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Radiocommunication Sector of ITU

Recommendation ITU-R P.311-14
(09/2013)

Acquisition, presentation and analysis of data in studies of radiowave propagation

P Series
Radiowave propagation

Foreword

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The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

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SNG	Satellite news gathering
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Note*: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R P.311-14

Acquisition, presentation and analysis of data in studies of radiowave propagation

(1953-1956-1959-1970-1974-1978-1982-1990-1992-1994-1997-1999-2001-2003-2005-2009-2013)

The ITU Radiocommunication Assembly,

considering

a) that for the design of communication systems, propagation prediction models with global validity are necessary;

b) that propagation and radiometeorological data are of fundamental importance for the development and testing of such prediction models;

c) that, to facilitate the comparison of data and results, it is desirable to acquire and present propagation and radiometeorological data in a uniform manner,

recommends

1 that data on tropospheric propagation, submitted to Radiocommunication Study Group 3, follow the principles and formats contained in Annex 1.

Annex 1

Data banks to support evaluation of prediction methods

1 Introduction

One of the essential requirements for the provision of reliable methods for prediction of radio propagation effects is the establishment of suitable computer data banks. Such data banks must:

– contain all data available that are of an adequate standard,

– be widely accepted as the source material on which to conduct testing,

– be readily available.

It is a principle of the data banks that they shall contain only such data as may be used for:

– testing prediction methods recommended by Radiocommunication Study Group 3 (and may of course be used to test other methods); and

– for the creation and updating of radiometeorological maps relevant to the prediction of radio propagation effects.

In special cases in studies on tropospheric propagation, where no prediction method has been adopted by Radiocommunication Study Group 3, tabular data remain in the annex of the relevant Recommendation to give guidance to the reader from the best measured data currently available.

The current data banks relate to:

– evaluation of prediction methods for terrestrial line-of-sight propagation;

– evaluation of prediction methods for Earth-space propagation;

– evaluation of prediction methods for interference or reliability over trans-horizon paths;

– radiometeorological data;

– evaluation of prediction methods for terrestrial land mobile services;

– evaluation of prediction methods for terrestrial broadcasting services;

– evaluation of prediction methods for mobile-satellite services;

– vegetation and building data.

Administrations are urged to submit their data to Radiocommunication Study Group 3 and/or the relevant Working Party (WP) in accordance with the requirements given in this Annex. Section 2 outlines the more administrative aspects related to the data banks, and the procedure for input of the new data for inclusion in the data banks. Section 3 gives the criteria with which the data submitted must comply to being accepted. Section 4 lists the testing criteria used. Section 5 lists all the tables of the data banks.

Blank pro forma for the data, showing in detail the nature and format of data required/available, are freely available from that part of the ITU-R website concerning Radiocommunication Study Group 3. Moreover, the total data banks are available in spreadsheet form from the same website. Paper and diskette copies of the format sheets, and diskette copies of the total data bank, can be made available, on request, from the Radiocommunication Bureau (BR).

Table III-1a is currently available as a separate database. The Table currently includes approximately 100 000 measurements recorded over 1 326 paths. They were obtained from measurements lasting from 10 min to 1 h. The database is also available from the Radiocommunication Study Group 3 website.

2 Responsibilities and updates

The responsibility for the data banks lies with Radiocommunication Study Group 3, taking full advantage of the WPs for technical input and management, and the services of the BR for publication and distribution. Responsibility as to the accuracy and significance of the data remains with the authors given in the references and/or with the administrations that have submitted the data. However, in order to facilitate the transformation of the given data to computer-data, and to ensure the quality of the data banks, the data shall first be reviewed by the relevant WP according to the set of criteria explained in § 3. Non-compliant data may still be accepted after additional information and/or adequate explanations are sought and received from the relevant administration.

Ensuring adequate procedures for technical maintenance and production of the data banks will be a continuing requirement to keep under review. It is proposed that each table of the data bank be allocated to a WP to consider, and that the relevant WPs nominate, for each table for which they are responsible, an individual to coordinate updates.

3 Acceptance criteria

Data given for inclusion in the data banks will be reviewed as to their suitability according to the following criteria:

– Compliance of the given information with the formats described in the blank proforma. In particular, the units of measure should consistently adhere to the ones listed in the table description sheets. With few exceptions they are based on the international system of units (SI system). For the definitions of terms, see Recommendation ITU-R P.310. It is recommended to use copies of the tables in the pro forma for submission of the data and to enter additional important information under "Remarks".

– For Tables I-1 and II-1, cumulative statistics of rainfall rate, rain attenuation and total attenuation, strictly concurrent data are requested. Strictly concurrent data means that the statistical analysis of rainfall rate and attenuation data shall only include measurements collected during identical time periods. In addition, if periods of rain attenuation or of total attenuation data are missing or are marked as invalid due to system failure or malfunction, then these periods of rainfall rate data shall be excluded from the statistical analysis for Tables I-1 and II-1. The same process shall be applied to rain attenuation or total attenuation data in the case of invalid periods of rainfall rate measurements. In any case the full statistics of valid rainfall rate data shall be provided in Table IV-1.

– For long-term and yearly cumulative statistics the observation period shall be an integer multiple of 12 months and the equipment up-time should be at least 90% of the total time reported.

– The worst-month cumulative statistics (see Recommendation ITU-R P.581) must have been derived from all the 12 monthly statistics of the relevant year. The equipment up-time must be at least 75% of each month.

– Accuracy of interpolation: when converting the measured cumulative statistics into the format requested (for several fixed percentages), interpolation may be required. For this, a sufficiently large number of reference levels must be chosen such that for successive reference levels the ratio of the probabilities is greater than 0.8 and less than 1.25. Extrapolated values should not be submitted.

– For terrestrial wideband data the receiver dynamic range should be at least 18 dB to provide for a minimum peak-to-noise ratio of 15 dB.

– For rainfall rate statistics, it is preferable that an integration time of 1 min be used for consistency with the prediction methods of Radiocommunication Study Group 3.

The above criteria shall be applied by the reviewers of the given data. In special cases, however, some of the criteria may be relaxed (e.g. in multipath phenomena the fade statistics show a definite linear trend in the tail of the distribution when plotted on a logarithmic-linear graph, so that interpolation becomes less of a problem). It is also appropriate to apply less stringent acceptance criteria in cases where the statistical data come from a region that is hardly represented in the respective data table. Data which are accepted in spite of not meeting the acceptance criteria (due to reasons given above) will be marked with a particular flag by the responsible table coordinator and are subject to removal from the data bank once a sufficient number of fully compliant data have been entered.

4 Testing criteria for comparing prediction methods

4.1 General considerations

In order to judge the relative merits of a prediction method, an objective set of criteria needs to be defined. In general, the data used for the comparison have to be suitable for the purpose of the application (see data acceptance criteria, § 3). While the database generally lists all data that are suitable for at least one type of test, some data entries may not be suitable for certain types of predictions and need therefore to be excluded from such tests. (Example: some of the data in Table III-1 are not suitable for testing trans-horizon reliability – they are therefore marked in the flag-field.) It is also important to exclude any dependent data (where one entry is a sub-set of another entry). However, data from measurements made at the same station during the same period with different elevation angle or polarization can be treated as independent data.

In addition, in most cases, the duration of the measurement (in multiples of years) is to be used as a weighting function. (Note that the duration is defined as the actual number of days made up by the complete set of valid data which is normally less than the time from start date to end date; the difference is the "down-time" of the experiment.)

The general requirements for models are (in decreasing order of importance).

4.1.1 Best performance in terms of testing variable

This testing variable (i.e. minimum mean of difference between predicted and measured value or minimum standard deviation of the difference) has to be agreed upon within the responsible WP. It should be noted that the test needs to be carried out on the full data set currently applicable and on agreed-upon sub-sets of the data.

4.1.2 "Physical basis" of the method chosen

Most propagation prediction methods used are semi-empirical in nature because the details of the physical process are either not precisely known or because the number of input parameters would simply be impractical to provide. The better the underlying physical principles are represented in a model, the better the chances that the model can also be applied in hitherto unexplored domains (new frequencies, new climatic zones, etc.). A purely empirical method that is simply derived from curve-fitting to measured data is normally not suitable for being applied outside the domain of the measurements made and should therefore be avoided.

4.1.3 "Simplicity"

This criterion, which to some degree may be interpreted as contradictory to the "physical basis" requirement should only be applied to keep the number of required input parameters to a minimum and to assure that the description of the algorithm lends itself to a clear and unambiguous implementation in a computer program. Nomographs can be highly useful simplified representations of a prediction method but they cannot be accepted as the method *per se*.

4.2 Testing variable for comparing rain attenuation predictions

Attenuation predictions are generally made for a number of transmission paths at a fixed set of probability levels. Data for comparison of prediction methods are to be tabulated at fixed probability levels, e.g. 0.001%, 0.01% and 0.1% of the year. The ratio of predicted to measured attenuation is calculated for each path. The natural logarithm of the ratios is used as a test variable. To compensate for the effects of contributions from attenuation sources other than rain as well as from measurement inaccuracies, which predominantly affect the lower attenuation values, the logarithm is to be multiplied by a scaling factor for values of measured attenuation of less than 10 dB. This scaling factor is a power function of the measured attenuation. The thus modified test variable closely follows a normal distribution. The mean and standard deviations of the (modified) test variable are then calculated to provide the statistics for prediction method comparison.

4.2.1 Procedure

– For each percentage of time, calculate the ratio of predicted attenuation, A_p (dB), to measured attenuation, A_m (dB), for each radio link:

$$S_i = A_{p,i} / A_{m,i} \tag{1}$$

where S_i is the above ratio calculated for the i-th radio link.

– Calculate the test variable:

$$\begin{aligned} V_i &= \ln S_i \, (A_{m,i} / 10)^{0.2} && \text{for } A_{m,i} < 10 \text{ dB} \\ &= \ln S_i && \text{for } A_{m,i} \geq 10 \text{ dB} \end{aligned} \tag{2}$$

– Repeat the procedure for each percentage of time.

– Calculate the mean μ_V, standard deviation σ_V, and r.m.s. value ρ_V, of the V_i values for each percentage of time:

$$\rho_V = \left(\mu_V^2 + \sigma_V^2\right)^{0.5} \tag{3}$$

NOTE 1 – (Weighting function). If some measured distributions are multi-year (n year) data then calculate the mean μ_V, standard deviation σ_V, and r.m.s. value ρ_V, of the n V_i values (e.g. if average year data from three years of observation are assessed, then use three times the same V_i value for each percentage of time).

NOTE 2 – (Assessment over decades of probability levels). For the assessment of prediction methods over decades of probability levels (e.g. from 0.001% to 0.1% of time) calculate the test variable V_i values for each percentage of time (preferred values are 0.001, 0.002, 0.003, 0.005, 0.01, 0.02, 0.03, 0.05, and 0.1), take into account a weighting function and calculate the mean $\overline{\mu}_V$, standard deviation $\overline{\sigma}_V$ and r.m.s. value $\overline{\rho}_V$ of all these V_i values over the required decades of probability levels.

In the comparison of prediction methods, the best prediction method produces the smallest values of the statistical parameters. It is to be noted that the logarithmic parameters can afterwards be converted to equivalent percentage parameters. The standard deviation, for example, leads to equivalent upper and lower percentage deviations:

$$D_{u,\ell} = [\exp(\pm\sigma_V)^{-1}] \times 100$$

which are measures of the spread of the predicted values with respect to the measured ones, normalized to an attenuation value of 10 dB.

The procedure provides a tool not only to assess the performance of the various prediction methods but also to give indications for their improvement. Graphical inspection of the spreads of A_p and A_m values may also give useful information about the relative merits of both experimental data and prediction methods.

Moreover, these statistical parameters may provide some information on the expected spread of actual attenuation values around a predicted one. For this purpose, the above scaling procedure can be used in the reverse direction, i.e. the normalized standard deviation for an attenuation level of 10 dB can be scaled to the standard deviation to be expected at another predicted attenuation level, A_p (dB), by the factor $(10/A_p)^{0.2}$.

It has to be noted that the ultimate limit for the accuracy of any prediction method is the accuracy with which the rain climatic conditions for a given location can be characterized by an assumed point rainfall intensity cumulative distribution.

4.3 Testing method for comparing fade duration predictions

4.3.1 Principle of the method

Fade duration can be described by two different cumulative distribution functions:

1. $P(d > D|a > A)$, the probability of occurrence of fades of duration d longer than D (s), given that the attenuation a is greater than A (dB).
2. $F(d > D|a > A)$, the cumulative exceedance probability, or, equivalently, the total fraction (between 0 and 1) of fade time due to fades of duration d longer than D (s), given that the attenuation a is greater than A (dB).

Data for comparison of fade duration prediction methods are tabulated for both a fixed individual fade duration D (e.g. 6 s, 180 s or 3 600 s) and for a fixed attenuation threshold A (e.g. 3 dB, 10 dB or 25 dB). The ratio of the predicted to the measured fraction of time is calculated for each radio link and the logarithm of this ratio is defined as the test variable. The mean and standard deviation of the test variable are then calculated to provide the statistics for prediction method comparison.

4.3.2 Procedure

Step 1a: For prediction methods of the probability of occurrence P, calculate the test variable as the natural logarithm of the ratio of predicted probability $P_p(d > D|a > A)$ to measured probability $P_m(d > D|a > A)$, for each attenuation threshold A and for each fade duration D defined in Tables I-8b and II-3b, and for each radio link:

$$\varepsilon_{P,i}(D, A) = \ln\left(\frac{P_p(D|A)}{P_m(D|A)}\right) \tag{4}$$

where:

$\varepsilon_{P,i}$: test variable calculated for the i-th radio link.

Step 1b: For prediction methods of the percentage of fade time F, subtract both the predicted fraction of time $F_p(d > D|a > A)$ and the measured fraction of time $F_m(d > D|a > A)$ from 1. Calculate the test variable as the natural logarithm of the ratio of these differences, for each attenuation threshold A and for each fade duration D defined in Tables I-8c and II-3c, and for each radio link:

$$\varepsilon_{N,i}(D, A) = \ln\left(\frac{1 - F_p(D|A)}{1 - F_m(D|A)}\right) \tag{5}$$

where:

$\varepsilon_{N,i}$: test variable calculated for the i-th radio link.

Step 2: For each prediction method, calculate the mean, standard deviation and r.m.s. values of the error ε_P or ε_N for each individual fade duration and for each attenuation threshold given in Tables I-8 and II-3.

If some measured distributions are multi-year (n years) data, then calculate the mean, standard deviation and r.m.s. values of the n $\varepsilon_{P,\mathrm{i}}$ or $\varepsilon_{N,\mathrm{i}}$ values (e.g. if average annual data from three years of observation are assessed, then use three times the same $\varepsilon_{P,\mathrm{i}}$ or $\varepsilon_{N,\mathrm{i}}$ value for each fade duration and attenuation).

In the comparison of prediction methods, the best prediction method produces the smallest values of the statistical parameters.

4.4 Testing method for comparing fade slope predictions

4.4.1 Principle of the method

The predicted distribution of fade slope used in this testing method is the cumulative distribution of a fade slope to be exceeded at a given attenuation threshold. It is dependent on attenuation level $A(t)$, on the time interval length Δt and on the 3 dB cut-off frequency of the low-pass filter which is used to remove tropospheric scintillation and rapid variations of rain attenuation from the signal.

Data for comparison of fade slope prediction methods are tabulated for both a fixed time percentage P (from 0.001% to 50%) and for a fixed attenuation threshold A (e.g. 3 dB, 10 dB or 25 dB). The ratio of the predicted to the measured fade slope is calculated for each radio link and the logarithm of this ratio is defined as the test variable. The mean and standard deviation of the test variable are then calculated to provide the statistics for prediction method comparison.

4.4.2 Procedure

Step 1: For each attenuation threshold A and for each fade slope value ζ defined in Table II-8b, calculate the test variable from the predicted exceedence probability $P_p(\zeta \mid A)$ and the measured exceedence probability $P_m(\zeta \mid A)$ for each radio link, as:

$$\varepsilon_i(\zeta, A) = 2 \cdot \frac{P_p(\zeta \mid A) - P_m(\zeta \mid A)}{P_p(\zeta \mid A) + P_m(\zeta \mid A)} \tag{6}$$

where:

ε_i: test variable calculated for the i-th radio link.

Step 2: Calculate the mean, standard deviation and r.m.s. values of the error ε for the combination of all experiments, and for each individual fade slope and for each attenuation threshold given in Table II-8b.

If some measured distributions are multi-year (n years) data, then calculate the mean, standard deviation and r.m.s. values of the n ε_i values (e.g. if average annual data from three years of observation are assessed, then use three times the same ε_i value for eachfade slope and attenuation).

In the comparison of prediction methods, the best prediction method produces the smallest values of the statistical parameters.

5 List of the data banks of Radiocommunication Study Group 3 concerning tropospheric propagation

5.1 Part I: Terrestrial line-of-sight path data

Table I-1: Line-of-sight rain attenuation statistics

Table I-2: Line-of-sight average worst-month multipath fading and enhancement in narrow bandwidths

Table I-3: Line-of-sight diversity data

Table I-4: Line-of-sight clear sky XPD and CPA statistics

Table I-5: Line-of-sight XPD and CPA statistics due to precipitation

Table I-6: Line-of-sight worst-month multipath channel characteristics and outage times

Table I-7: Line-of-sight multi-hop worst-month multipath fading and enhancement

Table I-8: Line-of-sight number of fade events and fade duration statistics

Table I-9: Line-of-sight annual attenuation statistics at optical wavelengths

Table I-10: Line-of-sight worst month attenuation statistics at optical wavelengths

Table I-11: Line-of-sight annual statistics of frequency diversity for millimeter wave and optical links

Table I-12: Line-of-sight worst month statistics of frequency diversity for millimeter wave and optical links

Table I-13: Line-of-sight time diversity statistics

Table I-14: Line-of-sight joint and differential rain attenuation statistics

5.2 Part II: Earth-space path data

Table II-1: Slant path annual rain attenuation and rain rate statistics

Table II-2: Slant path worst-month rain attenuation statistics

Table II-3: Slant path fade duration statistics

Table II-4: Slant path site diversity statistics

Table II-5a: Slant path annual XPD statistics

Table II-5b: Slant path annual XPD statistics conditioned to CPA

Table II-6: Slant path statistics of amplitude scintillations

Table II-7: Slant path standard deviations of scintillations

Table II-8: Slant path fade slope statistics

Table II-9: Slant path time diversity statistics

Table II-10: Slant path instantaneous frequency scaling statistics

5.3 Part III: Terrestrial trans-horizon path and rain scatter data

Table III-1: Clear-air trans-horizon basic transmission loss statistics

Table III-1a: Clear-air spot measurement data. (This table is a separate data bank (see § 1))

Table III-2: Rain scatter on terrestrial paths

Table III-3: Joint signal level probability distributions

5.4 Part IV: Radiometeorological data

Table IV-1: Statistics of rain intensity

Table IV-2: Rain integration time conversion factor

Table IV-3: Annual statistics of sky noise temperature

Table IV-4: Statistics of mean surface refractivity

Table IV-5: Statistics of rain event duration

Table IV-6: Statistics of evaporation ducts

Table IV-7: Statistics of cloud cover

Table IV-8: Spatial statistics dependence of rain intensity

Table IV-9: Total columnar water vapour content

Table IV-10: Total columnar cloud liquid water content

5.5 Part V: Terrestrial land mobile data

Table V-1: Terrestrial land mobile wideband statistics

Table V-2: Terrestrial land mobile narrow-band statistics

5.6 Part VI: Terrestrial point-to-area data

Table VI-1: Terrestrial point-to-area data

5.7 Part VII: Data for mobile-satellite services

Table VII-1: Wideband statistics for mobile-satellite links

Table VII-2: Narrow-band statistics of maritime mobile-satellite links

Table VII-3: Narrow-band statistics of land mobile-satellite links

Table VII-4: Narrow-band statistics of aeronautical mobile-satellite links

Table VII-5: Narrow-band statistics of broadcasting-satellite fades and fade durations

5.8 Part VIII: Vegetation and building data

Table VIII-1: Vegetation attenuation

Table VIII-2: Building entry loss

Table VIII-3: Loss characteristics of materials

5.9 Part IX: Noise

Table IX-1: White Gaussian radio noise