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This dissertation is dedicated to .

Acknowledgments

First, I would like to sincerely thank my research adviser Professor Adviser A. Member. I would like to extend my thanks to all my colleagues. Finally, I would like to thank my family.

Table of Contents

List of Tables

List of Figures

Abstract

This document describes how to use LATEX for correctly write and format your Ph.D dissertation.

Chapter 1

Introduction

1.1 Overview

Future microwave systems operating in an ever-crowded spectrum will require agile front-ends. Agility enables cognitive frequency response control suitable for dynamic spectral environments. Therefore, such sophisticated systems are not bound to single front-end architectures in contrast to past and current systems [1].

1.2 Microwave Filters from Past to Current

Filters are electric circuits with frequency-dependent characteristics. They are basically used to remove any undesirable-frequency portions of an input signal and enhance desired ones by providing transmission at frequencies that fall within their passband. Unwanted spurious signals as well as noise make the undesirable-frequency portions of the input signal. Filters utilize energy-storage elements to select or confine the signals within assigned spectral limits. Therefore, they are assumed as the most fundamental signal processing circuits.

1.2.1 Substrate-Integrated-Waveguide Technology

A basic structure of a typical SIW is shown in figure 1.1. This structure consists of a pair of periodic plated via arrays with specific spacing that well confines EM fields. Similar to conventional metallic waveguides, the SIW structure only supports the propagation of quasi-transverse electric (TE) modes. Transverse magnetic (TM) modes, if be excited, will immediately vanish because of discontinuous side walls that prevent longitudinal current flow. This makes the SIW structure very favorable for bandpass filter design because certain modes that are responsible for out-of-band parasitic responses can be avoided [2].

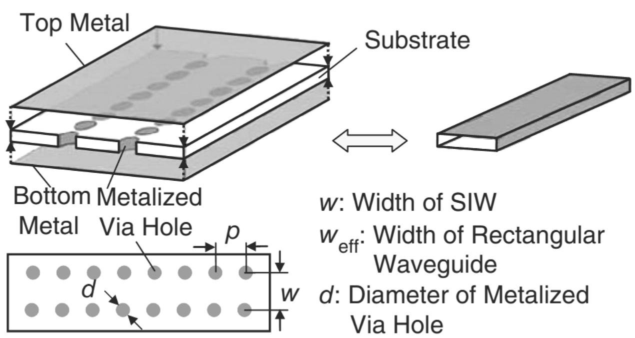

Figure 1.1: Structure of a simple SIW and its equivalent rectangular waveguide (from [2]).

The region of interest for the proper operation of the SIW is a function of vias diameter (d) and pitch (p), the spacing between adjacent via holes, relative to guided wavelength λ_C. This region is depicted in figure 1.2 [3]. Therefore, d and p should be selected appropriately so that bandgap effects and leakage loss over the entire bandwidth of interest are avoided. The frequency region of interest for TE_{10} mode is defined by the following set of basic but empirical

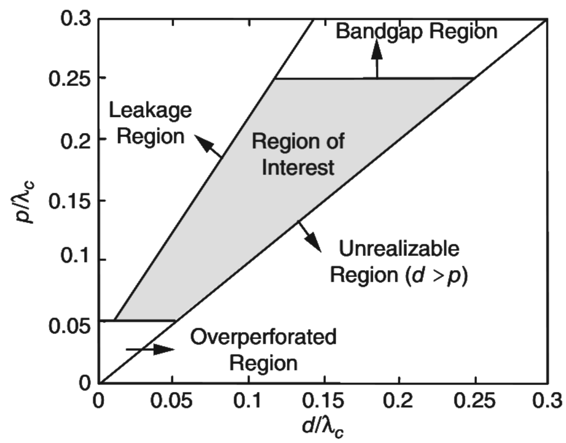

Figure 1.2: The frequency region of interest for the SIW operation (from [3]).

design rules [3]:

$$p > d \tag{1.1a}$$

$$p/\lambda_c < 0.25 \tag{1.1b}$$

$$a_1/k_0 < 1 \times 10^{-4} \tag{1.1c}$$

$$p/\lambda_c > 0.05 \tag{1.1d}$$

where a_1 is the total loss and k_0 is the wave number in free space. Equation (1.1a) guarantees that the circuit is physically realizable while (1.1b) is used to avoid any bandgap effect in the operating bandwidth of TE_{10} and other related modes. The leakage loss will be negligible if the condition in (1.1c) is met. A more stringent condition for negligible leakage losses is defined as $p \leqslant 2d$. Finally, (1.1d) is a mechanical condition that limits the number of vias to less than of 20% of the wavelength to keep the mechanical rigidity of the board.

The total loss determines the quality factor of the transmission line. A comparison of typical quality factor for a SIW transmission line, a 50-Ω mi-

Table 1.1: Comparison of the Q-factor of a SIW transmission line with respect to that of 50-Ω microstrip line, and a standard rectangular metallic waveguide all at Ka-band (from [4]).

Properties	Microstrip[1]	SIW[2]	Waveguide
Quality Factor	42	462	4613

[1]Substrate: $\epsilon_r = 2.33,\ tan(\delta) = 5 \times 10^{-4},\ h = 10$ mils, copper foil
[2]Width=200 mils

crostrip line, and a standard rectangular metallic waveguide, all operating in Ka-band, is shown in Table 1.1 [2]. It can be seen that the quality factor of the SIW is significantly larger than that of the microstrip line, but it is still lower than that of the standard waveguide.

1.3 Motivation

According to research conducted by the Pew Research Center, in 2013 cell phones were being used by 91% of adults in the United States [5]. This research also shows that 56% of U.S. adults use a smartphone while this value was 35% in 2011 as illustrated in figure 1.3 [6].

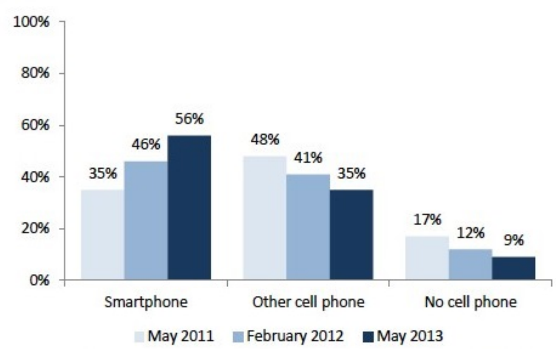

Figure 1.3: Changes in smartphone ownership of US adults between 2011 and 2013 (from [6]).

1.4 Research Objective

In this dissertation, an integrated microwave bandpass-bandstop filter cascade for radar systems with simultaneous transmit and receive is designed.

1.5 Outline of the Dissertation

This dissertation is devoted to ... .

To this end, following the Introduction, Chapter 2 provides ... .

Chapter 3 starts with detailed ... .

Chapter 4 first reviews ... .

Chapter 7 concludes the dissertation ... .

A new property of some thing is also the topic of Appendix A. The required fabrication steps will be covered in Appendix B. Appendix C presents the list of the abbreviations used in this dissertations and Appendix D provides the summary of publications resulted from this research.

Chapter 2

Design Fundamentals

Today, most microwave filter designs are accomplished with computer-aided design tools based on the *insertion loss* method. Filter design using this method consists of prescribing a desired frequency response for the filter, in terms of signal attenuation characteristics, when the filter is inserted between input and output ports. As opposed to the *image parameter* method, which does not have any methodical way of designing the filter, the *insertion loss* method has a systematic way to synthesize any desired frequency response including bandpass, bandstop, and phase characteristics. In this method, different design tradeoffs between insertion loss, cutoff slope, or linear phase response are available in order to achieve desired filter characteristics. In addition, at the expense of increasing the filter order, the designer can improve the filter performance in a straightforward manner [7]. The classic procedure for filter design using the *insertion loss* method consists of multiple steps:

1. Design of a lumped element lowpass filter with a normalized source impedance of $R_s = 1\ \Omega$ and a cutoff frequency of $\omega_c = 1$ rad/sec, known as the lowpass prototype.

2. Impedance scaling to obtain the desired source and load impedances.

3. Frequency scaling and transformation to convert the lowpass response to any desired bandpass, bandstop, or highpass response with any arbitrary cutoff frequency or bandwidth.

4. Filter implementation. In case of RF and microwave filters, this consists of the use of different techniques to convert the lumped elements to distributed elements suitable for the technology which will be used for realizing the microwave filter.

2.1 Characterization of Lowpass Prototype

A lowpass prototype of order N can be represented by a general doubly-terminated linear lossless two-port network shown in figure 2.1.

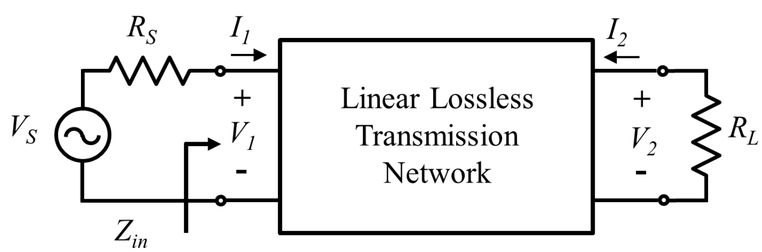

Figure 2.1: Doubly-terminated linear lossless two-port network.

From general filter theory and the definition of the generalized scattering parameters, the network reflection coefficient, $\rho\ (s)$, and transmission coefficient, $t(s)$, can be expressed respectively as [8]

$$\rho(s) = \frac{1}{\varepsilon_R} \frac{F(s)}{E(s)} \tag{2.1a}$$

$$t(s) = \frac{1}{\varepsilon} \frac{P(s)}{E(s)} \tag{2.1b}$$

where $E(s)$, $F(s)$, and $P(s)$ are polynomials in terms of s and are known as characteristics polynomials.

In (2.1a) ε_R and ε are real constant values that have been defined to normalize the highest-degree coefficients of the polynomials to unity. This guarantees that the maximum amplitude of the filter in the passband is also normalized to one. ε_R and ε are usually referred to as the ripple constant and ripple factor, respectively.

Chapter 3

Conclusions and Future Work

3.1 Summary of Work

The goal of this research was to develop state-of-the-art, frequency-agile, microwave filters for the current and next generation of radar systems capable of simultaneous transmit and receive. ... .

3.2 Future Work

The work presented in this dissertation can be expanded in the following areas.

3.2.1 Theory Expansion

One of benefits of active resonators compared to their tradition passive peers is improved unloaded quality factor through compensation of loss in the resonator.

...

References

[1] W. J. Chappell, E. J. Naglich, C. Maxey, and A. C. Guyette, “Putting the radio in “software-defined radio”: Hardware developments for adaptable RF systems”, *Proc. IEEE*, vol. 102, no. 3, pp. 307–320, Mar. 2014.

[2] X.-P. Chen and K. Wu, “Substrate integrated waveguide filter: Basic design rules and fundamental structure features”, *IEEE Microw. Mag.*, vol. 15, no. 5, pp. 108–116, 2014.

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[5] L. Rainie, *Cell phone ownership hits 91 percent of adults*, The Pew Research Center, 2013, (Accessed: 2 Nov. 2015). [Online]. Available: `http://www.pewresearch.org/fact-tank/2013/06/06/cell-phone-ownership-hits-91-of-adults/`.

[6] A. Smith, *Smartphone ownership 2013*, The Pew Research Center, 2013, (Accessed: 2 Nov. 2015). [Online]. Available: `http://www.pewinternet.org/2013/06/05/smartphone-ownership-2013/`.

[7] D. M. Pozar, *Microwave Engineering 4e*. New York, NY, USA: Wiley, 2012.

[8] R. J. Cameron, C. M. Kudsia, and R. R. Mansour, *Microwave filters for communication systems*. Hoboken, NJ, USA: Wiley-Interscience, 2007.

Appendix A

Fabrication Process

The step by step fabrication process used throughout this research is presented in this appendix.

Figure A.1 shows an overview of the fabrication flow and figure A.2 shows a cross-sectional view of the final product.

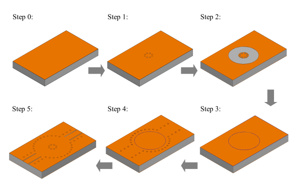

Figure A.1: Step by step fabrication procedure.

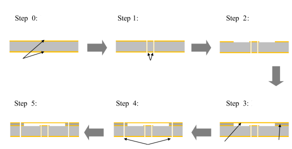

Figure A.2: Cross section of final product through the fabrication procedure.

Appendix B

List of Acronyms and Abbreviations

μC	Micro-Controller
ADC	Analog-to-Digital Converter
$BP-BS$	Bandpass-Bandstop
CAD	Computer-Aided Design
CDC	Capacitance-to-Digital Converters
CR	Cognitive Radio
CTE	Coefficient of Thermal Expansion
DAC	Digital-to-Analog Converter
DGS	Defective Ground Structure
DSA	Dynamic Spectrum Access
EM	Electromagnetic
EVM	Error Vector Magnitude
FIR	Frequency-Independent Reactive
FM	Frequency Modulation
$FPGA$	Field Programmable Gate Array
$GCPW$	Grounded Coplanar Waveguide
HTS	High-Temperature Superconductors
HV	High Voltage
IMD	Intermodulation Distortion

LCD	Liquid Crystal Display
LCP	Liquid Crystal Polymer
LNA	Low Noise Amplifire
$LTCC$	Low-Temperature Co-fired Ceramics
$MEMS$	Microelectromechanical System
$MMIC$	Monolithic Microwave-Integrated Circuit
NRN	Non Resonating Node
$NTIA$	National Telecommunications Information Administration
PA	Power Amplifire
PC	Personal Computer
PCB	Printed Circuit Board
QAM	Quadrature Amplitude Modulation
$QPSK$	Quadrature Phase Shift Keying
$RSEC$	Radar Spectrum Engineering Criteria
$RTSA$	Real-Time Spectrum Analyzer
SD	Software-Defined
SIW	Substrate-Integrated Waveguide
SRN	Slow Resonating Node
TE	Transverse Electric
TM	Transverse Magnetic
TMM	Thermoset Microwave Material
TZ	Transmission Zero

Appendix C

Summary of Contributions

Journal Papers:

[1] F. Last, C. B. Member, and A. A. Member, ”Novel Synthesis and Design”, *IEEE Trans. Des. Theory Techn.*, Vol. 100, No. 1, pp. 1000-2000, Jan. 2075.

Conference Papers:

[1] F. Last, and A. A. Member, "Best Design Method", in *IEEE 100th Eur. Des. Conf. (EDC)*, 2074, pp. 100-105.