THE ITU-R AND RADIOWAVE PROPAGATION

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ABSTRACT

Radio spectrum is an increasingly scarce resource. The growing demand for new services and for higher data rates in existing services, the trend towards ubiquitous mobile voice and data systems, and the convergence of communications and computing networks are placing unprecedented demands on the use of radio frequencies. It should be in the interest of the radio research community to ensure that the management and regulation of the spectrum is based on sound technical advice, not only to provide adequate spectrum for radio science interests, but more generally to guarantee that radio remains an efficient and viable communications medium. The Radiocommunication Sector of the International Telecommunication Union (ITU-R) prepares and issues *de facto* standards on technical characteristics and operational procedures for radiocommunication services. The technical bases for these Recommendations are verified and validated by groups of experts who judge the merit of results submitted by ITU Member States and ITU-R Sector Members. Much of the technical work of the ITU-R depends upon results of studies carried out within scientific agencies, often work that is reported through URSI channels. The current surge of new techniques and systems being applied to telecommunications requires new radio propagation information, especially for non-geostationary satellite-to-Earth paths, short range propagation within buildings, long range propagation into buildings and vehicles, better knowledge and modelling of atmospheric ducts, and the influence of climate and ionospheric parameters on propagation modelling in general. These and other issues are of interest to URSI and of concern to the ITU-R.

THE ITU-R AND ITS OBJECTIVES

The Radiocommunication Sector of the International Telecommunication Union (ITU-R) aims to ensure rational, equitable, efficient and economical use of the radio frequency spectrum and the geostationary orbit. One of the ways in which this aim is achieved is through the development of ITU-R Recommendations on the technical characteristics and operational procedures for radiocommunication services and systems. Recommendations represent authoritative texts intended to contain the best currently available information on a topic and as such they may be regarded as “standards” which have achieved international approval among the 189 Member States of the ITU.

Technical studies leading to the production of Recommendations are undertaken in the ITU-R Radiocommunication Study Groups (Table 1), each of which addresses a particular area of radio technology. In particular, ITU-R Study Group 3 (Radiowave propagation) has as its scope the “propagation of radiowaves in ionized and non-ionized media and the characteristics of radio noise, for the purpose of improving radiocommunication systems”. Here, the principal objective is to produce propagation information appropriate for spectrum planning and system design, whatever the frequency or service of interest. Such information then serves:

- as the basis of ITU-R Recommendations on radiowave propagation;
- as advice for developing countries, particularly in the planning of new services;
- other ITU-R Study Groups, particularly in their preparation for Radio Conferences for spectrum allocation.

There are currently 68 ITU Recommendations on radiowave propagation and these are published as the “P series” of ITU-R Recommendations [1].

THE ITU-R PROCESS

Given that the objective of the ITU-R is to produce relevant, accurate, up-to-date and applicable recommendations, what is the process by which these standards are generated and approved? The seven ITU-R Study Groups [2] are responsible for verifying the background science and technical work, and agreeing the draft text of new and revised Recommendations before seeking a consensus approval of the Recommendations by the Member States of the ITU.

Table 1 ITU-R Study Groups

Study Group	Scope
1	Spectrum Management
3	Radiowave Propagation
4	Fixed-satellite Service
6	Broadcasting Services
7	Science Services
8	Mobile, Radiodetermination, Amateur Services
9	Fixed Service

Each Study Group has a particular area of expertise and a suite of questions [3, 4] assigned to it which define the ITU-R priorities. Each Study Group allocates the work to smaller groups of experts (working parties, task groups, rapporteur groups, etc.) that seek to answer the questions relevant to the expertise. These working parties debate the merits of each document placed before them and from one or several inputs on a particular subject, draft the technical basis for a new or revised Recommendation. Study Group 3 (Radiowave propagation) has four working parties: 3J (Propagation fundamentals); 3K (Point-to-area propagation); 3L (Ionospheric propagation); and 3M (Point-to-point and Earth-space propagation).

With support from staff of the ITU Radiocommunication Bureau (BR), the work is usually carried out by organisations and agencies within each member state of the ITU and submitted to the appropriate group (e.g., working party) via the BR. The work submitted both provides the ITU-R (and hence all Members Countries of the ITU) with the best results in radiocommunication science and also gives the contributing country an opportunity to promote its expertise in the field.

Once the working party and study group have agreed a draft recommendation, the draft is approved either by correspondence (expedited approval) or via the Radiocommunication Assembly, which typically meets every two years.

In Australia the technical work relating to the ITU-R Study Group 3 is presented to the Australian Radiocommunication Study Group 3 (ARSG 3 - Chairman Carol Wilson). Once agreed by the ARSG 3 and the Australian Administration (Australian Communications Authority) it is presented and discussed at the study group level internationally and if found satisfactory is incorporated into the ITU-R Recommendations.

HOW URSI CAN ASSIST THE ITU-R

With the rapid development of new and innovative radio services, the need for effective system planning becomes increasingly important. Propagation prediction plays a vital role in this planning, not only to secure an acceptable service, but also to derive maximum spectrum efficiency in the form of frequency sharing, coordination and electromagnetic compatibility.

Table 2 gives examples of radio services or planning situations, together with associated propagation effects for which information has been, or is being, developed by Study Group 3.

Table 2 Principal radio propagation effects

Radio service or planning situation	**Propagation effects and considerations**
Terrestrial broadcasting and mobile services	Field strength vs. distance (diffraction, effects of vegetation and terrain, etc.), multipath, channel characterization, location variability, polarization
Mobile-satellite services	Shadowing from trees and buildings, user blockage, multipath, ionospheric scintillation, fade duration, polarization rotation
Short path indoor/outdoor systems (personal communications, RLANs)	Reflection and transmission loss from walls and floors, building penetration loss, diffraction by buildings and other obstacles, user blockage and movement, polarization mismatch, delay spread, antenna siting. Losses in vertical propagation through buildings (sharing with MSS feeders)
Radiolocation (Radar)	Ducting effects, forward and back scatter, rain attenuation.
Fixed-satellite services	Gaseous and hydrometeor attenuation, scintillation and refraction, radio sky noise, trans-ionospheric effects, cross-polarization, site diversity
Fixed (terrestrial line-of-sight) services	Gaseous and hydrometeor attenuation, atmospheric and surface multipath and associated fading, diffraction fading, other refractive effects, cross-polarization, signal distortion
Coordination and interference evaluation (fixed-satellite, mobile-satellite and terrestrial services)	Line-of-sight, diffraction, troposcatter, ducting and layer reflection, clutter, hydrometeor scatter, spurious emissions
Services above about 275 GHz	Atmospheric attenuation, rain, cloud and fog attenuation and scatter, sand and dust effects
Intersatellite services	Ionospheric and tropospheric effects on low elevation paths passing near the Earth
HF services	Ionospheric scintillation, field strength, reliability, variability, antenna characteristics, radio noise, especially for digital modulation systems

Recommendations developed for specific applications are shown in Table 3. The table is not exhaustive and is restricted to propagation prediction methods applicable to services currently receiving greatest attention.

Table 3 Summary of ITU-R Recommendations involving radio propagation predictions

Application	**Frequency range**	**Rec.**	**Output**
All services	10 kHz-30 MHz	P.368	Ground-wave field strength curves
Terrestrial broadcasting	30-3000 MHz 2-30 MHz 0.15-1.7 MHz	P.1546 P.533 P.1147	Field strength MUFs, sky-wave field strength Sky-wave field strength
Mobile (terrestrial)	30 MHz-3 GHz 1-3 GHz	P.1546 P.1146	Field strength curves Field strength
• short-range indoor	900 MHz - 100 GHz	P.1238	Path loss, delay spread
• short-range outdoor	300 MHz - 100 GHz	P.1411	Path loss, delay spread
• broadband radio access	20 - 50 GHz	P.1410	Service coverage
Mobile-satellite			
• maritime	0.8-8 GHz	P.680	Sea-surface fading, fade duration, adjacent satellite interference
			Path fading, fade and non-fade duration
• land	0.8-20 GHz	P.681	Sea-surface fading
• aeronautical	1-2 GHz	P.682	
Fixed-satellite	1-55 GHz	P.618	Path loss, diversity gain, XPD, noise temperature, scintillation statistics
Fixed links			
• line-of-sight	150 MHz-40 GHz	P.530	Path loss, diversity improvement, fading statistics

• transhorizon • HF	>30 MHz 2-30 MHz	P.617 P.533	Path loss MUFs, sky-wave field strength
Interference between stations on Earth surface	700 MHz - 30 GHz	P.452	Path loss
Earth-station frequency coordination	100 MHz - 105 GHz	P.620	Distance at which propagation loss required for acceptable interference levels is achieved

It must be appreciated that many of the prediction procedures listed in Table 3 rely on basic propagation data and information found in other recommendations of Study Group 3. For example, those methods that predict attenuation due to rain derive the basic rainfall intensity data from a recommendation containing worldwide maps of rainfall rate as a function of time percentage. Similarly, global maps exist for radio refractivity, atmospheric radio noise, certain ionospheric parameters, and for ground conductivity. Others specify models of certain propagation characteristics; e.g., reference atmospheres for refraction and for gaseous attenuation, models for the specific attenuation and height of rain, and reference ionospheric characteristics. In addition, recommendations have been prepared describing statistical models commonly used in the analysis of propagation data.

In order to become acquainted with the work program of the ITU-R, members and correspondents of URSI are encouraged to review the ITU-R Questions and the corresponding Recommendations relevant to their field of research. URSI scientists can then contribute to the development and improvement of recommendations through proposals submitted via national administrations (contact ARSG3 for more detail). Of particular value would be contributions containing radiometeorological and propagation measurement data, which are used not only for the development of prediction methods but also for their validation.

SPECIFIC ISSUES RELEVANT TO URSI

ITU-R is being challenged to seek frequency allocations that satisfy the ever-increasing global radiocommunication requirement. Most new systems and techniques require radio propagation information to assess their frequency sharing capabilities. Study Group 3 has extended the frequency range, the distance range and the time characteristics of its propagation prediction methods and is continuing to provide the latest advice based on current radio science.

Requirements of note include: propagation data for implementation of mobile-satellite services such as low-Earth orbit (LEO) satellite systems and digital broadcasting to mobile receivers; diffraction assessment, particularly for estimation of interference; accurate spatial and temporal modelling of climatic and ionospheric variables; and reflection and scattering properties of the Earth in frequency bands 2 MHz up to and beyond 300 GHz. Clearly these studies require basic radio science data and analysis, areas for which URSI can offer valuable assistance.

The strong market push for third generation wireless mobile communications and the expanding bandwidth requirements has led to the need for signal loss information for propagation into buildings and vehicles at fast information rates. These paths require data for design purposes that are not available in the open literature. In particular there is a great need for data on propagation through building materials and a study of the propagation as a function of building structure, as well as a function of urban structure.

Additional needs are generated by World Radio Conferences (WRCs) now held about every two to three years (the next in 2003) to allocate frequencies to specific radio services. The proliferation of new services and consequent demand for spectrum, plus the strong commercial implications related to frequency allocation, lend importance to the propagation features in allocated bands. This is particularly important when seeking allocations for new or expanding services, and candidate bands have to be assessed for potential sharing with existing services. Propagation models are required as part of such studies and these sometimes involve scenarios (e.g. frequencies, geometries, locations, environments) not adequately covered in existing ITU-R Recommendations. In such cases, Study Group 3 provides the best advice possible, based on the latest available radio science, often within a short time frame.

Propagation issues of particular current importance are found in both the SG 3 brochure or via the Australian Radiocommunication Study Group [5]. These identify the technical items to be addressed. It is incumbent upon both URSI and ITU-R to identify relevant trends in telecommunications that may result in future requirements for propagation information. Recent commercial endeavours wishing to exploit the satellite frequency bands around 20/30 and 40/50 GHz introduce the need for propagation data and models for system design in these bands. In another example, the coordination of high altitude (15-50 km) data relay platforms with those of satellites (Earth-space), there is the need for models of backscatter from the tops of rain cells, a potential interference situation.

Demand for communication services available anywhere anytime, reflected in the global development of the ITU International Mobile Telecommunications initiative (IMT-2000), has generated requirements for propagation information of various types, some already mentioned above. Implementation of wireless links to mobile and portable terminals (often to complete the last segment of a communication path) requires information on channel performance for a multiplicity of environments. For example, IMT-2000 covers a very wide range of radio operating environments, all the way from the satellite to indoor pico-cells. It is a multi-dimensional situation, involving different physical environments such as in-building, outdoor congested (urban), and outdoor rural. There are different mobility environments such as stationary, pedestrian, vehicular mobility, and high-speed applications. Finally there are different user density environments, including three-dimensional situations. The system needs to optimally adapt to all propagation environments (terrestrial and satellite) and all traffic environments that result. This can include mixed environments, where fast moving vehicles are moving on a roadway that is physically close to a pedestrian precinct.

An adaptive radio interface is envisaged for IMT-2000 to optimize performance in these widely differing propagation conditions. This adaptation will be controlled by software using digital signal processing technology. The design of such software, and the standards incorporated, will need to account for the propagation effects likely to be experienced at the frequencies envisaged (initially about 2 GHz but expected to include other frequencies as the demand grows).

SUMMARY

The foregoing has described the role of ITU-R Study Group 3 in developing propagation procedures and models used for system design and service planning. Most of this information finds its way into the ITU-R “P series” of recommendations that can be regarded as a set of “standard procedures” for worldwide application. The rapid growth of new radiocommunication systems is giving rise to an increasing number of sharing problems for which new and more accurate propagation information is required. Study Group 3 is responding to this challenge but can only do so if there are research programs and data that provide the basis for improved prediction of propagation characteristics. Those in URSI that have access to data and results that may assist in characterising the propagation channel in order to improve communication are encouraged to contact the Australian Radiocommunication Study Group 3 [5].

REFERENCES

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