International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R P.1144-6
(02/2012)

Guide to the application of the propagation methods of Radiocommunication Study Group 3

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 Annex 1 of 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, 2012

RECOMMENDATION ITU-R P.1144-6

Guide to the application of the propagation methods of Radiocommunication Study Group 3

(1995-1999-2001-2001-2007-2009-2012)

Scope

This Recommendation provides a guide to the Recommendations of Radiocommunication Study Group 3 which contain propagation prediction methods. It advises users on the most appropriate methods for particular applications as well as the limits, required input information, and output for each of these methods.

The ITU Radiocommunication Assembly,

considering

a) that there is a need to assist users of the ITU-R Recommendations P Series (developed by Radiocommunication Study Group 3),

recommends

1 that the information contained in Table 1 be used for guidance on the application of the various propagation methods contained in the ITU-R Recommendations P Series (developed by Radiocommunication Study Group 3);

2 that the information contained in Table 2 and Annex 1 be used for guidance on the use of the various digital maps of geophysical parameters necessary for the application of the propagation methods in *recommends* 1 above.

NOTE 1 – For each of the ITU-R Recommendations in Table 1, there are associated information columns to indicate:

Application: the service(s) or application for which the Recommendation is intended.

Type: the situation to which the Recommendation applies, such as point-to-point, point-to-area, line-of-sight, etc.

Output: the output parameter value produced by the method of the Recommendation, such as path loss.

Frequency: the applicable frequency range of the Recommendation.

Distance: the applicable distance range of the Recommendation.

% *time:* the applicable time percentage values or range of values of the Recommendation; % time is the percentage of time that the predicted signal is exceeded during an average year.

% *location:* the applicable per cent location range of the Recommendation; % location is the percentage of locations within, say, a square with 100 to 200 m sides that the predicted signal is exceeded.

Terminal height: the applicable terminal antenna height range of the Recommendation.

Input data: a list of parameters used by the method of the Recommendation; the list is ordered by the importance of the parameter and, in some instances, default values may be used.

The information, as shown in Table 1, is already provided in the Recommendations themselves; however, the Table allows users to quickly scan the capabilities (and limitations) of the Recommendations without the requirement to search through the text.

TABLE 1

ITU-R radiowave propagation prediction methods

Method	Application	Type	Output	Frequency	Distance	% time	% location	Terminal height	Input data
Rec. ITU-R P.368	All services	Point-to-point	Field strength	10 kHz to 30 MHz	1 to 10 000 km	Not applicable	Not applicable	Ground-based	Frequency Ground conductivity
Rec. ITU-R P.452	Services employing stations on the surface of the Earth; interference	Point-to-point	Path loss	100 MHz to 50 GHz	Not specified but up to and beyond the radio horizon	0.001 to 50 Average year and worst month	Not applicable	No limits specified, within the surface layer of the atmosphere. (Not suitable for aeronautical applications)	Path profile data Frequency Percentage time Tx antenna height Rx antenna height Latitude and longitude of Tx Latitude and longitude of Rx Meteorological data
Rec. ITU-R P.528	Aeronautical mobile	Point-to-area	Path loss	125 MHz to 15.5 GHz	0 to 1 800 km (for aeronautical applications 0 km horizontal distance does not mean 0 km path length)	1 to 95	Not applicable	H1: 1.5 m to 20 km H2: 1 to 20 km	Distance Tx height Frequency Rx height Percentage time
Rec. ITU-R P.530	Line-of-sight fixed links	Point-to-point line-of-sight	Path loss Diversity improvement (clear air conditions) XPD[2] Outage Error performance	Approximately 150 MHz to 1 00 GHz	Up to 200 km if line-of-sight	All percentages of time in clear-air conditions; 1 to 0.001 in precipitation conditions[1] And worst month for attenuation	Not applicable	High enough to ensure specified path clearance	Distance Tx height Frequency Rx height Percentage time Path obstruction data Climate data Terrain information
Rec. ITU-R P.533	Broadcasting Fixed Mobile	Point-to-point	Basic MUF Sky-wave field strength Available receiver power Signal-to-noise ratio LUF Circuit reliability	2 to 30 MHz	0 to 40 000 km	All percentages	Not applicable	Not applicable	Latitude and longitude of Tx Latitude and longitude of Rx Sunspot number Month Time(s) of day Frequencies Tx power Tx antenna type Rx antenna type

TABLE 1 (*continued*)

Method	Application	Type	Output	Frequency	Distance	% time	% location	Terminal height	Input data
Rec. ITU-R P.534	Fixed Mobile Broadcasting	Point-to-point via sporadic E	Field strength	30 to 100 MHz	0 to 4 000 km	0 to 50	Not applicable	Not applicable	Distance Frequency
Rec. ITU-R P.617	Trans-horizon fixed links	Point-to-point	Path loss	> 30 MHz	100 to 1 000 km	20, 50, 90, 99, and 99.9	Not applicable	No limits specified within the surface layer of the atmosphere. (Not suitable for aeronautical applications)	Frequency Tx antenna gain Rx antenna gain Path geometry
Rec. ITU-R P.618	Satellite	Point-to-point	Path loss Diversity gain and (for precipitation condition) XPD[2]	1 to 55 GHz	Any practical orbit height	0.001-5 for rain attenuation; 0.001 – 50 for total attenuation, 0.001-1 for XPD[2] Also worst month for attenuation	Not applicable	No limit	Meteorological data Frequency Elevation angle Height of earth station Separation and angle between earth station sites (for diversity gain) Antenna diameter and efficiency (for scintillation) Polarization angle (for XPD[2])
Rec. ITU-R P.620	Earth station frequency coordination	Coordination distance	Distance of which the required propagation loss is achieved	100 MHz to 105 GHz	Up to 1 200 km	0.001 to 50	Not applicable	No limits specified within the surface layer of the atmosphere. (Not suitable for aeronautical applications)	Minimum basic transmission loss Frequency Percentage of time Earth-station elevation angle
Rec. ITU-R P.679	Broadcast satellite	Point-to-area	Path loss Effect of local environment	0.5 to 5.1 GHz	Any practical orbit height	Not applicable	No limits specified	No limits specified	Frequency Elevation angle Features of local environment
Rec. ITU-R P.680	Maritime mobile satellite	Point-to-point	Sea-surface fading Fade duration Interference (adjacent satellite)	0.8-8 GHz	Any practical orbit height	To 0.001% via Rice-Nakagami distribution Limit of 0.01% for interference[1]	Not applicable	No limit	Frequency Elevation angle Maximum antenna boresight gain
Rec. ITU-R P.681	Land mobile satellite	Point-to-point	Path fading Fade duration Non-fade duration	0.8 to 20 GHz	Any practical orbit height	Not applicable Percentage of distance travelled 1 to 80%[1]	Not applicable	No limit	Frequency Elevation angle Percentage of distance travelled Approximate level of optical shadowing

TABLE 1 (*continued*)

Method	Application	Type	Output	Frequency	Distance	% time	% location	Terminal height	Input data
Rec. ITU-R P.682	Aeronautical mobile satellite	Point-to-point	Sea-surface fading Multipath from ground and aircraft during landing	1 to 2 GHz (sea-surface fading) 1 to 3 GHz (multipath from ground)	Any practical orbit height	To 0.001% via Rice-Nakagami distribution(1)	Not applicable	No limit for sea-surface fading Up to 1 km for ground reflection during landing	Frequency Elevation angle Polarization Maximum antenna boresight gain Antenna height
Rec. ITU-R P.684	Fixed Mobile	Point-to-point Point-to-area	Sky-wave field strength	30 to 150 kHz	0 to 16 000 km	50	Not applicable	Not applicable	Latitude and longitude of Tx Latitude and longitude of Rx Distance Tx power Frequency Ground constants Season Sunspot number Hour of day
Rec. ITU-R P.843	Fixed Mobile Broadcasting	Point-to-point via meteor-burst	Received power Burst rate	30 to 100 MHz	100 to 1 000 km	0 to 5	Not applicable	Not applicable	Frequency Distance Tx power Antenna gains
Rec. ITU-R P.1147	Broadcasting	Point-to-area	Sky-wave field strength	0.15 to 1.7 MHz	50 to 12 000 km	1, 10, 50	Not applicable	Not applicable	Latitude and longitude of Tx Latitude and longitude of Rx Distance Sunspot number Tx power Frequency
Rec. ITU-R P.1238	Mobile RLAN	In-building propagation methods	Path loss Delay spread	900 MHz to 100 GHz	Within buildings	Not applicable	Not applicable	Base: about 2-3 m Mobile: about 0.5-3 m	Frequency Distance Floor and wall factors
Rec. ITU-R P.1410	Broadband radio access	Point-to-area	Coverage Temporal coverage reduction due to rain	3 to 60 GHz	0-5 km	0.001 to 1 (for calculating reduction in coverage due to rain)	Up to 100	No limit; 0-300 m (typical)	Frequency Cell size Terminal heights Building height statistical parameters

TABLE 1 (*continued*)

Method	Application	Type	Output	Frequency	Distance	% time	% location	Terminal height	Input data
Rec. ITU-R P.1411	Mobile	Short-path propagation methods	Path loss Delay spread	300 MHz to 100 GHz	< 1 km	Not applicable	Not applicable	Base: about 4-50 m Mobile: about 0.5-3 m	Frequency Distance Street dimensions Structure heights
Rec. ITU-R P.1546	Terrestrial services	Point-to-area	Field strength	30 to 3 000 MHz	1 to 1 000 km	1 to 50	1 to 99	*Tx/base:* effective height from less than 0 m to 3 000 m *Rx/mobile:* ≥1 m	Terrain height and ground cover (optional) Path classification Distance Tx antenna height Frequency Percentage time Rx antenna height Terrain clearance angle Percentage locations Refractivity gradient
Rec. ITU-R P.1622	Satellite optical links	Point-to-point	Absorption loss Scattering loss Background noise Amplitude scintillation Angle of arrival Beam wander Beam spreading	20 to 375 THz	Far-field Earth-to-space optical links	Not applicable	Not applicable	No limit	Wavelength Terminal height Elevation angle Turbulence structure parameter
Rec. ITU-R P.1623	Satellite	Point-to-point	Fade duration, fade slope	10 to 50 GHz	Any practical orbit height	Not applicable	Not applicable	No limit	Frequency Elevation angle Attenuation threshold Filter bandwidth
Rec. ITU-R P.1812	Terrestrial services	Point-to-area	Field strength	30 MHz to 3 000 MHz	Not specified but up to and beyond the radio horizon	1 to 50	1 to 99	No limits specified, within the surface layer of the atmosphere. (Not suitable for aeronautical applications)	Path profile data Frequency Percentage time Tx antenna height Rx antenna height Latitude and longitude of Tx Latitude and longitude of Rx Meteorological data
Rec. ITU-R P.1814	Terrestrial optical links	Point-to-point	Absorption loss Scattering loss Background noise Amplitude scintillation Beam spreading	20 to 375 THz	No limit	Not applicable	Not applicable	No limit	Wavelength Visibility (in fog) Path length Turbulence structure parameter

TABLE 1 *(end)*

Method	Application	Type	Output	Frequency	Distance	% time	% location	Terminal height	Input data
Rec. ITU-R P.1853	Terrestrial satellite	Point-to-point	Rain attenuation for terrestrial paths Total attenuation and tropospheric scintillation for Earth-space paths	4 to 40 GHz for terrestrial paths 4 to 55 GHz for Earth-space paths	Between 2 and 60 km for terrestrial paths GEO satellite	Not applicable	Not applicable	No limit	Meteorological data Frequency Elevation angle Height of earth station Separation and angle between earth station sites (for diversity gain) Antenna diameter and efficiency (for scintillation)
Rec. ITU-R P.2001	Terrestrial services	Point-to-point	Path loss	30 MHz to 50 GHz	3 to 1 000 km	0 to 100	Not applicable	No limits specified, within the troposphere	Path profile data Frequency Percentage time Tx antenna height, gain and azimuthal direction Rx antenna height, gain and azimuthal direction Latitude and longitude of Tx Latitude and longitude of Rx Polarization

(1) Time percentage of outage; for service availability, subtract value from 100.

(2) XPD: Cross-polarization discrimination.

TABLE 2

ITU-R digital maps of geophysical parameters

Recommendation ITU-R	Description	Grid resolution	Spatial interpolation required (see Annex 1)	Interpolation in probability	Interpolation of the variable	File names
P.839	Mean annual 0°C isotherm height (km) (zerodeg)	1.5° × 1.5°	Bi-linear	Not applicable	Not applicable	ESA0HEIGHT.TXT
P.837	Rain rate exceedance probability (%) (rain rate)	1.125° × 1.125°	Bi-linear	Not applicable	Not applicable	ESARAIN_xxx_v5.TXT; xxx = PR6, BETA, MT
P.1511	Topographic altitude (a.m.s.l.) (km) (altitude)	0.5° × 0.5°	Bi-cubic	Not applicable	Not applicable	TOPO0DOT5.TXT
P.836	Total columnar water vapour exceedance probability (%) (IWVC)	1.125° × 1.125°	Bi-linear(1)	Logarithmic	Linear	ESAWVC_xx_v4.TXT; xx = 01, 02, 03, 05, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95, 99
P.836	Surface water vapour density exceedance probability (%) (Rho)	1.125° × 1.125°	Bi-linear(1)	Logarithmic	Linear	SURF_WV_xx_v4.TXT; xx = 01, 02, 03, 05, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95, 99
P.836	Water vapour scale height	1.125° × 1.125°	Bi-linear	Logarithmic	Linear	VSCH_xx_v4.TXT; xx = 01, 02, 03, 05, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95, 99
P.1510	Mean annual surface temperature (temperature)	1.5° × 1.5°	Bi-linear	Not applicable	Not applicable	ESATEMP.TXT
P.453	Median value of the wet term of the refractivity (Nwet)	1.5° × 1.5°	Bi-linear	Not applicable	Not applicable	ESANWET.TXT
P.453	Refractivity gradient in the lowest 65 m of the atmosphere (N-units/km)	1.5° × 1.5°	Bi-linear	Not defined	Not applicable	DNDZ_xx.TXT; xx = 01, 10, 50, 90, 99
P.840	Columnar cloud liquid water exceedance probability (%) (CLW)	1.125° × 1.125°	Bi-linear	Logarithmic	Linear	ESAWREDP_xx_v4.TXT; xx = 01, 02, 03, 05, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95, 99
P.840	Statistical distribution of total cloud liquid water content	1.125° × 1.125°	Bi-linear	Not applicable	Not applicable	WRED_LOGNORMAL_MEAN_v4.TXT, WRED_LOGNORMAL_STDEV_v4.TXT, and WRED_LOGNORMAL_PCLW_v4.TXT

TABLE 2 *(end)*

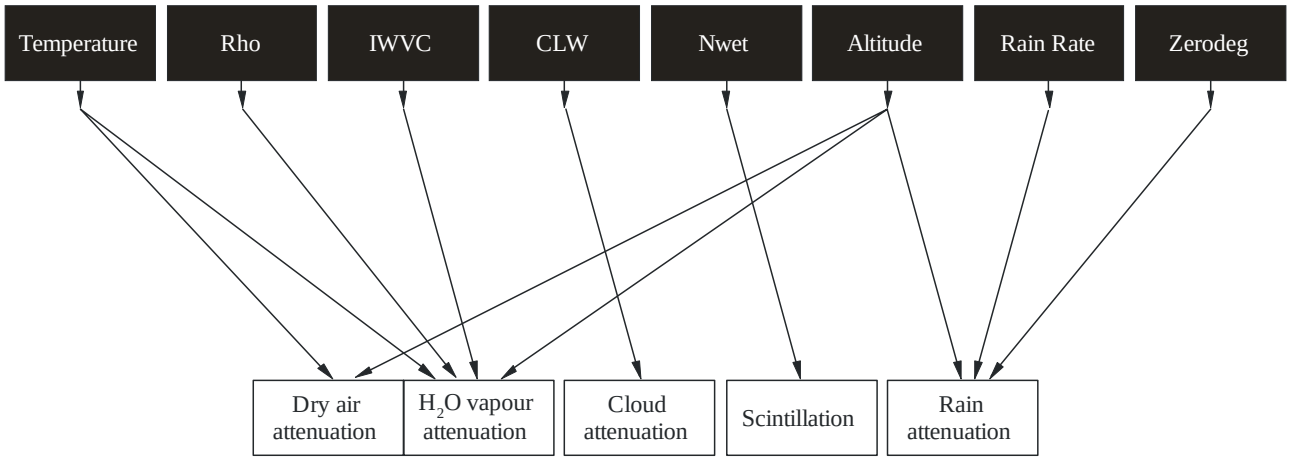
Recommendation ITU-R	Description	Grid resolution	Spatial interpolation required (see Annex 1)	Interpolation in probability	Interpolation of the variable	File names
P.617	Troposcatter climate zones	0.5° × 0.5°	Not applicable	Not applicable	Not applicable	TropoClim.txt
P.2001	Surface level refractivity and gradient in the lowest 1 km of the atmosphere	1.5° × 1.5°	Bi-linear	Not applicable	Linear	DN_Median.txt DN_SupSlope.txt DN_SubSlope.txt
P.2001 and P.534	Critical frequency for sporadic-*E* (F_0E_s)	1.5° × 1.5°	Bi-linear	Linear	Linear	FoEs50.txt FoEs10.txt FoEs01.txt FoEs0.1.txt

IWVC: integrated water vapour content.

(1) The variables at the surrounding grid points are scaled to the desired altitude prior to spatial interpolation per the scaling procedure in the applicable Recommendation.

For easy reference, Fig. 1 shows the relationship between the geophysical maps (black boxes) and propagation effects (white boxes).

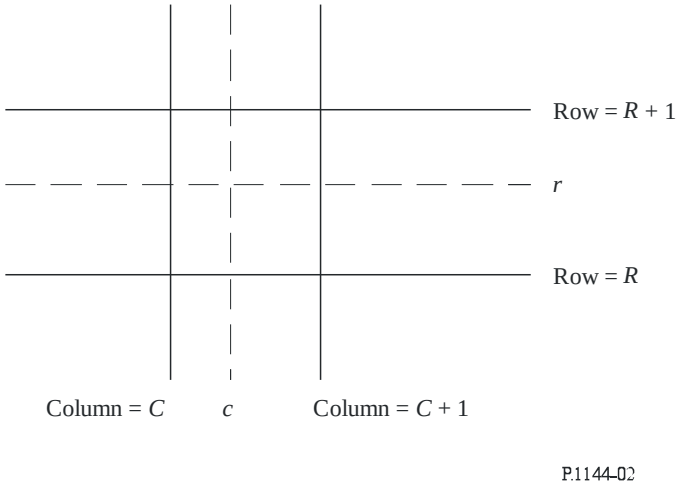
FIGURE 1



Annex 1

1 Bi-linear interpolation

FIGURE 2



Given: Values at four surrounding grid points: $I(R,C)$, $I(R,C+1)$, $I(R+1,C)$, and $I(R+1,C+1)$.

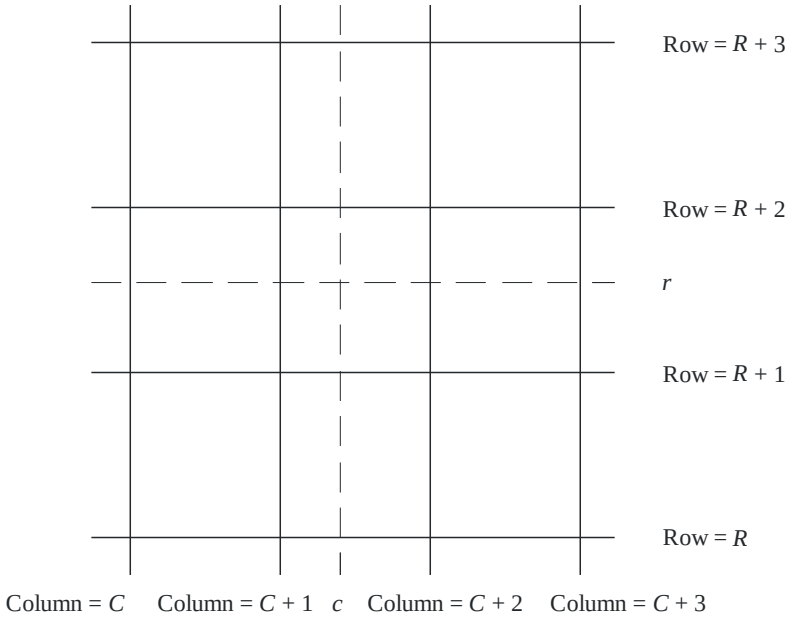
Problem: Determine $I(r,c)$, where r is a fractional row number and c is a fractional column number, using bi-linear interpolation.

Solution: Calculate:

$$\begin{aligned} I(r,c) = \quad & I(R,C)\,[(R+1-r)(C+1-c)] \\ & + I(R+1,C)\,[(r-R)(C+1-c)] \\ & + I(R,C+1)\,[(R+1-r)(c-C)] \\ & + I(R+1,C+1)\,[(r-R)(c-C)] \end{aligned}$$

2 Bi-cubic interpolation

FIGURE 3



Given: Values at 16 surrounding grid points:

$I(R,C)$, $I(R,C+1)$, $I(R,C+2)$, $I(R,C+3)$,

$I(R+1,C)$, $I(R+1,C+1)$, $I(R+1,C+2)$, $I(R+1,C+3)$,

$I(R+2,C)$, $I(R+2,C+1)$, $I(R+2,C+2)$, $I(R+2,C+3)$,

$I(R+3,C)$, $I(R+3,C+1)$, $I(R+3,C+2)$, $I(R+3,C+3)$.

Problem: Calculate $I(r,c)$, where r is a fractional row number and c is a fractional column number, using bi-cubic interpolation.

Solution:

Step 1: For each row, x, where $x = \{r,\ r+1,\ r+2,\ r+3\}$, compute the interpolated value at the desired fractional column c as:

$$RI(X,c) = \sum_{j=C}^{C+3} I(X,j)\,K(c-j)$$

where:

$$K(\delta) = \begin{cases} (a+2)|\delta|^3 - (a+3)|\delta|^2 + 1 & \text{for} \quad 0 \le |\delta| \le 1 \\ a|\delta|^3 - 5a|\delta|^2 + 8a|\delta| - 4a & \text{for} \quad 1 \le |\delta| \le 2 \\ 0 & \text{for} \quad 2 \le |\delta| \end{cases}$$

and

$$a = -0.5$$

Step 2: Calculate $I(r,c)$ by interpolating the one-dimensional interpolations, $RI(R,c)$, $RI(R+1,c)$, $RI(R+2,c)$, and $RI(R+3,c)$ in the same manner as the row interpolations.