Samuel Silver
(Editor)

Monograph on Radio Waves and Circuits

XIIIth General Assembly of URSI. London. 1960

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XIIITH GENERAL ASSEMBLY OF URSI LONDON 1960

Edited by

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GENERAL INTRODUCTION

This being the first of the series of URSI General Assembly monographs on radio waves and circuits, some remarks on the history and objectives of the Commission are in order.

URSI Commission VI (Radio Waves and Circuits) has as its domain of responsibility in URSI a broad range of subjects: information and communication theory, circuit theory, antennas, waveguides, and more generally applied electromagnetic theory. The Commission originated as an offshoot from the Commission on Radiophysics under the direction of Prof. Balth. van der Pol. Prof. van der Pol recognized the need for a unit within URSI to deal with the many expanding new areas of research, the new developments in applied mathematics, a need for a coordinating unit which would bring together engineers, physicists, and mathematicians on problems which were regarded as purely ancillary by the other Commissions whose interests were turning more and more to the geophysical and cosmological import of radio propagation research. Hence the broad scope and diversity of subject matter falling to Commission VI.

All through the current General Assembly the Commission has been organized on the basis of three Subcommissions.

VI. 1 Information and Communication Theory
VI. 2 Circuit Theory
VI. 3 Antennas, Waveguides and Electromagnetic Theory.

The Chairmen of the respective Subcommissions during the triennium 1957–1960 have been Dr. F. L. Stumpers (Netherlands), Prof. Ing. B. D. H. Tellegen (Netherlands), and Prof. G. Sinclair (Canada) upon whom devolved the great portion of the task of carrying out the work of the Commission. The seeming diversity in subject matter, together with the fact that research in the fields of Commission VI does not require the same sort of international collaboration as does research in propagation and radioastronomy, has given the work of Commission VI a rather different character from that of most of the other Commissions. However, the foresight and genius of Prof. van der Pol in setting up the Commission have proved themselves in the growth of the Commission, its effectiveness in stimulating new areas of study, and as the medium for effecting exchange of information and ideas between scientists of many countries. The Commission has become an international forum for discussion of topics which are regarded as of peripheral interest

in other international unions but which are vital to the growth of the individual fields and, in concert, to the growth of communications.

The monograph represents the work of Commission VI proper. The programme of Commission VI for the XIIIth General Assembly was projected first at the previous Assembly in 1957 and was developed subsequently jointly by the Subcommissions Chairmen, by the Vice-chairman of the Commission, Mr. J. Loeb, and by the Chairman of the Commission. The final format was established at the meeting of the Coordinating Committee in Brussels. It was agreed at that meeting that only a limited number of papers (all invited) would be presented fully at the technical sessions. These constitute the main body of the monograph.

The subject matter of the technical sessions was chosen on the basis of current importance and interest. Special attention was given to material in which the three Subcommissions have a common interest with the view of synthesizing a central core of activity for the Commission as a whole. The underlying unity of the fields of the Commission has become increasingly evident particularly in the recent developments of space communications, and the future will see a greater element of unity of subject matter rather than diversity in the work of the Commission. Several sessions were formulated as joint sessions with the other Commissions on such topics where the overlap of interests and techniques was prominent. In the present monograph only those sessions for which Commission VI had the prime responsibility are covered.

The Chairman, the Vice-chairman, and the Chairmen of the Subcommissions served as chairmen of the technical sessions. In addition Prof. H. M. Barlow served as chairman of the session on Surface Waves and Prof. A. C. B. Lovell served as co-chairman with the writer of the joint session of Commissions V and VI on Antennas and Data Processing.

Mention must also be made of the contributions made by Dr. James R. Wait, who as chairman of an *ad hoc* committee on Surface Waves set up at the General Assembly in 1957, did much to the development of the programme of the XIIIth General Assembly. The chairmen of the sessions not only carried the burden of organizing their sessions but also served as editors for the preparation of the monograph.

Each session, in accordance with the rules of URSI, had an English speaking and a French speaking reporter. The tasks of these individuals are most demanding and one can hardly express our indebtedness to those scientists who devoted many evening hours during the General Assembly

and subsequently to putting the proceedings into order. Reports of discussions have not been sent to the participants for review and, therefore, the reader and participants are asked to be indulgent of the editors in the preparation of the monograph.

Prof. Balth. van der Pol passed away in October 1959. He had helped immeasurably in the work of the Commission during the tenure of the present Chairman, giving him freely of his energies and his guidance. We missed greatly his sparkling wit, his incisive criticism and summations, and his fine sense of diplomacy which made our previous General Assemblies such memorable occasions. The growth and structure of Commission VI is but one of many monuments to his genius as a scientist and administrator. It is with great sadness but deep appreciation that we dedicate this first monograph of Commission VI to his memory.

SAMUEL SILVER
Chairman, Commission VI
(term ending September 1960)

Berkeley, California, 1961

SECTION I

BOUNDARY VALUE AND SCATTERING PROBLEMS

Chairman: G. SINCLAIR

FOREWORD

The subject of boundary value and scattering problems has been in the forefront of the technical programmes of Commission VI for a number of years. Steady progress has been made in developing solutions for the scattering of electromagnetic waves by bodies of various shapes, from the configurations for which the vector wave equation is separable and exact solutions can be obtained in the form of series of characteristic functions to those for which the wave equation is non-separable and approximation techniques must be employed.

In general the methodology of obtaining approximate solutions is well established for the limiting cases when the dimensions are large compared with the wavelength and when the dimensions are small compared with the wavelength. Bridge between these limiting conditions still remains a subject of interest, and continuing progress in this direction has been made as diffraction phenomena have been analyzed on the basis of various models such as creeping waves and diffracted rays. The objective of this session was to review the status of the field and some of the recent developments.

Prof. Siegel, in the first paper (p. 11), presents a review prepared by himself and his co-workers on scattering by bodies whose dimensions are such that resonance phenomena occur. This work carries the treatment of scattering and diffraction beyond the Rayleigh region (dipole approximation) into the domain where the dimensions of the body are comparable with the wavelength.

In the second paper (p. 38), Prof. Wainstein gives a resumé of the work done in the U.S.S.R. by himself and his colleagues. This paper, which is in effect the report of the National Committee of the U.S.S.R., contains an extensive bibliography which is welcomed heartily by workers in the field. The paper was presented by Prof. Fock since Prof. Wainstein unfortunately could not be present.

The third paper (p. 41) is a contribution of a new technique by Prof. Timman and Dr. Kleinman. The paper deals in particular with the subject of diffraction by a strip. It offers not only a new solution to the problem but delineates a mathematical technique which may find application to many other problems.

Prof. Fock, in the fourth paper (p. 71), deals with a problem of long history, the hollow cylinder of finite length. In this paper Prof. Fock develops some new approximation procedures which lend themselves particularly to

numerical treatment and thus make possible the extraction of results of direct practical importance.

The presentation of the papers was followed by a panel discussion. The discussion points out the interrelationship of a number of contributions and some of the problems presently engaging the attention of workers in the field of electromagnetic diffraction and boundary value problems.

NOTE INTRODUCTIVE

Depuis un certain nombre d'années les questions relatives aux problèmes des valeurs limites et à la dispersion ont figuré en tête des programmes scientifiques de la Commission VI. Des progrès constants ont été atteints en trouvant des solutions pour des problèmes de dispersion des ondes électromagnétiques par des corps de dimensions variées, depuis les configurations pour lesquelles l'équation vectorielle de l'onde peut être séparée et pour lesquelles des solutions exactes peuvent être obtenues sous forme de séries de fonctions caractéristiques, jusqu'aux configurations pour lesquelles l'équation de l'onde n'est pas séparable et pour lesquelles des méthodes d'approximation doivent être utilisées.

En général, la méthodologie pour l'obtention de solutions approchées est bien établie pour les cas limites quand les dimensions sont grandes comparativement à la longueur d'onde et quand les dimensions sont petites comparativement à cette longueur. La liaison entre ces conditions limites reste un sujet de grand intérêt, et des progrès incessants sont atteints grâce à l'analyse des phénomènes de diffraction sur la base de modèles différents tels que les ondes glissantes et les rayons diffractés.

Cette séance avait pour but de passer en revue la situation de ce domaine ainsi que quelques-unes des réalisations récentes.

Dans la première communication (p. 11), le Professeur Siegel et ses collaborateurs présentent une revue sur la dispersion par des corps dont les dimensions sont telles qu'un phénomène de résonance se révèle. Ce travail transpose le traitement de la dispersion et de la diffraction au-delà de la région de Rayleigh (approximation du dipôle) dans le domaine où les dimensions du corps sont comparables à la longueur d'onde.

Dans la deuxième communication (p. 38), le Professeur Wainstein donne un résumé des travaux réalisés en URSS. Cette communication, qui constitue le rapport du Comité National de l'URSS, contient une bibliographie étendue qui sera appréciée par les chercheurs intéressés dans la question. Le Professeur Wainstein n'ayant pu assister à la réunion, le Professeur Fock présente la communication.

La troisième communication (p. 41) est une contribution sur une nouvelle technique du Professeur Timman et du Dr. Kleinman; elle traite de la diffraction par un ruban. Elle présente non seulement une nouvelle solution au problème, mais expose aussi une nouvelle technique mathématique pouvant s'appliquer à d'autres problèmes.

Dans la quatrième communication (p. 71), le Professeur Fock traite un problème ayant une longue histoire, celui du cylindre creux de longueur finie. L'auteur expose quelques nouveaux procédés d'approximation qui se prêtent particulièrement au traitement numérique et permettent ainsi l'obtention de résultats de grande importance pratique.

La présentation des communications fut suivie d'une discussion dirigée; celle-ci met en évidence l'inter-relation entre un certain nombre de contributions et quelques problèmes qui retiennent, pour le moment, l'attention des chercheurs dans le domaine de la diffraction électromagnétique et des valeurs limites.

THE RESONANCE REGION *

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ABSTRACT

The scattering of electromagnetic waves or acoustic waves by various shapes has been subjected to many analyses and resultant methods of approximation. These methods are usually conceived for a region where the wavelength is either large or small with respect to body dimensions. Some small wavelength techniques are considered 'exact' because they yield correct terms, at least correct leading terms, in asymptotic expansions. Some long wavelength series or expansions are also considered 'exact' because they are either convergent series or again asymptotic expansions. The subject for analysis here is that region, in the ratio of dimensions to wavelength, where neither type of the above expansions satisfactorily approximates the correct physics. Also, the above approximate methods never describe the criterion, dependent upon geometry, for the range of wavelengths for which the small wavelength or long wavelength expansion holds. That is, no method yields an exact bound which is dependent upon geometry below which (or above which) the method yields a correct representation. In this paper we state bounding criteria and compare the results with spheroid and cone answers to exhibit the consistency of results. This required the correcting of previously reported cone and spheroid asymptotic answers and the obtaining of new spheroid results. These required additions and corrections have been made.

RESUME

La diffraction des ondes électromagnétiques ou acoustiques par divers obstacles a été étudiée par plusieures méthodes d'analyse approximative. Ces méthodes sont ordinairement appliquées dans une région dans laquelle la longueur des ondes est ou longue ou courte par rapport aux dimensions de l'obstacle consideré. Quelques techniques pour des ondes courtes sont con-

* The work on the cone was performed by J. W. Crispin and K. M. Siegel while the effort on the spheroid was contributed by K. M. Siegel and F. B. Sleator.

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siderées ≪exactes≫ parce qu'elles fournissent, au moins au commencement de l'expansion asymptotique, des termes exacts. De même, quelques techniques pour des ondes longues sont qualifiées ≪exactes≫, parce qu'elles donnent une série convergente ou encore une expansion asymptotique. Le but de ce travail est de considérer la région où les deux possibilités ci-dessus ne se présentent pas, c'est-à-dire où le rapport de la longueur d'onde aux dimensions de l'obstacle ne s'applique pas d'une manière satisfaisant aux techniques mentionées plus haut. De plus ces méthodes approximatives ne nous donnent jamais la dépendance de la solution sur la configuration de l'obstacle, même sous des conditions où les expansions des ondes, courtes ou longues, sont valables. C'est-à-dire qu'il n'existe pas d'expansion valable quelque soit la configuration, même dans les cas où ce rapport prend des valeurs extrêmes. Nous présentons, dans cette étude, des frontières limites et comparons nos résultats avec ceux d'un sphéroïde et d'un cône pour mettre en évidence la consistence de notre méthode. Il fallait que nous corrigions nos résultats antérieurs asymptotiques, et développions des résultats nouveaux pour le sphéroïde. Ces additions et améliorations ont été apportées.

INTRODUCTION

At the last URSI General Assembly and at the URSI Toronto Symposium on Electromagnetic Theory an extensive discussion took place on the question of what was known about scattering amplitudes for scatterers whose major dimensions are of the same order of magnitude as the wavelength. We have means of obtaining asymptotic expansions when the wavelength is either large or small compared with the dimensions of the body. We have used small wavelength asymptotic theory to obtain results for scatterers which have points by patching onto the short-wavelength asymptotic theory the known exact solutions for the half plane, circular aperture, wedge and cone. This has allowed the use of small-wavelength asymptotic theory for large bodies with singularities.

The question we focus on today involves the resonance region. It is our belief that we should attempt to obtain first order results and analyze these before we discuss methods of obtaining asymptotic expansions; a crude method of obtaining an approximation to the first order answer, based on correct physics, is more useful, at least in the initial stages of an investigation, than an apparently exact theory which is 'stretched' to hold in the resonance limit. For certain bodies such a 'stretching' procedure will work, while for