UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electronics and Computer Engineering

PERFORMANCE EVALUATION OF SUBSTRATE INTEGRATED WAVEGUIDE BAND-STOP FILTERS

Tan Gan Siang

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A thesis submitted
in fulfillment of the requirement for the degree of Master of Science
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DECLARATION

I declare that this thesis entitled “Performance Evaluation of Substrate Integrated Waveguide Band-stop Filters” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	....
Date	:	....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering.

Signature	:	....
Supervisor Name	:	....
Date	:	....

ABSTRACT

This thesis presents the findings of the research work done on the evaluation and performance of substrate integrated waveguide (SIW) band-stop filters. The conventional waveguide has the advantages of low-insertion losses and high Q in microwave communication systems but their physical sizes of rectangular waveguides are large. The introduction of substrate integrated waveguide with similar properties of low insertion loss that can be integrated with planar circuits fulfill the requirement of microwave communication systems. Many researches have carried out detail research work on SIW band-pass filters but not many researches have spent enough time on the research of performance of SIW band-stop filters. In the construction of SIW band-stop filters, resonators feature significantly to realize the structure. Resonators can be constructed from closed sections of SIW. Circular and radial shape cavity resonators are proposed to design the SIW band-stop filters. The SIW band-stop filters are designed by coupling the cavity resonator to the SIW line. The effects on the variation of parameters value of each type of resonators are investigated. CST microwave studio is used for all the simulation work in this research. The designs of the SIW band-stop filters have been realized by using standard PCB process. The measured results are found to be in consistent to the simulated results. The dual-radial cavity resonators SIW band-stop filter has shown enhanced performance in 9GHz band-stop response with a high stopband attenuation level and provide better roll-off of 0.15dB/MHz. These provide better frequency selectivity as compared to the rectangular cavity resonator in the previous research work. This band-stop filter can be used to provide better signal rejection in the X-band.

ABSTRAK

Tesis ini membentangkan hasil penyelidikan yang telah dilakukan tentang penilaian dan prestasi penapis batas jalur pandu gelombang substrat bersepadu (SIW). Pandu gelombang konvensional mempunyai kelebihan pada kehilangan sisipan rendah dan Q yang tinggi dalam sistem komunikasi gelombang mikro akan tetapi saiz fizikal pandu gelombang segi empat tepat adalah besar. Pengenalan pandu gelombang substrat bersepadu dengan sifat-sifat kehilangan sisipan rendah dan boleh disepadukan dengan litar satah memenuhi keperluan sistem komunikasi gelombang mikro dimasakini. Banyak pengelidik telah melakukan penyelidik mendalam atas penapis jalur lulus SIW tetapi tidak ramai penyelidik telah memberi masa yang mencukupi atas penyelidikan tentang prestasi penapis batas jalur SIW. Dalam pembinaan penapis batas jalur, penyalun atau resonator merupakan bahagian penting untuk menrealisasikan strukturnya. Penyalun boleh dibinadari SIW dengan bahagian tertutup mengelilingnya. Penyalun bulatan dan jejarian dicadangkan untuk mereka bentuk penapis batas jalur SIW. Penapis batas jalur SIW direka bentuk dengan menggandingkan penyalun rongga kepada talian SIW. Kesan perubahan nilai parameter-parameter bagi setiap jenis penyalun dikaji dan selidik. CST studio gelombang mikro digunakan untuk semua kerja simulasi dalam kajian ini.Rekaan penapis batas jalur SIW telah dihasilkan dengan menggunakan proses standard Papan Litar Tercetak. Keputusan pengukuran yang diambil adalah didapati bersama dengan keputusan simulasi. Penapis batas jalur SIW dengan penyalun rongga jejarian duaan telah menunjukkan prestasi peningkatan pada 9GHz dengan pelemahan batas jalur yang tinggi dan mempunyai 0.15dB/MHz kecerunan yang lebih baik. Ini memberi pemilihan frekuensi yang lebih baik dari penyalun rongga segi empat tepat dalam kerja penyelidikan sebelumnya. Penapis batas jalur ini boleh digunakan untuk memberikan isyarat penolakan yang lebih baik dalam X-band.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATION

EM	-	Electromagnetic
RF	-	Radio Frequency
RX	-	Receive
SIW	-	Substrate Integrated Waveguide
SIRW	-	Substrate Integrated Rectangular Waveguide
TE	-	Transverse Electric
TEM	-	Transverse Electromagnetic
TM	-	Transverse Magnetic
TX	-	Transmit
W	-	Width of Substrate Integrated Rectangular Waveguide
D	-	Diameter of Substrate Integrated Rectangular Waveguide

LIST OF SYMBOLS

C	-	Capacitance
L	-	Inductance
R	-	Resistance
ω	-	Angular frequency
ω_c	-	Angular cut-off frequency
ω_o	-	Angular centre frequency
K	-	Electric current density
α	-	Bandwidth scaling factor
c	-	Speed of light
λ	-	Wavelength
λ_o	-	Centre frequency wavelength
λ_g	-	Centre guide wavelength
Z_0	-	Characteristic impedance
f_o	-	Centre frequency
f_c	-	Cut-off frequency
f_r	-	Resonant frequency
β	-	Propagation constant
ε_o	-	Permittivity of free space

ε_r - Relative permittivity

h - Substrate thickness

μ_r - Relative permeability

LIST OF PUBLICATIONS

Journals:

Husain, M. N., Tan, G. S., & Tan, K. S. (2014). Enhanced Performance of Substrate Integrated Waveguide Bandstop Filter using Circular and Radial Cavity Resonator. *International Journal of Engineering & Technology*, 6(2), pp. 1268-1277. *(Scopus)*

Conference papers:

Husain, M. N., Tan, G. S., & Tan, K. S. (2014). Rectangular, Circular and Radial Cavity Resonator Substrate Integrated Waveguide Bandstop Filter. In: IEEE, *Student Conference On Research & Development (SCOReD)*. Putrajaya, Malaysia, 16-17 December 2013.

Husain, M. N., Tan, G. S., & Tan, K. S. (2014). Design of a Substrate Integrated Waveguide Filter using Dual-Radial Cavity Resonator. In: IEEE, *Region 10 Technical Symposiun (TENSYMP)*. Kuala Lumpur, Malaysia, 14-16 April 2014.

CHAPTER 1

INTRODUCTION

1.0 Background

The demand for microwave communication systems with high performance such as low insertion loss and high selectivity is always a challenge in this field of engineering. The high demand of higher volume of channels has made the frequency spectrum to become more crowded so much so, interference between close neighbouring channels occurs and becomes a problem. The rapid growth in the telecommunication industry is the main reason and to meet the challenges now and in the future, extensive researches on microwave components to reduce the interferences between close neighbouring channels are being carried. Among the many critical components, microwave filter is one which provide significant roles in a microwave communication system, mainly, in frequency selectivity, featuring small insertion loss and large return loss. One way to efficiently utilize the electromagnetic spectrum is to ensure enhanced performance of the microwave filters.

In microwave communication systems, signals play a very important role in delivering information. Problems occur as there is always noise in the signals or there is only a certain range of signal that is desired. Therefore, filter is an important device to provide solution to this problem. The general requirements of filters are small insertion loss, large return loss and high frequency selectivity. A high frequency selectivity filter has efficiency in frequency application due to the small guard frequency band between each channel. Another feature is that filters on demand must be small in size to cater for the industry.

Conventional rectangular waveguides are well known to have low loss and high quality factor as compared to planar counter parts. They are normally used in low-loss microwave circuit design. Because of its enclosed structure, there is no leakage of electromagnetic energy throughout the propagation. However, the integration of both planar and non-planar circuits is difficult and bulky. One of the disadvantages of conventional waveguide is their huge size as a device. A concept that can offer the solution to the integration of waveguide is substrate integrated waveguide. It is a technique that can reduce the cut-off frequency of a rectangular waveguide which the waveguide is partly or fully filled with dielectric substrate. Thus, the reduction by a factor of $1/\sqrt{\varepsilon_r}$ is achieved in comparing with the conventional rectangular waveguide that is air-filled.

Integrated waveguide techniques was filed patented in 1995 (Flanick *et al.*, 1995). The propose of substrate integrated waveguide (SIW) in the other way call post wall waveguide or laminated waveguide was investigated theoretically and practically by (Uchimura *et al.*, 1998). SIW is formed by having two periodic rows of metalized via-holes. According to the paper regarding the review of current research trends in SIW, a number of papers regarding SIW had been published in the IEEE between year 2005 to 2008 (Bozzi *et al.*, 2009). These lead to the production of novel modelling techniques for SIW components and outstanding performance SIW circuits and systems. Because of the almost similar operating mechanism of an SIW to a conventional rectangular waveguide, the characteristic of SIW is almost similar but the Q-factor of an SIW is less than conventional rectangular waveguide with air medium due to the dielectric filling and volume reduction (Cassivi, 2002).

Filters are the most popular device among the passive SIW components. A variety of different filter topologies were presented. A band-pass filter is designed by etching complementary split-ring resonators on the SIW surface to achieve circuit miniaturization (Dong *et al.*, 2009). Then, a series of cross-slot structures etched on the SIW dual-mode band-pass filter to miniaturize the filter was presented (Chen *et al.*, 2012). A band-pass filter using Quarter Substrate Integrated Waveguide Resonator loaded with a fractal-shaped was presented (Zhang *et al.*, 2011). A compact band-pass filter using quarter SIW cavity resonator with source-load cross coupling was presented (Deng *et al.*, 2011). A pseudo-elliptic SIW filters with higher-order mode resonances was presented (Salehi *et al.*, 2013). A SIW cross-coupling filter with multilayer hexagonal cavity was presented (Bo *et al.*, 2013). An X-band differential band-pass filter with high common-mode suppression using substrate integrated waveguide cavity was presented (Jin *et al.*, 2014).

There were only a few of numerical methods developed and published for SIW structures to obtain a high computational efficiency. One of the methods was presented with the combination of method of moments (MOM) and cylindrical eigenfunction expansion (Wu *et al.*, 2008). A boundary integral-resonant mode expansion (BI-RME) method was applied to analyze the lossless SIW (Bozzi *et al.*, 2006). The modelling of SIW components based on BI-RME method makes it possible to determine the wideband expression of the frequency response of SIW components without repeated frequency-by-frequency electromagnetic analyses. This algorithm has improved with the modelling of lossy SIW interconnects and components (Bozzi *et al.*, 2008). The full wave electromagnetic simulation software such as Computer Simulation Technology (CST) and