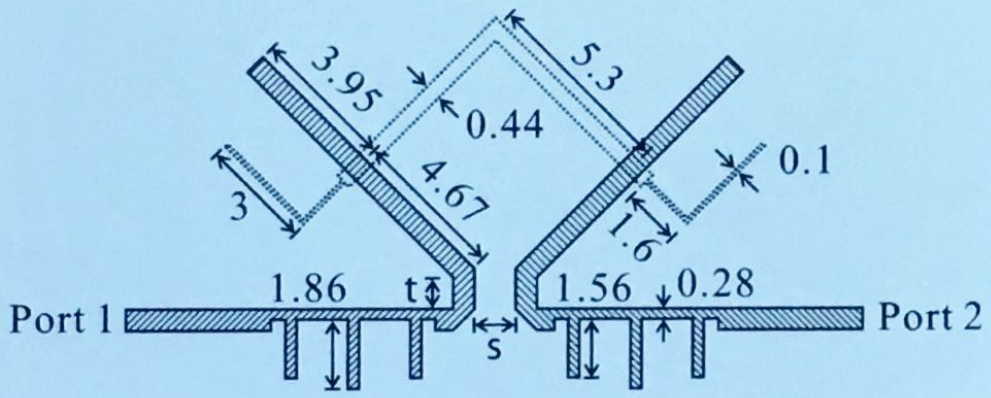
Wiley Series in Microwave and Optical Engineering • Kai Chang, Series Editor

Microwave Bandpass Filters for Wideband Communications



LEI ZHU
SHENG SUN
RUI LI

WILEY

MICROWAVE BANDPASS FILTERS FOR WIDEBAND COMMUNICATIONS

LEI ZHU
Nanyang Technological University, Singapore

SHENG SUN
The University of Hong Kong, Hong Kong

RUI LI
Institute of Microelectronics, Singapore

WILEY
A JOHN WILEY & SONS, INC., PUBLICATION

CONTENTS

PREFACE

Microwave filters have been widely used and considered as indispensable building blocks in modern wireless and telecommunication systems. The history of microwave filters can be tracked back before World War II. The early contribution was primarily made to systematically establish two well-known network-oriented design methodologies with resort to the characteristic parameters of image impedances and attenuation functions. In particular, the latter has been widely applied nowadays as the most efficient approach for the synthesis of a variety of microwave filters. By introducing a closed-form transfer function, such as the Chebyshev function, a set of design formulas can be established to instantly determine all the element values involved in a filter topology with specified frequency responses, such as equal-ripple in-band response. Until the 1980s, this approach had been applied as a unique methodology in the design of many standard microwave filters, such as bandpass filters with narrow passband on homogeneously filled waveguide or coaxial transmission lines. Since then, as this approach is highly desired in radiofrequency (RF) and microwave integrated circuits and modules for wireless communication, extensive research has been carried out to explore a variety of microwave filters on inhomogeneous dielectric substrates, such as single-layer printed circuit board (PCB) and multilayer low-temperature cofired ceramic (LTCC). In this context, the conventional synthesis approach is applied to estimate the initial dimensions of a filter without accounting for frequency dispersion, discontinuity effects, and so on. With the help of full-wave simulators,

the final layout of a filter is determined through multiple-round electromagnetic simulations on its overall structure toward gradually obtaining the specified filtering performances. Of all these filters, various bandpass filters on a planar configuration have been extensively studied and developed to achieve highly specified filtering functionalities, such as dual-/triple-band and wideband, as required in advanced wireless communications.

Accompanying the recent interest in the development of ultra-wideband (UWB) wireless systems, the required fractional bandwidth has been doubled or significantly widened as compared with those for the traditional narrowband systems. Under the nondispersive lumped-element assumption, the conventional synthesis methodology is no longer capable of designing a bandpass filter covering a wide or ultra-wide passband with a fractional bandwidth of about 110%. Until now, much research has focused on exploring a variety of (ultra)-wideband filters based on the different design approaches. Among them, the technique using the multi-mode resonator (MMR) has been considered one of the most popular solutions in forming a class of (ultra)-wideband filters. As its distinctive feature, multiple resonant modes of the so-called MMR are simultaneously excited to constitute a specified wide or ultra-wide passband. Based on this simple concept, various UWB bandpass filters with different geometrical layouts have been studied since 2005 by us and many other groups in the world. In addition, a direct synthesis method has been recently developed to provide an efficient approach for designing this class of UWB filters. The primary motivation of this book is to summarize the many excellent works in the research topic of wideband filters, and to give a systematic guideline in efficient and accurate design of microwave bandpass filters for wideband application.

In organizing this book, we have attempted to address all the fundamental theory related to the filter design using a resonator with multiple resonant modes. Starting with the introduction of the basic transmission line theory and network analysis, the traditional narrowband filter design theory and analysis of microwave resonators are conducted. Then, we present and characterize a variety of multi-mode resonators (MMRs) with stepped-impedance or loaded-stub configurations using the matured transmission line theory, and further apply them for the design and development of varied microwave wideband filters on single or composite transmission lines. Later on, a direct synthesis approach is presented to provide a series of useful design charts and tables for the proposed MMR-based bandpass filters. After that, we move to give our brief overview on many other works reported by

the peers in our society. We hope that this book would be a good reference to the readers who are carrying out their academic research or development work on microwave wideband filters, circuits and antennas.

Herein, we would like to thank all the authors and coauthors of the literatures, listed in the references, for their contributions to this book. In particular, we would like to thank Professor Wolfgang Menzel at University of Ulm in Germany for his close collaboration in this research. As the first author of this book, Professor Zhu would like to give his sincere gratitude to all his other supervised PhD students, Dr Hang Wang, Dr Jing Gao, Dr Sai Wai Wong, Ms Sha Luo, and Mr Teck Beng Lim for their technical contribution to the exploration of various MMR-based filters. Finally, we would like to give our appreciation to Professor Kai Chang at Texas A & M University, Editor-in-Chief of this book series, for his passional invitation. Also, we are pleased to acknowledge the willing and professional cooperation of the publishers. Without their encouragement and assistance, we could not have accomplished this book.

LEI ZHU
SHENG SUN
RUI LI

August 19, 2010