The first edition of *Foundations for Microwave Engineering* was published in 1966. The text has remained continuously in use since that time, but it has become clear that it no longer gives an adequate account of modern microwave engineering practice. Since the publication of the first edition there has been a dramatic advance in the microwave field brought about by the development of solid state transistors that can provide amplification and signal generation well into the millimeter wavelength region. Along with the widespread use of solid state devices, compatible transmission line structures and passive components were developed that could be integrated with the solid state devices into compact miniaturized microwave systems. These developments made it mandatory that the text be thoroughly revised if it were to continue serving the needs of the student and the practicing microwave engineer.

In the revised addition I have adhered to the same general philosophy that governed the preparation of the first edition. Fundamental principles are stressed and complete derivations are provided for all significant formulas and relationships. All important fundamental concepts and principles are covered to the extent possible within a text of reasonable size. The applications of basic theory and principles are illustrated through detailed analysis of a large number of important components that find widespread use in practical microwave systems.

Chapter 1 is an updated introductory chapter. Chapter 2 is essentially the same as in the original edition and provides a comprehensive summary of basic electromagnetic theory that is needed as background for proper understanding of the rest of the text. Many students will already have knowledge of this material before they pursue a course in microwave engineering. For these students, Chapter 2 will serve as a concise reference or review of familiar material.

Chapter 3 is very different from that in the first edition. The first part of this chapter provides a more basic introduction to waves on transmission
lines using distributed circuit models. The propagation of pulse signals is also covered. The second part of this chapter is a long section covering the characteristics of planar transmission lines, such as microstrip lines, coupled microstrip lines, strip lines, and coplanar lines or waveguides. The treatment is considerably broader than what is available in any other current text. Most of the formulas for the quasi-TEM mode parameters are derived using conformal mapping methods in a new Appendix III and are not just quoted from the literature. Several new formulas for attenuation have been derived as well as suitable modifications of existing formulas to account for anisotropic substrates. The last part of the chapter covers the basic properties of rectangular and circular waveguides, as in the original edition.

Chapter 4 develops the basic microwave circuit theory and includes detailed discussions of the impedance, admittance and scattering matrix descriptions of microwave junctions. New material has been added on signal flow graphs and the generalized scattering matrix for power waves. The material on small aperture coupling has been updated to include radiation reaction that will account for power transmission through an aperture and thereby lead to physically meaningful equivalent circuits for small apertures.

Chapter 5 treats a number of topics related to impedance matching and transformations. The old topic of impedance matching with lumped reactive elements has been revived because this is now frequently used in microwave integrated circuits. The design of complex load terminations has also been included because this is required for microwave solid state amplifier design. The available power at any point in a lossless reciprocal network is an invariant quantity. This concept is explained in terms of the impedance mismatch factor. The invariance of the impedance mismatch factor places an important constraint on the design of interstage matching networks in a microwave amplifier and is used in Chapter 10 in the design of microwave amplifiers. The last part of Chapter 5 discusses multisection quarter-wave transformers and tapered transmission lines. A new example of a microstrip half-wave filter design based on the quarter-wave transformer as a prototype circuit has been included.

A variety of passive components are described along with detailed analysis in Chapter 6. In addition to those components described in the original edition, new material has been added on coupled-microstrip-line directional couplers, the branch-line coupler, hybrid junctions, and the Wilkinson power divider. New material on electronic controlled attenuators and phase shifters has also been added.

Chapter 7 on resonators has been expanded to include new material on microstrip resonators and dielectric resonators. The old material on Fabry–Perot resonators has been deleted in order to make room for a short section on cavity perturbation theory.

Chapter 8 on periodic structures and filters now includes a detailed treatment of gap-coupled and edge-coupled microstrip filters. The treatment
of admittance and impedance inverters was rewritten in order to more fully explain the use of inverters in filter design.

Apart from a brief discussion of gyatron tubes, Chapter 9 on microwave tubes remains essentially the same as in the first edition.

The old Chapter 10 on masers has been replaced by a new chapter on microwave solid state amplifier design. This chapter gives a complete discussion of the scattering matrix approach to small signal narrow band amplifier design. The treatment is self-contained and all important relations for gain, stability, and low noise design are derived. A design strategy for low noise single stage and double stage amplifiers is developed along with considerations for the necessary tradeoffs that must be made between input and output VSWR, gain, low noise figure, and stability.

The original Chapter 11 on parametric amplifiers has been retained without any change.

A new Chapter 12 on oscillators and mixers has been added. This chapter is of limited scope because of the need to keep the overall length of the text within reasonable bounds. Solid state oscillators using Gunn devices and IMPATT diodes are described in a qualitative way only. An introduction to transistor oscillator design based on small signal scattering matrix parameters is provided. Included in this discussion is the relationship between the two-port and three-port scattering matrix description of a transistor because this is needed in order to efficiently analyze the effect of an impedance inserted in series with one of the transistor leads for feedback purposes.

Many textbooks provide introductory treatments of diode mixers without any consideration of the embedding network. Such treatments do not provide a good understanding of diode mixers because it is the impedance properties of the embedding network that determine the diode voltages at the various harmonic frequencies. The introductory treatment of diode mixers in Chapter 12 does include the embedding network and this should provide the student with a more complete understanding of mixer analysis and design. The last part of the chapter describes the harmonic balancing method for the analysis of mixers.

I have tried to provide a broad, comprehensive, and self-contained treatment of the fundamental theory and principles, and the methods of analysis and design that are the foundations for microwave engineering. There are, of course, limitations because all books must have a finite length. Many references have been included for the benefit of the reader who wishes to pursue a given topic in greater depth or refer to the original papers that a lot of the material has been based on. This text, in many respects, is a compilation of the work of a great many people. Unfortunately, it has not been possible to always give proper credit to those who were the originators of new concepts and the inventors of new devices.

It is my belief that the revised edition will prove to be useful for both senior elective as well as beginning graduate level courses in microwave engineering, and will also serve as a useful reference source on fundamental
principles for the practicing microwave engineer. There is clearly much more material in the revised edition than can be covered in a one semester course. The last four chapters alone would provide sufficient material for a one semester course on active microwave circuits.

As an instructor I have always believed that it was very important to fully understand where formulas came from and how they are derived in order to present the material to students in a meaningful way. It is for this reason that I have attempted to make the text self-contained. In presenting many of the topics to undergraduate students I will only outline the basic approach used and will omit the details. It is my hope that other instructors will also view the detailed derivations that are provided in the text as a useful source of information in preparing a microwave engineering course and not as material that must always be presented in class. A number of topics that can be omitted in an undergraduate course are identified by a star. The problems based on these sections are also identified by a star.

In recent years the microwave engineering course that I have taught to seniors at Case Western Reserve University has drawn heavily on the material in Chapters 3 through 5, which is very basic core material. In addition, topics have been selected from Chapters 6 and 7 on components and resonators in order to illustrate the application of basic microwave circuit theory. The last quarter of the semester has been generally devoted to microwave solid state amplifier design along with a brief coverage of oscillators and mixers.

A better selection of problems and a solutions manual has been prepared for the revised edition. Over the past several years I have also prepared a number of short stand alone computer programs that provide useful tools to remove the drudgery of solving many of the homework problems. These programs are included on a floppy disk along with user instructions as part of the solutions manual. The programs cover the calculation of the characteristics of various planar transmission lines, including attenuation; the cutoff frequency, propagation constant, and attenuation of the dominant mode in rectangular and circular waveguides; impedance transformation along a transmission line; input and output impedances, admittances, and reflection coefficients for a linear two-port, which can be described in terms of impedance, admittance, or scattering matrix parameters; double-stub and lumped element impedance matching with frequency scans; two-port and three-port scattering matrix parameters for a transistor; and a rather long program that implements a design strategy for low noise one- and two-stage microwave amplifiers with various imposed constraints. Students have generally found these programs to be of significant help in problem solving. They have enjoyed working with the microwave amplifier design program. Without a computer program, the design of a microwave amplifier using potentially unstable devices and subject to various constraints on gain, noise figure, and input and output VSWR, is not feasible for students to carry out. The scope of each program
has been purposefully limited in order to ensure that the student will be fully aware of the solution strategy involved.

Many users of the first edition have provided me with helpful comments on the original material. In addition, I have received many helpful comments and suggestions from the following reviewers of the material for the revised edition. They are Chin-Lin Chen, Purdue University; M. Yousif El-Ibiary, University of Oklahoma; Irving Kaufman, Arizona State University; Stuart Long, University of Houston; Glenn S. Smith, Georgia Institute of Technology; and Robert J. Weber, Iowa State University. For the most part their suggestions and recommendations have been incorporated.

The new material for the revised edition was typed by Sue Sava. I would like to acknowledge the professional skill with which she prepared this material as well as her willingness to rearrange her schedule so as to meet various deadlines.

The last acknowledgment is to my wife Kathleen, who was willing to give up many other activities so that the revision could be carried out. Her encouragement and support of the project never faltered, and without it the revision could not have been undertaken.

Robert E. Collin