RECOMMENDATION ITU-R P.1148-1

STANDARDIZED PROCEDURE FOR COMPARING PREDICTED AND OBSERVED HF SKY-WAVE SIGNAL INTENSITIES AND THE PRESENTATION OF SUCH COMPARISONS*

(Question ITU-R 222/3)

(1995-1997)

The ITU Radiocommunication Assembly,

considering

a) that the overall accuracy of prediction procedures needs to be assessed;

b) that the effect of proposed changes to prediction procedures needs to be determined;

c) that detailed information regarding the modal, spatial, temporal and related accuracies will assist with the future development of such procedures,

recommends

1 that the following procedure given in Annex 1 be adopted for the comparison of predicted and observed HF sky-wave signal intensities;

2 that such comparisons be presented in the manner shown in Annex 2.

ANNEX 1

1 Introduction

The method described is a standardized procedure for comparing predicted and observed sky-wave signal intensities at frequencies between 2 and 30 MHz. Such comparisons provide information on the accuracy of prediction methods and on desirable improvements to them. It is important that administrations and organizations keep the ITU-R informed on the current status of their comparisons. Some sample results of comparisons are contained in this Recommendation.

2 General

In order to obtain comparable results, the same data set and the same procedure should be applied when making comparisons between predicted and observed signal intensities. The most recent data base should be used. This is an ITU-R-agreed data set and provides a wide range of observations with respect to distance, month, sunspot number, frequency and geographical zone.

The output from the comparisons should be:

– count,

– mean difference (dB),

– standard deviation (dB).

"Count" indicates the number of samples used in the comparisons. The "mean difference" provides a measure of the deviation between predicted and observed monthly median signal intensities. The most important parameter for assessing the accuracy of the monthly median signal intensities given by a particular prediction method is the standard deviation (see equations (1) and (2)) but it should be noted that this provides no information about the accuracy on individual days.

* A computer program associated with the procedure described in this Recommendation is available; for details, contact the ITU Radiocommunication Bureau.

In order to find systematic deviations (e.g. as a function of distance or geographical zone) of a particular prediction method, comparisons should be made for a variety of different subsets or combinations of subsets of data. The purpose of the detailed subsets of comparisons is to give hints for the detection of systematic weaknesses of the method under consideration. The choice of a certain prediction method should not be based on favourable results obtained for a particular subset (e.g. distance range).

3 Subsets for which comparisons should be made

Different comparisons, i.e. the calculation of mean difference and standard deviation (see Annex 2), should be made for the following parameters:

3.1 Frequencies, *f*

– single frequency,

– all frequencies of the same circuit,

– frequency groups:

$$2 \leq f \leq 5 \text{ MHz}$$
$$5 < f \leq 10 \text{ MHz}$$
$$10 < f \leq 15 \text{ MHz}$$
$$15 < f \leq 30 \text{ MHz}$$

3.2 Path great-circle distance, *D*

$$0 < D < 1\,000 \text{ km}$$
$$1\,000 \leq D < 2\,000 \text{ km}$$
$$2\,000 \leq D < 3\,000 \text{ km}$$
$$3\,000 \leq D < 4\,000 \text{ km}$$
$$4\,000 \leq D < 5\,000 \text{ km}$$
$$5\,000 \leq D < 7\,000 \text{ km}$$
$$7\,000 \leq D < 9\,000 \text{ km}$$
$$9\,000 \leq D < 12\,000 \text{ km}$$
$$12\,000 \leq D < 15\,000 \text{ km}$$
$$15\,000 \leq D < 18\,000 \text{ km}$$
$$18\,000 \leq D < 22\,000 \text{ km}$$
$$22\,000 \leq D \leq 40\,000 \text{ km}$$

3.3 Geomagnetic latitude, Φ (North or South, at path midpoint)

$$0° \leq \Phi \leq 20°$$
$$20° < \Phi \leq 40°$$
$$40° < \Phi \leq 60°$$
$$\Phi > 60°$$

3.4 Sunspot numbers, R_{12}

$$0 < R_{12} < 15$$
$$15 \leq R_{12} < 45$$
$$45 \leq R_{12} < 75$$
$$75 \leq R_{12} < 105$$
$$105 \leq R_{12} < 150$$
$$R_{12} \geq 150$$

3.5 Season (at path midpoint)

Month	Season	
	Northern Hemisphere	Southern Hemisphere
November, December, January, February	Winter	Summer
March, April	Spring	Autumn
May, June, July, August	Summer	Winter
September, October	Autumn	Spring

3.6 Local time *h* (at path midpoint)

Intervals of 1 h throughout the 24 h; e.g. $00 < h \leq 01$ etc.

3.7 Solar zenith angle χ (at path midpoint)

Intervals of 30° from 0° to 180°; e.g. $0° \leq \chi < 30°$ etc.

3.8 Predicted modes

E modes

F2 modes

3.9 Origin of data

This information can be helpful in finding a possible geographical dependence.

3.10 Ratio of transmitted frequency to predicted monthly median basic MUF

This ratio should also be calculated for all subsets as indicated in § 3.1 to 3.9:

– only below path monthly median basic MUF,

– only above path monthly median basic MUF,

– below and above path monthly median basic MUF.

4 Comparison procedure

4.1 Prediction program requirements for parameters to be predicted

If the prediction computer program allows a minimum elevation angle to be specified as an input parameter, it is set to 3° to be consistent with the data bank.

The following parameters are transferred from the prediction program to the comparison program:

– general information: month, year, sunspot number;

– circuit information: circuit identifier, frequency, great-circle distance, geographical coordinates, geomagnetic latitude at path midpoint;

– 24 predicted hourly values (always monthly median values) of:

a) signal intensity;

b) path basic MUF (in tenths of a MHz in order to store 24 values in an 80 column line with three digits each);

c) the percentage of days per month when the frequency is below the path basic MUF (in order to store 24 values in an 80 column line with three digits each) if the predictions do not give monthly median signal intensity for all days of the month.

4.2 Comparison program requirements and output

Differences are calculated as the predicted monthly median sky-wave signal intensities minus values derived from measurements (i.e. predicted minus measured). Note that cases where there is a prediction but no valid measurement and cases where there is a measurement but no prediction are disregarded.

The following parameters are evaluated:

– count (number of cases where measured and predicted values are available for comparison)

– mean difference $= \frac{\sum (p - m)}{n}$ (1)

where:

p : predicted

m : measured

n : count.

– standard deviation $= \sqrt{\frac{\sum (p - m)^2 - \frac{(\sum (p - m))^2}{n}}{n - 1}}$ (2)

Table 2 provides an example of the type of output produced by the comparison computer program.

4.3 Graphic representation

In the histograms in Figures 1 and 2, columns of 5 dB are generated (e.g. –2.5 to 2.5 dB, 2.6 to 7.5 dB, 7.6 to 12.5 dB ...) in the range –32.5 dB to +37.5 dB. Each subset listed in § 3 should be accompanied by a histogram.

4.4 Measures to be taken if a prediction does not give the median signal intensity for all days of the month

In some cases where predictions give the median signal intensity only for a certain "fraction of days" per month (expressed as a percentage (see § 4.1 c)), the measured and predicted values cannot be compared directly. Only when the fraction of days is at least 99% are the measured and predicted values directly comparable. In all other cases a conversion procedure must be applied to the measured values. If the fraction of days is, for example, 50%, proper ionospheric reflection occurs on 15 days of the month and the predicted median signal intensity is valid for those 15 days only. The prediction does not give any information on the signal intensity on the other 15 days of the month. A measured monthly median, however, is derived from 30 daily values (including the 15 days without proper reflection). Consequently, the measured monthly median is likely to be lower than the predicted median.

If a data bank contains all daily values the measured value corresponding to the predicted fraction of days can be derived by determining the median value for the predicted fraction of days. (Note that Data Bank D1 does not contain daily values.) The following procedure describes how the measured (30 day) monthly median signal intensity can be converted to the same fraction of days per month as that given for the predicted signal intensity:

Step 1: Calculate the f/(path basic MUF) ratio.

Step 2: If the data bank does not contain deciles (Data Bank D1 does not) take the measured value as the 50% value and calculate 10% and 90% values by means of Table 1. This table requires information about the ratio f/(path basic MUF) and whether or not the great circle path crosses the 60° corrected geomagnetic latitude (north or south). The actual ratio should be interpolated linearly between the values contained in the table.

TABLE 1

90% and 10% deviations from the predicted monthly median value of signal intensity (dB), arising from day-to-day variability

Corrected geomagnetic latitude [(1)]	< 60°		≥ 60°	
Transmitting frequency/predicted basic MUF	90%	10%	90%	10%
≤ 0.8	–8	6	–11	9
1.0	–12	8	–16	11
1.2	–13	12	–17	12
1.4	–10	13	–13	13
1.6	–8	12	–11	12
1.8	–8	9	–11	9
2.0	–8	9	–11	9
3.0	–7	8	–9	8
4.0	–6	7	–8	7
≥ 5.0	–5	7	–7	7

(1) If any point on that part of the great circle which passes through the transmitter and the receiver and which lies between control points located 1 000 km from each end of the path reaches a geomagnetic latitude of 60° or more, the values of ≥ 60° have to be used (see Recommendation ITU-R P.1239, Fig. 2).

Step 3: Calculate the Gaussian distribution from the 10%, 50% and 90% values of measured field strength from Step 2. Read a "corrected measured" value from this Gaussian distribution applying half of the value of "fraction of days" per month given by the prediction.

Step 4: Compare the signal intensity of the prediction with the corrected measured value derived in Step 3.

5 Comparison procedure for daily measured values

If a data bank of daily measured values is available, the comparison should be performed using the following method:

Step 1: Given the median and decile values of a quantity x as predicted by the computer program REC533, based on the method contained in Recommendation ITU-R P.533, the monthly mean $M(x)$ and variance $V(x)$ are calculated by:

$$M(x) = X_{50} + \frac{\sigma_u - \sigma_l}{\sqrt{2\pi}}$$

and:

$$V(x) = \frac{\sigma_u^2 + \sigma_l^2}{2} - \left[M(x) - X_{50}\right]^2$$

with:

$$\sigma_u = \frac{X_{90} - X_{50}}{1.282} \qquad \sigma_l = \frac{X_{50} - X_{10}}{1.282}$$

where X_{50} is the median and X_{90} and X_{10} are the upper and lower deciles, respectively, of the predicted magnitude.

Step 2: Given a data bank containing daily measured values, the monthly mean $M(y)$ and variance $V(y)$ of the daily values y are calculated by:

$$M(y) = \frac{1}{N} \sum_{i=1}^{N} y_i$$

and:

$$V(y) = \frac{1}{N-1} \left[\sum_{i=1}^{N} y_i^2 - N \cdot M^2(y) \right]$$

where y_i, $i = 1, 2, ... N$, $N \leq 31$, are the daily samples of the measured quantity.

Step 3: Given the monthly means $M(x)$, $M(y)$, and variances $V(x)$, $V(y)$, of the predictions and measurements, respectively, the mean $M(z)$, variance $V(z)$ and standard deviation $S(z)$ of the difference $z = x – y$ are calculated by:

$$M(z) = M(x) - M(y)$$

$$V(z) = V(x) + V(y)$$

and:

$$S(z) = \sqrt{V(z)}$$

Given the means $M_j(z)$, variances $V_j(z)$ and numbers of samples N_j for an individual month j, the mean $M(z)$, variance $V(z)$ and standard deviation $S(z)$ of a subset of values including a range of m months are calculated by:

$$M(z) = \frac{\sum_{j=1}^{m} N_j \cdot M_j(z)}{\sum_{j=1}^{m} N_j}$$

$$V(z) = \frac{1}{\sum_{j=1}^{m} N_j - 1} \left[\sum_{j=1}^{m} \left[\left(N_j - 1 \right) \cdot V_j(z) \right] + \sum_{j=1}^{m} N_j \cdot M_j^2(z) - \frac{\left[\sum_{j=1}^{m} N_j \cdot M_j(z) \right]^2}{\sum_{j=1}^{m} N_j} \right]$$

and:

$$S(z) = \sqrt{V(z)}$$

ANNEX 2

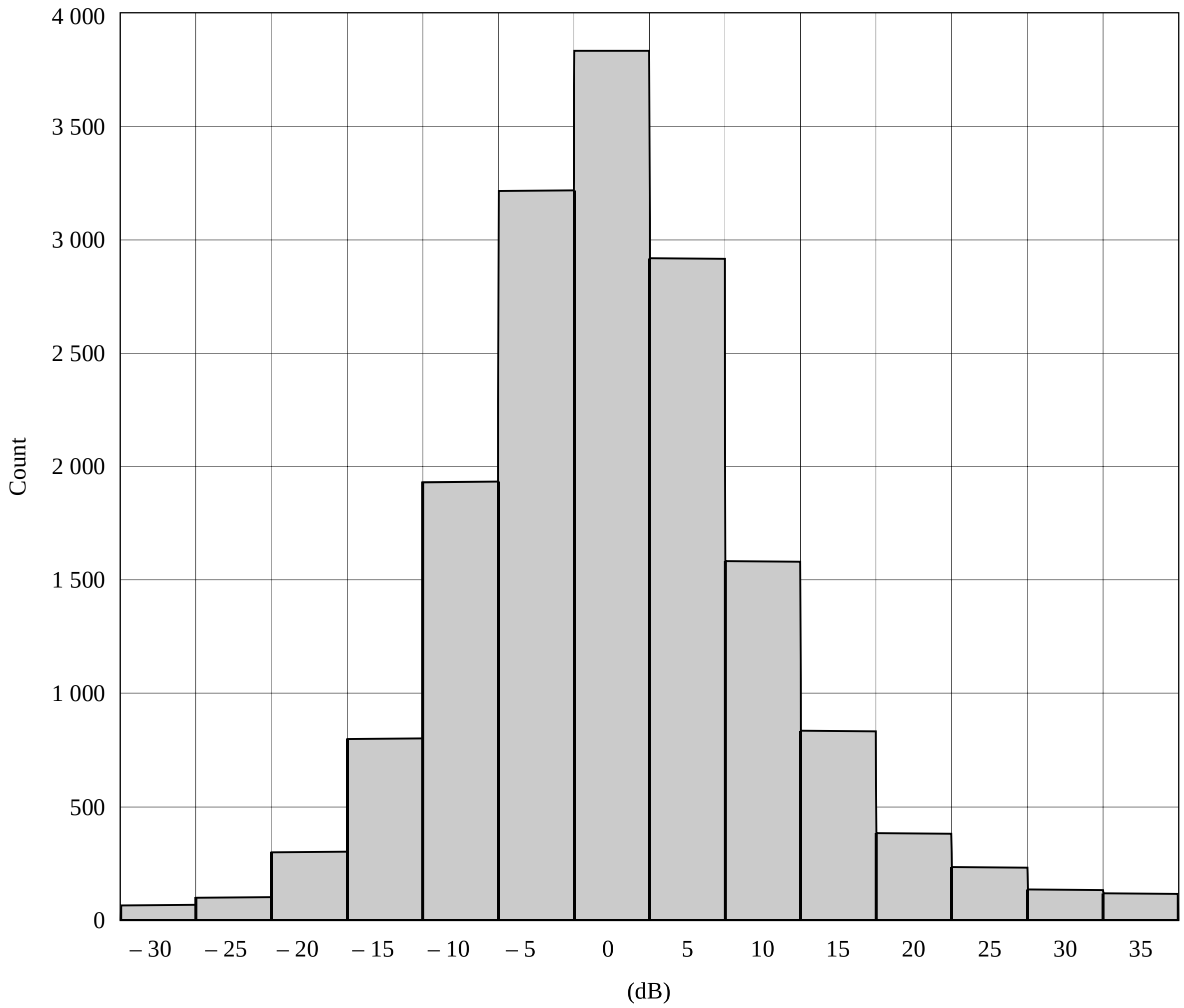
TABLE 2

An example of the tabular output produced by the comparison computer program

Subset	Below and above MUF		
	Count	Mean difference (dB)	Standard deviation (dB)
Frequency groups (MHz):			
2- 5	4 030	–1.7	9.1
> 5-10	4 004	–0.3	10.6
> 10-15	5 270	–0.4	9.9
> 15-30	2 964	3.7	12.1
Distance (km):			
0- 999	6 439	–0.3	7.7
1 000- 1 999	1 144	1.5	7.4
2 000- 2 999	151	0.1	6.9
3 000- 3 999	975	3.8	13.6
4 000- 4 999	126	1.0	7.4
5 000- 6 999	2 785	–1.2	14.5
7 000- 8 999	59	–0.9	7.3
9 000-11 999	2 223	–1.0	11.1
12 000-14 999	607	1.2	9.6
15 000-17 999	1 093	3.4	9.2
18 000-21 999	0	0.0	0.0
22 000-40 000	666	–2.0	12.1
Geomagnetic latitude (degrees) at path midpoint:			
0-20	2 806	1.5	10.7
> 20-40	5 120	–0.5	8.9
> 40-60	6 226	–0.3	9.0
> 60	2 116	0.3	16.0
Sunspot number:			
0- 14	1 333	1.2	9.7
15- 44	5 229	2.5	10.3
45- 74	2 969	–0.5	10.3
75-104	2 121	–3.4	10.8
105-149	2 789	–1.5	9.9
> 149	1 827	–0.7	10.4
Season:			
Winter	3 919	0.6	11.2
Spring	4 018	0.3	10.5
Summer	4 165	–0.4	9.7
Autumn	4 166	–0.2	10.4
Local time at path midpoint (h):			
> 00-04	2 557	–0.6	11.2
> 04-08	3 165	0.8	9.7
> 08-12	3 182	0.9	9.8
> 12-16	2 955	0.3	10.0
> 16-20	2 228	–1.6	10.6
> 20-24	2 181	–0.1	11.6
Origin of data:			
Germany	10 499	1.1	11.4
Japan	4 119	–2.3	7.5
China	428	1.4	7.7
India	182	–2.2	9.0
Deutsche Welle	783	–1.4	10.0
BBC/EBU	161	–0.4	10.7
Australia	96	–0.7	5.9
All data:	16 268	0.0	10.5

FIGURE 1

An example of a histogram of predicted versus measured field strength produced by the comparison computer program



All data below and above MUF:

Count: 16 268
Mean difference: 0.0 dB
Standard deviation: 10.5 dB

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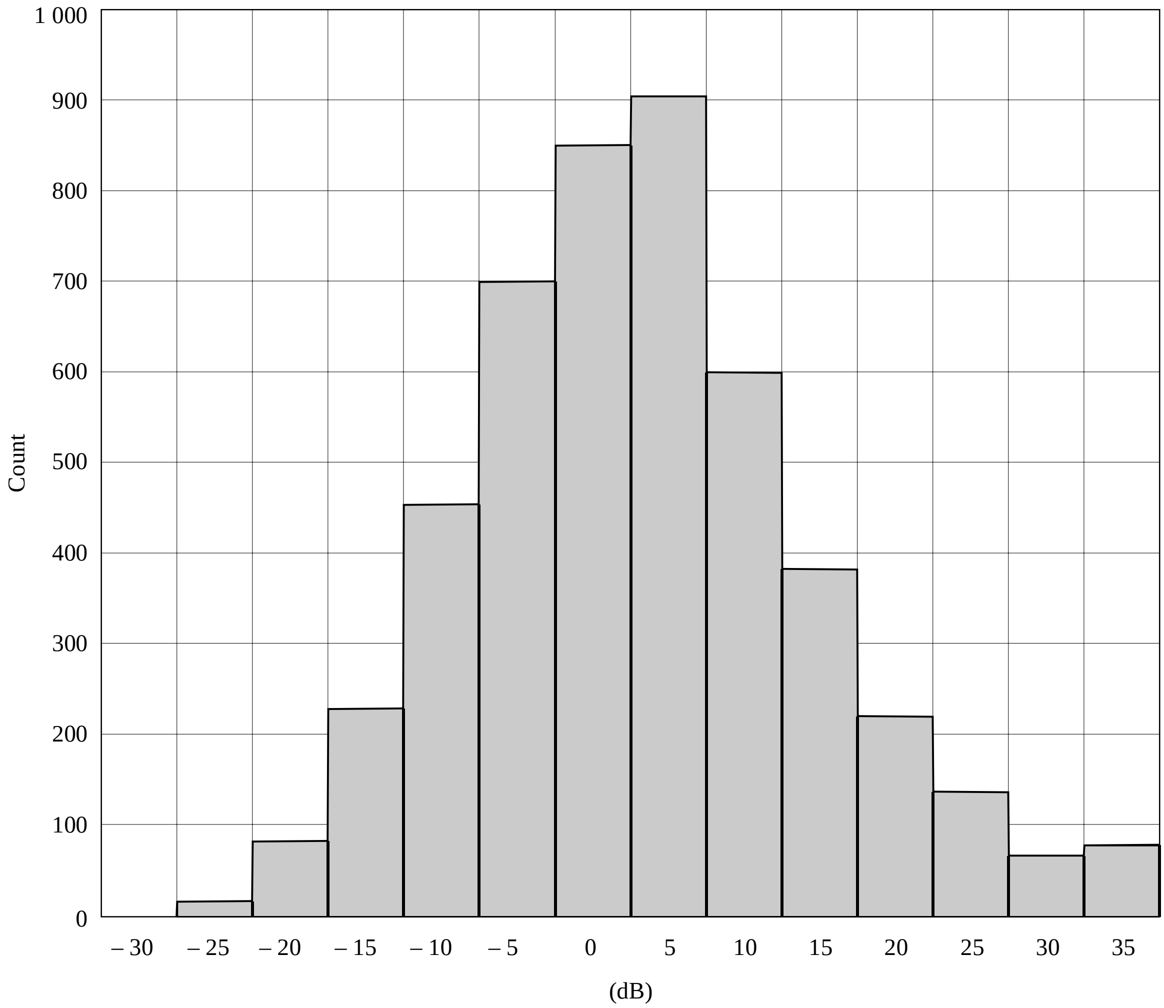
FIGURE 2

A further example of a histogram of predicted versus measured field strength produced by the program



All data for frequencies above MUF:

Count: 4 707
Mean difference: 3.0 dB
Standard deviation: 11.7 dB

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