Ring Band-pass Filter (RBPF) for Global Positioning System (GPS)

Nazatul Fariza Binti Abdul Halim
Kamariah Binti Ismail
Faculty of Electrical Engineering,
Universiti Teknologi MARA,
40450 Shah Alam,Selangor,Malaysia.
Email: fariezahalim@yahoo.com

Abstract –This paper presents the design, simulation and analysis of a band-pass filter based on ring shape for microwave application. In designing the filter, Tschebycheff approach was used and simulation was carried out using commercial simulation software. The prototype filter was fabricated on the RT Duroid 4350B dielectric substrate (ε_r) with the value of 3.48. The operating frequency is from 1.559 to 1.610 GHz with the cut-off frequency at 1.584 GHz and bandwidth of 51MHz.

Keywords: Filter, microstrip, ring filter, GPS.

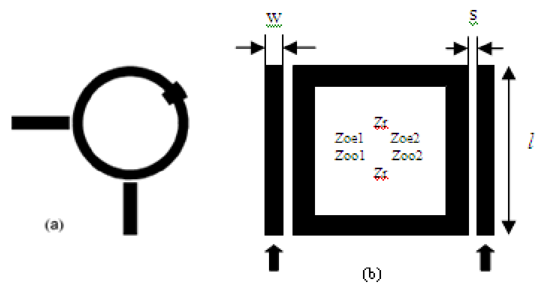

Fig.1. [3] (a) Ring resonator with symmetrical feed lines and a notch (b) The form of a ring band-pass filter

I. INTRODUCTION

Microstrip is a type of electrical transmission line which can be fabricated using printed circuit board (PCB) technology and is used to convey microwave frequency signals. It consists of a conducting strip separated from ground plane by a dielectric layer known as the substrate. It is less expensive than traditional waveguide technology, as well as being far lighter and more compact. The microstrip laminates has a special dielectric substrate that confines the signal. Hence less loss occurs [1].

Microwave filters are very versatile and used in many applications such as channel separation in frequency division multiplexing (FDM), the removal of harmonics in oscillators or amplifier, noise reduction and to reject signals at particular frequencies in band-stop or band-pass filter applications [1]. A microstrip ring resonator has many attractive features, including small size, narrow band, and low fabrication costs. Ring resonators have been used in designing oscillators, filters, mixers, etc [2]. A general microstrip ring filter consists of a pair feed lines, coupling gaps, and a ring whose circumference is equal to the guided wavelength as shown in Fig.1 (a) [3].

In this work the design of RBPF involved the adjustment of the perturbation along the ring which are indicated by length (l), width (w) or the adjustment of the coupling gaps(s) as depicted in Fig.1(b) [3], for Global Positioning System (GPS) application.

GPS is a U.S. space-based worldwide navigation satellite system. It provides consistent positioning, navigation, and timing services to users in the whole wide world on a constant basis in all weather, day and night, wherever on or near the earth. The frequency band allocated for Malaysia for this GPS system ranges from 1559 – 1610 MHz [4].

II. SCOPE OF WORKS

This work consists of designing, simulation, fabrication and analysis of the filter based on the Rogers Duroid substrates. It consists of two microstrip lines and two microstrip coupled-lines.

The designing and simulation were carried out using commercial software, *Genesys*. Band-pass filter was designed based on the following specification:

Table 1
Band-pass Filter Design Specification

Number of order (n)	2
Center Frequency	1.584 GHz
Lower cut-off frequency	1.559 GHz
Upper cut-off frequency	1.610 GHz
Bandwidth	51 MHz

EM simulation was carried out to determine the physical shape and performance of the filter. Then fabrication of a prototype Tschebyscheff ring band-pass filter on Rogers Duroid substrate with the dielectric of 3.48 for original dimension was realized.

III. METHODOLOGY

A flow chart as illustrated in Fig.2 described all the steps taken in designing and realizing the RBPF.

A. Design procedure for ring band-pass filter

The ring band-pass filter was developed on Rogers Duroid substrate with a specification as shown in Table 2.

Table 2
Rogers Duroid Substrate Properties

Microstrip substrate

Dielectric Constant	3.48
Height	1.524 mm
Loss tangent	0.001
Roughness	0.0000 mm
Frequency	1.584 GHz

Microstrip conductor

Thickness	0.01 mm
Resistivity	1.000 rel Au

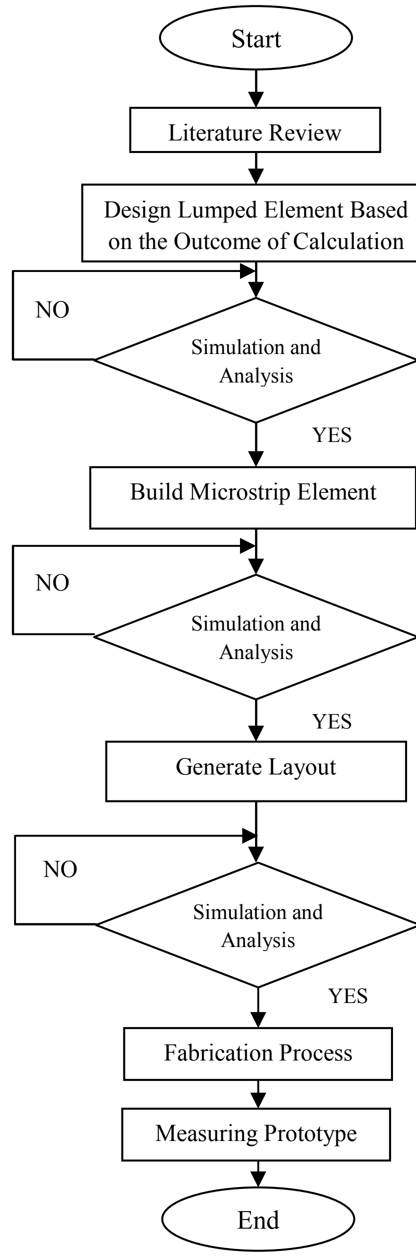

Fig.2 Design Flow Chart

The parameters involved are impedances of the ring (Zr), even-mode characteristic impedance (Zoe_1 and Zoe_2) and odd-mode characteristic impedance (Zoo_1 and Zoo_2) of the coupled line. The design of ring filter is as depicted in Fig.3 [3].

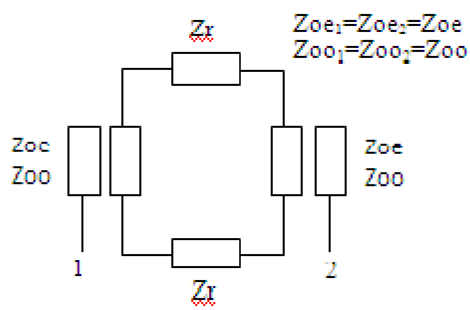

Fig.3 Diagram of quarter-wavelength side-coupled ring

The values for this impedance as shown in Fig.3 were calculated and obtained using the following equations [3], where

$$\theta = \frac{\pi f}{2 f_0} \tag{1}$$

$$T_z = \frac{\sin\left(\frac{\pi f_{tz}}{2 f_0}\right)^2}{1+\cos\left(\frac{\pi f_{tz}}{2 f_0}\right)^2} \tag{2}$$

$$Y_{oo} = \frac{T_z Y_{oe}}{Z_r\left(2Y_{oe} - \frac{T_z}{Z_r}\right)} \tag{3}$$

$$Z_r = \frac{2T_z x + T_z^2 Y_{oe} Z_0 + Y_{oe}\left(-Z_0 + S_Q - x\sqrt{\frac{P+Q+R}{Y_{oe} x^2}}\right)}{2xY_{oe}} \tag{4}$$

where

$$P = 4xZ_0T_z^3 - Y_{oe}Z_0^2T_z^4(x^2-2) + 4T_{zx}(S_Q - Z_0) \tag{5}$$

$$Q = 2T_z^2Y_{oe}Z_0\left(Z_0\,(x^2-2) + S_Q\right) \tag{6}$$

$$R = -Y_{oe}Z_0\left(Z_0(x^2-2) + 2S_Q\right) \tag{7}$$

$$S_Q = \sqrt{(1-x^2)\left(T_z^2-1\right)^2 Z_0^2} \tag{8}$$

r_f ratio (<1) between the first transmission zero frequency and the center frequency.

$$f_{tz} = r_f f_0 \tag{9}$$

y passband ripple(in decibels) with

$$x = -10^{\frac{-y}{20}} \tag{10}$$

The equations from (1) to (10) were used with the desired value of r_f, y and Zoe to design a coupled-line ring filter.

B. CAD simulation

EM simulation was carried out using *Genesys*. The schematic diagram of RBPF is as illustrated by Fig.4. The frequency response for the lumped elements simulation is as shown in Fig.5. It shows that the insertion loss approach zero and the return loss is less than -20 dB.

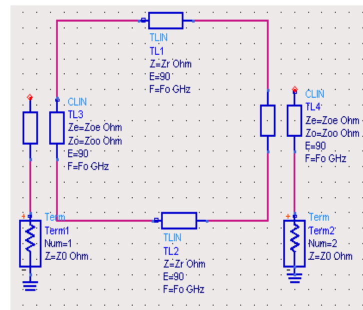

Fig.4 The lumped element

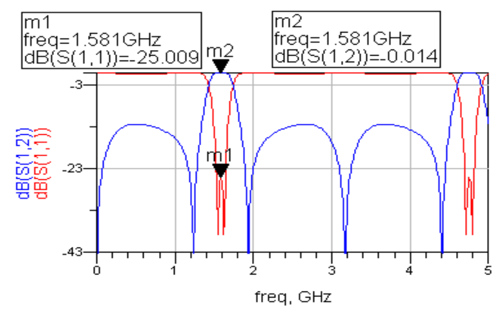

Fig.5 The frequency response based on schematic diagram of RBPF

Fig.5 shows the ideal response of the side coupled ring filter center at 1.58 GHz for Z_r = 31.681 Ω, Zoe_1 = Zoe_2 = 69.50 Ω and Zoo_1 = Zoo_2 = 10.288 Ω. This lumped element was then converted into microstrip form which can be seen in Fig.6. The width (w), length (*l*) and the gap(s) for the microstrip line and coupled line were obtained from the line calculator based on the values of impedances.

Lastly, the layout of the RBPF was then created as depicted in Fig.7. Fig.8 illustrates the frequency response of the simulated RBPF. The insertion loss has approached to 0 dB while the return loss is less than -20 dB.

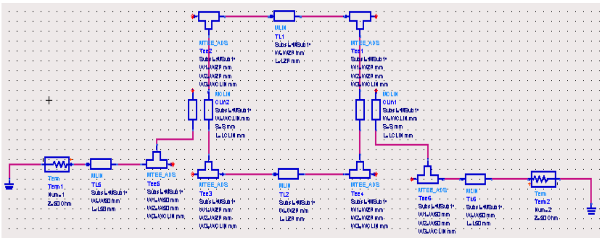

Fig.6 The microstrip form of ring filter

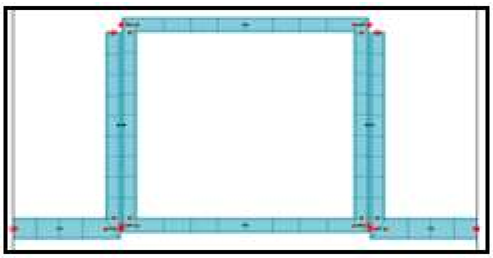

Fig.7 The microstrip layout

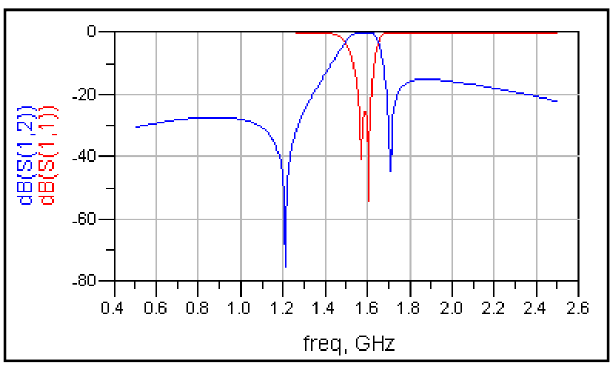

Fig.8 The simulated frequency response of RBPF

IV. RESULT AND DISCUSSION

Fabrication of the prototype was accomplished based on the Rogers Duroid substrate is as shown in Fig.9. Measurement of the parameters of the prototype was carried using a vector analyzer (VNA). Standard calibration procedure was used prior to the measurement [5]. Fig.10, Fig.11 and Fig.12 revealed the measured result.

There was slight discrepancy between measured and simulated values. This difference in value may be due to the insertion of the connector. Simulation was carried out on the RBPF without the connector. It is also may be due to defect of fabrication. A slight different in the width (w) and length (*l*) of the copper strip will have an effect on the frequency response of the graph. The placement of the connector on the 50 Ω transmission line also can be the cause of the discrepancy. The connector should be connected at the end of the line and not in the middle of the line.

Table 3
Comparison of simulated result and measured results

	Simulated result using *Genesys*	Measured result
Center frequency(f_c)	1.581 GHz	1.54 GHz
Lower cut-off frequency(f_l)	1.570 GHz	1.208 GHz
High cut-off frequency(f_h)	1.606 GHz	1.65 GHz
Insertion loss(S_{12})	-0.105 dB	-1.314 dB
Return loss (S_{11})	-26.347 dB	-12.847 dB
Bandwidth	156 MHz	442 MHz

Fig.9 Fabricated ring band-pass filter

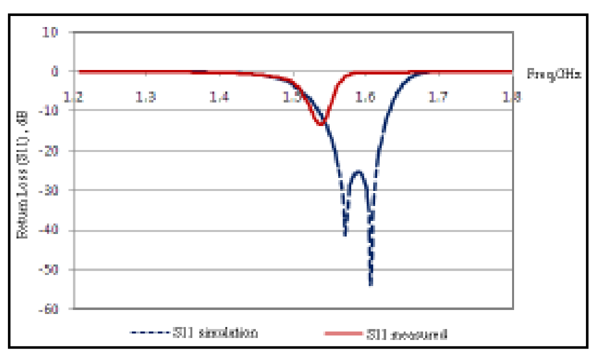

Fig.10 Graph for measurement of return loss (S11)

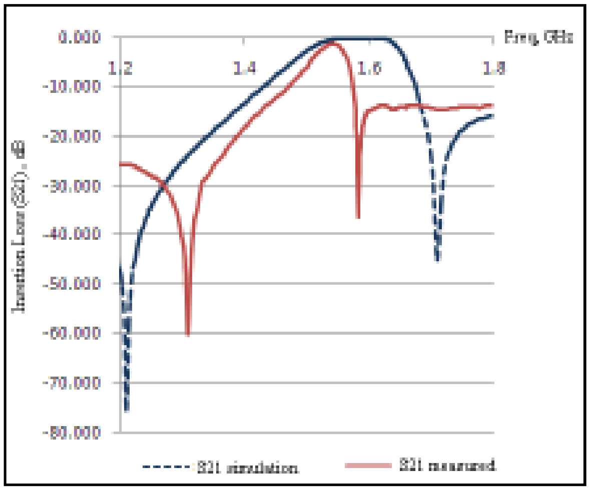

Fig.11 Graph for measurement of insertion loss (S21)

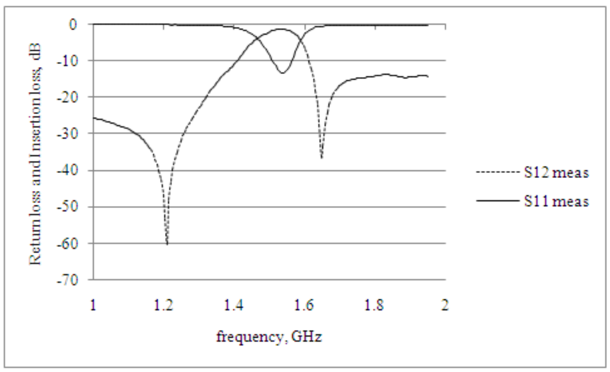

Fig.12 The graph of Measured S11 and S21

V. CONCLUSION

A ring band-pass filter for GPS application was successfully designed, simulated, fabricated and analyzed on RT Duroid 4350B. It was small, compact, light and very low cost fabrication. There was a slight discrepancy between measured and simulated values.

VI. FUTURE DEVELOPMENT

This ring filter can be further developed on different substrates of Rogers Duroid or other high-k substrates and in a different frequency range for other various applications.

ACKNOWLEDGEMENT

The author would like to thank to Kamariah Ismail, Dr. Mohd Khairul Mohd Salleh and Suhana Sulaiman and also all the team of researchers from the Microwave Technology Center at Universiti Teknologi MARA.

REFERENCES

[1] Prof. Zaiki Awang PhD, SMIEEE, "Microwave System Design", Microwave Technology Centre Universiti Teknologi MARA, 2008.

[2] Chang.K, "Microwave ring circuit and antennas", Wiley, New York, 1996.

[3] Dr. Mohd Khairul Mohd Salleh, Gaëtan Prigent, Olivier Pigaglio, and Raymond Crampagne, "Quarter-Wavelength Side-Coupled Ring Resonator for Bandpass Filters", IEEE Trans. Microwave Theory and Techniques, Vol.56, No.1, January 2008.

[4] Spectrum Plan, November 2006

[5] M. H. Jarvis Drive, "Model 372XXA Vector Network Analyzer, Maintenance Manual," July 1996.