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| **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** |

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.

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| 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 |

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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.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* 1above.

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:*   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*0*Es*) | 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).



Annex 1

# 1 Bi-linear interpolation



*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:

*I*(*r,c*) *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*)]

# 2 Bi-cubic interpolation



*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**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:



where:



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.