International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R P.678-3
(07/2015)

Characterization of the variability of propagation phenomena and estimation of the risk associated with propagation margin

P Series
Radiowave propagation

1865 - 2015

International Telecommunication Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

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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Series of ITU-R Recommendations

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P	**Radiowave propagation**
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
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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.678-3

Characterization of the variability of propagation phenomena and estimation of the risk associated with propagation margin

(1990-1992-2013-2015)

Scope

This Recommendation provides three prediction methods of:

– the expected year-to-year variation of the worst-month time fraction of excess;

– the inter-annual variability of rainfall rate and rain attenuation statistics;

– risk parameters associated with the variation of rain attenuation statistics.

The ITU Radiocommunication Assembly,

considering

a) that knowledge of the variability of propagation phenomena is required to allow proper cost and performance trade-offs to be made in the analysis of system reliability, availability and quality;

b) that a prediction procedure to estimate risk parameters associated with the variation of propagation statistics is required for the formulation of performance criteria of radiocommunication system;

c) that a prediction procedure exists for the estimation of the statistics of the year-to-year variations in the annual worst-month time fraction of excess as defined in Recommendation ITU-R P.581,

recommends

1 that Fig. 1 of Annex 1 be used for the estimation of the expected year-to-year variation of the annual worst-month time fraction of excess;

2 that the expected variation about a long-term average predicted value be reported as a function of return period;

3 that the inter-annual variability of rainfall rate and rain attenuation statistics around a long-term average statistics be computed from Annex 2;

4 that the risk parameters associated with the variation of propagation statistics be computed from Annex 3.

NOTE 1 – The return period is the average time interval between two consecutive occurrences of a defined stochastic event. For a long series of observation, the value of the return period is $1/P$ (times the average interval between all pairs of consecutive events) where P is the probability of occurrence of the event. For example, the median value of a long series of annual worst-month time fraction of excess values would have a two-year return period.

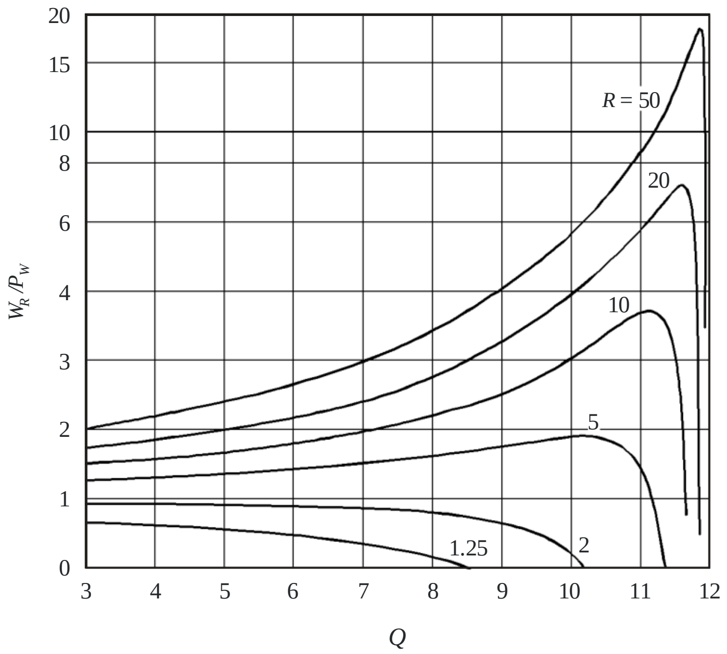
NOTE 2 – The risk is defined as the probability that the yearly guaranteed availability is not fulfilled.

Annex 1

Estimation of the expected year-to-year variation of the annual worst-month time fraction of excess

FIGURE 1

Dependance of W_R/P_W on Q for several value of the return period R (years)



P_W: average annual worst-month time fraction of excess

W_R: annual worst-month time fraction of excess associated with a return period of R years

Q: worst-month quotient, a propagation climatic factor (see Recommendation ITU-R P.841)

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Note 1 – P_W, W_R, Q should be referred to the same pre-selected threshold value.

Annex 2

Inter-annual variability of rainfall rate and rain attenuation statistics

For a desired location, the inter-annual fluctuations of rainfall rate and rain attenuation statistics around the long-term Complementary Cumulative Distribution Function (CCDF) p are normally distributed with mean p and yearly variance σ^2 so that:

$$\sigma^2(p) = \sigma_C^2(p) + \sigma_E^2(p) \tag{1}$$

where:

σ_E^2: is the variance of estimation

σ_C^2: is the inter-annual climatic variance.

The following prediction method provides a step-by-step procedure to compute $\sigma^2(p)$ associated with the probability of exceedance p.

The following parameters are required:

p: probability of exceedance ($0 \le p \le 1$)

r_c: climatic ratio.

The values of r_c, the climatic ratio, are an integral part of this Recommendation and are available in the form of digital maps provided in the file R-REC-P.678-3-201507-I!!ZIP-E.zip.

These maps were derived from 50 years of Global Precipitation Climatology Centre (GPCC) data over land and from 34 years of Global Precipitation Climatology Project (GPCP) data over the ocean.

Step 1: For the desired probability of exceedance, p, compute:

$$C = \sum_{i=-N+1}^{N-1} c_U(i\Delta t, p) \tag{2}$$

where:

$$\begin{aligned} N &= 525960 \\ \Delta t &= 60 \\ c_U(i\Delta t, p) &= \exp(-a \cdot |i\Delta t|^b) \end{aligned} \tag{3}$$

with:

$$\begin{aligned} b &= b_1 \cdot \ln(p) + b_2 \\ a &= 0.0265 \quad s^{-1} \\ b_1 &= -0.0396 \\ b_2 &= 0.286 \end{aligned} \tag{4}$$

Step 2: The variance of estimation σ_E^2 is computed from:

$$\sigma_E^2(p) = \frac{p(1-p)}{N} \cdot C \tag{5}$$

Step 3: Extract the variable r_c for the four points closest in latitude (Lat) and longitude (Lon) to the geographical coordinates of the desired location.

Step 4: From the values of r_c at the four grid points, obtain the value $r_c(Lat, Lon)$ at the desired location by performing a bi-linear interpolation, as described in Recommendation ITU-R P.1144.

Step 5: The inter-annual climatic variance σ_C^2 is computed such that:

$$\sigma_C^2(p) = \left(r_c(Lat, Lon) \cdot p\right)^2 \qquad (6)$$

If a predicted, rather than an experimental, CCDF is used, the predicted CCDF will not exactly match the actual rainfall rate or rain attenuation (e.g. measured CCDF of rain attenuation will not exactly match the CCDF of rain attenuation predicted by Recommendation ITU-R P.618). In this case, an additional error, $\sigma_M^2(p)$, must be considered in which case equation (1) becomes:

$$\sigma^2(p) = \sigma_C^2(p) + \sigma_E^2(p) + \sigma_M^2(p) \qquad (7)$$

where $\sigma_M^2(p)$ is the error in the predicted CCDF. To assess the impact of the variance $\sigma^2(p)$, it is convenient to refer to the 68% confidence interval $\left[p - \sigma(p), p + \sigma(p)\right]$ that corresponds to plus or minus one standard deviation around the probability for a normally distributed quantity.

The procedure is applicable for time percentages of exceedance from 2% to 0.01% (i.e. $0.0001 \le p \le 0.02$) and for the frequency range from 12 to 50 GHz.

Annex 3

Estimation of the risk associated with propagation margin

Given a fixed rain attenuation A_r exceeded for a given probability p $(0 \le p \le 1)$ such as $P(A > A_r) = p$, the risk $\Re$ (meaning the probability) that the yearly probability $p_\Re$ $(0 \le p_\Re \le 1)$ is exceeded satisfies:

$$\Re = Q\left(\frac{p_\Re - p}{\sigma(p)}\right) \qquad (8)$$

or equivalently:

$$p_\Re = \sigma(p)Q^{-1}(\Re) + p = \sqrt{2}\sigma(p)erfc^{-1}(2\Re) + p \qquad (9)$$

where $\sigma(p)$ can be computed from Annex 2 and where (see Recommendation ITU-R P.1057):

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty \mathrm{e}^{-\frac{t^2}{2}} \mathrm{d}t$$

Importantly, note that $p_\Re = p$ in equation (8) leads, as expected, to $\Re = 0.5$.