UNIVERSITI PUTRA MALAYSIA

MINIATURIZATION OF MICROSTRIP BANDPASS FILTERS USING MULTILAYER CONFIGURATION FOR WIDEBAND APPLICATION

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By

HELMI ADAM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

October 2009

UPM

DEDICATION

This thesis is dedicated to

My Beloved Parents

And

My Country “INDONESIA”

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

MINIATURIZATION OF MICROSTRIP BANDPASS FILTERS USING MULTILAYER CONFIGURATION FOR WIDEBAND APPLICATION

By

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October 2009

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Faculty: Engineering

This thesis presents new designs of wideband bandpass filter for X-band application using various resonator configurations in multilayer microstrip. Strong coupling required for wideband filter is realized by arranging multiple layers of microstrip lines on different dielectric substrates and overlapping these lines.

For the first design, half wavelength coupled lines resonator is used to design wideband X-band bandpass filter, and the resonator is rotated to make the filter more compact. The measured passband return loss for this filter is better than -12.4 dB and the insertion loss is less than 2.5 dB.

For second design, microstrip hairpin resonator is employed to build the miniaturized bandpass filter. Since adjacent hairpin resonator lines are placed at different levels, there are two possible ways to change coupling strength by varying the overlapping gap between two resonators; vertically and horizontally. Both have different benefit,

one can reduce the filter length, and obtain symmetrical response. The other can reduce filter width, giving sharper rejection at high frequency. Both configurations produce very small and compact filter size, at 5.0 x 14.6 mm^2 and 3.2 x 16.1 mm^2 for the first and second proposed filter type respectively. The measured passband insertion loss for both filters are less than 2.3 dB and the passband return loss is better than -16 dB for the first filter type and -13 dB for the second filter type.

Multilayer configuration gives freedom to choose any resonator shape and combine with another shape to make the filter in very compact size. For the last design in this thesis, hairpin resonator has been combined with half wavelength coupled lines resonator in multilayer configuration. Both different resonator shapes are placed on two different substrates with different dielectric constants, whereby the hairpin resonators are placed on the bottom layer and the straight line resonators are placed on the upper layer. The hybrid between hairpin resonator and half wavelength coupled lines configuration has made the filter even more compact and produce a very small filter size, only at 10 x 10 mm^2. The measured passband return loss for this filter is better than -12.5 dB and the insertion loss is less than 2.3 dB.

All of the filters are fabricated on 0.254 mm thickness R/T Duroid 6010 and R/T Duroid 5880 with dielectric constant 10.2 and 2.2 respectively using standard photolithography technique. Two layers of substrate are joined using epoxy adhesion which has dielectric constant of 3.6. This epoxy layer is included in simulation. Broader bandwidth produced by those filter configurations are proven able to cover the whole X-band frequencies of 44% bandwidth at 10.2 GHz center frequency with

excellent Chebyshev responses. The measured results agree well with the simulated responses. The measured responses and group delay exhibit that all of designed filters have good performance.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENGECILAN MIKROSTRIP JALUR LALUAN TURAS MENGGUNAKAN TATARAJAH PELBAGAI LAPIS UNTUK PENGGUNAAN JALUR LEBAR

Oleh

HELMI ADAM

Oktober 2009

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Tesis ini membentangkan reka bentuk baru penapis jalur laluan jalur lebar untuk aplikasi X-band menggunakan pelbagai konfigurasi alat resonan dalam mikrostrip pelbagai lapis. Gandingan kuat diperlukan untuk jalur lebar di sedari dengan menyusun lapisan-lapisan berganda baris-baris pada dielektrik substrak yang berbeza dan baris-baris ini bertindih.

Untuk reka bentuk pertama, alat resonan pasang baris separuh panjang gelombang digunakan mereka bentuk turas laluan jalur lebar X-band, dan alat resonan itu diputar untuk membuat turas lebih padat. Dengan tatarajah ini, lebar jalur lebih luas boleh dicapai bagi meliputi keseluruhan frekuensi X-band. Ukuran kehilangan balikan jalur laluan untuk penapis ini adalah lebih baik daripada -12.4 dB dan kehilangan sisipan adalah lebih baik daripada 2.5 dB.

Untuk reka bentuk kedua, pin jalur mikro alat resonan digunakan untuk menghasilkan penapis jalur laluan bersaiz kecil. Sejak pin baris-baris alat resonan

berhampiran ditempatkan di peringkat berlainan, terdapat dua kemungkinan cara-cara untuk mengubah kekuatan gandingan dengan mempelbagaikan jurang pertindihan antara dua alat resonan; secara menegak dan secara mendatar. Kedua-duanya mempunyai manfaat, satu boleh mengurangkan panjang penapis, dan mendapatkan gerak balas yang simetri. Yang lain boleh mengurangkan kelebaran penapis, memberikan penolakan lebih tajam dalam frekuensi tinggi. Kedua-dua konfigurasi menghasilkan saiz penapis yang sangat kecil dan padat masing- masing pada 5.0 x 14.6 mm^2 dan 3.2 x 16.1 mm^2 untuk cadangan penapis yang pertama dan kedua. Ukuran kerugian-kerugian sisipan jalur laluan untuk kedua-dua penapis adalah kurang daripada 2.3 dB dan kehilangan balikan jalur laluan adalah lebih baik daripada -16 dB untuk penapis jenis pertama dan -13 dB untuk penapis jenis kedua.

konfigurasi pelbagai lapis memberi kebebasan untuk memilih jenis bentuk alat resonan, dan mengabung dengan bentuk yang lain untuk menjadikan penapis bersaiz yang amat padat. Dalam reka bentuk lain, pin alat resonan telah digabungkan dengan panjang separuh gelombang alat resonan dalam konfigurasi pelbagai lapis. Kedua-dua alat resonan yang berbeza bentuk di tempatkan pada dua substrak berbeza dengan pemalar dielektrik berbeza, pin resonator di tempatkan pada dasar lapisan dan resonator bergaris lurus di tempatkan pada lapisan atas. Hibrid antara pin resonator dan konfigurasi baris-baris gabungan separuh gelombang menjadikan penapis lebih padat dan menghasilkan saiz penapis yang sangat kecil, hanya pada 10 x 10 cm^2. Ukuran kehilangan balikan jalur laluan untuk penapis ini adalah lebih baik daripada -12.5 dB dan kehilangan sisipan adalah lebih baik daripada 2.3 dB.

Kesemua penapis-penapis itu di buat pada ketebalan 0.254 mm RT duroid dan RT duroid 5880 dengan pemalar dielektrik masing-masing ialah 10.2 dan 2.2 menggunakan piawai teknik photolithography. Dua lapisan-lapisan substrak disambungkan dengan menggunakan lekatan epoksi dengan pemalar dielektrik 3.6. Lebar jalur yang lebih lebar dihasilkan oleh konfigurasi-konfigurasi penapis membuktikan berupaya menutupi seluruh frekuensi X-band dengan menghasilkan 44% jalur lebar pada 10.2 GHz frekuensi pusat dengan respon Chebyshev yang cemerlang. Hasil-hasil ukuran menyetujui dengan baik hasil-hasil simulasi. tindak balas ukuran dan kumpulan tundaan menunjukkan yang kesemua reka bentuk penapis mempunyai prestasi yang baik.

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I certify that a Thesis Examination Committee has met on 15 October 2009 to conduct the final examination of Helmi Adam on his thesis entitled "Miniaturization of Microstrip Bandpass Filters using Multilayer Configuration for Wideband Application" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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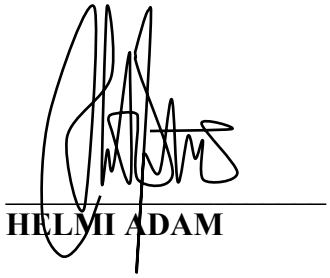
DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



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LIST OF ABBREVATIONS

BPF	Bandpass Filter
CAD	Computer-Aided Design
CPW	Coplanar Waveguide
DGS	Defected Ground Structure
FBW	Fractional Bandwidth
HTS	High Temperature Superconductor
LTCC	Low-Temperature Cofired Ceramic
MIC	Microwave Integrated Circuit
MEMS	Microelectromechanic Systems
MMIC	Monolithic Microwave Integrated Circuits
VNA	Vector Network Analyzer
WLAN	Wireless Local Area Network

h	Substrate thickness
w	Resonator/ line width
l	Resonator/ line length
d	Overlapping gap distance
ε_0	Permittivity of vacuum
ε_r	Relative dielectric constant
ε_{eff}	Effective dielectric constant
μ_0	Permeability of vacuum
η	Impedance of free space
c	Speed of light in vacuum
λ	Free space wavelength
λ_g	Guided wavelength
Z_0	Characteristic impedance
v_p	Phase velocity
β	Propagation constant
γ	Complex propagation constant
f_o	Center frequency
ω	Angular frequency
ΔBW	Fractional bandwidth
θ	Electrical length
g	Normalized lowpass prototype parameter values
n	Filter order
L_{AR}	Passband ripple
Q_e	External quality factor

k	Coupling coefficient
S_{11}	Return loss
S_{21}	Insertion loss

CHAPTER 1

INTRODUCTION

1.1 Background

The rapid growth of microwave wireless communication systems demands a huge amount of communication devices, such as microwave filters and antennas. Microwave bandpass filters used in many microwave applications are the fundamental component that contributes to the overall performance of a communication system. For building modern broadband wireless communication systems such as satellite and mobile communication systems, wideband bandpass filter with high performance and very small size is required.

Filters can be designed and fabricated on various materials, planar structure such as microstrip is widely used to build filter since they can be fabricated by using standard printed circuit technologies easily and low cost. Many researches on microstrip filters have been proposed to minimize the filter size and improving filter performance. The developments of CAD tools such as electromagnetic simulator help researchers to design filter. With CAD simulator, complicated design can be simplified efficiently, it opens possibility for researchers to develop new filter design. Recent advances in novel materials and fabrication technologies (Hong & Lancaster, 2001), including high-temperature superconductors (HTS), low-temperature cofired ceramics (LTCC), monolithic microwave integrated circuits

(MMIC), microelectromechanic system (MEMS), and micromachining technology, also stimulated the development of new filter design.

1.2 Problem Statement and Motivation

Miniaturization is the main challenge of filter design, the trend of miniaturization creates a demand for new filter circuit design. Many planar filter structures such as open line resonator filter, closed loop resonator filter, filter with stub, have been proposed to minimize the filter size. Among the diverse of filter structures, open line resonator such as parallel coupled resonator and hairpin coupled resonator is widely preferred for building bandpass filter, due its simple design and easy to control bandwidth. Another benefit is its flexibility to fold the resonator to a more compact form.

However coupled open line resonator based filter is only suitable for designing narrowband filter. High coupling is required for wideband filter that is limited by the gap between two resonators. Unlike open end resonator filter, close loop ring resonator filter is able to deliver wide bandwidth, but the bandwidth is not as easy as open end resonator filter to be controlled. Another type of bandpass filter which can produce wide bandwidth is a filter utilizing short circuited stub. This type of filter is being widely used for designing ultra wideband filter due to its wide bandwidth. But the size of this filter is typically big and, plus the needs for vias as short circuit that add more cost and complexity for fabrication.