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Microwave Engineering

with

Wireless Applications

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Preface

Necessity is said to be the mother of invention and it was necessity that played a large part in the creation of this book. The authors have been teaching high frequency engineering to undergraduate students for some years. Finding suitable texts to support these lecture courses has been a problem. Microwave engineering texts tend to fall into two categories. Firstly there are the specialist texts, dealing in great detail with one particular aspect, and costed well beyond the typical resources of most University students. Secondly there are the more affordable texts which are broadly based, but not so comprehensive. Their treatment of many topics is insufficient to give the student a good grounding in the subject, and do not lead to a point where circuits and systems can be realised. As a result we felt that we could not actually recommend any books for the students to purchase, instead we provided a reading list of books which were obtainable from the library, and which together covered the syllabus material to a reasonable extent. Often the students relied entirely on the lecture notes we provided.

Clearly there was a requirement for a reasonably comprehensive introductory book to high frequency and microwave engineering, which went into sufficient depth in the various topics, provided good background information to the student but still remained affordable. This is a very tough target to reach, but we believe that the text you are holding largely meets these requirements.

Microwaves are playing a larger and more important role in everyday life. We define the region of microwaves to be between 1 GHz and 100 GHz (30 cm to 3 mm free space wavelength). The main applications are in the fields of communications and radar systems. The boom in mobile radio communications has meant that extra bandwidth is required and the high frequency spectrum is becoming overcrowded. Hence mobile telephones now operate in the microwave region. Indeed, many of the new future developments in the communications field will occur at microwave frequencies as the majority of lower frequencies are already in use. In conjunction with wireless local area networks operating at microwave and millimetre wave frequencies for connection of computing and other equipment, the term *wireless* has been revived and has again taken on great importance in modern engineering. This fact is reflected in the subtitling of this book.

The figure below shows a generalised microwave heterodyne transmitter/receiver system, showing the typical components which make up the system. In outlining the structure of this book, we shall refer to this system, illustrating the relevance of each chapter on these components and sub-systems.

Chapter 1 is concerned with transmission lines. The transmission line is the connecting line between the various components in the system, and comes in many different forms depending on particular technology and application. This chapter introduces the particular problems of high frequency analysis where the signal wavelengths are of the same order of magnitude as, or smaller than, the circuit dimensions. These problems necessitate a different approach from normal circuit analysis, involving the concepts of characteristic impedance and reflection of power.

A typical microwave heterodyne transmitter/receiver system

In many situations we need to consider the transmission of microwave signals in terms of electromagnetic wave concepts, rather than voltages and currents. Chapter 2 is concerned with the description of electromagnetic waves, and their analysis provides the basis for the investigation of many effects. These include signal propagation in free space, the reflection of signals from targets (as illustrated in the diagram) and to the behaviour of transmission lines such as waveguides.

Chapter 3 is concerned with matching techniques. The reflection effects described in Chapter 1 can lead to non-optimum circuit performance and even damage to components. It is vital that components are well matched and this chapter describes the design techniques for achieving these matching conditions. This effects all the components and interconnections in the illustrated system.

Chapter 4 is concerned with two commonly used analysis tools, the matrix representation of microwave circuits, and signal flow diagrams. Once the circuit has been analysed, it is often a simple task to invert the analysis to provide a design process for the circuit. These techniques can be applied to any of the linear components in the system, such as amplifiers, filters and phase shifters.

The next two chapters concentrate on two specific types of transmission line which are the most commonly used. Firstly Chapter 5 deals with waveguide structures, which are more commonly used for high power and low loss transmission. Consequently they are typically used in the connections to the transmitting

antenna in the system example, and may even form the antenna itself.

A very commonly used transmission line structure is microstrip and this is dealt with in Chapter 6. This is a planar structure, very similar in form to printed circuit boards, but requiring a greater dimensional tolerance and higher specification dielectric support. These are light-weight, small structures but which are limited to relatively low power levels. In the illustrated system, microstrip is likely to be used as the transmission line connections between and within such circuits as the receiver amplifiers, filters, mixers, etc.

Chapter 7 concerns itself with passive devices such as attenuators, filters and phase shifters. As can be seen from the figure, such devices occur in different parts of the system, requiring different specifications. Hence this chapter deals with the basic configurations available and the design approaches which can be used to meet a given specification.

Chapter 8 is concerned with the various control devices such as diodes and transistors and their modelling to derive equivalent circuits. These components are then used in the active circuits such as mixers, detectors and amplifiers, the design of which are described in the next few chapters.

Chapter 9 deals with detectors and mixers, which are based on diodes. Again these occur in different parts of the system and again have different specifications and configurations.

Chapter 10 is concerned with control circuits such as limiters, attenuators, switches and phase shifters based on the active elements described in Chapter 8.

Chapter 11 deals with amplifiers and oscillators, which are mainly based on transistors. The chapter describes the different forms available and the design approaches required.

Chapter 12 is concerned with measurements at microwave frequencies. The measurement parameters include frequency, power, noise and reflection and transmission parameters. The particular difficulties of, and special equipment required for, microwave measurements are detailed. In terms of the example system, all the individual components and interconnections will have to be characterised at some stage in the system development.

Chapter 13 deals with antennas, as illustrated in the example system these act as both transmitters and receivers of microwave signals. The chapter describes the main antenna structures in common use, defines the characteristic terms which specify the performance of antennas, and provides the transmission and radar equations required for overall system design.

We would like to thank the authors of the University of Leeds Summer School on Microwave Subsystem Design for permission to use some of the material from their course note book. Finally we would like to dedicate this book to our wives, Debs and Barbara, for putting up with us while we prepared it.

S. R. PENNOCK & P. R. SHEPHERD