Antennas

Volume 2
Applications

S Drabowitch and C Ancona

Translated by
Meg Sanders

Consultant:
E Roubine

HEMISPHERE PUBLISHING CORPORATION
A Subsidiary of Harper & Row, Publishers, Inc.
Washington New York London

Original French language edition
Antennes: Applications © 1986 Masson, Paris

Revised and updated 1988

English edition first published 1988 by North Oxford Academic Publishers Ltd, a subsidiary of Kogan Page Ltd, 120 Pentonville Road, London N1 9JN

Published in the U.S.A. by
Hemisphere Publishing Corporation

Library of Congress Cataloging-in-Publication Data
Antennes. English.
Antennas.
Translation of: Antennes.
Includes bibliographies and indexes.
Contents: v. 1. General principles/E. Roubine and J. C. Bolomey—v. 2. Applications/S. Drabowitch and C. Ancona.
1. Antennas (Electronics) I. Roubine, E. (Elie) II. Title.
TK7871.6.A513 1988 621.38′028′3 87-12111
ISBN 0–89116–278–X (v. 1)
ISBN 0–89116–279–8 (v. 2)
Printed and bound in Great Britain

Antennas

Volume 2

Applications

Contents

Part 1

Large antennas

S. Drabowitch

Chapter 1

Structures—Applications—Methods

The expression 'large antennas' denotes those radiating structures whose characteristic dimensions are very much greater than the wavelength. This condition permits highly directive antennas with considerable gain to be realized, and permits given radiation patterns to be very precisely synthesized.[1]

These possibilities explain their multiple applications in terrestrial or space telecommunications, radar and radioastronomy. The same condition, moreover, means that it is possible to treat problems of electromagnetism posed by such structures using certain mathematical models whose complexity depends on the level of precision required: geometric optics, physical optics, vectorial or scalar models, Kirchhoff's or Fresnel's approximations, and asymptotic forms, etc. The choice of mathematical model to be used depends on the problem to be treated.

In general, the work of the engineer consists firstly of a problem of synthesis: defining the general structure of an antenna with certain 'external' characteristics imposed in advance, while respecting a set of economic, technological and mechanical constraints.

In this phase, only the simplest models—geometric optics, scalar waveform optics—will be used to choose the general structure to meet all these requirements and to complete the pre-project phase rapidly.

Following this, the project will require more detailed analysis. The possibilities presented by numerical calculation allow the use of relatively precise methods, although the duration of calculation is often the limiting factor. In addition, it is common for parasitic phenomena, difficult to calculate, to give rise to significant disturbances in the approximations. An experimental evaluation can sometimes be made: methods for automatic measurement allow certain data to be recorded in a digital form, directly usable by the computer.

An important aspect of the engineer's work lies in the choice of calculation models in the phases of synthesis and analysis, and in the experimental phase involved in any study resulting in a practical realization.

---

(1) For example, an aperture of diameter D and wavelength λ can radiate a beam with aperture $\theta \sim \lambda/D$ radians. Its maximum theoretical gain is $(\pi D/\lambda)^2$ and its polar pattern can be synthesized with a sampling step λ/D.

A: Structures and applications

1: Structures

In the choice of a radiating structure for a particular problem, many types of antenna can be envisaged [1]. Most large antennas, however, are derived from two main types: focusing systems and arrays.

A focusing system comprises a primary source, generally associated with one or more reflectors and, sometimes, a dielectric lens, which transform the phase characteristic of the primary wave and, to a lesser degree, its amplitude characteristic, so as to give the desired characteristics to the radiation from the whole unit. An important class of focusing systems is that of rotationally symmetric (circularly symmetric) systems (Chapter 3), of which the parabolic reflector and the Cassegrain antenna are important examples (fig. 1). When the characteristics of radiation are not circularly symmetric, the focusing system used is, itself, not circularly symmetric: this is the case with offset or doubly curved reflectors used, for example, in early-warning radars (fig. 2), (Chapter 4.C).

In reception, the focusing system concentrates the energy received from an incident plane wave in a 'focal' zone, in the form of a 'diffraction pattern' (Chapter 3.H). It is important to know the structure of this pattern, since its effect on the radiation at the primary source will determine the overall behaviour of the system during reception (Chapter 3.I)—its gain factor, noise temperature, etc.

The properties of the primary source evidently play a dominant role in the system as a whole (Chapter 2). It can perform several functions (transmission, reception, tracking, polarization, etc.) (fig. 3). Its study is difficult since its dimensions are not large in terms of the wavelength, so the approximation methods adopted must be sufficiently precise and must be handled carefully, to avoid serious errors. It is in this context that the role of experimentation will often be most important.

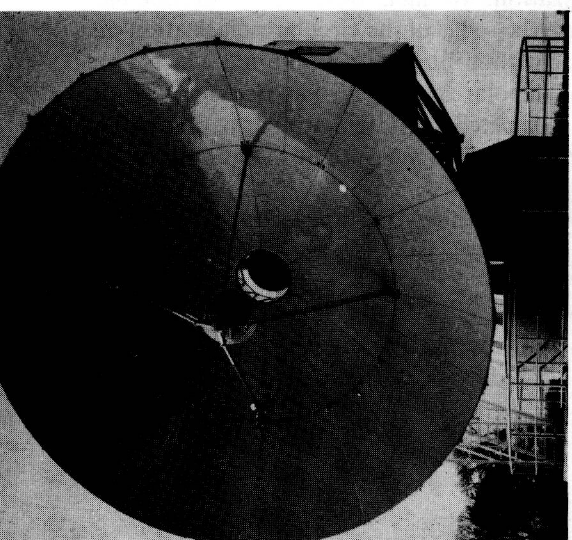
An array (Chapter 5) is made up of a group of identical elements, placed on the nodes of a network with a generally plane and regular mesh of squares or triangles. The interelement spacing, or 'step' of the array, is a fundamental parameter. The elements are supplied by a feed network which defines an array excitation, generally with fixed amplitude. The radiation phase of the elements, however, is controlled by phase shifters usually controlled by computer.

The importance of array antennas lies in the possibility of creating a beam of radiation that can be oriented in a quasi-instantaneous way. This is obtained by imposing a constant phase gradient between adjacent array elements, depending on the direction in which the beam is to point.

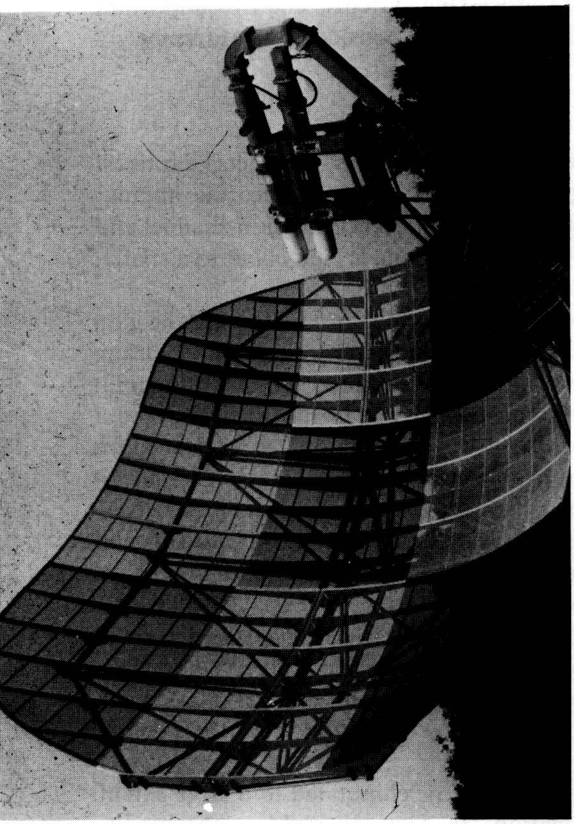
Even with the same basic structures, large antennas can have differing external appearances: a great variety of antennas can be obtained by combining focusing structures and arrays (figs 4 and 5).

2: External characteristics required for particular applications

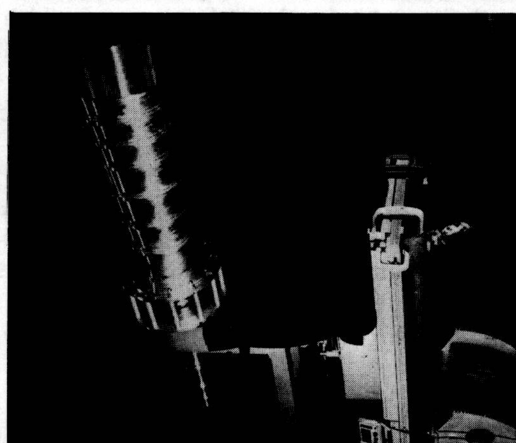
The external characteristics are taken here to be the overall properties of an



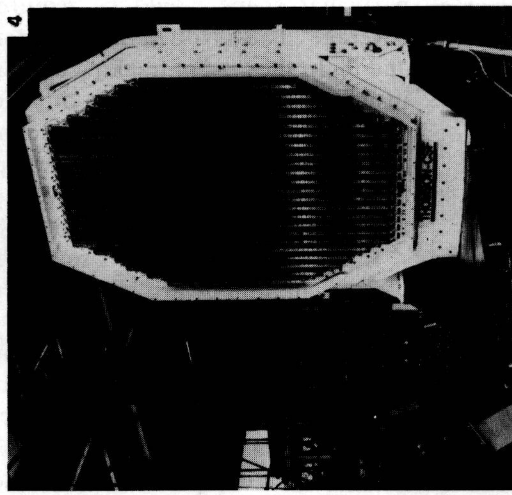
1



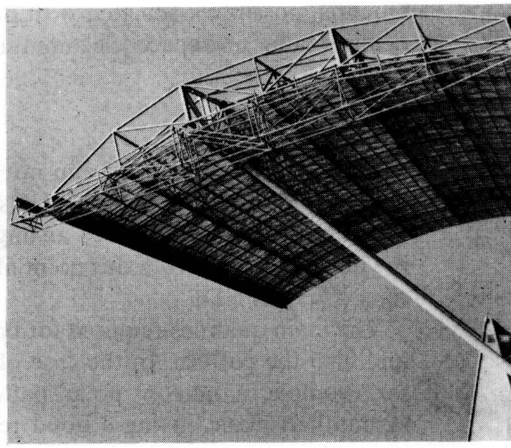
2



3



4



5

antenna, possibly associated with data processing systems. The two important fields of radar and space telecommunications will be considered as examples.

(a) Radar

1—General points

A radar antenna has as its aim not only the illumination of objects of interest and reception of the echo, but also the production of an accurate angular distribution: in this sense, it is an angular information transmission channel and it will be seen that, from this point of view, the antenna is equivalent to a spatial filter (Chapter 6.D).

The main qualities required for both reception and transmission are the gain and also the pattern. In the case of an air-traffic radar with a rotating beam, for example, a narrow polar pattern would be required in the horizontal (azimuthal) plane, giving a good resolving power, but in the vertical plane a particular shape would be required to give a certain degree of 'elevation coverage'. This involves the important problem of pattern synthesis (Chapters 4 and 6). In the case of tracking antennas, the narrowness of the beam is, in itself, insufficient to determine the direction of targets precisely enough: to this end multiple angular interpolations, either simultaneous (monopulse) or successive (conical scanning), have been developed (Chapter 4.B).

These methods show the angular pointing error by tracking curves, the slope and linearity of which are essential characteristics.(1)

In all systems, the aim is to avoid parasitic echoes (clutter) and interference, whether natural or artificial, active or passive, by demanding that the sidelobe levels should be very low.

The echoes produced by clouds and rain can be eliminated to a large extent, through the use of circular polarization. In fact, obstacles with circular symmetry, such as water drops, reverse the sense of the circular polarization on reflection. This is not generally the case with wanted echoes (aircraft) which, as a result of their complex geometry, often depolarize the echo wave (see page 83). It is this depolarized component which is detected by a circular polarization radar: the ellipticity ratio of the antenna, therefore, is a measure of the quality of the radar from this point of view.

A number of specific points are made below on various types of radar antennas.

2—Polar diagram in the vertical plane

Consider a target of equivalent cross-section σ and altitude h. Its elevation β and range r with respect to the radian are related by:

$$r = \frac{h}{\sin \beta}$$

(1) These methods constitute simple examples in which the directive properties of the antenna are observed as part of a signal processing system.