Propagation Prediction Methods for International Regulation: the Work of ITU-R Study Group 3

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Abstract – **The radio frequency spectrum is shared by a ever-increasing set of services with different requirements. An international framework to manage the radio spectrum and to prevent interference requires agreed propagation prediction tools. Within the International Telecommunication Union, Radiocommunication sector (ITU-R), Study Group 3 develops such propagation advice. Members from around the world contribute research results – measurements, modelling and testing – to provide methods for all types of radio systems across the spectrum. This paper describes the work of Study Group 3 and how the research community can be involved.**

Index Terms — **Propagation, international, spectrum, regulation, ITU-R.**

1. Introduction

While it is often observed that the past few decades have seen a spectacular growth in the number and type of radio devices that are a part of everyday life for millions of people, it is worthwhile to consider the breadth of this phenomenon.

Mobile telephones and wireless computing have moved radio technology into consumer-grade products. While television and radio broadcasting are well-established technologies, they have been enhanced with real-time coverage of sports, weather, traffic, emergencies and live entertainment, via electronic news-gathering with new radio technologies. Air travel relies on air-traffic control, guidance systems, GPS and radar. Road traffic uses keyless entry, garage door openers, traffic alerts, electronic toll payments, collision avoidance radar, hands-free headsets, and police radar. Retailers rely on checkout scanners, wireless inventory control, and RFID security systems. Weather forecasting is based on active and passive sensing systems collecting data from the earth's surface and from space.

Beyond these daily applications, there are specialist uses of radiocommunications, such as defence, emergency services, radioastronomy, amateur radio, taxi and fleet dispatch, and maritime operations, extending the list of radio systems and services which have become essential, or at least highly desirable, to life in the developed world.

All these systems require spectrum in which to operate with freedom from harmful interference. Although research has brought improvements in spectral efficiency, and increased the upper frequency limit for practical applications, the demand for spectrum continues to exceed availability.

The International Telecommunication Union (ITU) is an organization within the United Nations system where governments and the private sector coordinate global telecommunication networks and services [1]. A major function of the ITU is the management of the radio spectrum, carried out by the Radiocommunication Sector (ITU-R). The Radio Regulations [2], is a treaty-level international agreement on spectrum usage; national spectrum plans of individual countries are based on this framework.

Changes to the Radio Regulations, to accommodate new technologies, occur on a four-year cycle. Study Group 3 supports this effort by providing propagation expertise.

2. ITU-R Study Group 3

Propagation prediction methods are widely used in system design, such as estimating a link margin or coverage area. Improvements in prediction lead to better system design, allowing lower power or more effective use of bandwidth.

There is also a need for propagation prediction methods in estimating the likelihood of interference between different systems in the same frequency band. This is essential in the evaluation of new frequency allocations.

Propagation prediction methods developed in Study Group 3 are based on inputs from researchers around the world. Extensive measurement campaigns coupled with modelling of the underlying physical processes are used to develop step-by-step methods for calculation of impairments such as attenuation or depolarisation. These are tested against a database of measurements maintained by Study Group 3.

Technical studies are conducted in four Working Parties (WP). Their scope and a few outcomes are described here.

(1) Working Party 3J: Propagation fundamentals

WP 3J addresses fundamental topics in physics, meteorology and statistics which are used in the specific prediction methods developed in the other Working Parties. For example, WP 3J maintains global data and models on climatic variables such as rain rate and atmospheric refractive index. WP 3J is responsible for models of specific attenuation due to atmospheric gases and rain, diffraction over terrain, and the effects of vegetation.

A recent activity in WP 3J has been the expansion of advice on building entry loss in Recommendation ITU-R P.2040 [1], for various building types and over a wide frequency range. This is an essential component for evaluating new frequency allocations in urban and suburban environments, particularly for fifth generation (5G) mobile broadband and the Internet of Things (IoT).

[1] Recommendations available at http://www.itu.int/rec/R-REC-P/en

(2) Working Party 3K: Point-to-area propagation

WP 3K develops point-to-area prediction methods for mobile and broadcasting services.

Recommendation ITU-R P.1238 describes indoor communication systems, particularly for WLAN and mobile phone services, in the range 300 MHz to 100 GHz. The prediction methods include a site-general model for loss, including between floors of a building, and for delay spread, as well as advice on the use of site-specific (e.g. ray-tracing) models and the effect of materials, furnishings and movement of people in the room.

Recommendation ITU-R P.1411 covers short-range (up to 1 km) outdoor environments, including urban high-rise, urban/suburban low-rise, residential and rural in the frequency range 300 MHz to 100 GHz, with specific measurement results at key frequency bands. Prediction methods are provided for path loss and delay spread on line-of-sight and non-line-of-sight scenarios.

Recommendation ITU-R P.1546 provide prediction methods for mobile systems (including mobile phones) and for broadcasting in the frequency range 30 MHz to 3 GHz. The core of this Recommendation is a series of curves, based on extensive measurement campaigns, providing field strength exceeded at various percentages of time and for fixed frequencies, for a range of transmitter antenna heights and a fixed receiver height. Procedures are then provided to extrapolate or interpolate to other time percentages, frequencies and antenna heights, and to take account of local terrain variations. This Recommendation was used by the ITU in replanning broadcasting frequencies across Europe, North Africa and the Middle East.

(3) Working Party 3L: Ionospheric propagation and radio noise

WP 3L studies propagation in and through the ionosphere, in support of HF systems and trans-ionospheric effects for satellites; it also addresses radio noise.

Recommendation ITU-R P.372 characterises background levels of radio noise over the frequency range 0.1 Hz to 100 GHz. It covers both naturally-occuring noise (solar, cosmic, atmospheric and lightning) as well as that of human origin in a range of environments from rural to urban. It is important, but extremely challenging, to update the statistics on human-generated noise on a regular basis.

(4) Working Party 3M: Point-to-point, earth-space and interference propagation

WP 3M provides propagation prediction methods for point-to-point terrestrial systems, satellite systems (both fixed and mobile), and for the evaluation of interference.

Recommendations ITU-R P.530 and P.618 provide step-by-step procedures to evaluate propagation impairments for line-of-sight terrestrial and for satellite paths, respectively. They make use of climatic data from WP 3J to calculate effects such as gas and rain attenuation, refraction, multipath, and diffraction as a function of frequency, location and geometry. They are widely referenced for system design in industry.

Recommendation ITU-R P.452 provides calculations for interference between a transmitter and a receiver which are both on the surface of the Earth, at frequencies above 100 MHz. While propagation methods for system design typically concentrate on losses, to establish a link margin, the emphasis in this Recommendation is signal enhancements which potentially cause harmful interference. The Recommendation covers mechanisms which occur at large percentages of time: line-of-sight, diffraction over terrain or buildings, and tropospheric scatter, and then those for short periods of time: multipath enhancements of the line-of-sight signal, ducting from surface or elevated atmospheric layers, reflection and refraction from atmospheric layers, and scattering by raindrops or other hydrometeors.

3. Working Methods of Study Group 3

The Working Parties of Study Group 3 meet about once a year to consider new measurements and models. Input documents from members propose changes or extensions to the Recommendations; these are discussed and evaluated in detail during the meeting. If agreed, the WP results are adopted by the Study Group and then approved by the 193 member countries of the ITU before being published.

Study Group 3 Recommendations are intended to contain the most accurate and comprehensive advice at the time, but are subject to frequent improvement and extension. Input from the research community is therefore always welcomed.

Participation in Study Group 3 is either through a national government delegation or a company ("sector") or research ("academia") membership. Information is available at [3, 4] or from the author of this paper.

4. Conclusion

Accurate prediction of radiowave propagation is an essential tool for system design and deployment as well as for assessment of inter-system interference. ITU-R Study Group 3 develops internationally-agreed propagation prediction methods for these purposes, using the expertise of scientists and engineers from around the world. Participation in Study Group 3 allows researchers to have a direct influence on the future of radio technology at the highest regulatory levels, and provides contact with leading propagation researchers from many countries. New participants, particularly from the university and research sector, are always welcome.

References

[1] http://www.itu.int/en/about/Pages/default.aspx
[2] http://www.itu.int/en/publications/ITU-R/pages/publications.aspx?parent=R-REG-RR-2012&media=electronic
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