

H. Sizun

Radio Wave Propagation for Telecommunication Applications

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With 161 Figures

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Foreword

The first radio links, wireless telegraphy, were established at the beginnings of the twentieth century by Marconi, who drew upon the theory developed by Maxwell and upon the experimental researches conducted by Hertz. In France, such renowned scientists, mathematicians, physicists and experimenters as Poincaré, Blondel and the Général Ferrié played a crucial role in the development of radiocommunications, more particularly through theoretical and experimental researches which contributed to a better understanding of the different propagation media. Following the Second World War, the researchers and engineers of the newly created *Centre National d'Etudes des Télécommunications* (CNET), among whom may be mentioned Jean Voge, François du Castel, André Spizzichino or Lucien Boithias, made decisive contributions to the understanding of the propagation of radio waves, in particular in the context of their application to telecommunications. Although the CNET has now become *France Telecom Recherche & Développement*, the present book is in keeping with this approach, which has been going on for more than half a century. By providing the reader with some of the most recent researches in this field, Hervé Sizun offers here an essential complement to the work by Lucien Boithias *Radiowave Propagation*, first published in 1983 in the *Collection Technique et Scientifique des Télécommunications*, and published in an English version in 1987 by McGraw-Hill.

As a field of research, the propagation of radio waves remains intensively investigated, and the researches conducted in this context have led to a large number of results with applications not only in the field of radiocommunications, but also in such other fields as remote detection. While Maxwell's equations have of course remained unchanged, the ever increasing telecommunication needs require to develop a modelling of the propagation of radio waves under an ever wider range of conditions as regards such parameters as the environment, the frequency range or the bandwidth.

A first reason explaining the renewal of activity in the field of radio propagation is the notion of mobility. Telecommunication services should indeed be provided for the largest and most varied types of environments, at home, in workplaces and also increasingly during displacements. Although this can be to some extent achieved through the use of the routing capabilities of fixed networks, radio nevertheless possesses a considerable intrinsic advantage in this context. However, since non line-of-sight situations tend more than often to become the rule, this very mobility induces a number of problems in terms of propagation. While the physical characteristics of the atmosphere still exert their influence,

these characteristics nonetheless tend to become secondary compared to the influence of the configuration of human land-use.

A second reason which may be offered for the renewal of interest in the propagation of radio waves is the tendency towards the use of higher frequency ranges and correlatively towards the increase of the bandwidth of the transmitted signals. During the first half of the twentieth century, the waves used in radio links had a wavelength larger than one meter. In terms of bandwidth, such waves simply cannot offer the capacities of several tens and hundreds of megahertz, nor their equivalent information rates, that present day telecommunication needs call for. As a result, this has led to the implementation of decimetre, centimetre and millimetre-length waves.

The relation between the size of obstacles and the wavelength is a decisive parameter when constructing approximations of physical laws which are to be applied to the propagation of radio waves. It is therefore apparent that significant differences in the modelling of propagation phenomena will arise at this point. Finally, high rate digital transmissions are particularly sensitive to the frequency selectivity of the propagation channel and this broadband characterisation is essential for a better evaluation of the effects induced by propagation distortions on the quality of the numerical signal. The major topics in the study of propagation thus undergo evolutions which are driven by the changes in telecommunication needs. These evolutions are of course taken into account in the present book. For instance, the relative importance of propagation studies devoted to ionospheric links, to interurban links or to forward-scatter microwave links has somewhat declined in the last recent years compared to propagation studies devoted to mobiles in and outside buildings or to short-distance radio links operating in the millimetre band.

These developments are well reflected in this book, where the interactions between the theoretical understanding of the physical environment, the construction of approximations of electromagnetic laws adequate to specific conditions of propagation and experimental contributions are clearly shown. Special emphasis is also laid in this book on significant results which are relevant for the evaluation of the influence of propagation on numerical communications and on their quality.

The author has had the relatively rare opportunity of successively working over the course of his career on several of the main topics which are addressed in this book: first on the ionosphere, and later on point-to-point microwave links and mobile radio links. This has allowed him in this book to bring together different fields of study which too often are considered apart from one another. Further, the author was part in the conception and the realisation of several series of measurements whose results, after contributing to the enrichment of the experimental databases of the *International Telecommunication Union*, are presented here. This experience allows him to stand back and fully appreciate the actual significance of the different parameters involved in the propagation of radio waves. The practical character of the results presented in this book should also be emphasised, as well as the variety of models which are described here. As might be indeed stressed here, there does not, and will not, exist any universal model that

could be applied to all the multiple problems that radiocommunications present us with.

From a didactic point of view, this book is organised into four main parts, consisting each of one or two chapters where the most significant results are presented, and of different appendices exploring in more depth certain crucial points. Chapters 2 and 3 are thus devoted to the characteristics of the physical environment, the atmosphere, which is involved in all the situations studied in this book, and to a presentation of the main results concerning the mechanisms of propagation, refraction, reflection or diffraction. These two chapters are supplemented by Appendices B, E, K and O, where the properties of hydrometeors and the calculation methods are examined in more detail. The second part of the book is devoted to the propagation of radio waves in ionised media: refractions and reflections in the ionosphere are indeed still being used for certain long-distance links. As a complement, Appendices A and E present a description of the solar activity and of the disturbances induced by this activity. The third part of the book, consisting of Chapters 5 and 6, supplemented by Appendices D, I and J, is devoted to an analysis of horizontal and oblique fixed links, primarily in direct line-of-sight propagation. Finally, the last part of the book addresses the characterisation of radio mobile propagation: the different applicable types of models are thus successively described in Chapter 7, while Appendices L, M and N address in more detail such subjects as geographical databases, the experimental measurement of the directions of arrival as well as some specific problems associated with their modelling.

By way of conclusion, this book which, as should be the case for any good book devoted to the propagation of radio waves, harmoniously combines a theoretical, a physical and an experimental approaches to this subject, should provide a large amount of practical information for designers of radiocommunication systems who more than often tend to view the propagation of radio waves as a source of multiple and varied distortions rather than as a fascinating field of studies.

Jean-Claude Bic

*To my parents
To my wife Marie-Thérèse,
To my children Jean-Michel, Ronan and Guénaelle.*

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