Chapter 0

Introduction

The central theme of this book concerns the basic principles and applications of microwave devices and circuits. Microwave techniques have been increasingly adopted in such diverse applications as radio astronomy, long-distance communications, space navigation, radar systems, medical equipment, and missile electronic systems. As a result of the accelerating rate of growth of microwave technology in research and industry, students who are preparing themselves for, and electronics engineers who are working in, the microwave area are faced with the need to understand the theoretical and experimental design and analysis of microwave devices and circuits.

0-1 MICROWAVE FREQUENCIES

The term *microwave frequencies* is generally used for those wavelengths measured in centimeters, roughly from 30 cm to 1 mm (1 to 300 GHz). However, *microwave* really indicates the wavelengths in the micron ranges. This means microwave frequencies are up to infrared and visible-light regions. In this revision, microwave frequencies refer to those from 1 GHz up to 10^6 GHz. The microwave band designation that derived from World War II radar security considerations has never been officially sanctioned by any industrial, professional, or government organization. In August 1969 the United States Department of Defense, Office of Joint Chiefs of Staff, by message to all services, directed the use of a new frequency band breakdown as shown in Table 0-1. On May 24, 1970, the Department of Defense adopted another band designation for microwave frequencies as listed in Table 0-2. The Institute of Electrical and Electronics Engineers (IEEE) recommended new microwave band designations as shown in Table 0-3 for comparison.

TABLE 0-1 U.S. MILITARY MICROWAVE BANDS

Designation	Frequency range in gigahertz
P band	0.225– 0.390
L band	0.390– 1.550
S band	1.550– 3.900
C band	3.900– 6.200
X band	6.200– 10.900
K band	10.900– 36.000
Q band	36.000– 46.000
V band	46.000– 56.000
W band	56.000–100.000

TABLE 0-2 U.S. NEW MILITARY MICROWAVE BANDS

Designation	Frequency range in gigahertz	Designation	Frequency range in gigahertz
A band	0.100–0.250	H band	6.000– 8.000
B band	0.250–0.500	I band	8.000– 10.000
C band	0.500–1.000	J band	10.000– 20.000
D band	1.000–2.000	K band	20.000– 40.000
E band	2.000–3.000	L band	40.000– 60.000
F band	3.000–4.000	M band	60.000–100.000
G band	4.000–6.000		

TABLE 0-3 IEEE MICROWAVE FREQUENCY BANDS

Designation	Frequency range in gigahertz
HF	0.003– 0.030
VHF	0.030– 0.300
UHF	0.300– 1.000
L band	1.000– 2.000
S band	2.000– 4.000
C band	4.000– 8.000
X band	8.000– 12.000
Ku band	12.000– 18.000
K band	18.000– 27.000
Ka band	27.000– 40.000
Millimeter	40.000–300.000
Submillimeter	>300.000

0-2 MICROWAVE DEVICES

In the late 1930s it became evident that as the wavelength approached the physical dimensions of the vacuum tubes, the electron transit angle, interelectrode capacitance, and lead inductance appeared to limit the operation of vacuum tubes in microwave frequencies. In 1935 A. A. Heil and O. Heil suggested that microwave voltages be generated by using transit-time effects together with lumped tuned circuits. In 1939 W. C. Hahn and G. F. Metcalf proposed a theory of velocity modulation for microwave tubes. Four months later R. H. Varian and S. F. Varian described a two-cavity klystron amplifier and oscillator by using velocity modulation. In 1944 R. Kompfner invented the helix-type traveling-wave tube (TWT). Ever since then the concept of microwave tubes has deviated from that of conventional vacuum tubes as a result of the application of new principles in the amplification and generation of microwave energy.

Historically microwave generation and amplification were accomplished by means of velocity-modulation theory. In the past two decades, however, microwave solid-state devices—such as tunnel diodes, Gunn diodes, transferred electron devices (TEDs), and avalanche transit-time devices have been developed to perform these functions. The conception and subsequent development of TEDs and avalanche transit-time devices were among the outstanding technical achievements. B. K. Ridley and T. B. Watkins in 1961 and C. Hilsum in 1962 independently predicted that the transferred electron effect would occur in GaAs (gallium arsenide). In 1963 J. B. Gunn reported his "Gunn effect." The common characteristic of all microwave solid-state devices is the negative resistance that can be used for microwave oscillation and amplification. The progress of TEDs and avalanche transit-time devices has been so swift that today they are firmly established as one of the most important classes of microwave solid-state devices.

0-3 MICROWAVE SYSTEMS

A microwave system normally consists of a transmitter subsystem, including a microwave oscillator, waveguides, and a transmitting antenna, and a receiver subsystem that includes a receiving antenna, transmission line or waveguide, a microwave amplifier, and a receiver. Figure 0-1 shows a typical microwave system.

In order to design a microwave system and conduct a proper test of it, an adequate knowledge of the components involved is essential. Besides microwave devices, the text therefore describes microwave components, such as resonators, cavities, microstrip lines, hybrids, and microwave integrated circuits.

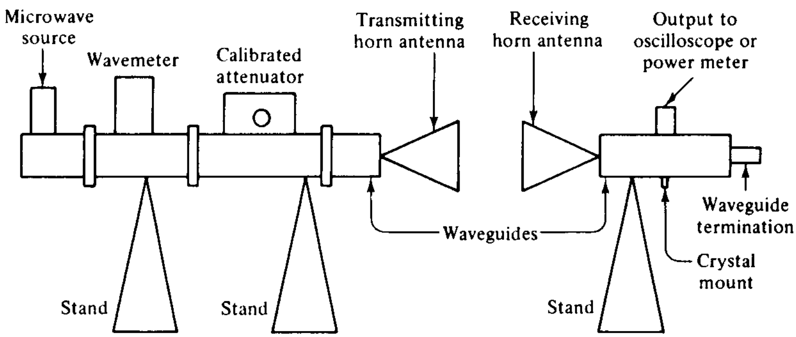

Figure 0-1 Microwave system.