Preface

Antenna engineering has developed into a highly specialized field of radio engineering which in turn is subdivided into many special branches. This treatise will deal with antennas made of wires, masts, and towers for frequencies up to about 30 megacycles. Antennas for higher frequencies are nowadays factory-designed and factory-built, and the operating and plant engineers are relieved of the design problems.

There is a very extensive experience with antennas within our range of interest, but unfortunately there is only a relatively small amount of published material on techniques. In contrast, there is a vast literature on antenna and radiation theory. It is the purpose of this book to attempt to compile a sufficient amount of useful engineering information to enable nonspecialists to handle many of the ordinary antenna problems that arise in point-to-point, ground-to-air, and military communications, and in broadcasting. Some of the more advanced antenna designs suggested by very-high-frequency and ultrahigh-frequency techniques are included because the day is approaching when these principles will have to be applied at the lower frequencies as the spectrum conditions become more difficult.

Transmission lines are inseparably related to antennas, so a chapter on this subject is included, together with a chapter on impedance-matching networks.

An author of a book on techniques is confronted with many difficult situations because he must try to convey a sense of judgment in significant values and wise compromise in the presence of the many empirical conditions that surround each individual problem. The successful solution of an engineering problem involves many arbitrary decisions and is largely a matter of personal ingenuity and resourcefulness in applying sound electrical and mechanical principles. For that reason some of our statements made in the discussion of the various topics should not be interpreted too rigorously. Our intention has been to provide a certain amount of guiding counsel for those who need it even though it was necessary to oversimplify to some extent.

There are three basic aspects of antenna engineering. The first per-

tains to radiation characteristics and includes all matters of the distribution of radiant energy in space around an antenna system, as well as the current distributions that produce the radiation pattern. The second pertains to antenna circuitry and involves such matters as self- and mutual impedances, currents, potentials, insulation, and feeder systems that will yield the desired current distributions. Third there is the structural engineering which has to do with all the mechanical details of supports, rigging, materials, strengths, weights, hardware, assembly, adjustability, stability, and maintenance. While each aspect must be separately developed, the final design must be an integration of the three, with a minimum of compromise and within reasonable economic limits.

The purpose of a transmitting antenna is to project radiant energy over a given wave path in the most effective and economical manner. The purpose of a receiving antenna is to absorb a maximum power from a passing wave field, with the maximum exclusion of noise and interfering signals. The transit of a wave field between the two depends upon the physics of wave propagation. The antenna engineer must be familiar with wave propagation to be able to design antenna systems of maximum effectiveness. Wave propagation is a vast and complicated statistical subject, and for that reason the space that can be devoted to the subject in this book is limited to the barest essentials. Sources of detailed information are indicated for reference and study. It may be expected that future developments in our knowledge of propagation will have their influence on future antenna design.

The design formulas for the various types of antennas are presented without proof and may be regarded as recipes. Their theory and derivation may be found in the literature, together with more complete information of a related nature. Also, many data curves and tables are taken from recognized sources, although these are sometimes rearranged for greater utility. Some of the information is from unpublished sources and includes much original material. The appendixes contain reference data of general use to the antenna engineer.

The nomenclature used for bands of frequencies is based primarily on their propagation characteristics. These terms are also approximately in accord with the nomenclature adopted by the International Telecommunications Union at its Atlantic City conference in 1947. The use of these broad terms has a brevity and convenience that is very desirable in writing and talking about frequencies, provided that one thinks about them as having indistinct boundaries.

One must recognize rather large overlaps in the bands of frequencies propagated as listed, and the bands shown are indicative only. They blend gradually from one into the other, the amount and the extreme ranges varying with the state of the ionosphere and ground characteristics.

The three frequency groupings also roughly define three different classes of design technique for antennas, and we have taken them up in this order. To a certain extent, high-frequency design techniques may be applied to antennas used for optical propagation, but antennas for the frequencies propagated optically become still another class of techniques based on rigid prefabricated structures.

Term	Abbreviation	Approximate band	Most useful propagation
Low frequency (long wave)	LF or lf	Up to 500 kilocycles	Ground waves
Medium frequency (medium wave)	MF or mf	200–5,000 kilocycles	Both ground and sky waves
High frequency (short wave)	HF or hf	3–40 megacycles	Sky waves propagated by way of the ionosphere

Wherever possible we have used the meter-kilogram-second system of units in the formulas. However, in a practical work of this nature it is necessary to adhere to prevalent engineering usage of heterogeneous systems of units. For example, in the United States it is standard engineering practice in broadcasting to base the performance of an antenna on millivolts per meter at 1 mile and to use conductivities in the centimeter-gram-second electromagnetic system of units. The general use of the English system of measurements leads also to the frequent use of such units in formulas. To avoid confusion, the particular units used are explicitly given where necessary, even though this requires a certain amount of repetition. This is done so that one can select and use an isolated formula conveniently.

Nomenclature with respect to wave polarization follows the standardized usage where the orientation of the electric vector of the wave field with respect to the earth defines the polarization. Vertical polarization is understood when the electric vector of the wave is normal to the earth's surface, and horizontal polarization when the electric vector is parallel to the earth. Intermediate polarizations also exist.

Comprehensive bibliographies are given at the end of each chapter, and a more general bibliography is given in Appendix I. The papers listed are those which have a definite reference value to the antenna engineer when he is searching for fundamental information, experimental data, and history of the art, as reported in original researches. Collectively they comprise many thousands of pages of information that cannot possibly be condensed into any single volume. As one advances further and further in the antenna-engineering art, the need for reference to these original sources becomes more pressing and the value of an extensive bibliography becomes evident.

Superscript numbers are used in the text to indicate relevant sources of information. Numbers under 1000 relate to those references listed at the end of the particular chapter in which they are cited. References in the 1000 series are to be found in Appendix I.

The book *Antennas* by J. D. Kraus[1002] is a useful one for those desirous of becoming familiar with the theoretical principles of antennas. It is a synthesis of the latest theories of radiation from antennas and the methods for computing radiation patterns and impedances, and reduces the need to refer to the large number of original research papers distributed through the literature of many years.

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