International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R P.841-7
(08/2022)

Conversion of annual statistics to worst-month statistics

P Series
Radiowave propagation

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.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from http://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Recommendations

(Also available online at http://www.itu.int/publ/R-REC/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
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
V	Vocabulary and related subjects

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

Electronic Publication
Geneva, 2022

RECOMMENDATION ITU-R P.841-7

Conversion of annual statistics to worst-month statistics

(Question ITU-R 201/3)

(1992-1999-2001-2003-2005-2016-2019-2022)

Scope

This Recommendation provides methods for the conversion of annual percentage into worst-month percentage for propagation related parameters.

Keywords

Worst-month statistics, annual statistics, conversion method

The ITU Radiocommunication Assembly,

considering

a) that for design of radiocommunication systems the required statistics of propagation effects pertain to the worst-month period of reference;

b) that the concept of worst-month is defined in Recommendation ITU-R P.581;

c) that the reference statistics for many radiometeorological data and propagation prediction methods is "the long-term average annual" distribution;

d) that consequently there is a need for a method that provides for the conversion of the "annual" to the "worst-month" statistics;

e) that the worst-month cumulative probability and the worst-month exceedance probability are needed,

recommends

that, when monthly statistics are not available, the method given in Annex 1 be used to convert exceedance probability to worst-month exceedance probability and convert cumulative probability to worst-month cumulative probability.

Annex 1

1 The average annual worst-month exceedance probability[1], p_w, is calculated from the average annual exceedance probability, p, using the conversion factor Q:

$$p_w = Q\,p \qquad (1)$$

where $1 \leq Q \leq 12$, and both p and p_w refer to the same threshold levels.

[1] The terms exceedance probability, time fraction of excess and complementary cumulative distribution function (CCDF) are synonymous.

The cumulative probability, q, and worst-month cumulative probability, q_w, can be converted to the exceedance probability, p, and worst-month exceedance probability, p_w, and vice versa as follows:

$$q = 100 - p, \qquad q_w = 100 - p_w \tag{2}$$

$$p = 100 - q, \qquad p_w = 100 - q_w \tag{3}$$

2 Q is a two parameter (Q_1, β) function of p (%):

$$Q_{(p)} = \begin{cases} 12 & \text{for} \quad p \le \left(\frac{Q_1}{12}\right)^{\frac{1}{\beta}} \% \\ Q_1 \, p^{-\beta} & \text{for} \quad \left(\frac{Q_1}{12}\right)^{\frac{1}{\beta}} < p \le 3\% \\ Q_1 \, 3^{-\beta} & \text{for} \quad 3\% < p \le 30\% \\ Q_1 \, 3^{-\beta} \left(\frac{p}{30}\right)^{\frac{\log\left(Q_1 3^{-\beta}\right)}{\log(0.3)}} & \text{for} \quad 30\% < p \end{cases} \tag{4}$$

3 The calculation of the average annual time exceedance probability from the given value of the average annual worst-month time exceedance probability is done through the inverse relationship:

$$p = p_w / Q \tag{5}$$

and the dependence of Q on p_w can be easily derived from the above given dependence of Q on p. The resulting relationship for $12\,p_0 < p_w(\%) < Q_1\,3^{(1-\beta)}$ is ($p_0 = (Q_1/12)^{1/\beta}$):

$$Q = Q_1^{1/(1-\beta)}\, p_w^{-\beta/(1-\beta)} \tag{6}$$

4 For global planning purposes the following values for the parameters Q_1 and β should be used:

$$Q_1 = 2.85, \quad \beta = 0.13$$

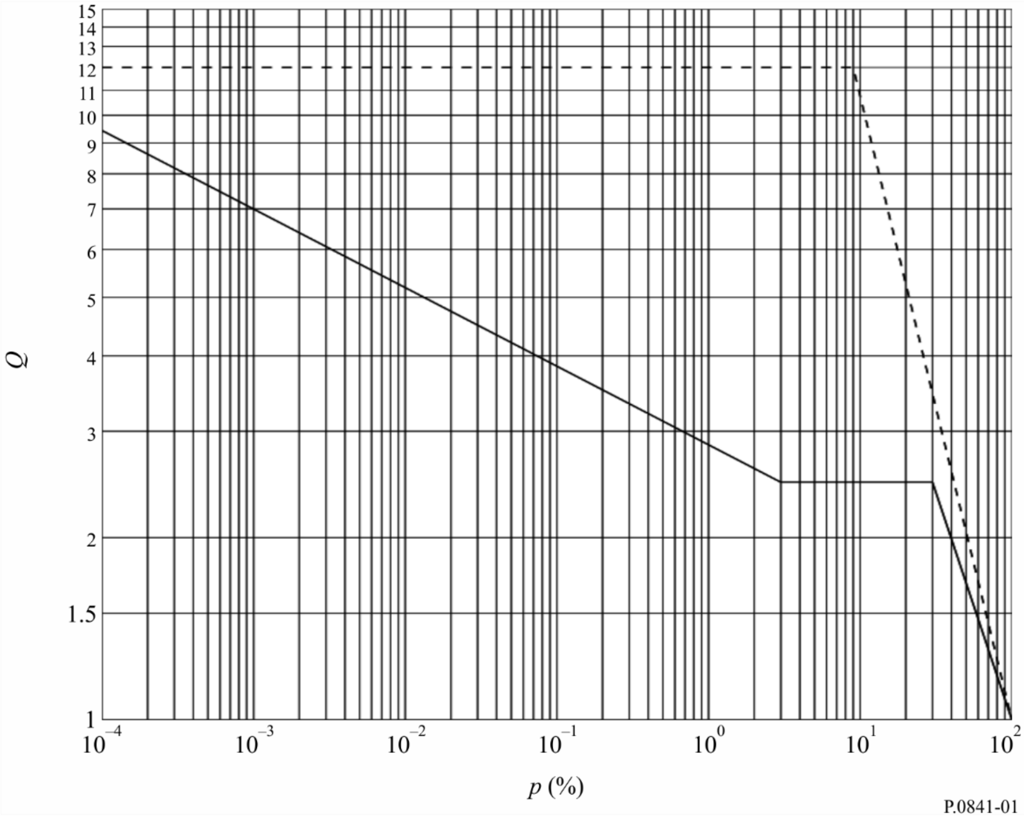
(see Fig. 1). This leads to the following relationship between p and p_w:

$$p(\%) = 0.30\; p_w(\%)^{1.15} \tag{7}$$

for $1.9 \times 10^{-4} < p_w(\%) < 7.8$.

FIGURE 1

Solid line: *Q* vs. *p* with parameters Q_1 = 2.85 and β = 0.13; dashed line: theoretical upper bound



For global rain rate applications, the following values for the parameters Q_1 and β should be used:

$Q_1 = 2.82$, $\beta = 0.15$, for tropical, subtropical and temperate climate regions with frequent rain $Q_1 = 4.48$, $\beta = 0.11$, for dry temperate, polar and desert regions (see Fig. 2). This leads to the following relationship between p and p_w:

$$p(\%) = 0.30\, p_w(\%)^{1.18} \tag{8}$$

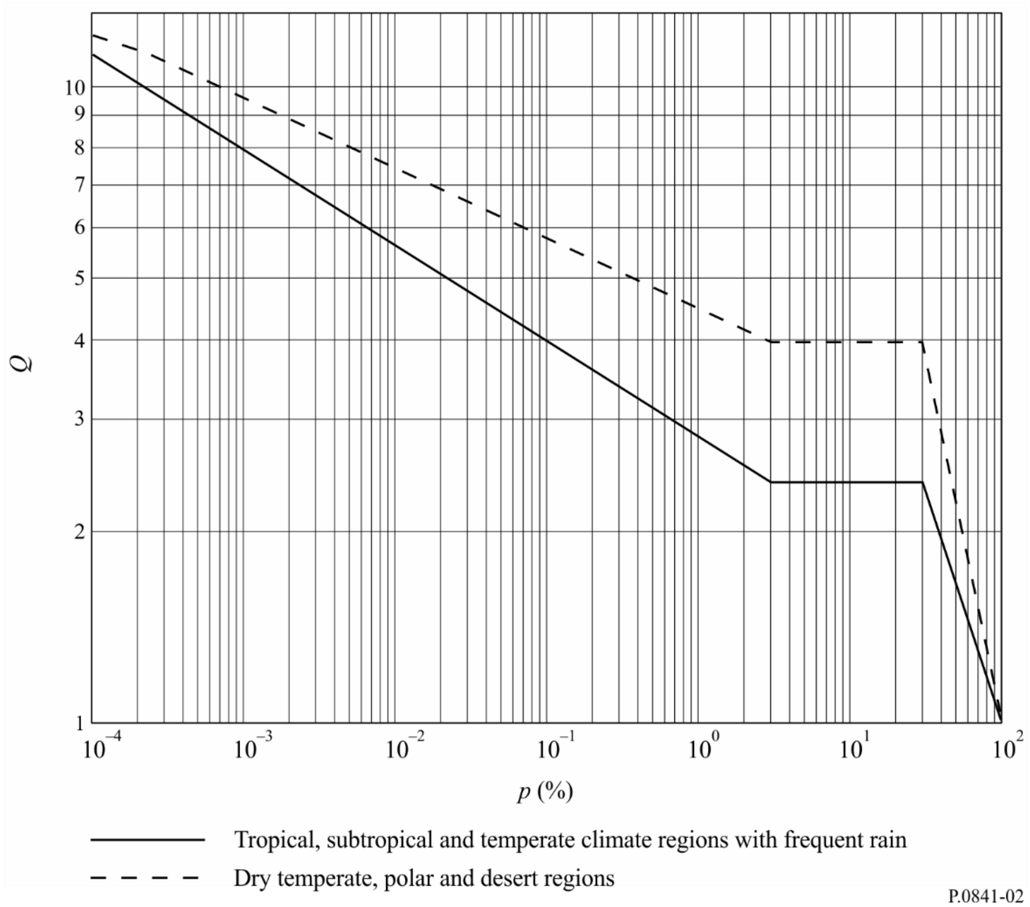
where $7.7 \times 10^{-4} < p_w(\%) < 7.17$, for tropical, subtropical and temperate climate regions with frequent rain:

$$p(\%) = 0.19\, p_w(\%)^{1.12} \tag{9}$$

where $1.5 \times 10^{-3} < p_w(\%) < 11.91$, for dry temperate, polar and desert regions.

FIGURE 2

Example of the dependence of *Q* on *p* with global subregion parameters



5 For more precision the values of Q_1 and β for the different climatic regions and various propagation effects given in Table 1 should be used where appropriate.

6 For trans-horizon paths of land or sea, the β and Q_1 values are calculated from those values for sea and land given in Table 1, where N_s is the local surface refractivity of the Earth lying in the troposcatter common volume.

7 Entries under rain rate for Australia are based on 6-min time interval measurements taken from 20 sites over periods lasting from 25 to 101 years. Examples of site locations for each climatic region in Australia are given in the first column of Table 1. Entries under rain rate for Brazil have been derived for measurements of rainfall rates at nine sites over a 46-year period using fast response rain gauges.

TABLE 1

β and Q_1 values for various propagation effects and locations

	Rain effect terrestrial attenuation	Rain effect slant path attenuation	Rain rate	Multipath	Trans-horizon land	Trans-horizon sea
Global	0.13, 2.85	0.13, 2.85		0.13, 2.85	0.13, 5.8-0.03exp (Ns/75)	0.13, 5.8-0.03exp (Ns/75)
Tropical, subtropical and temperate climate regions with frequent rain			0.15, 2.82			
Dry temperate, polar and desert regions			0.11, 4.48			
Europe North West	0.13, 3.0	0.16, 3.1		0.13, 4.0	0.18, 3.3	
Europe North West 1.3 GHz						0.11, 4.9
Europe North West 11 GHz						0.19, 3.7
Europe Mediterranean	0.14, 2.6	0.16, 3.1				
Europe Nordic	0.15, 3.0	0.16, 3.8		0.12, 5.0		
Europe alpine	0.15, 3.0	0.16, 3.8				
Europe Poland	0.18, 2.6					
Europe Russian Federation	0.14, 3.6					
Europe UK 40 and 50 GHz		0.13, 2.54				
Congo	0.25, 1.5					
Canada Prairie and North	0.08, 4.3					
Canada Coast and Great Lake	0.10, 2.7					

TABLE 1 *(continued)*

	Rain effect terrestrial attenuation	**Rain effect slant path attenuation**	**Rain rate**	**Multipath**	**Trans-horizon land**	**Trans-horizon sea**
Canada Central and Mountains	0.13, 3.0					
United States of America Virginia		0.15, 2.7				
Russian Federation North European region			0.10, 4.57			
Russian Federation Central and West European region			0.16, 2.38			
Russian Federation Middle Volga region and South Ural			0.10, 4.27			
Russian Federation Central Steppe and South European region			0.15, 2.69			
Russian Federation West Siberian region			0.14, 3.72			
Russian Federation Middle Siberian Plateau and Jakutia			0.11, 5.04			
Russian Federation South Far East			0.13, 3.53			
Australia Temperate/ coastal			0.17, 2.65			
Australia Subtropical/ coastal			0.15, 3.15			
Australia Tropical/arid			0.12, 4.35			

TABLE 1 *(end)*

	Rain effect terrestrial attenuation	**Rain effect slant path attenuation**	**Rain rate**	**Multipath**	**Trans-horizon land**	**Trans-horizon sea**
Brazil Equatorial			0.13, 2.85			
Brazil Tropical maritime			0.21, 2.25			
Brazil Tropical inland			0.13, 3.00			
Brazil Subtropical			0.13, 2.85			
Indonesia	0.22, 1.7					
Japan Tokyo	0.20, 3.0					
Japan Yamaguchi		0.15, 4.0				
Japan Kashima		0.15, 2.7				
South Korea			0.12, 4.6			
Kyrgyzstan Flat regions			0.09, 5.95			
Kyrgyzstan Mountainous regions			0.10, 6.70			
Kyrgyzstan Coastal region of Ysyk-Kol lake			0.14, 4.73			
China South			0.15, 3.12			
China North			0.13, 4.12			
China Desert			0.10, 5.40			