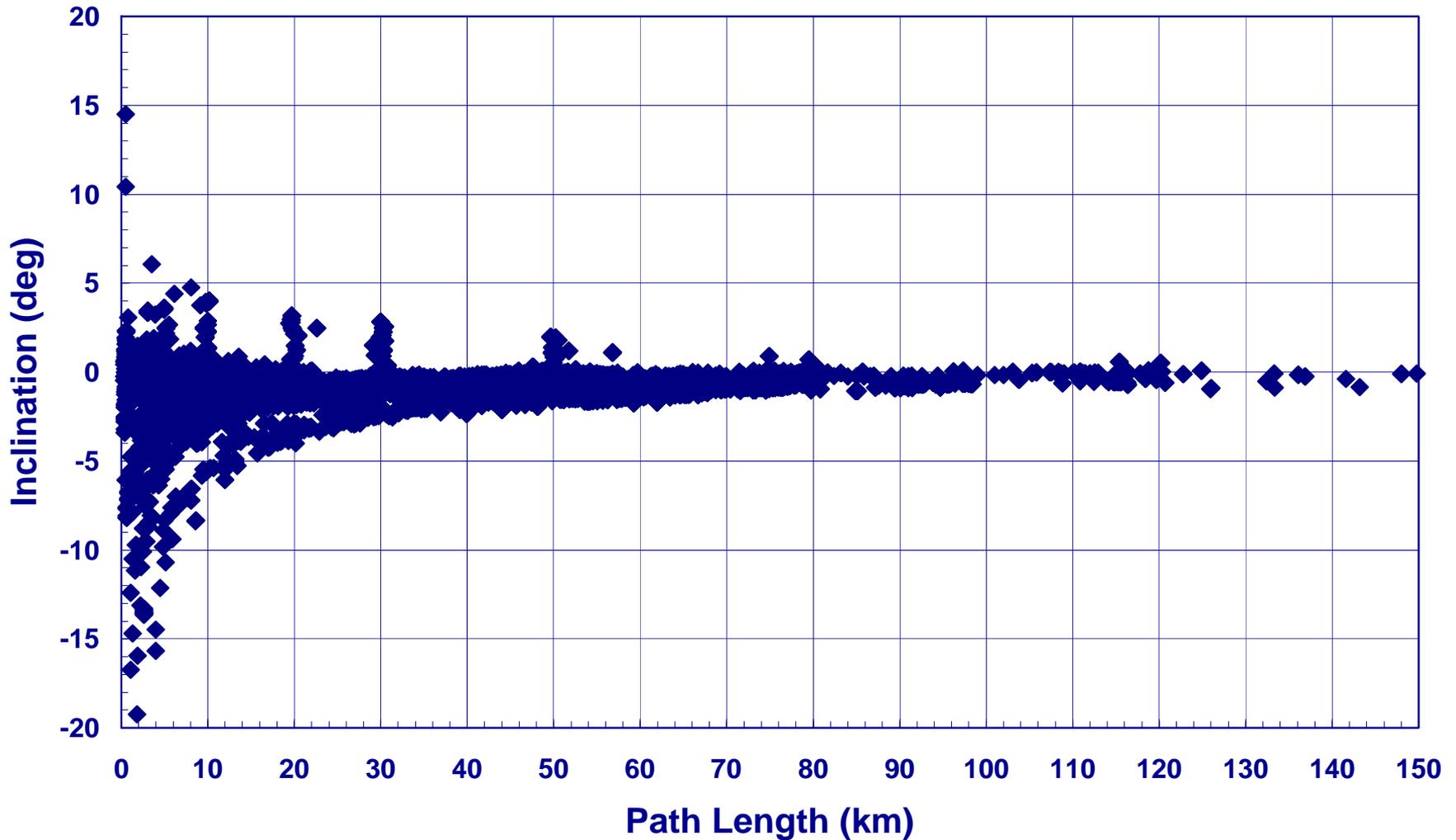
Experimental Data – CG 3K-1 and ITS
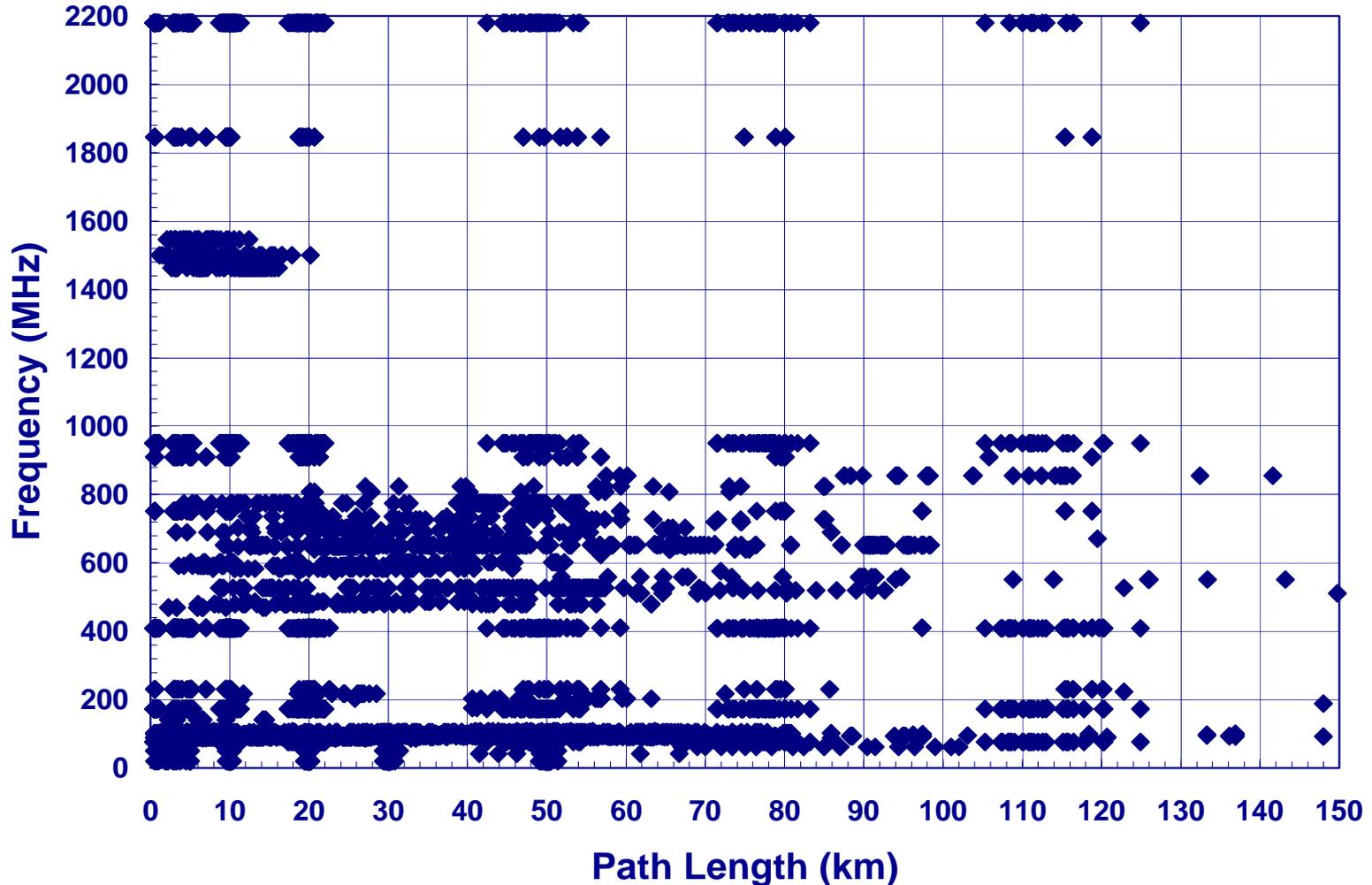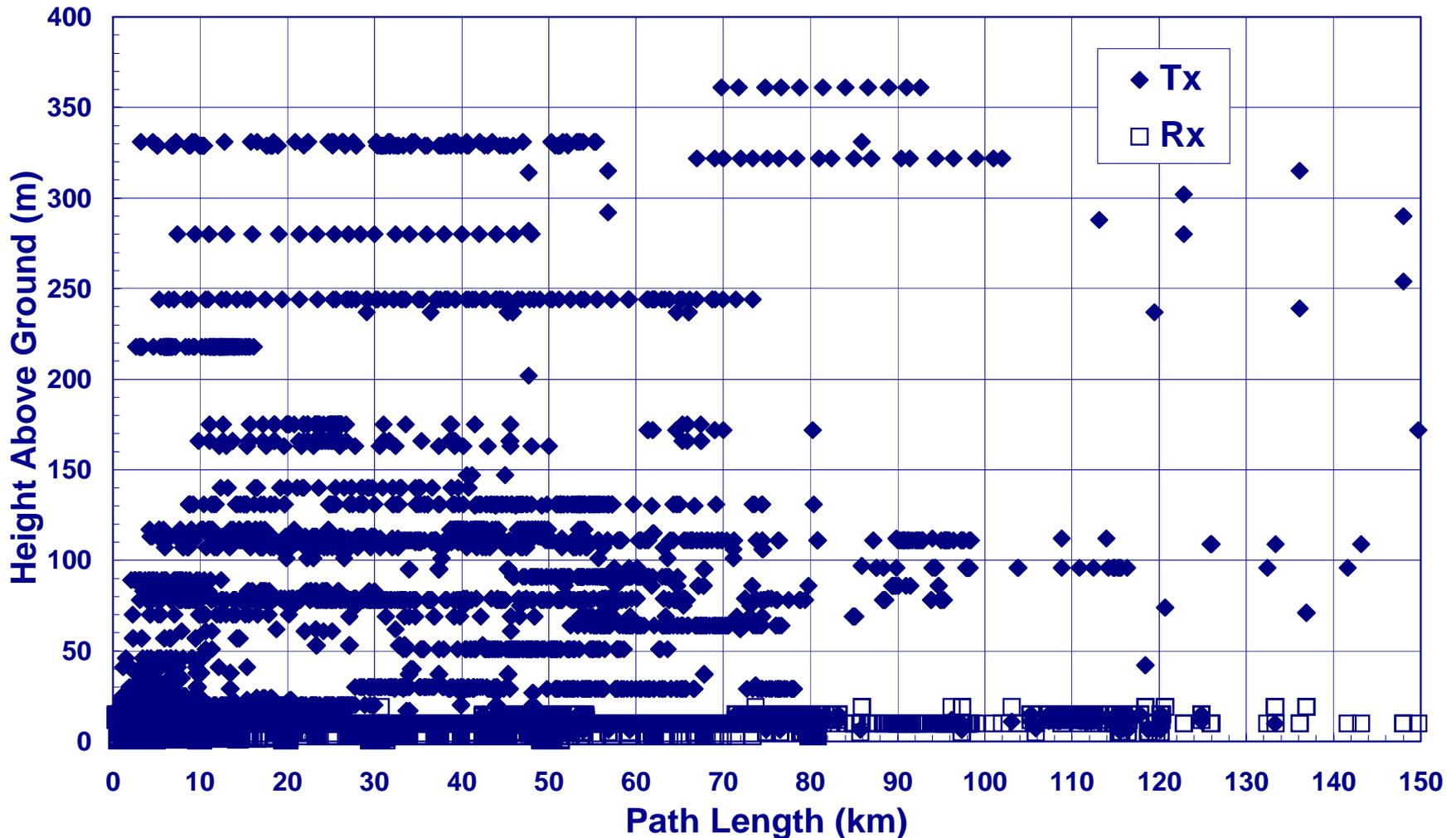
Experimental Data – CG 3K-1 and ITS

Experimental Data – CG 3K-1 and ITS

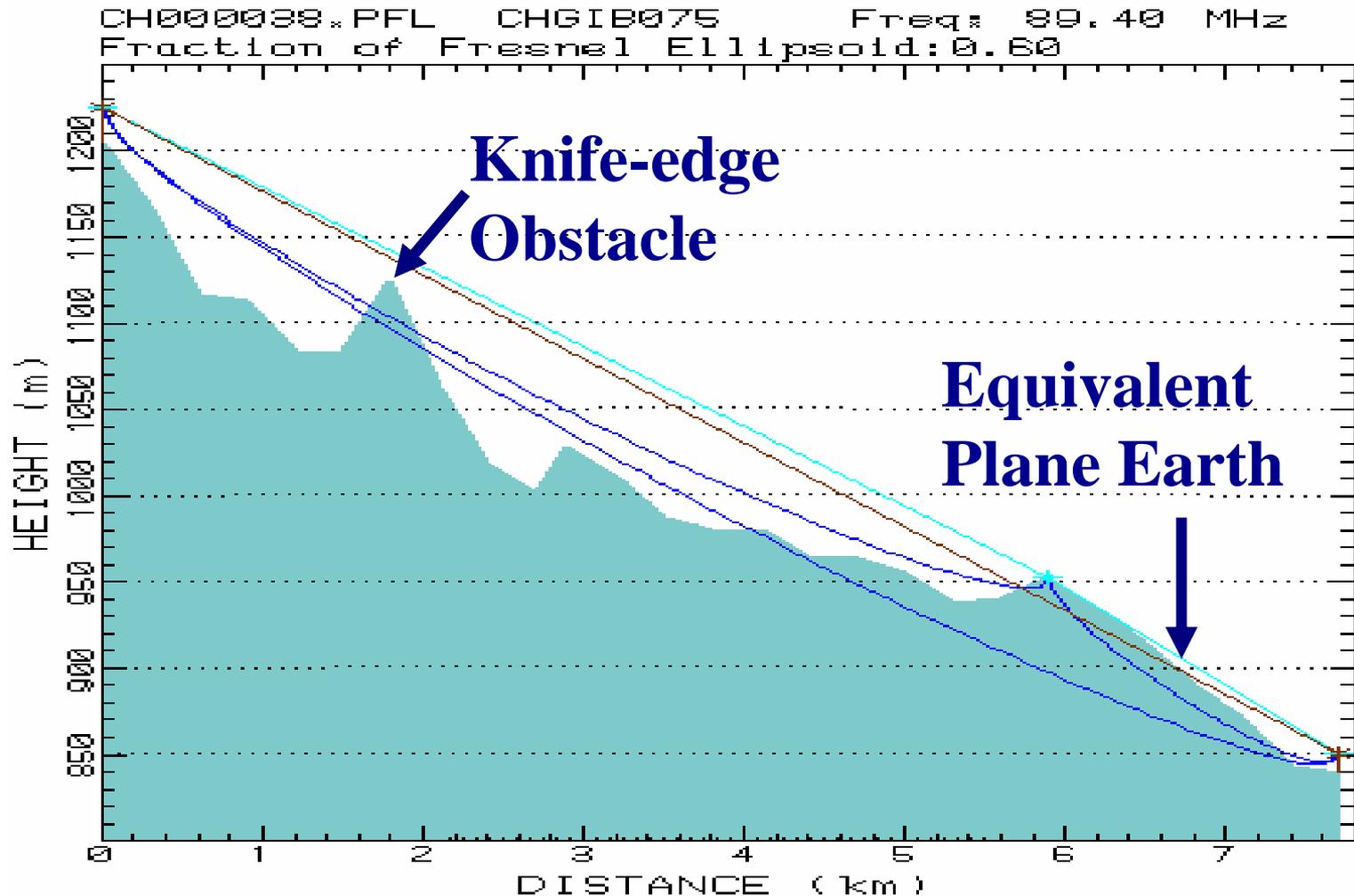# Experimental Data – CG 3K-1 and ITS
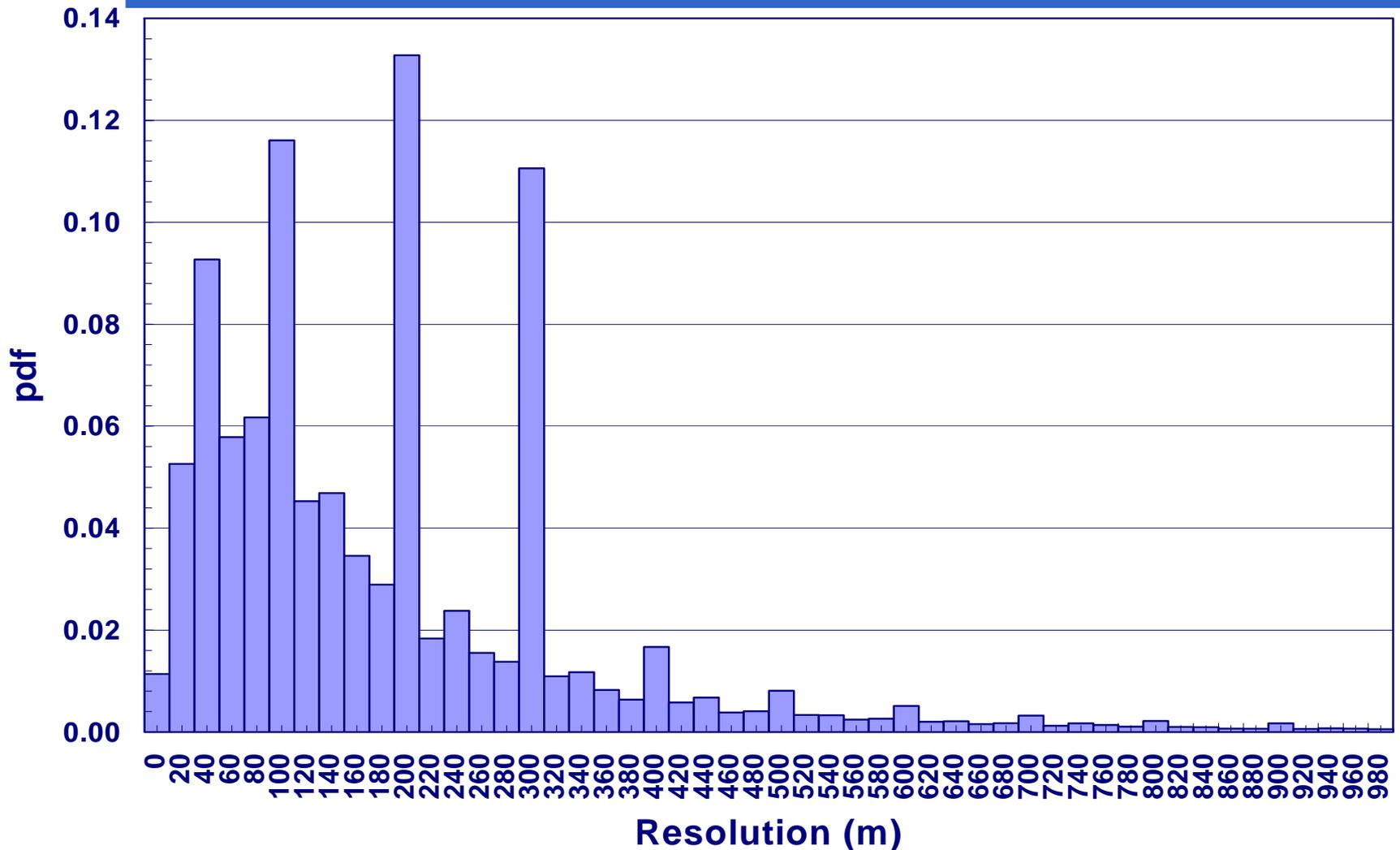
Prediction Methods

❍ 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;

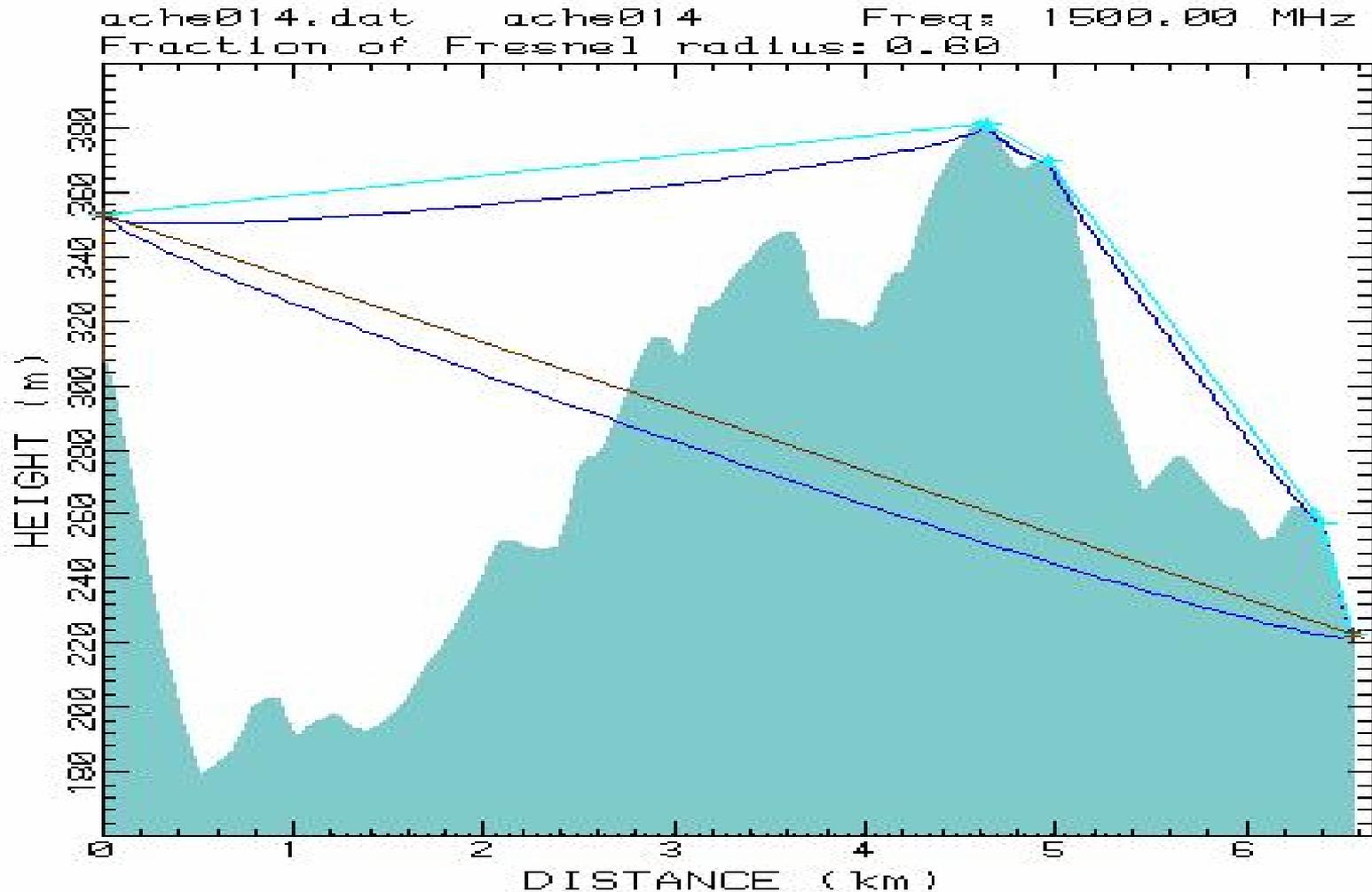○ Linear interpolation between the two predicted values otherwise.
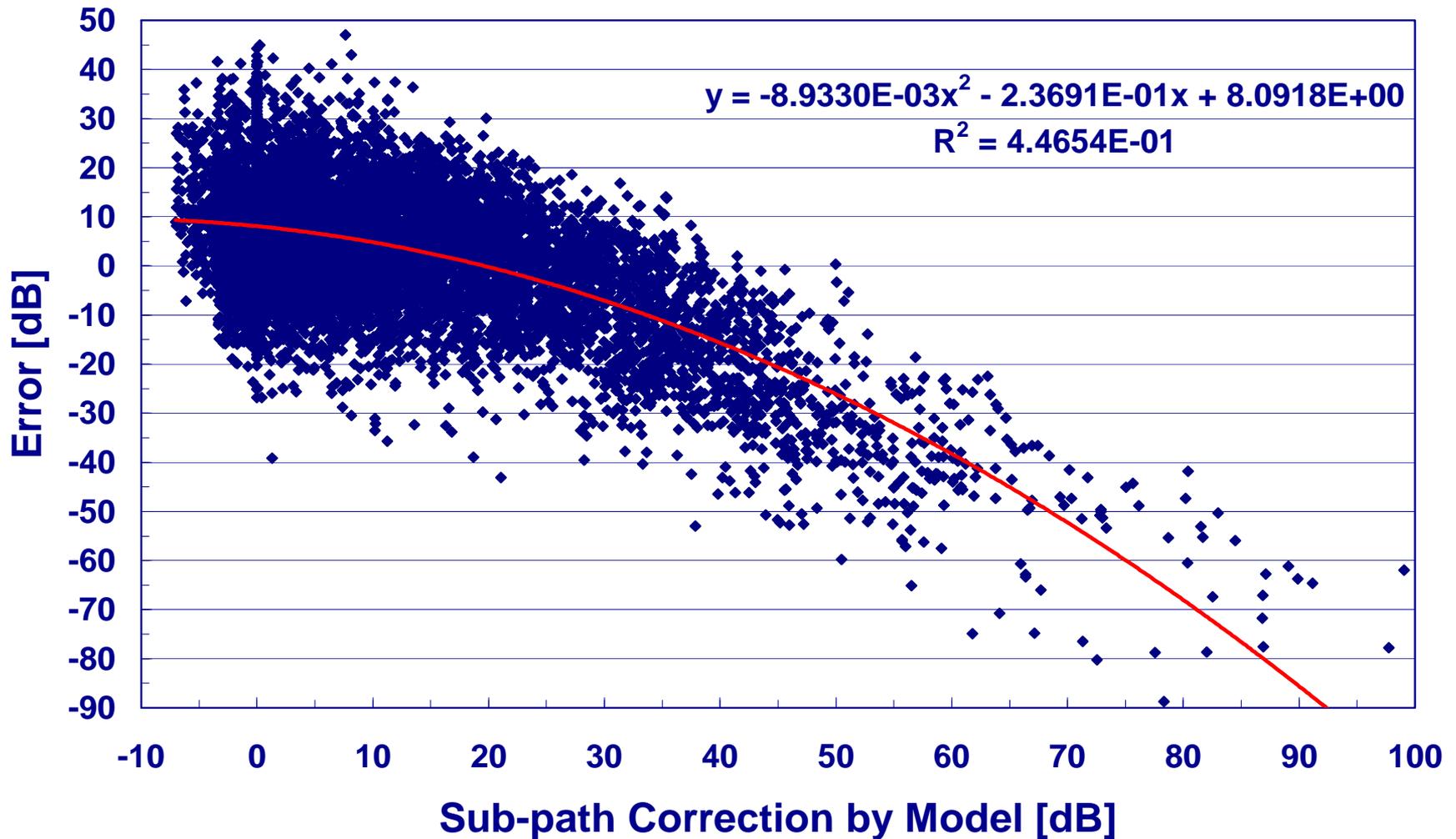
Prediction Methods: sub-path models

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Prediction Methods: sub-path models

$$y = -8.9330\text{E-}03x^2 - 2.3691\text{E-}01x + 8.0918\text{E+}00$$
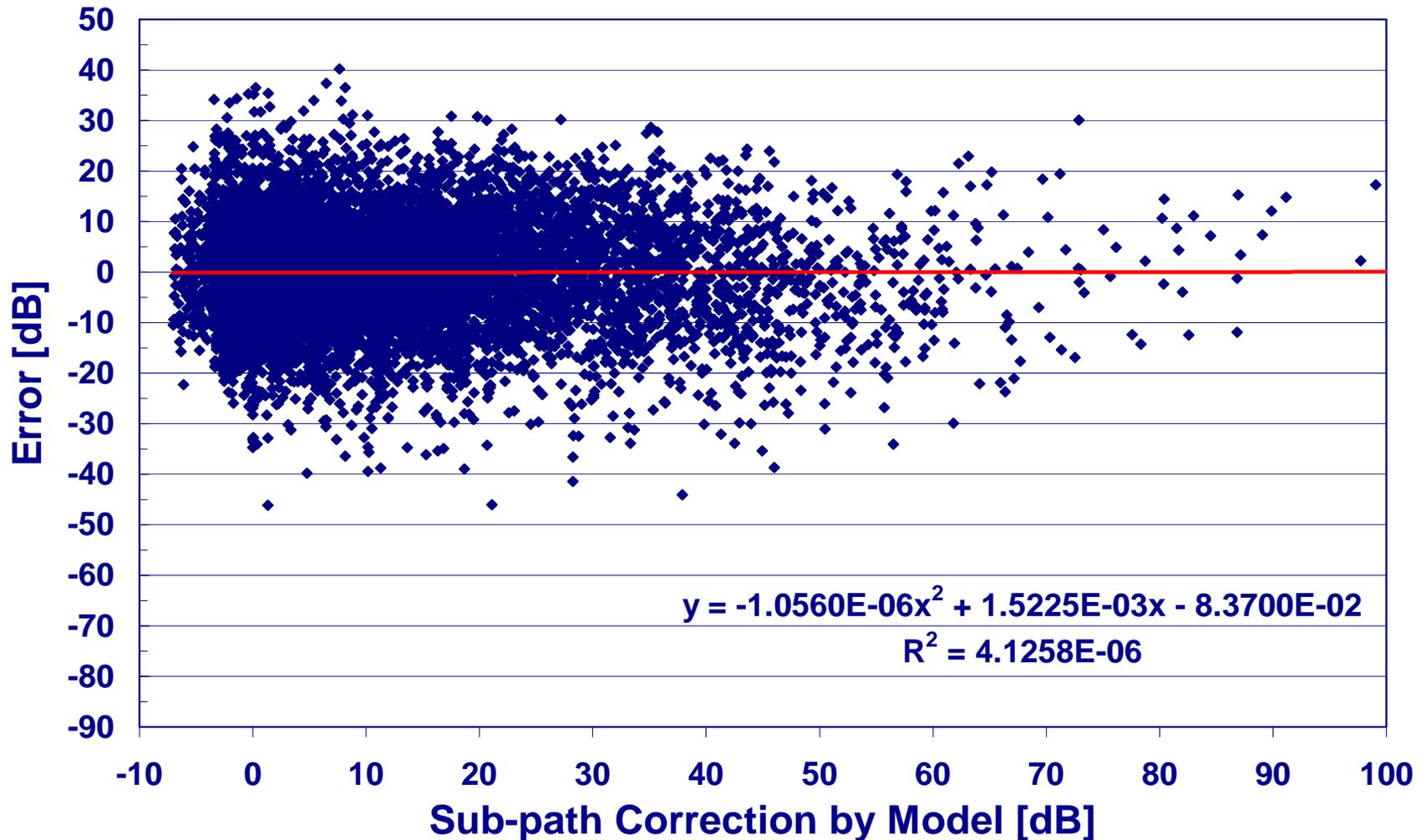$$R^2 = 4.4654\text{E-}01$$

Error [dB]
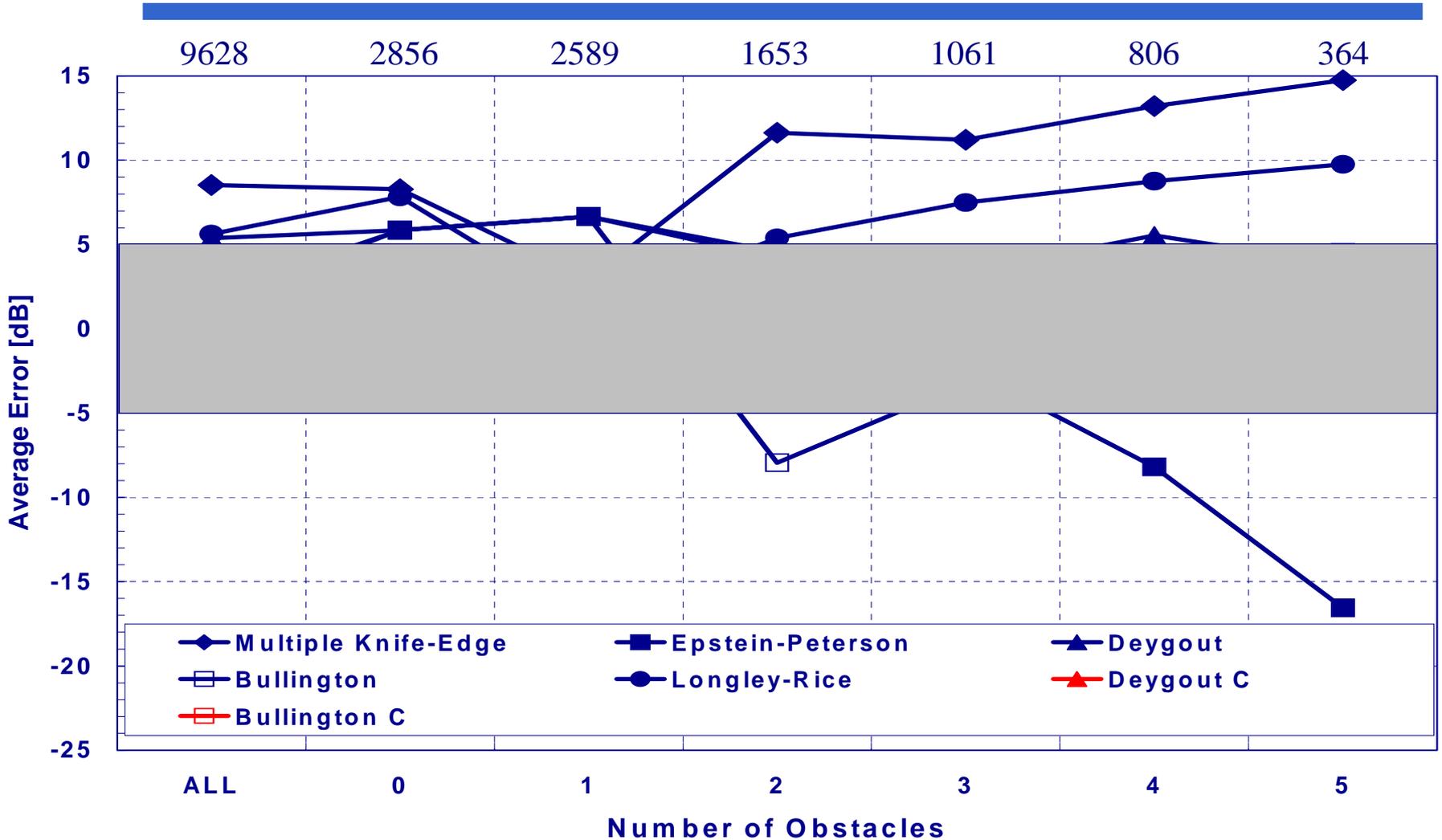
Sub-path Correction by Model [dB]

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.
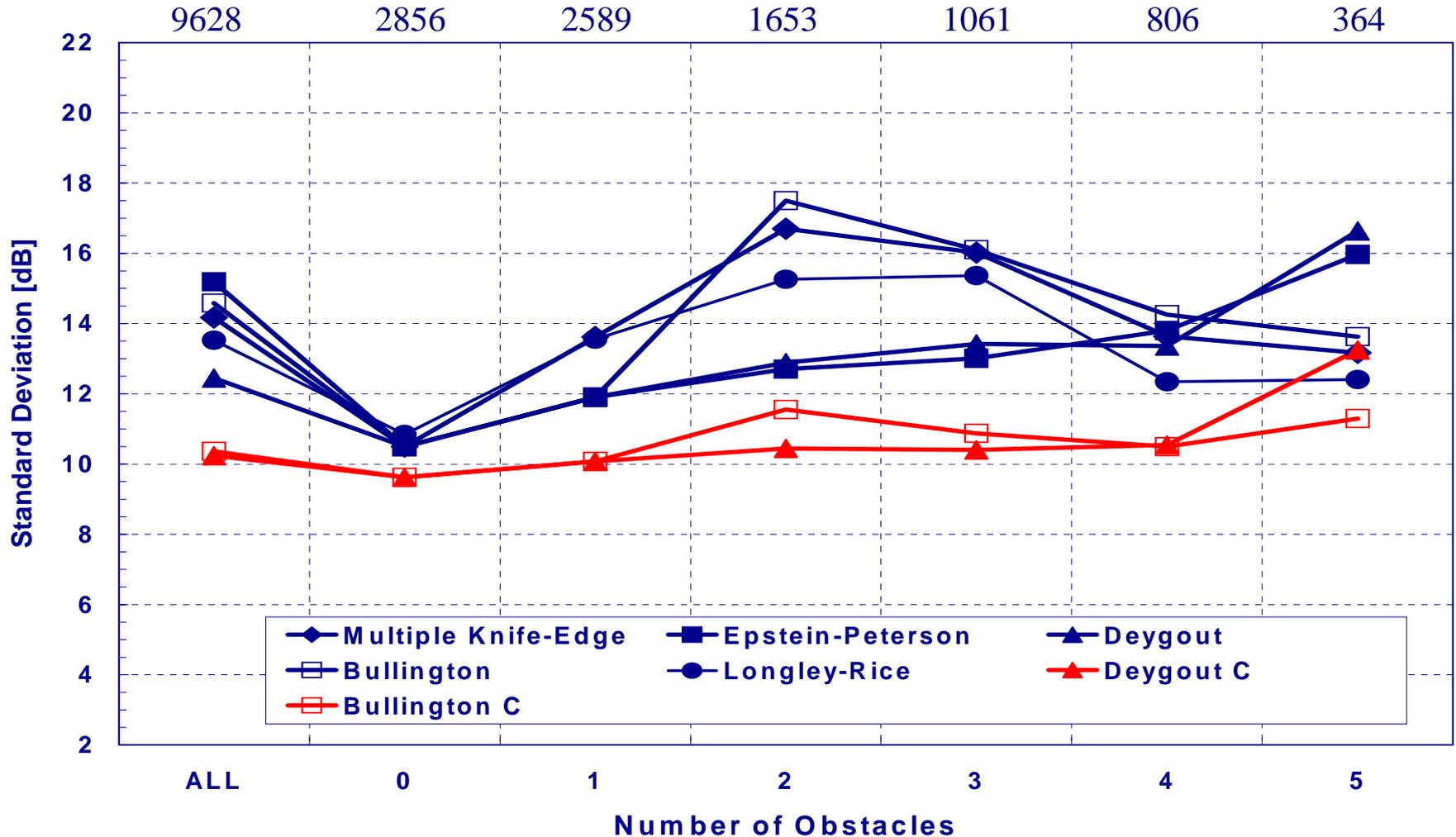
Prediction Methods: sub-path models

$$y = -1.0560E-06x^2 + 1.5225E-03x - 8.3700E-02$$

$$R^2 = 4.1258E-06$$

Error [dB]

Sub-path Correction by Model [dB]

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

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

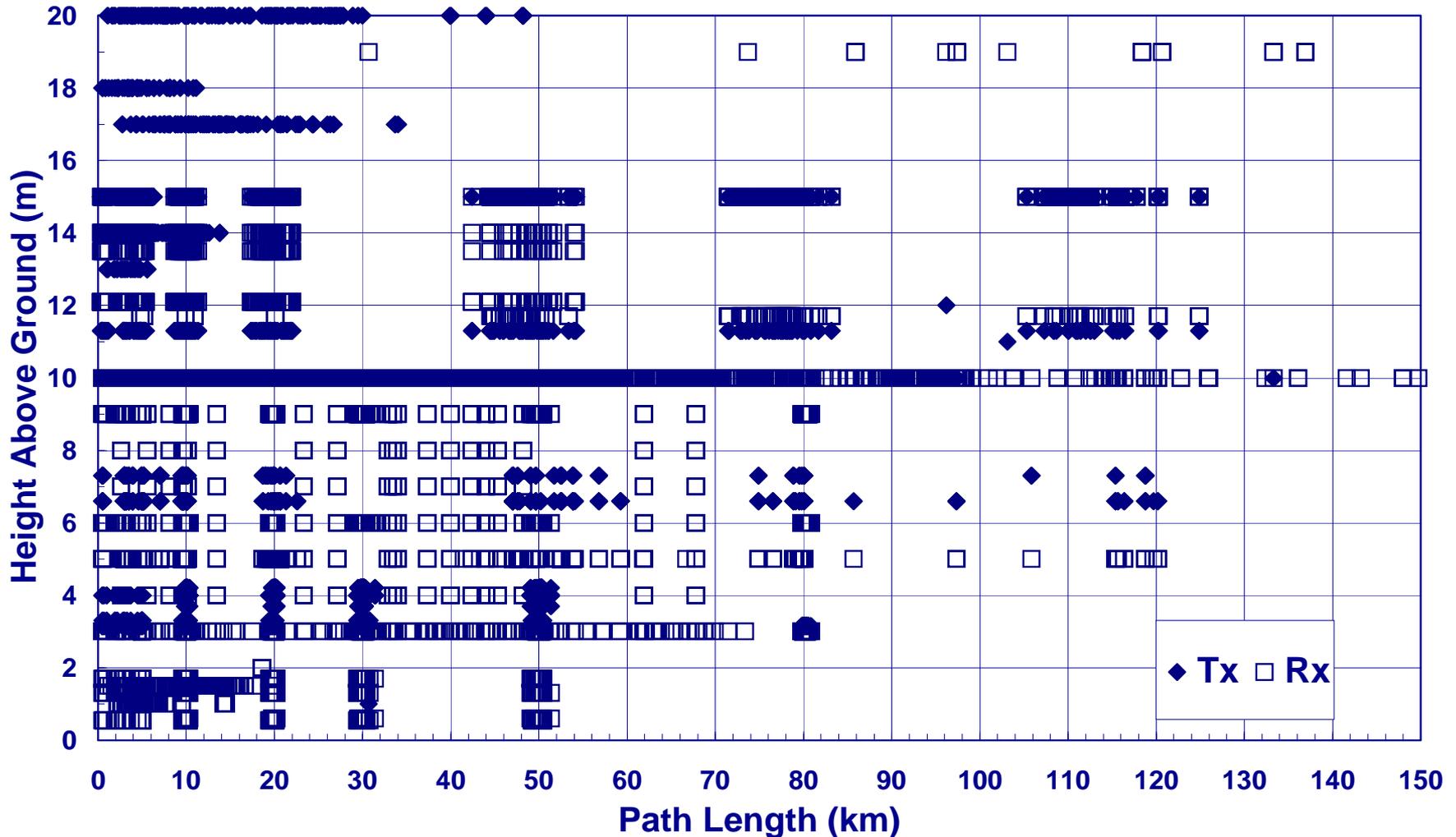# Results from the CG 3K-1/ITS links – results from different data bases

Data Base	Number	Average (dB)	Standard Deviation (dB)
ALL	9628	-0.04	10.24
EBU	3332	0.03	9.78
ITS	5861	-0.21	10.53
HTI	435	1.66	9.57

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.

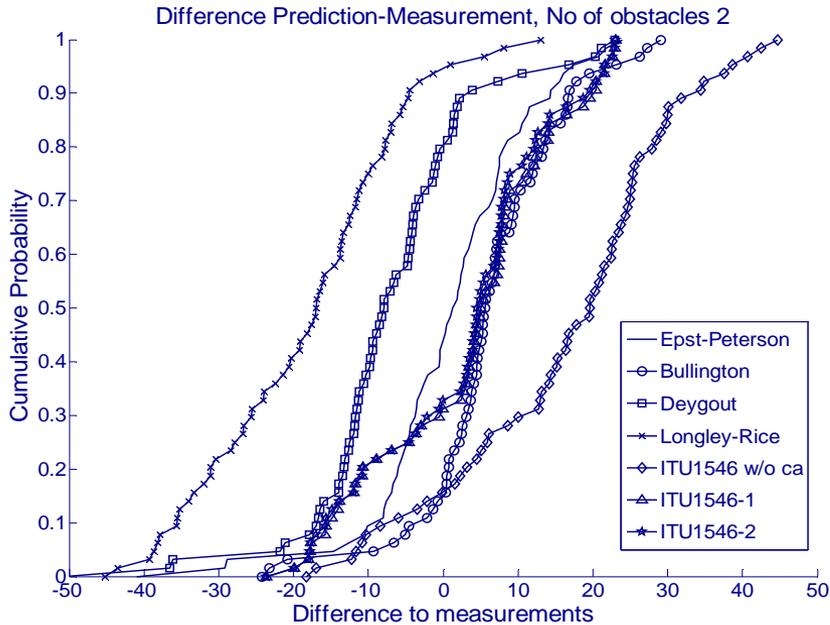◦ **Standard deviations of errors are still large!**

End of Part 1
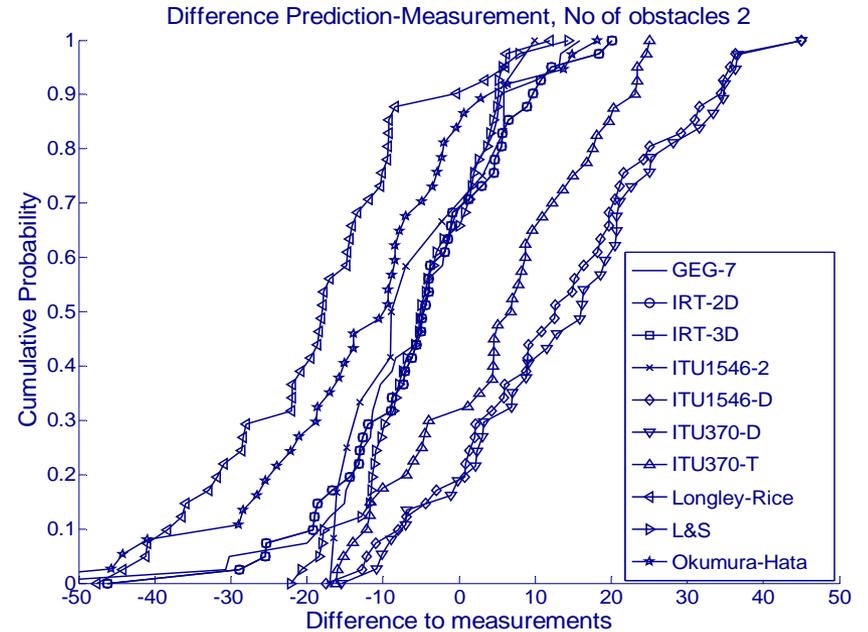
Experimental Data – DBSG3 and ITS

Experimental Data: HTI

Difference Prediction-Measurement, No of obstacles 2

Legend (left plot):
- Epst-Peterson
- Bullington
- Deygout
- Longley-Rice
- ITU1546 w/o ca
- ITU1546-1
- ITU1546-2

Difference Prediction-Measurement, No of obstacles 2

Legend (right plot):
- GEG-7
- IRT-2D
- IRT-3D
- ITU1546-2
- ITU1546-D
- ITU370-D
- ITU370-T
- Longley-Rice
- L&S
- Okumura-Hata

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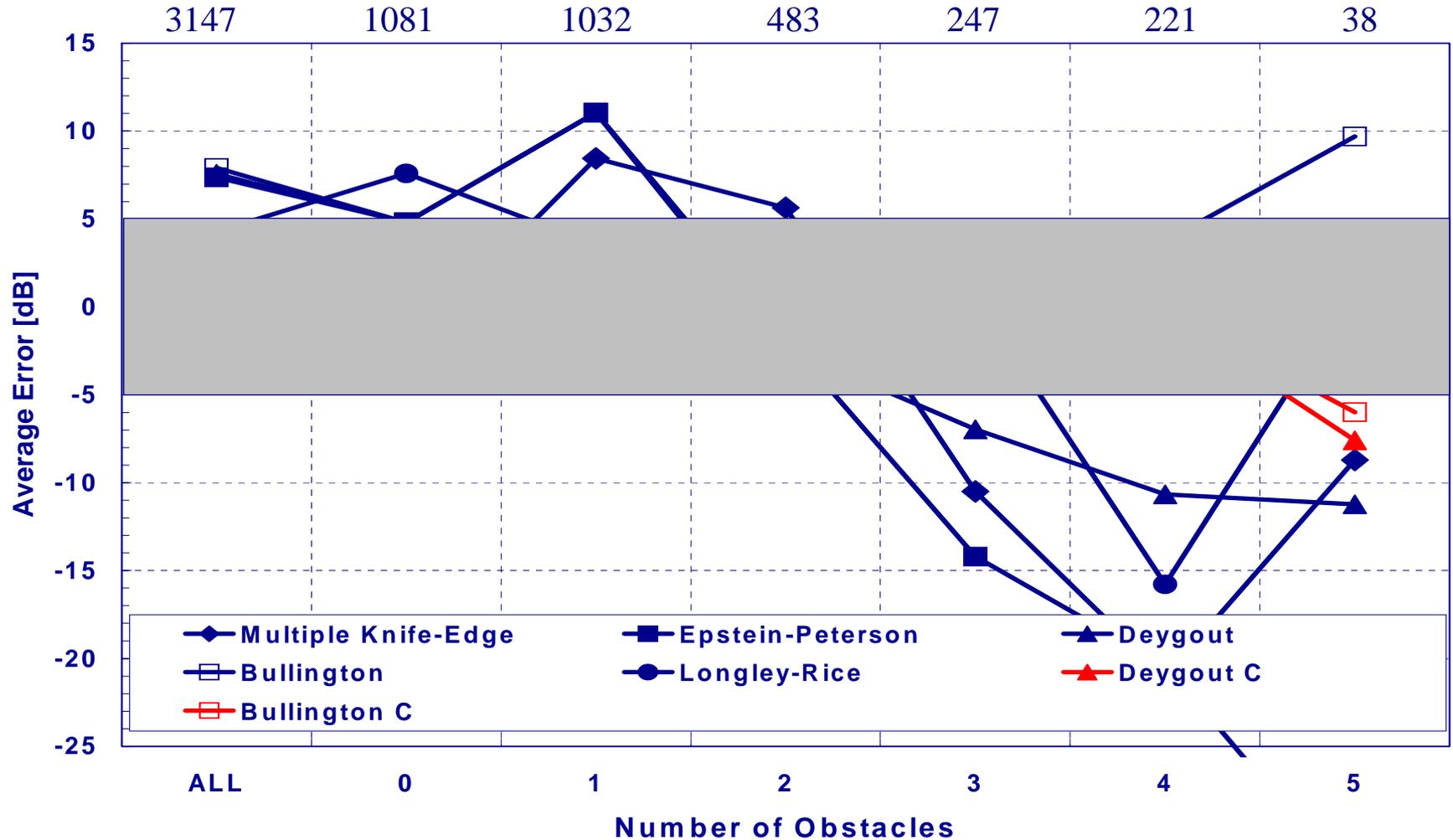
CDF of errors by different models implemented by L&S Telcom using profiles with 2 obstacles
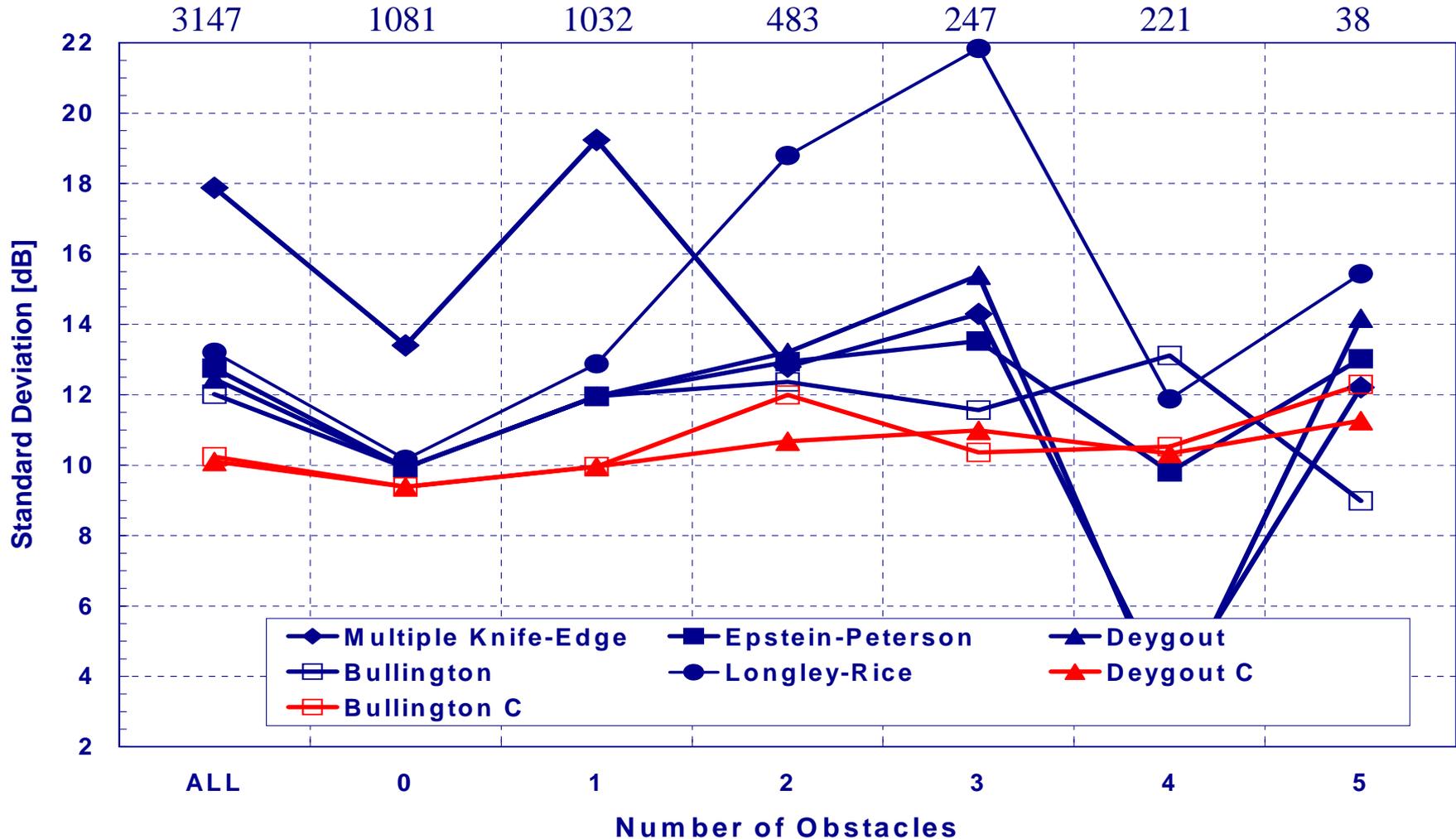
Experimental Data: HTI

◦ 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.
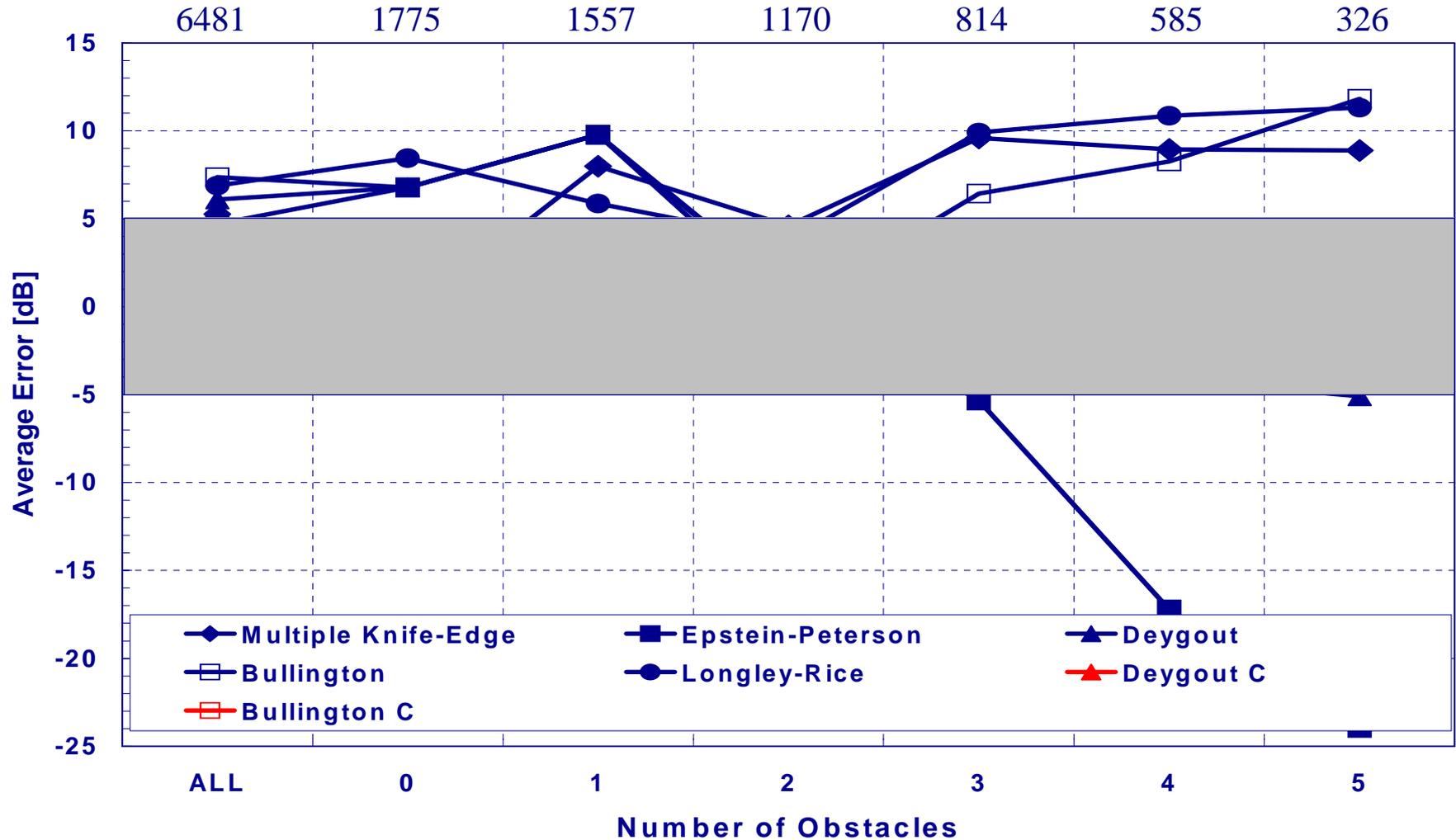
Results from the CG 3K-1/ITS links – links without sub-path structures

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Results from the CG 3K-1/ITS links – links with sub-path structures

Results from the CG 3K-1/ITS links – links with sub-path structures