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Rutherford Appleton Laboratory [UK]

MODEL COMPARISONS (INCLUDING THE PTP ROUNDED OBSTACLE MODEL) USING THE CLEANED CG DATABASE

CONTENTS

1 Introduction

This document summarises the statistical results from testing P.1812, incorporating various modified diffraction models, against the cleaned-up 3K1 Correspondence Group measurement dataset described in CGD-?? ("Measurement Data for improving ITU-R Recommendation P.1812").

2 Models

Apart from an implementation of P.1546-3, the models are all based on P.1812. The different versions of P.1812 are all obtained by substituting the current 3-edge diffraction model with various other diffraction models. The list of models is:

- P.1546-3
- P.1812 as published (3-edge diffraction model)
- P.1812, but using the Bullington diffraction model (including the empirical, path length dependent, correction term and the line-of-sight taper, as described in 3K1 Correspondence Group Document CGD-05).
- P.1812, but using 3 variations of the US FCC PTP diffraction model that incorporates corrections for rounded obstacles. This model is described below.
- P.1812, but using the long path distance correction to the Bullington method given in 3K1 Correspondence Group Document CGD-16.

2.1 The PTP model

The Point-to-Point (PTP) radio propagation model was given in a 1998 FCC Notice of Proposed Rulemaking for FM service. Although this model has not been officially adopted by the FCC, the model is often used by consulting engineers and by Commission staff to estimate the coverage provided by FM radio stations. The model[1] and test results can be found on the FCC website at http://www.fcc.gov/oet/fm/ptp/.

A feature of the PTP model is that it blends knife-edge and smooth-Earth diffraction losses in a way that takes account of the terrain roughness. In our implementation, three different assumptions have been made about which edges the knife-edge/smooth-Earth blend should apply to.

In the basic PTP method P.1812 is run as normal. In the diffraction calculation, a roughness factor is used. The roughness factor is found for each edge, R_p, R_r and R_t. To calculate a roughness factor, a straight line least squares fit is made to all available points within 10km of the edge, but not including the TX or RX points. The standard deviation of the terrain heights about this line is calculated and ΔH is set to 90% of this value. The interpolation factors R_p, R_r or R_t are found using the equation $R = 75/(\Delta H + 75)$. The loss for the edge is then calculated from:

PTP Edge Loss = $J(v) + R \times(S(v) - J(v))$

where $S(v)$ is the smooth earth loss calculated using the approximation:

$$S(v) = \max(21.66 + 27.35v, 0)$$

and where v and $J(v)$ are as defined in P.1812.

[1] H.K.Wong "Field Strength Prediction in Irregular Terrain–the PTP Model", November 1, 2002.

The basic PTP method can be applied to all edges, or just the principle edge and the losses can be combined in various ways. The basic PTP method was applied using 3 variations.

1. PTP method applied at the principal edge only
2. PTP method applied at all 3 edges with the combination of losses based on the value of the R factor on the principal edge
3. PTP method applied at the principal edge only with the combination of losses based on the value of the R factor on the principal edge

For method 1 Ld50 = Lm50 + (1.0 - exp(- Lm50 / 6.0)) * (Lt50 + Lr50);

For method 2 Ld50 = Lm50 + (1.0 - exp(- Lm50 / 6.0)) * (Lt50 + Lr50) * (1.0 - R);

For method 3 Ld50 = Lm50 + (1.0 - exp(- Lm50 / 6.0)) * (Lt50 + Lr50) * (1.0 - R);

For reference, P1812 uses:

Ld50 = Lm50 + (1.0 - exp(- Lm50 / 6.0)) * (Lt50 + Lr50 + 10.0 + 0.04 * d);

A similar approach is used at time β_0.

There is further potential for optimising the R-based combination method.

3 Data

The dataset used for testing was the "cleaned" 3K1 Correspondence Group measurement database as described in the Correspondence Group Document on "Measurement Data for improving ITU-R Recommendation P.1812". As well as the original 19 datasets (15 EBU, 2 US, ABU, Swiss) used for the 3-edge/Bullington comparisons presented in Document CGD-05, this database contains 7 additional datasets (COST-210 and the Sandell measurements sorted into 6 frequency bands).

The database is available for download in XML and the CG .csv file format. The subset of data used in this model testing used 5316 links/data files as defined by the data flags:

IsValid = 1

IsWorstMonth = 0

IsTopHeightInGroup = 1

InputsValid = 1

IsLongTerm = 0 and 1

4 Metrics

In this report, we present results in the standard form of statistical means and standard deviations of the difference between the model predicted path loss and the measured path loss.

These simple statistical quantities are only valid as metrics if the distribution of errors is Gaussian. The model-minus-prediction errors in the original "raw" datasets were often non-Gaussian. In particular several distributions were bimodal. However, the model errors for the datasets in the "cleaned" database are generally consistent with a Gaussian distribution (based on chi-square and Kolmogorov-Smirnov tests) and so we limit our metrics to the mean and standard deviation.

In the results we present the mean and standard deviation for each dataset within the database. We also provide means and standard deviations of all the data treated as one single, large dataset (>10,000 measured points). Three ways of combining the different datasets were used:

1. Results labelled "ALL" are obtained by simply considering all data points with equal weight, irrespective of data source. This is would be appropriate if all data is equally good and unbiased (for example, correctly calibrated, and with clutter correctly identified). The results are representative of the conformance of the model to measurements made in a variety of conditions, geographical locations, and by different methods and operators, but include contributions from measurement, as well as model, errors.
2. Results labelled "Mean of datasets" give an "average" mean and standard deviation of the 26 individual datasets, obtained by simply taking the mean of the individual means and standard deviations. This approach gives equal weight to each dataset, rather than to each measurement, and so gives undue emphasis to the results from the smaller datasets.
3. Results labelled "Corrected mean" are only given for the standard deviation. These are obtained by (a) "correcting" the individual measurement values by subtracting the mean measurement value of the dataset to which the individual measurement belongs; (b) considering all the "corrected" measurement values to belong to the same statistical distribution, and (c) calculating the standard deviation of this aggregated dataset. The rationale for this is the belief that several of the individual datasets include significant measurement biases (discussed later). The standard deviation calculated using the simple method of 1 above will therefore give an unduly pessimistic estimate, as it will include a contribution from the measurement error offsets between the means of the individual datasets. The "corrected mean" approach attempts to remove the measurement errors to first order.

5 Results

The testing results are given in Table 1.

The results are more easily interpreted from the figures. Figure 1 shows the mean errors and Figure 2 the standard deviations of the errors, broken down by model and measurement dataset.

Figure 3 shows, in expanded detail, the prediction error statistics of P.1812 using (a) the 3-edge diffraction method, (b) the Bullington diffraction method, and (c) the long path distance correction to the Bullington method given in Document CGD-16.

Figure 4 shows the effect of including, or ignoring, the clutter information given in the database. Only a few of the datasets include clutter information.

Dataset	No. of points	P.1812		P.1812 (Bull+Taper)		P.1546		P.1812 (NO CLUTTER)		P.1812 (Bull+Bacon)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ABU	108	-21.2	14.4	-24.0	14.1	-4.7	10.7	-21.2	14.4	-21.5	13.9
BBC	56	-12.3	8.2	-16.5	7.3	2.2	8.9	-12.3	8.2	-13.1	7.1
BBCL	25	-15.6	11.4	-18.1	10.6	-0.5	13.8	-15.6	11.4	-18.0	10.6
BBCn	252	-4.4	8.0	-9.2	7.4	0.7	10.1	-4.4	8.0	-7.0	7.9
ERT	9	-1.4	8.9	-6.2	5.6	-15.3	21.0	-1.4	8.9	-6.2	5.6
HOL	69	2.0	6.9	-4.3	7.6	3.9	5.1	-5.4	6.7	0.7	6.5
IRT	584	2.6	7.8	-2.4	5.9	-4.2	11.1	-1.1	7.4	-1.4	6.1
IRTL	154	10.2	18.8	5.8	13.0	11.9	17.0	-15.4	19.9	6.2	13.2
IRTs	63	-3.0	8.4	-9.6	7.0	4.6	8.2	-3.0	8.4	-2.9	8.1
ORF	54	14.2	8.8	4.0	9.2	-6.8	12.4	14.2	8.8	6.0	10.1
RAI	83	0.4	6.5	-3.5	7.4	-20.0	11.9	0.4	6.5	-3.4	7.5
S	107	-6.4	10.6	-8.7	8.0	-3.8	8.2	-11.3	10.6	-8.8	8.3
SUI	1114	-1.4	10.0	-5.5	8.9	-5.5	12.0	-1.4	10.0	-4.6	9.0
TDF	64	8.1	14.6	-5.5	10.4	-7.5	16.0	8.1	14.6	-3.2	9.6
YLE	100	7.1	7.2	-1.7	6.8	3.6	4.6	-2.9	6.4	4.7	6.6
YLEs	51	-4.3	11.0	-9.8	10.0	-3.4	9.7	-12.2	10.2	-3.9	10.8
Swiss	405	5.5	13.5	-3.7	7.7	-7.4	13.6	5.5	13.5	-3.5	7.9
USPhase1	4917	-15.3	12.5	-24.9	11.3	-2.5	14.2	-15.3	12.5	-8.7	10.7
USPhase2	1642	-0.6	10.9	-7.8	11.2	11.6	16.1	-0.6	10.9	0.1	11.9
COST210	65	-4.7	7.8	-7.9	8.4	3.5	12.6	-4.7	7.8	-0.9	12.0
Sandell_Band_I	120	-7.5	7.0	-15.5	6.5	-0.2	9.0	-7.5	7.0	-7.4	7.1
Sandell_Band_II	242	-8.1	11.7	-15.5	9.3	2.9	9.2	-8.1	11.7	-8.1	11.8
Sandell_Band_III	295	-4.4	12.3	-11.1	11.9	6.5	12.0	-4.4	12.3	-4.2	12.3
Sandell_Band_IV	250	-6.2	12.2	-11.3	12.5	7.7	12.0	-6.2	12.2	-5.7	12.3
Sandell_Band_V	174	-5.1	11.1	-11.6	14.3	5.4	16.4	-5.1	11.1	-5.0	11.2
Sandell_Band_VI	42	-4.2	12.1	-10.1	11.6	9.3	20.2	-4.2	12.1	-3.8	12.4
ALL	11045	-7.5	14.1	-15.2	14.1	0.0	15.0	-8.3	13.7	-5.6	11.2
Mean of datasets		-2.9	10.5	-9.0	9.4	-0.3	12.2	-5.2	10.4	-4.8	9.7
Corrected mean			11.6		10.5		13.6		11.6		10.4

(a)

Dataset	No. of	P.1812		PTP Main Edge		PTP Main 3 Edge + R		PTP Main Edge + R	
	points	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ABU	108	-21.2	14.4	-20.0	13.4	-20.7	13.8	-22.1	13.6
BBC	56	-12.3	8.2	-8.8	6.9	-8.9	7.5	-11.7	7.1
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BBCn	252	-4.4	8.0	-0.3	10.5	0.5	10.6	-3.2	10.0
ERT	9	-1.4	8.9	1.8	11.8	2.5	13.1	1.3	10.9
HOL	69	2.0	6.9	5.1	9.0	6.5	8.3	1.3	8.8
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ORF	54	14.2	8.8	10.5	10.2	11.7	10.6	8.8	9.7
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SUI	1114	-1.4	10.0	-2.1	11.3	-1.3	11.5	-3.1	10.9
TDF	64	8.1	14.6	11.4	18.3	13.8	19.5	9.2	18.2
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USPhase1	4917	-15.3	12.5	-14.0	13.2	-11.7	13.2	-17.7	13.1
USPhase2	1642	-0.6	10.9	2.7	15.5	4.5	15.7	-0.1	15.5
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Sandell_Band_I	120	-7.5	7.0	-7.9	7.2	-6.7	7.1	-10.1	7.0
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Sandell_Band_III	295	-4.4	12.3	-2.7	12.7	-3.0	12.6	-4.8	12.2
Sandell_Band_IV	250	-6.2	12.2	-5.4	12.4	-5.3	12.3	-5.9	12.4
Sandell_Band_V	174	-5.1	11.1	-4.8	11.2	-4.8	11.2	-5.0	11.2
Sandell_Band_VI	42	-4.2	12.1	-3.7	12.7	-3.7	12.7	-3.7	12.7
ALL	11045	-7.4	14.1	-6.4	15.9	-4.9	15.8	-9.0	16.1
Mean of datasets		-2.9	10.5	-1.5	12.6	-0.7	12.9	-3.1	12.2
Corrected mean			11.6		13.6		13.9		13.4

(b)

Table 1: Results (model predicted path loss minus measured path loss)

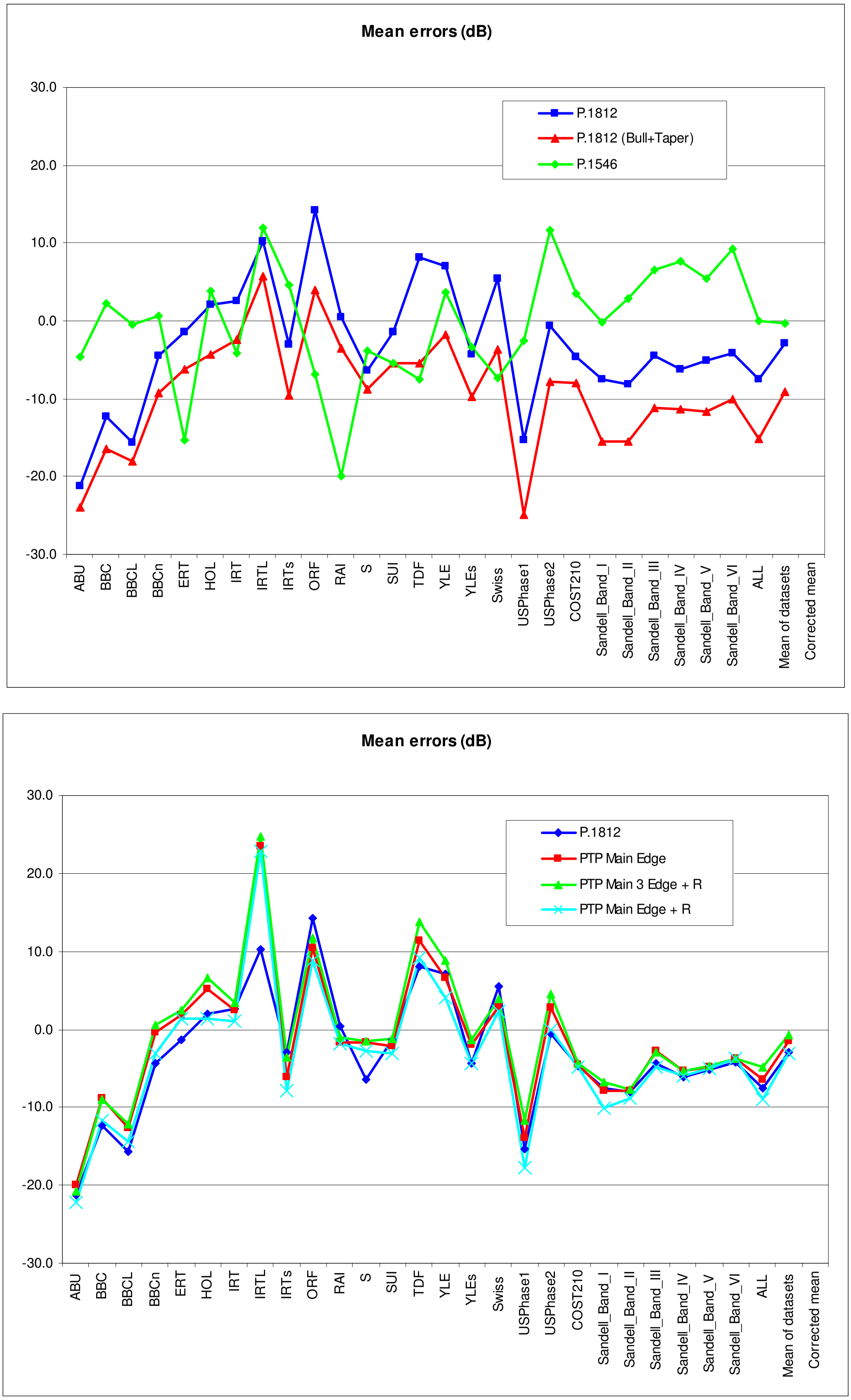
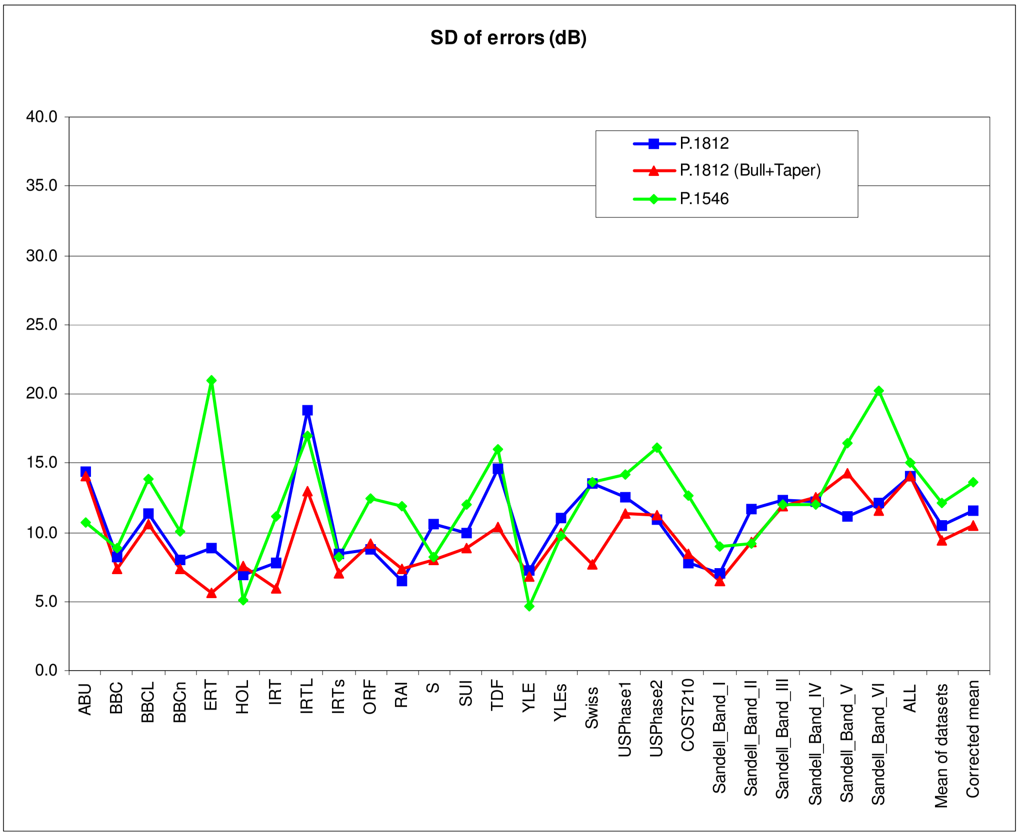


Figure 1: Mean errors (model-measurement)



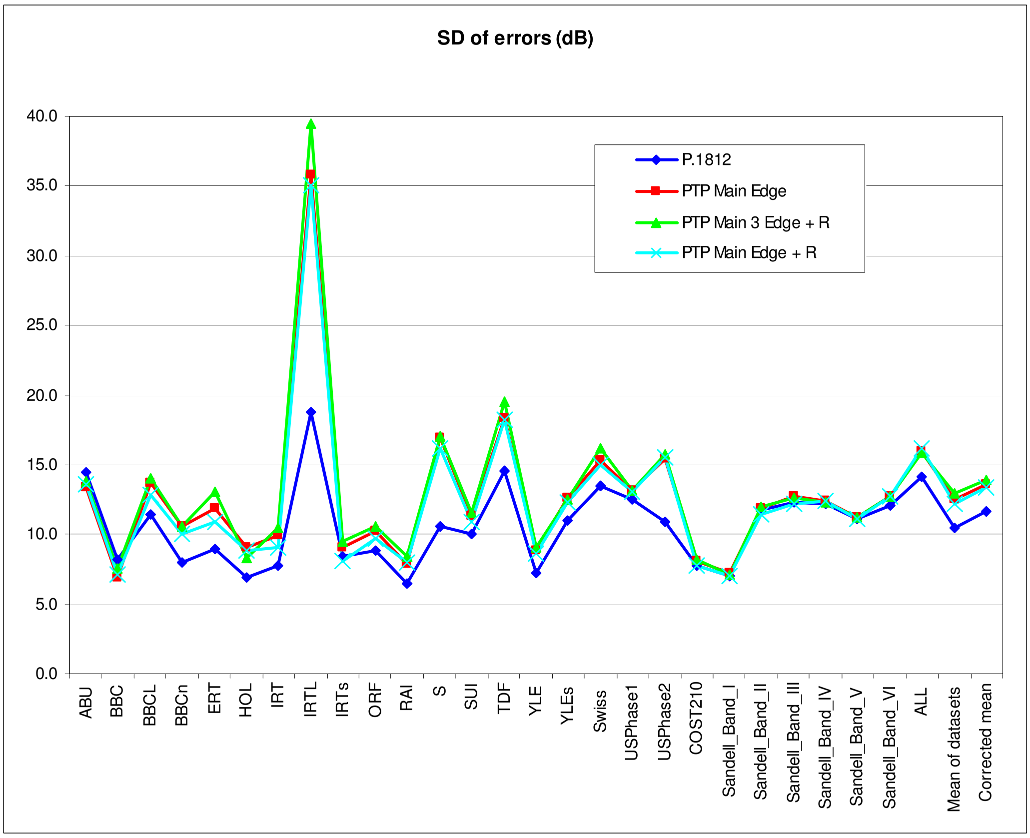


Figure 2: SD of errors (model-measurement)

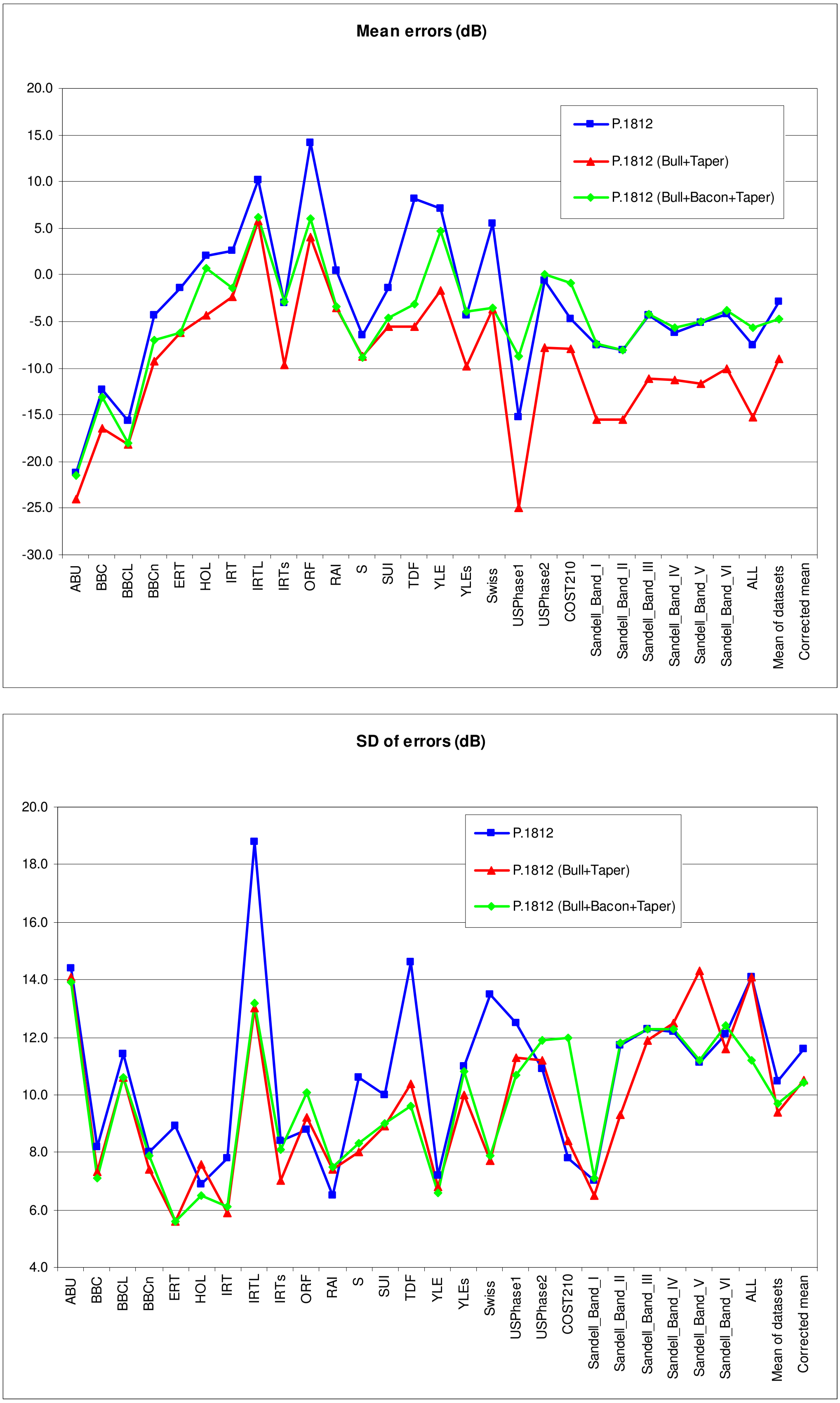
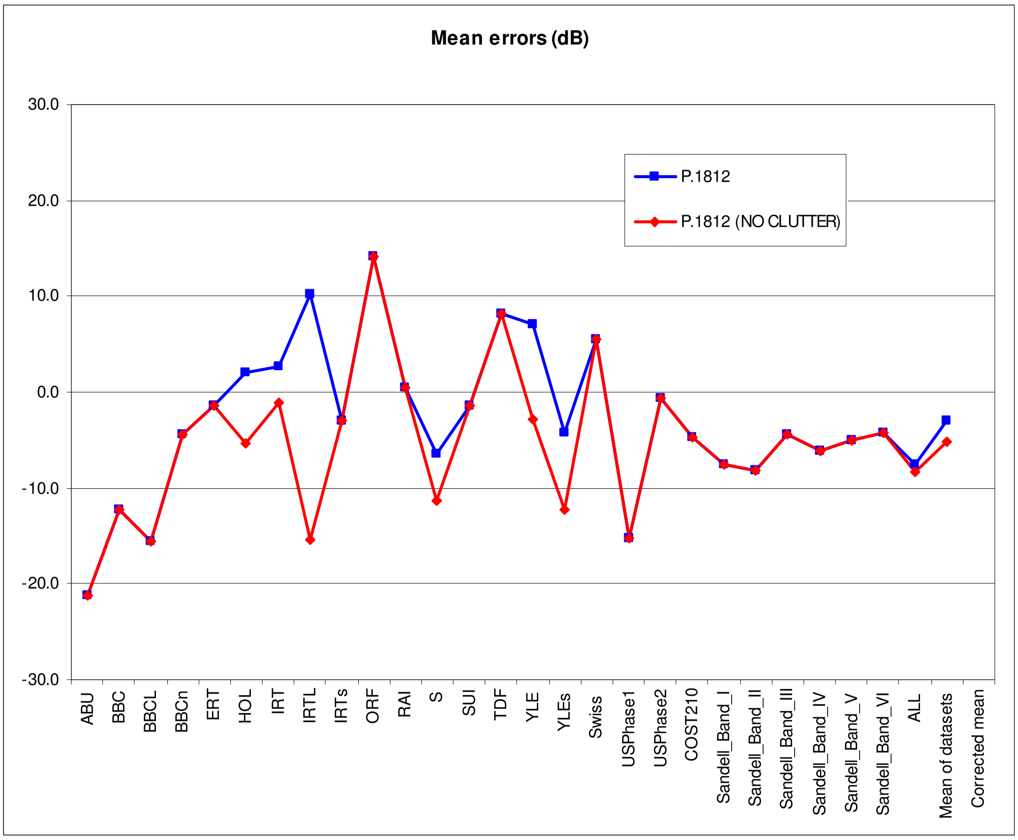


Figure 3: 3-edge, Bullington and "adjusted" Bullington model



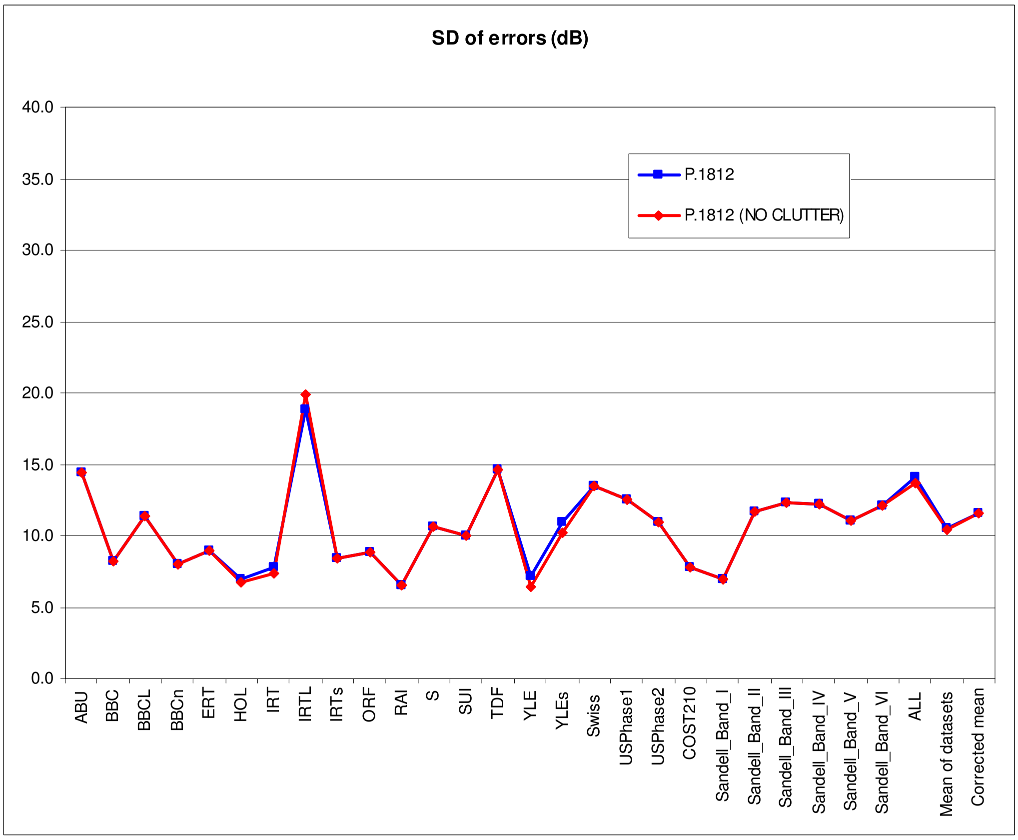


Figure 4: Effect of clutter on mean and SD of errors (model-measurement)

6 Discussion

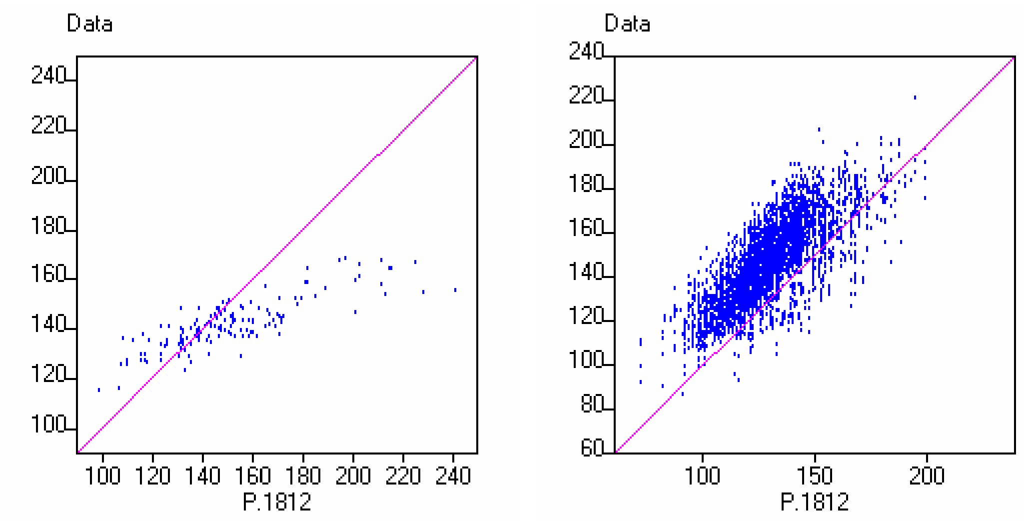
Figure 1 shows that the mean errors vary greatly from dataset to dataset. This agree with the more limited diffraction results on the unfiltered data obtained in Document CGD-05. Indeed the dataset-to-dataset variation in the mean error is generally larger than the variation between models. What is more, the terrain-based diffraction models (3-edge, Bullington and PTP) all show the same trends/biases in the means on different datasets (P.1546 is rather different because its "diffraction model" is not based on a full terrain profile analysis).

The obvious conclusion of these trends is that they are more due to biases in the measurements than to differences in the models themselves. This has already been discussed in Section 6.3 of Document CGD-05, and further in Document CGD-?? ("Measurement Data for improving ITU-R Recommendation P.1812"). So for example, the "over-prediction" of path loss by all models on the IRTL dataset is most likely due to calibration or dynamic range problems in the measurement data. In contrast, the "under-prediction" of path loss by all models on the USPhase1 data is probably due path clutter that is not identified in the CG database. These conclusions are supported by

a) the standard deviations of Figure 2: the USPhase1 data shows a standard deviation that is similar to the other datasets, compatible with a clutter "offset", while the standard deviation of the IRTL dataset is exceptionally high;

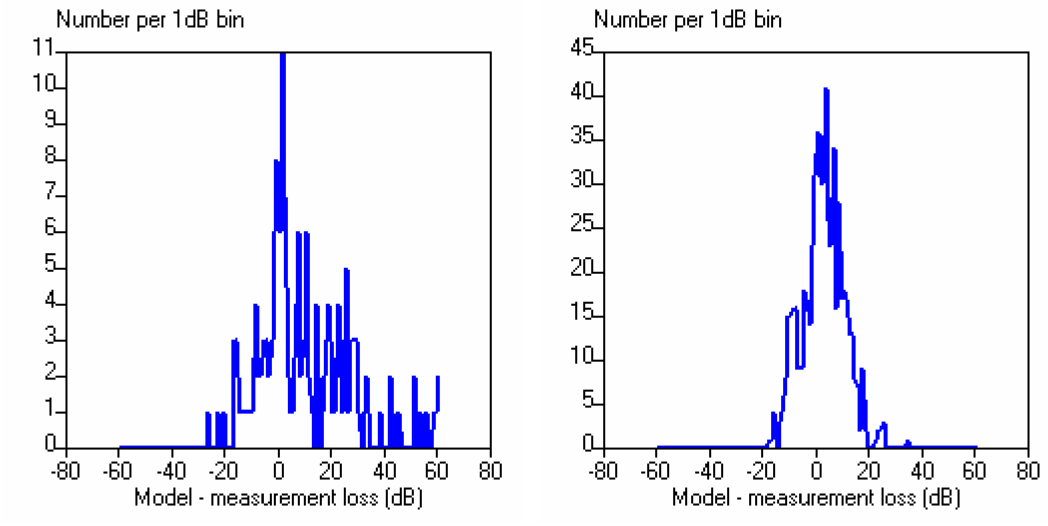
b) the scatter plots of the P.1812 predicted path loss against measurements shown in Figure 5: the scatter plot "slope" indicates a calibration error or dynamic range problem;

c) the histogram of the prediction errors shown in Figure 6 and Figure 7: the IRTL histogram is broader than that of the IRT dataset, while the USPhase1 and USPhase2 histograms are similar in shape, although with a mean offset for USPhase1.



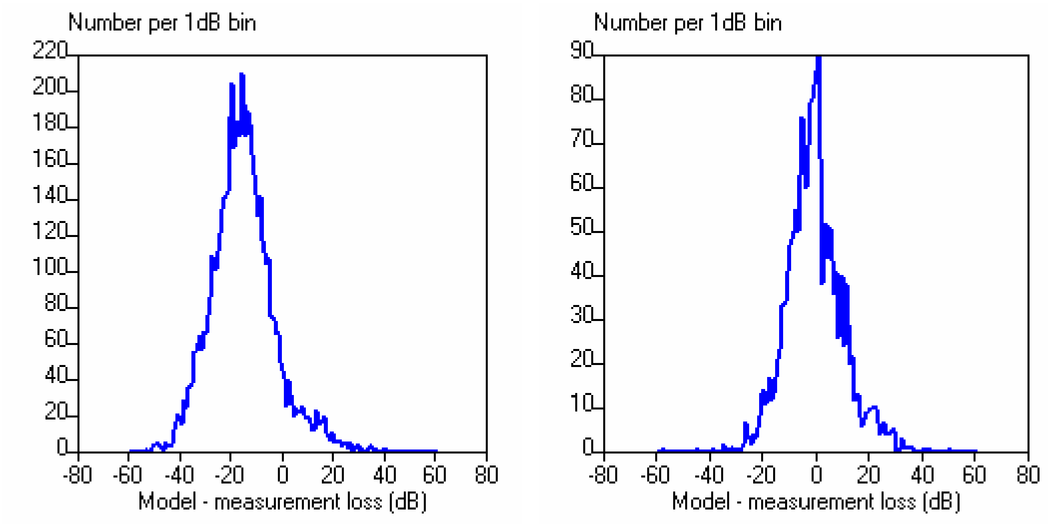
(a) (b)

Figure 5: P.1812 (3-edge) model against measurements for (a) IRTL and (b) USPhase1



(a) (b)

Figure 6: Histograms of (a) IRTL and (b) IRT



(a) (b)

Figure 7: Histograms of (a) USPhase 1 and (b) USPhase2

It is not therefore possible to make firm conclusions on the efficacy of a model based on the values of the mean prediction errors. This is of course well known, and most "practical" diffraction models (including the 3-edge and Bullington models in P.1812) incorporate empirical correction factors to take some account of environmental "unknowns" (such as clutter). However it is clear from Figure 1 that the Bullington version of P.1812 underpredicts loss compared with the 3-edge version on all datasets. In general, both models are underpredicting path loss compared with P.1546-3. As it happens, the mean prediction error for P.1546-3 on the whole aggregated dataset (the ALL result) is 0.0dB!

The various PTP models all give results that are close to the basic P.1812 results, so the inclusion of smooth-Earth obstacles does not make a significant difference.

Considering the standard deviations of Figure 2, there is much less variation between datasets (apart from IRTL) confirming that standard deviation is a better metric than the mean. The standard deviation of the Bullington version of P.1812 is generally (but not always) lower than that of the 3-edge version and of P.1546-3. For the aggregated datasets (ALL), the standard deviations of 3-edge and Bullington P.1812 are identical (14.1dB) and not much less than P.1546 (15.0dB), but the "Corrected mean" standard deviation is best for Bullington

(10.5dB) followed by 3-edge (11.6dB) with P.1546 a poor third (13.6dB). The PTP models all give standard deviations that are worse than the basic P.1812 model.

Figure 3 shows, in expanded detail, the prediction error statistics of P.1812 using (a) the 3-edge diffraction method, (b) the Bullington diffraction method, and (c) the long path distance correction to the Bullington method given in Document CGD-16. It shows that the CGD-16 model has overall mean errors similar to the 3-edge model and smaller than the Bullington model, and on individual datasets, generally lies between the two. The standard deviation of the CGD-16 model generally reproduces the lower standard deviation of the Bullington method, and overall is actually better than either the 3-edge or Bullington versions of P.1812, at 11.2dB (ALL) and 10.4dB ("Corrected mean").

Figure 4 compares the statistics of (3-edge) P.1812 when the clutter information provided in the CG database files is either included or excluded. Clutter information is only available for 6 of the datasets. In all cases, using clutter increases the prediction loss as expected, although in two cases, the magnitude of the mean prediction error also increases. Surprisingly, ignoring the clutter generally *decreased* the standard deviation of the error, and gave a smaller standard deviation overall. However, it is difficult to make any conclusions about the efficacy of the P.1812 clutter model based on these small differences.

Conclusion

On the basis of the models tested here, the "Long path distance correction to the Bullington method" given in Document CGD-16 gives the best overall performance.