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Interpretation and Classification of P-Series Recommendations in ITU-R

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Abstract

As ITU-R Recommendations is widely implemented for countries all over the world, the role and status of ITU-R Recommendations are increasingly prominent in the field of radio engineering. ITU and ITU-R Study Groups are summarized. Furthermore, the operating mode of the third study group, and the input documents are interpreted in detail. Lastly, from both wireless system design and electromagnetic compatibility analysis perspective, all of 79 P-series Recommendations are analyzed and classified, and the main contents of each Recommendation are summarized. The above research promote P-series Recommendations are widely used in China.

Keywords

ITU, P-Series Recommendations, Classification, Radiowave Propagation, Propagation Prediction Method

1. Introduction

With the trend of globalizing of radio communication technology, every nation is now focusing on international standardization of the technology. As an international standard in the world, the recommendations from the International Telecommunication Union (ITU) is widely recognized, which is formulated by the ITU Radio communication sector (ITU-R) and stated by ITU members. Except the recommendations [1] cited in the Radio Regulation, others are not required to be carried out by the member countries. However, as ITU recommendations are made by administrations, radio communication operators, equipment manufacturers and other relevant organizations' expert from all over the world, the recommendations have extremely high execution validity and are carried out by countries around the world more and more commonly.

In the ITU-R recommendations, there are 79 valid P-series recommendations, covering the basic elements of non-ionized media radio wave propagation, radio meteorological data, land point to area propagation path prediction method, ionosphere propagation characteristics, useful and useless signal point to point and earth to space path radio waves propagation, which has significant meaning to people working on radio wave propagation and wireless system design. Thus everyone who are engaged in radio communication research and wireless system design should have a total acquaintance with them and choose appropriate ones. While the P-series is systematic and full of classical theories, and only part of it is translated into Chinese, the selection turns out to

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be difficult.

In order to facilitate better understanding and using of these recommendations for experts, scholars and engineers who are engaged in radio wave propagation research as well as to fully play the P-series' guidance role, we put 79 valid P-series recommendations into different categories according to their classification of the contents, highly summarize them and extract their core content from the overview of the radio wave propagation research while regarding the design of wireless system and electromagnetic compatibility analysis as the foothold [2]. After the classification process, on the one hand, to the greatest extent it can help users to find the required content from numerous recommendations, on the other hand, it can directly help the users comprehensively understand and master the ITU-R P series recommendations, so as to fully play to the guiding role of the recommendations and promote a widely application in our country.

2. ITU-R SG3

ITU mainly has three sectors, namely the telecommunication standard sector (ITU-T), the radio communication sector (ITU-R) and the telecommunication development sector (ITU-D). ITU-R has six study groups, which are spectrum management (SG1), radio wave propagation (SG3), space services (SG4), terrestrial services (SG5), broadcasting services (SG6) and science services (SG7) respectively. SG3 mainly focus on propagation of radio waves and the characteristics of radio noise in ionized and non-ionized media with the purpose of improving the performance of radio communication systems. SG3 has four Working Parties (WP3J\WP3K\WP3L\WP3M), and the four parties are responsible for all the research work mainly drafting ITU-R P-series recommendations.

The publication of SG3 mainly involves the research of the basic elements of radio propagation, the modelling analysis of the wireless environment, and the methods of the propagation prediction in different environment and frequency. The main participating countries are the United States, China, South Korea, Japan, Australia, Brazil, Germany, Luxemburg, Canada, Spain, France, Italy, etc. [3]-[8]. In June 2013, China submitted the 8 contributions to WP3J, WP3K, WP3L, WP3M, relevant to the wave propagation prediction method for high-speed train's wireless communication system [9], rain attenuation prediction model [10], the results of the propagation prediction of indoor and outdoor mobile communication [11]. Among these contributions, propagation prediction of high-speed railway radio service issues proposed by the China Research Institute of Radio Wave Propagation was accepted by SG 3 expert and was finally put into the 3K chairman report.

3. ITU-R P-Series Recommendation

Without any exception, all the radio communication services or systems have one or more radio wave transmit links, namely the signal transmit links between the transmit and receive antenna ports of the system. In the transmit links, the radio waves simply transmit in natural environment and will be affected and restricted by the environment between the transmit and receive antennas. Without any doubt, the transmission of the radio waves has a great influence on the validity and effectiveness of radio communication. Also the influence varies from different radio communication services or systems.

Given this, SG3 carried out a series of in-depth research on radio wave transmission, and have solved five major fields of problems. First, what's the natural environment for radio wave transmission, namely the main content of the research on radio atmosphere. Second, how the natural media influence the transmission of radio waves, namely the research on radio wave propagate effect. Third, how to predict the radio wave transmit effect of radio communication services or systems. Fourth, how to overcome or utilize the radio wave propagate effect while designing wireless system or circuit. Fifth, the electromagnetic compatibility problem, namely how to ensure that all kinds of radio communication services or systems work effectively while not interfering each other. The first two points are the fundamental problem of the radio wave propagation research, and the last three points are problems concerning about the application matters of radio wave propagation model. **Figure 1** gives the general presentation of radio wave propagate research.

On basis of the contents, the P-series recommendations are classified into six categories: terms' definition and basic materials, the environment of radio wave propagation, the propagation in ionosphere, the propagation in non-ionization media, propagation measurement and analysis, electromagnetic compatibility. And the propagation in ionosphere can be divided into radio wave propagation effect and radio wave propagation predict method. The portions of the six categories are shown in **Figure 2**.

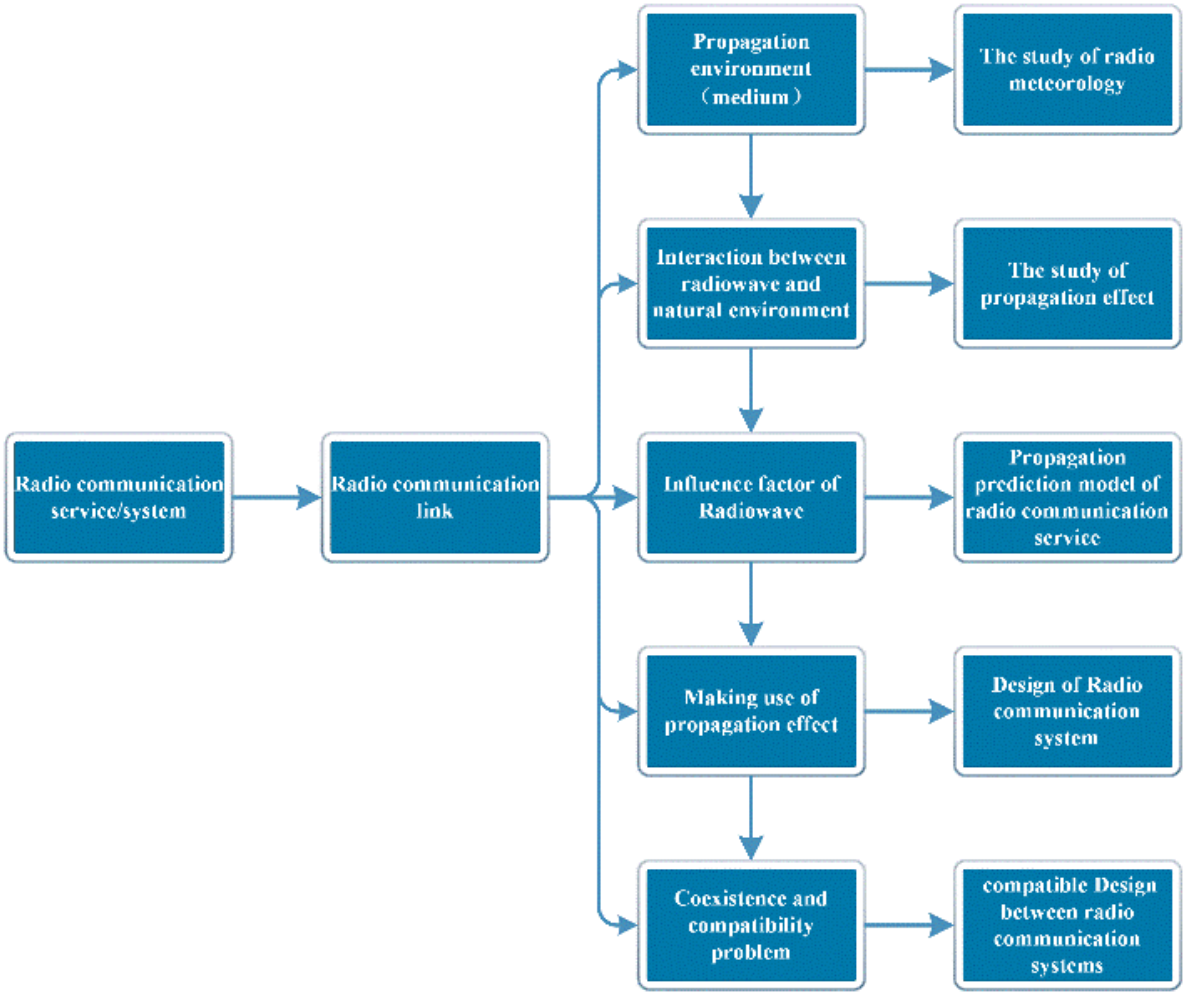

Figure 1. The summarization of the radiowave propagation research.

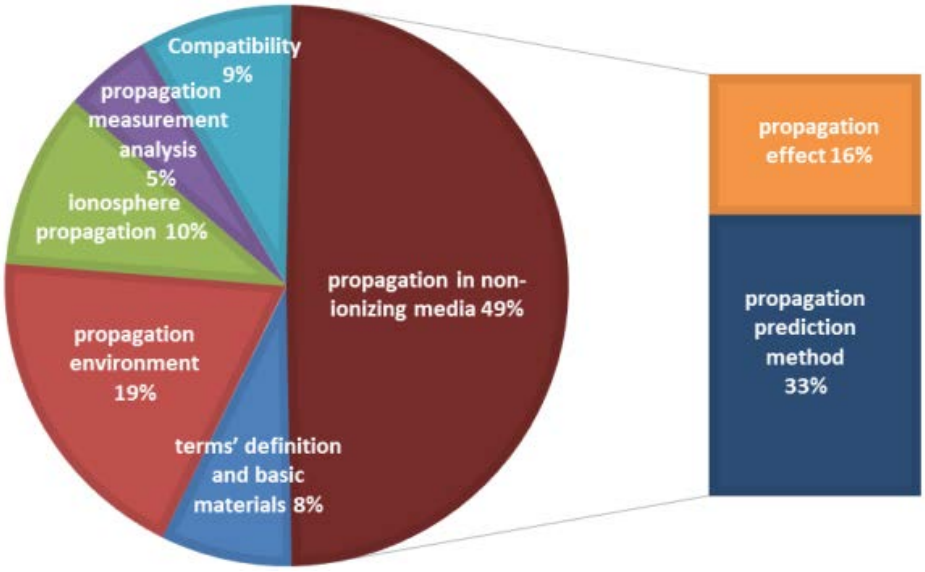

Figure 2. The classification of the P-series recommendations.

3.1. Terms' Definition and Basic Materials

The P-series recommendations specifically explained the terms concerning about radio wave and influence made by atmosphere, land and its coverings on propagation, and give definitions on maximum and minimum transmit frequency, worst month, etc. In addition, the recommendations provide the basic materials including the theory of probability and statistics, the numerical terrain database. This part is mainly complicated by 3J, as shown in **Table 1**.

3.2. The Environment of Radio Wave Propagation

The study of the environment of radio wave propagation is for the purpose of gathering natural environment information, and laying the foundation for mastering the mechanism of radio wave propagation. The main factors that influence the propagation of radio wave are atmosphere and land with its coverings, and atmosphere can be divided into four layers, namely magnetosphere, ionosphere, stratosphere and troposphere. They are the main media that influence the radio wave, and land with its coverings are the only boundary conditions of radio wave [12].

Terrestrial electrical parameters and ionosphere have great influence on medium wave and long wavelengths and wave with frequency below them. Ionosphere reflection is the major propagation method for shortwave. And troposphere and land coverings are the main factors that influence the propagation of ultra-short wave and microwave.

Therefore, the 3J and 3L working groups in SG3 conduct some research focusing on radio wave propagation environment, mainly including ionosphere's reference characteristics, troposphere (especially the lower layers of atmosphere under 1 km altitude)'s refractive index, the variation of space distribution of moisture as well as its ramification (rain, fog, cloud) and sandstorm, land's electric characteristic and variation of land's temperature, humidity and atmospheric pressure changing from time to locations [13]. The results are summarized as the P-series recommendations shown in **Table 2**.

3.3. Ionosphere Propagation

The study of ionosphere propagation is mainly about the interaction of radio waves and ionization media. Ionosphere is the atmosphere between 60 km and about 2000 km to 3000 km. Ionosphere mainly affect the propagation of radio waves with frequencies lower than high frequency. Radio waves with lower frequencies can't pass through ionosphere but being reflected to the land. The propagation of VHF and waves with higher frequencies can ignore the ionosphere's influence [14], especially the microwave which can transmit through the whole atmosphere. So the P-series recommendations specially studied the radio waves with frequencies lower than ultra-short wave propagation problems. This part of recommendations are mainly accomplished by 3 L work group, and shown in **Table 3** in detail.

3.4. Propagation in Non-Ionizing Media

Radio wave is mainly influenced by non-ionizing media such as troposphere, land with its coverings, and thus it

Table 1. P-series recommendations about definitions and basic materials.

Serial number of recommendations	Authorized Date	Corresponding Core content in recommendations
P.310-9	1994-08	Definitions of terms relating to propagation in non-ionized media
P.341-5	1999-10	The concept of transmission loss for radio links
P.373-9	2013-09	Definitions of maximum and minimum transmission frequencies
P.581-2	1990-06	The concept of "worst month"
P.1057-3	2013-09	Probability distributions relevant to radiowave propagation modelling
P.1144-6	2012-02	Guide to the application of the propagation methods of Radiocommunication Study Group 3

Table 2. P-series recommendations about the radiowave propagation environment.

Serial number of recommendations	Authorized date	Corresponding Core content in recommendations
P.371-8	1999-07	Choice of indices for long-term ionospheric predictions
P.372-11	2013-09	Radio noise
P.453-10	2012-02	The radio refractive index: its formula and refractivity data
P.527-3	1992-03	Electrical characteristics of the surface of the Earth
P.532-1	1992-03	Ionospheric effects and operational considerations associated with artificial modification of the ionosphere and the radio-wave channel
P.678-2	2013-09	Characterization of the natural variability of propagation phenomena
P.832-3	2012-02	World Atlas of Ground Conductivities
P.835-5	2012-02	Reference Standard Atmospheres
P.836-5	2013-09	Water vapour: surface density and total columnar content
P.837-6	2012-02	Characteristics of precipitation for propagation modelling
P.839-4	2013-09	Rain height model for prediction methods
P.1058-2	1999-10	Digital topographic databases for propagation studies
P.1239-3	2012-02	ITU-R reference ionospheric characteristics
P.1510	2001-02	Annual mean surface temperature
P.1511	2001-02	Topography for Earth-to-space propagation modelling

Table 3. P-series recommendations about the ionospheric propagation.

Serial number of recommendations	Authorized date	Corresponding Core content in recommendations
P.531-12	2013-09	Ionospheric propagation data and prediction methods required for the design of satellite services and systems
P.533-12	2013-09	Method for the prediction of the performance of HF circuits
P.534-5	2012-02	Method for calculating sporadic-E field strength
P.684-6	2012-02	Prediction of field strength at frequencies below about 150 kHz
P.843-1	1997-08	Communication by meteor-burst propagation
P.1147-4	2007-08	Prediction of sky-wave field strength at frequencies between about 150 and 1700 kHz
P.1240-1	2007-02	ITU-R methods of basic MUF, operational MUF and ray-path prediction
P.1321-4	2013-09	Propagation factors affecting systems using digital modulation techniques at LF and MF

produces various propagation effect, such as the scattering and attenuation made by rain and sands, multipath propagation, focusing effect, atmosphere duct propagation, diffraction, scattering and reflection caused by surficial materials, etc. Furthermore, for different radio service and system, the influence from non-ionizing media is different. So how to predict the influence in different radio services and systems appears to be necessary. The 3K and 3M working groups in SG3 have carried out deep research on the prediction method of radio wave propagation effect and model in non-ionizing media, and summarized as the P-series recommendations shown in **Tables 4-6**. **Table 4** summarized various propagation effect that the recommendations involve.

According to difference applied range, propagation in non-ionizing medium prediction methods in P-series Recommendations are divided into two types: terrestrial service and space service. The two methods are listed in **Table 5** and **Table 6** respectively. Prediction methods mainly contain broadcast service, fixed service, mobile service (including terrestrial, maritime and aerospace mobile service) and so on.

Table 4. P-series recommendations about radiowave propagation effect in non-ionizing medium.

Serial number of recommendations	Authorized date	Corresponding Core content in recommendations
P.525-2	1994-08	Calculation of free-space attenuation
P.526-13	2013-11	Propagation by diffraction
P.676-10	2013-09	Attenuation by atmospheric gases
P.833-8	2013-09	Attenuation in vegetation
P.834-6	2007-01	Effects of tropospheric refraction on radiowave propagation
P.838-3	2005-03	Specific attenuation model for rain for use in prediction methods
P.840-6	2013-09	Attenuation due to clouds and fog
P.841-4	2005-03	Conversion of annual statistics to worst-month statistics
P.1322	1997-08	Radiometric estimation of atmospheric attenuation
P.1406-1	2007-08	Propagation effects relating to terrestrial land mobile and broadcasting services in the VHF and UHF bands
P.1407-5	2013-09	Multipath propagation and parameterization of its characteristics
P.1815-1	2009-10	Differential rain attenuation
P.2040	2013-09	Effects of building materials and structures on radiowave propagation above about 100 MHz

Table 5. P-series recommendations about propagation prediction method of terrestrial service.

Serial number of recommendations	Authorized date	Corresponding Core content in recommendations
P.368-9	2007-02	Ground-wave propagation curves for frequencies between 10 kHz and 30 MHz
P.528-3	2012-02	Propagation curves for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands
P.530-15	2013-09	Propagation data and prediction methods required for the design of terrestrial line-of-sight systems
P.617-3	2013-09	Propagation prediction techniques and data required for the design of trans-horizon radio-relay systems
P.1146	1995-10	The prediction of field strength for land mobile and terrestrial broadcasting services in the frequency range from 1 to 3 GHz
P.1238-7	2012-02	Propagation data and prediction methods for the planning of indoor radio communication systems and radio local area networks in the frequency range 900 MHz to 100 GHz
P.1409-1	2012-02	Propagation data and prediction methods for systems using high altitude platform stations and other elevated stations in the stratosphere at frequencies greater than about 1 GHz
P.1410-5	2012-02	Propagation data and prediction methods required for the design of terrestrial broadband radio access systems operating in a frequency range from 3 to 60 GHz
P.1411-7	2013-09	Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz
P.1546-5	2013-09	Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz
P.1791	2007-01	Propagation prediction methods for assessment of the impact of ultra-wideband devices
P.1812-3	2013-09	A path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands
P.1814	2007-08	Prediction methods required for the design of terrestrial free-space optical links
P.1817-1	2012-02	Propagation data required for the design of terrestrial free-space optical links
P.1816-2	2013-09	The prediction of the time and the spatial profile for broadband land mobile services using UHF and SHF bands
P.2001-1	2013-09	A general purpose wide-range terrestrial propagation model in the frequency range 30 MHz to 50 GHz

Table 6. P-series recommendations about propagation prediction method of space service.

Serial number of recommendations	Authorized date	Corresponding Core content in recommendations
P.618-11	2013-09	Propagation data and prediction methods required for the design of Earth-space telecommunication systems
P.679-3	2001-02	Propagation data required for the design of broadcasting-satellite systems
P.680-3	1999-10	Propagation data required for the design of Earth-space maritime mobile telecommunication systems
P.681-7	2009-10	Propagation data required for the design of Earth-space land mobile telecommunication systems
P.682-3	2012-02	Propagation data required for the design of Earth-space aeronautical mobile telecommunication systems
P.1621-1	2005-03	Propagation data required for the design of Earth-space systems operating between 20 THz and 375 THz
P.1622	2003-04	Prediction methods required for the design of Earth-space systems operating between 20 THz and 375 THz
P.1623-1	2005-03	Prediction method of fade dynamics on Earth-space paths
P.1853-1	2012-02	Tropospheric attenuation time series synthesis
P.2041	2013-09	Prediction of path attenuation on links between an airborne platform and Space and between an airborne platform and the surface of the Earth

3.5. Propagation Measurement Analysis

In order to build the radio propagation model and verify the analysis to propagation model, SG3 Research Group gives suggestions, which focus on troposphere data collection, ionospheric measurement and spatial wave field strength measurement, about transmission test and analysis. Details are listed in **Table 7**.

3.6. Radio Electromagnetic Compatibility

Radio wave propagation can not only be applied to the design of wireless system and hardwired, but also be used for the electromagnetic compatibility analyses of the systems and services. In order to ensure various legitimate radio communication systems and stations working effectively, the 3M working group in SG3 take on the obligation to calculate, predict and evaluate the interference effect which includes the interference between radio stations, interference between space station and radio station and the influence factor of frequency sharing. Details are listed in **Table 8**.

4. Conclusion

This paper introduces ITU and ITU-R Study Group and briefly summarizes their Recommendations. Furthermore, the operating mode of the third study group and the input documents are interpreted in detail. Lastly, from both wireless system design and electromagnetic compatibility analysis perspective, all of 79 P-series Recommendations are analyzed and classified, and the main contents of each Recommendation summarized. The Recommendations are divided into six categories which are Terms' Definition and Basic Materials, Radiowave Propagation Environment, Ionospheric Propagation, Propagation in Non-ionizing Medium, Measurement and Analysis of Propagation Characteristics and Electromagnetic Compatibility. The classification of P-series Recommendations has directive significance to ITU-R Recommendations and positive effect on promoting ITU-R Recommendations widely used in China.

Acknowledgements

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Table 7. P-series recommendations about measurement and analysis of propagation characteristics.

Serial number of recommendations	Authorized date	Corresponding Core content in recommendations
P.311-14	2013-09	Acquisition, presentation and analysis of data in studies of tropospheric propagation
P.845-3	1997-08	HF field-strength measurement
P.846-1	1995-10	Measurements of ionospheric and related characteristics
P.1148-1	1997-05	Standardized procedure for comparing predicted and observed HF sky-wave signal intensities and the presentation of such comparisons

Table 8. P-series recommendations about the electromagnetic compatibility.

Serial number of recommendations	Authorized date	Corresponding Core content in recommendations
P.452-15	2013-09	Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz
P.619-1	1992-03	Propagation data required for the evaluation of interference between stations in space and those on the surface of the Earth
P.620-6	2005-03	Propagation data required for the evaluation of coordination distances in the frequency range 100 MHz to 105 GHz
P.842-5	2013-09	Computation of reliability and compatibility of HF radio systems
P.844-1	1994-08	Ionospheric factors affecting frequency sharing in the VHF and UHF bands (30 MHz - 3 GHz)
P.1060	1994-08	Propagation factors affecting frequency sharing in HF terrestrial systems
P.1412	1999-10	Propagation data for the evaluation of coordination between Earth stations working in the bidirectionally allocated frequency bands

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References

[1] http://www.itu.int/pub/R-REC

[2] http://www.itu.int/rec/R-REC-P/en

[3] German. Propagation Measurements. ITU-R Document 3J/62-E, Jun 2013.

[4] Korea. Path Loss Measurements for Mobile-Phone to Mobile-Phone Direct Communications in High-Rise Urban at 3.7 GHz. ITU-R Document 3K/71-E, Jun 2013.

[5] United States of America. Propagation Curves for Aeronautical Mobile and Radio Navigation Services Using the VHF, UHF and SHF Bands. ITU-R Document 3K/48-E, Jun 2013.

[6] UK Propagation and Prediction Methods for the Planning of Short-Range Outdoor Radio-Communication Systems and Radio Local Area Networks in the Frequency Range 300 MHz to 100 GHz. ITU-R Document 3K/56-E, Jun 2013.

[7] France, European Space Agency (ESA). Propagation Data Required for the Design of Earth-Space Land Mobile Telecommunication Systems. ITU-R Document 3M/119-E, Jun 2013.

[8] China. Propagation Prediction Methods for High-Speed Train Services. ITU-R Document 3K/59-E, Jun 2013.

[9] China. Supporting information towards Propagation Prediction Method for High-Speed Train Wireless Communication Systems. ITU-R Document 3K/62-E, Jun 2013.

[10] China. Modification to Rainfall Rate Adjustment Factor for Modelling and Prediction Methods of Rain Attenuation Statistics. ITU-R Document 3J/16-E, Jun 2012.

[11] China. Propagation Data and Prediction Methods Required for the Design of Terrestrial Line-of-Sight Systems. ITU-R Document 3J/45-E, Jun 2013.

[12] John, A. (2008) Richards, Radio Wave Propagation an Introduction for the Non-Specialist. Springer Press.

[13] Lavergnat, J. and Sylvain, M. (2000) Radio Wave Propagation: Principles and Techniques. John Wiley & Son Press.

[14] Haslett, C. (2008) Essentials of Radio Wave Propagation. Cambridge University Press.