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| on testing variables used for the selectionof prediction methods |

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# 1 Scope

The material in this Fascicle is defining the criteria for testing propagation prediction methods as indicated in Recommendation ITU-R P.311 in view of their adoption in P-series Recommendations.

# 2 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).

## 2.1 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 Working Party. 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.

## 2.2 “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.

## 2.3 “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*.

# 3 Testing variable for comparing rainfall rate predictions

Rainfall rate predictions are generally made for a number of specific locations 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 relative error between the predicted rainfall rate values and the measured ones must be used as testing variable to test rainfall rate prediction models.

‑ For each percentage of time, calculate the relative error of predicted rainfall rate, Rp (mm/h), to measured attenuation, Rm (mm/h), for each radio link:

 $Vi = \frac{R\_{p,i}-R\_{m,i}}{R\_{m,i}}$ (1)

‑ 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 *Vi* values for each percentage of time:

  (2)

NOTE 1 – (Weighting function). If some measured distributions are multi-year (n year) data then calculate the mean μV, standard deviation σV, and r.m.s. value ρV, of the n Vi values (e.g. if average year data from three years of observation are assessed, then use three times the same Vi 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 10% of time) calculate the test variable *Vi* 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, 0.1, 0.2, 0.3, 0.5, 1, 2, 3, 5, and 10), take into account a weighting function and calculate the mean  standard deviation  and r.m.s. value  of all these *Vi* values over the required decades of probability levels.

# 4 Testing variable for comparing rain attenuation predictions

## 4.1 Principles of the methodology

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 Procedure

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

 *Si*  *Ap,i*/ *Am,i* (1)

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

– Calculate the test variable:

 *Vi*  ln *Si* (*Am,i* / 10)0.2 for *Am,i*  10 dB (2)

  ln *Si* for *Am,i*  10 dB

– 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 *Vi* values for each percentage of time:

  (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* *Vi* values (e.g. if average year data from three years of observation are assessed, then use three times the same *Vi* 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 *Vi* 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  standard deviation  and r.m.s. value  of all these *Vi* 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:

 

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 *Ap* and *Am* 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, *Ap* (dB), by the factor (10 / *Ap* )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.

# 5 Testing method for comparing fade duration predictions

## 5.1 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.

## 5.2 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 *Pp*(*d > D|a > A*) to measured probability *Pm*(*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:

  (4)

where:

 ε*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 *Fp*(*d > D|a > A*) and the measured fraction of time *Fm*(*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:

  (5)

where:

 ε*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* ε*P*,i or ε*N*,i values (e.g. if average annual data from three years of observation are assessed, then use three times the same ε*P*,i or ε*N*,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.

# 6 Testing method for comparing fade slope predictions

## 6.1 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 Δ*t* 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.

## 6.2 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 *Pp*(ζ | *A*) and the measured exceedence probability *Pm*(ζ | *A*) for each radio link, as:

  (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 each fade slope and attenuation).

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

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