International Journal of Technology (2014) 1: 32-39
ISSN 2086-9614

MULTIBAND BANDPASS FILTER (BPF) BASED ON FOLDED DUAL CROSSED OPEN STUBS

Gunawan Wibisono[1*], Teguh Firmansyah[1], Purnomo S. Priambodo[1], Agus S. Tamsir[1], Taufiq A. Kurniawan[1], Achmad B. Fathoni[1],

[1]*Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia, Kampus Baru UI, Depok 16424, Indonesia*

(Received: May 2013 / Revised: December 2013 / Accepted: December 2013)

ABSTRACT

A compact multiband bandpass filter (BPF) based on folded dual crossed open stubs (DCOS) is designed and analyzed. Two Crossed Open Stubs (COS) are used to generate concurrent six-band BPF, where the center frequency located at 0.95 GHz, 1.85 GHz, 2.65 GHz, 3.35 GHz, 4.375 GHz, and 5.25 GHz. The proposed BPF based on folded Dual Crossed Open Stubs (DCOS) is an expansion of tri-band BPF based on a single COS, where the second COS is used to generate second additional tri-band. To achieve miniaturization structure of proposed BPF, the DCOS is folded. The proposed BPF will be designed and analyzed by using Advanced System Design (ADS). The performances of multiband BPF which characterized by return loss, insertion loss, voltage standing wave ratio (VSWR), and group delay, are conducted by simulation, measurement and analysis. It is shown that the simulation and fabrication results of insertion loss, return loss, VSWR, and group delay of the proposed multiband BPF are satisfied to design requirements. However, the center frequencies of fabricated the proposed multiband BPF are shifted average to 5–30 MHz lead to simulated results. This is due to some errors in fabricated process including imperfect dimension of fabricated BPF, soldering between connector to substrate and cable losses.

Keywords: Folded dual crossed open stubs; Multiband BPF

1. INTRODUCTION

In recent years, the rapid progress in mobile and wireless technologies have increased the need of integrating more than one communication technology or standard into a single system (Hosein, 2005), where different standards may operate in different frequency bands. Multiband radio frequency (RF) and microwave modules play an important role in variety of modern communication systems. Microwave multiband bandpass filters (BPFs), is one of the most important modules in the front end circuit. Conventionally, in designing multiband BPF, the principle of stepped impedance resonators (SIRs) are often used as a building block, due to their multiband behaviors, simple structure and well established design methodology (Xue & Chu, 2009; Chu, 2008; Packiaraj & Ramesh, 2006). However, the resonance frequencies of the SIRs are dependent each other. The filter design is quite complicated and it is not convenient to meet specific bandwidth requirement. Tri-section SIR as enhancement of SIR had been proposed to design multiband BPF (Packiaraj & Ramesh, 2006; Zhu & Gao, 2011).

[*] Corresponding author's email: gunawan@eng.ui.ac.id, Tel. +62-21-7270078, Fax. +62-21-7270077
Permalink/DOI: http://dx.doi.org/10.14716/ijtech.v5i1.151

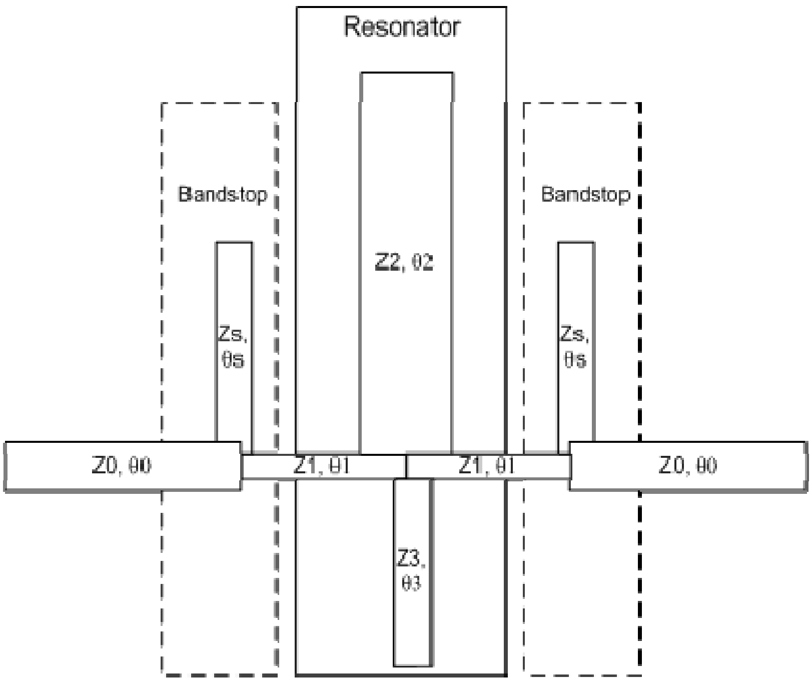
One of the most effective methods to realize high performance BPF, is to create transmission zero located at upper and lower side of the pass band, called cross resonator (Zhu & Gao, 2011; Chu et al., 2009; Wenjie et al., 2010a; Wenjie et al., 2010b).

Compare with SIR, the cross resonator has low dependence resonance frequencies. The cross resonator method had been implemented to create multiband frequency by using crossed open stubs (COS) (Chu et al., 2009) and crossed short stubs (CSS) (Wenjie et al., 2010a). Combination of COS and CSS can be used to design quadband BPF (Wenjie et al., 2010b). However the implementation of COS had large size filter, so it needs modification to achieve miniaturization. In (Chu et al., 2009), COS and CSS methodologies are used to design triple band BPF. While in (Wenjie et al., 2010a), only single COS is used to design triple band BPF. In this research, the method proposed by (Wenjie et al., 2010a) is expanded, by adding other COS as the second resonator and the proposed method called DCOS. In order to get six frequencies with small configuration (compact dimension), some modifications have been done.

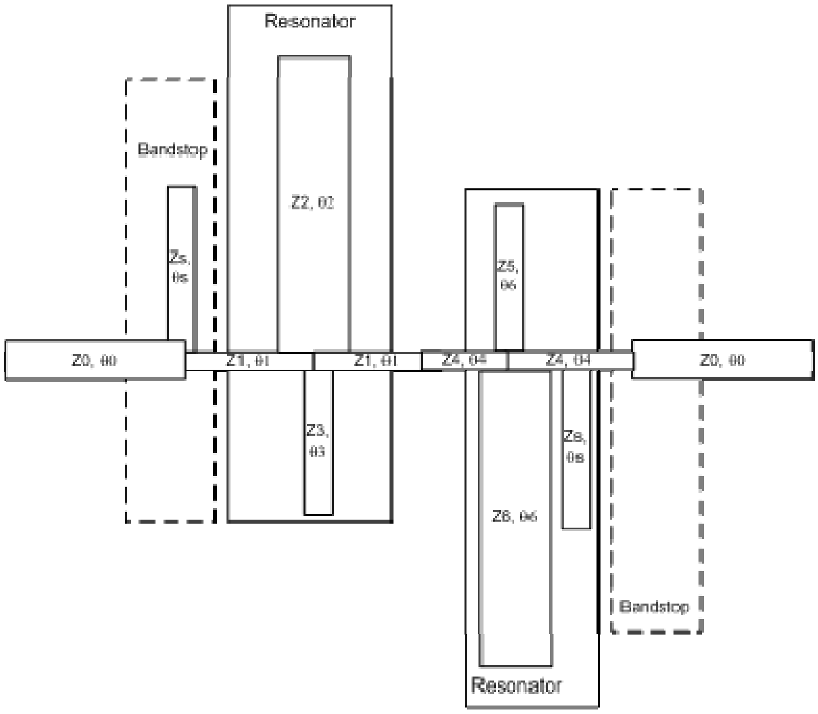
In this paper, six-band BPF operating at frequency 0.9 GHz for GSM, 1.85 GHz for 3G, 2.65 GHz for LTE, 3.35 GHz for WiMAX, 4.375 GHz for HiperLAN and 5.25 GHz for WLAN based on 4 crossed stubs and two/dual COS (DCOS) will be designed and analyzed. To achieve miniaturization or compact design, DCOS is folded. The proposed six-band BPF with folded DCOS will first be designed and analyzed by using Advanced Design System (ADS) and then verified by measurement data. The six-band BPF design and the obtained results are presented in the following sections.

2. DESIGN OF THE PROPOSED MULTIBAND BPF

Figure 1(a) shows the tri-band BPF based on short stubs and COS (Wenjie et al., 2010b). Three passband centres that are located at 1.85 GHz for GSM, 3.35 GHz for WiMAX and 5.25 GHz for WLAN band can be generated by this tri-band BPF.



(a)



(b)

Figure 1(a) Tri-band BPF based on COS (Wenjie et al., 2010b); (b) the proposed multiband BPF based on folded DCOS

Figure 1(b) shows the proposed multiband BPF based on folded DCOS. The proposed multiband BPF is consisted of two (2) tri-band BPF based on COS, so there are 2 resonators use in multiband BPF. The value of Zi (i = 1,2,…,6) in Figure 1.(b) can be found by using the ABCD matrix approached which has been used by Wenjie et al. (2010b). The ABCD matrix of the DCOS structure can be written as:

$$\begin{bmatrix} A_{Ds} & B_{Ds} \\ C_{Ds} & D_{Ds} \end{bmatrix} = \begin{bmatrix} \cos\theta_1 & jZ_1\sin\theta_1 \\ \frac{j\sin\theta_1}{Z_1} & \cos\theta_1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \frac{j\sin\theta_2}{Z_2} & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \frac{j\sin\theta_3}{Z_3} & 1 \end{bmatrix} \begin{bmatrix} \cos\theta_1 & jZ_1\sin\theta_1 \\ \frac{j\sin\theta_1}{Z_1} & \cos\theta_1 \end{bmatrix}$$
$$\text{x} \begin{bmatrix} \cos\theta_4 & jZ_4\sin\theta_4 \\ \frac{j\sin\theta_4}{Z_4} & \cos\theta_4 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \frac{j\sin\theta_5}{Z_5} & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \frac{j\sin\theta_6}{Z_6} & 1 \end{bmatrix} \begin{bmatrix} \cos\theta_4 & jZ_4\sin\theta_4 \\ \frac{j\sin\theta_4}{Z_4} & \cos\theta_4 \end{bmatrix} \quad (1)$$

By using the same approaches in Wenjie et al. (2010b), the DCOS are used to replace λ0/4 line. The ABCD matrix of the λ0/4 connection line is given as Wenjie et al. (2010b)

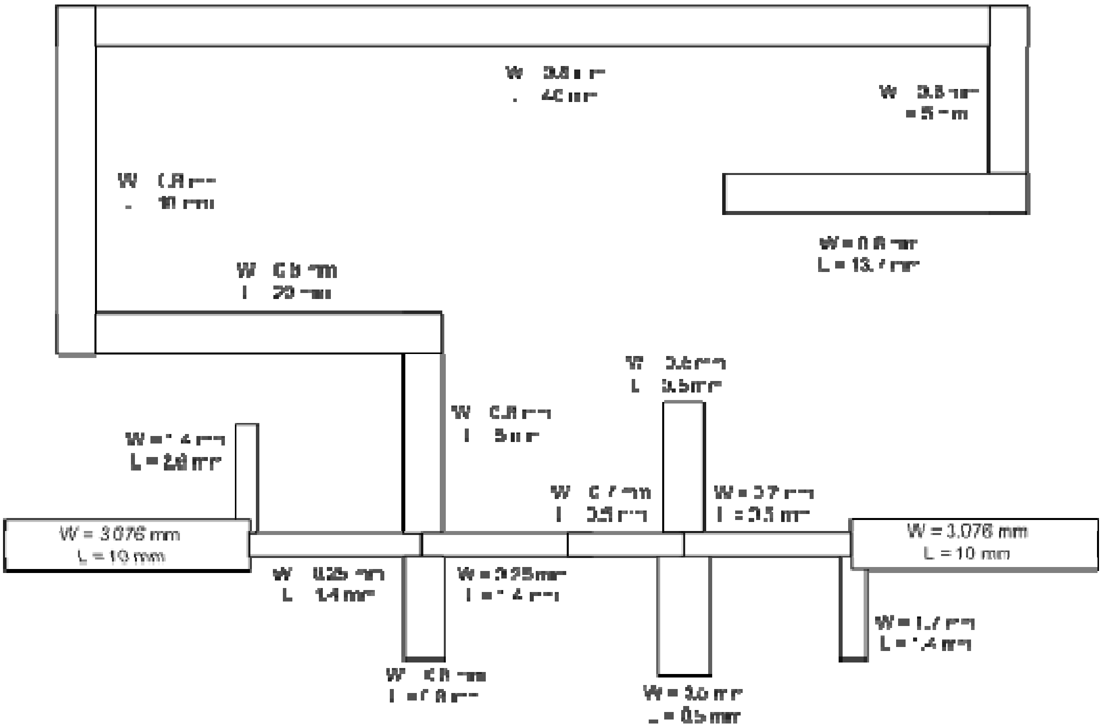
$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cos\theta_0 & jZ\sin\theta_0 \\ jY\sin\theta_0 & \cos\theta_0 \end{bmatrix} \quad (2)$$

Because the DCOS are used to replace the λ0/4, is thus set to 90^o, then

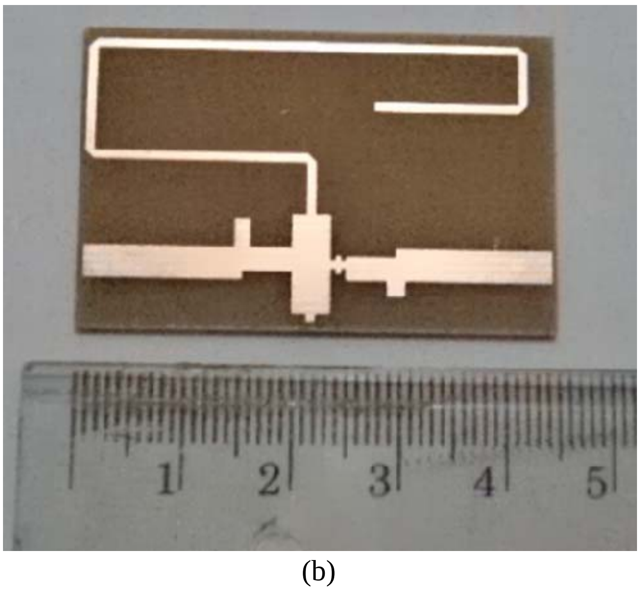
$$\begin{bmatrix} A_{Ds} & B_{Ds} \\ C_{Ds} & D_{Ds} \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 0 & jZ \\ jY & 0 \end{bmatrix} \quad (3)$$

By solving Equation (3), the value of Zi (where i = 1, 2, … , 6) can be found.

To demonstrate the usefulness of the proposed design concept for six-band BPF, a microstrip BPF has been designed with the following specification. The center frequencies of six bands are 0.95 GHz, 1.85 GHz, 2.65 GHz, 3.35 GHz, 4.375 GHz, and 5.25 GHz. The design requirements for all frequencies are the value of return loss < -10 dB and voltage standing wave ratio (VSWR) is 1–2. The BPF has been designed to be fabricated using copper metallization on the substrate FR4 with a relative dielectric constant of 4.3, a loss tangent of 0.002 and a thickness of 1.6 mm. The optimized geometry and the fabricated of schematic diagram of the proposed multiband BPF based on folded DCOS, are shown on Figures 2(a) and 2(b), respectively.



(a)

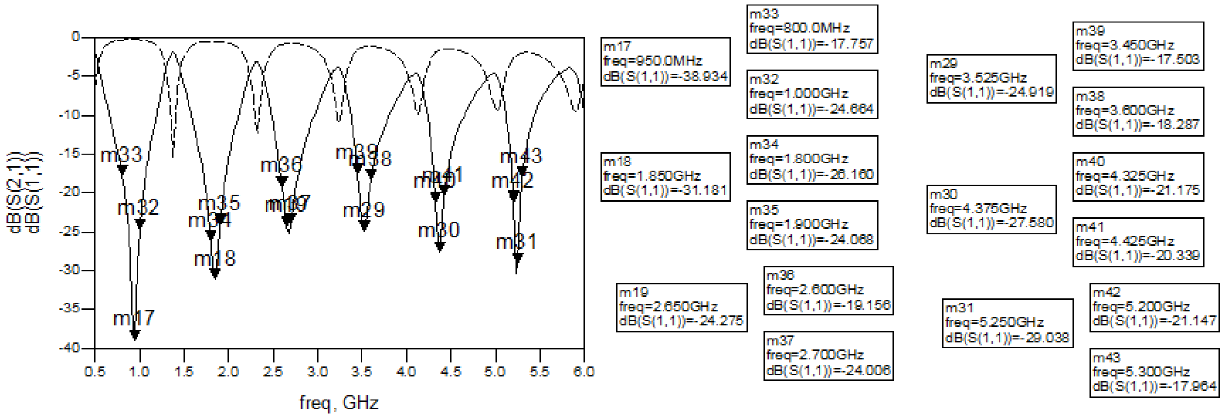


(b)

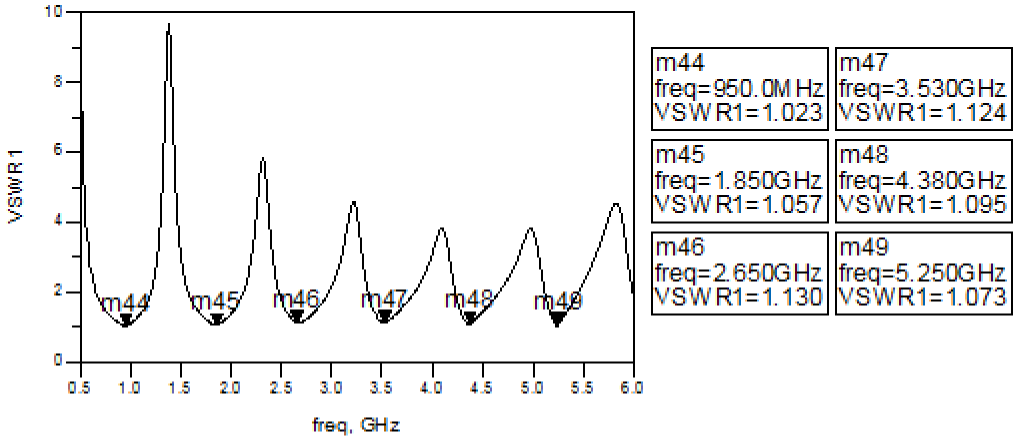
Figure 2. (a). The optimized geometry of the proposed multiband BPF (not in scale), (b). the fabricated of schematic diagram of the proposed multiband BPF

3. RESULTS AND DISCUSSION

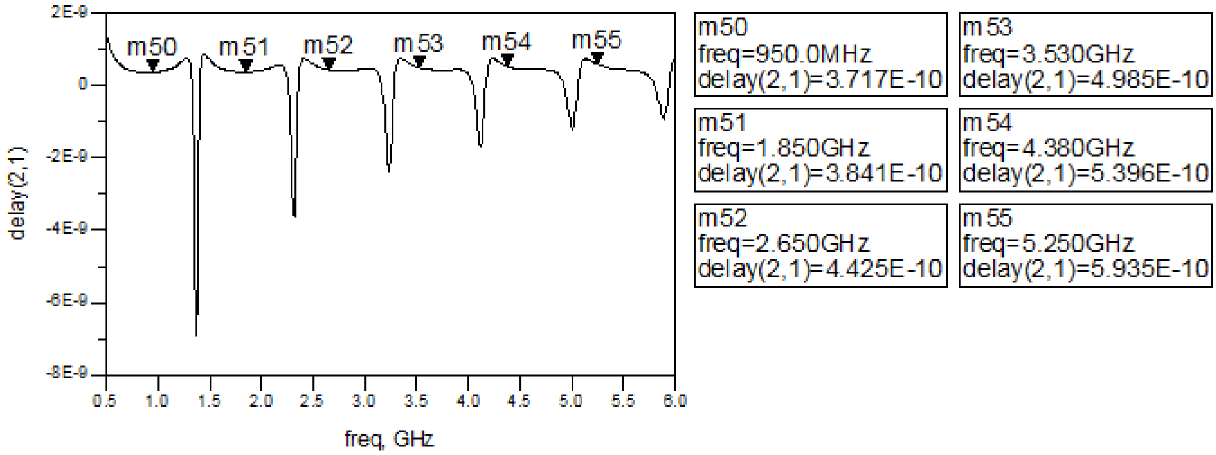
Figures 3(a), (b), and (c) show simulation results for return loss (S11) and insertion loss (S21), VSWR, and group delay of the proposed multiband BPF based on DCOS, respectively.



(a)



(b)



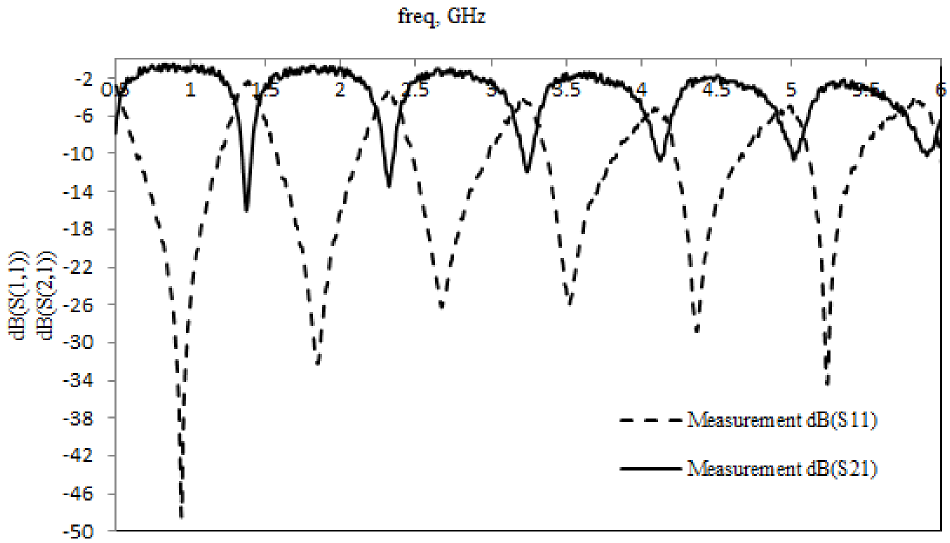
(c)

Figure 3 Simulation results of multiband BPF based on Folded DCOS: (a) return loss and insertion loss; (b) VSWR; (c) group delay

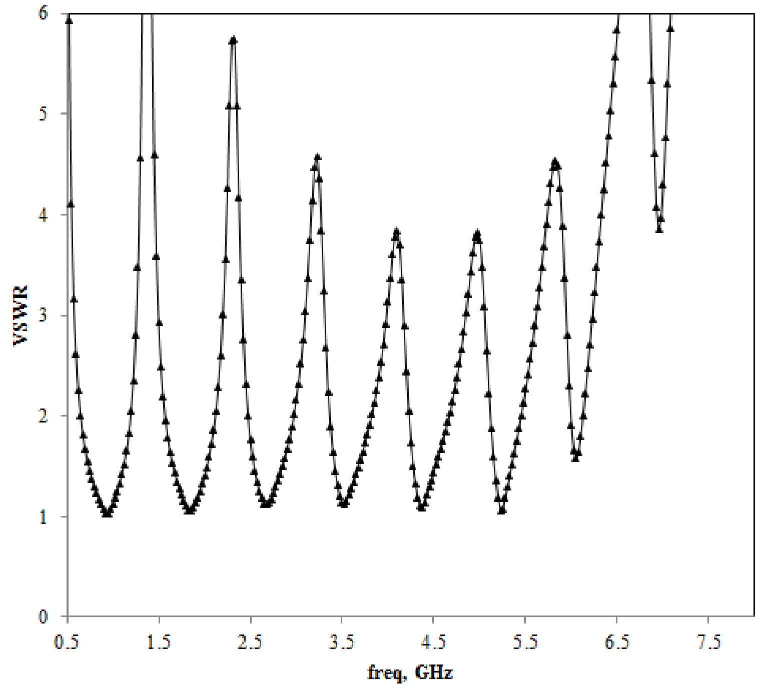
It is shown from Figure 3(a) that, six passbands are located separately around at 0.95 GHz (0.7–1.3 GHz), 1.85 GHz (1.5–2.3 GHz), 2.65 GHz (2.4–3.1 GHz), 3.35 GHz (3.2–3.9 GHz), 4.375

GHz (4.2–4.8 GHz), and 5.25 GHz (5.0–5.7 GHz), respectively. While the transmission zeros created by the COS can be observed to locate at 0.6 GHz, 1.3 GHz, 2.3 GHz, 3.2 GHz, 4.0 GHz, and 5.7 GHz, respectively. The figure also shows that the bandwidths of the proposed multiband BPF are 100 MHz at centre frequency 0.95 GHz, 100 MHz at 1.85 GHz, 100 MHz at 2.65 GHz, 80 MHz at 3.35 GHz, 80 MHz at 4.375 GHz, and 80 MHz at 5.25 GHz respectively. The bandwidth of simulation results is satisfied to the design requirements. The simulation results of VSWRs of the proposed multiband BPF based on folded DCOS is shown at Figure 3(b). It shows that the VSWR value is satisfied to the design requirements. Figure 3(c) also shows that the simulation results of group delay of the proposed multiband BPF. It can be seen that all values of group delay is less than 1 ns for all centre frequencies, which indicated that the proposed filter doesn't cause phase change significantly.

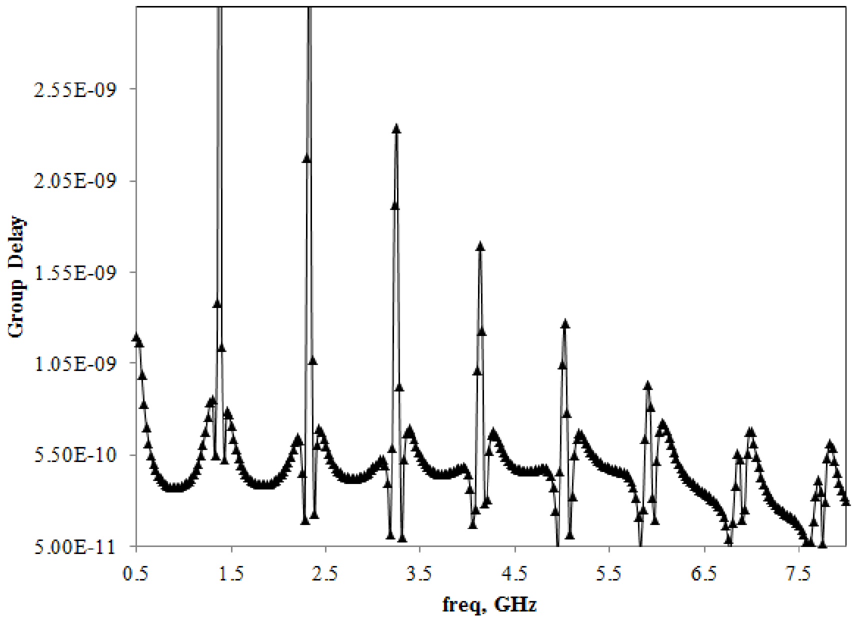
The fabricated S11 and S21, VSWR, and group delay results of the proposed multiband BPF is shown in Figures 4(a), 4(b), and 4(c), respectively.



(a)



(b)



(c)

Figure 4. Fabricated results of the proposed multiband BPF with folded DCOS (a). S11 and S21, (b). VSWR, (c). group delay

It is shown from Figure 4 that the fabricated S11 and S21, VSWR and group delay results of multiband BPF are satisfied to design requirements. It can also be seen from Figure 4(a) that six passbands are located centrally at 0.95 GHz, 1.855 GHz, 2.657 GHz, 3.40 GHz, 4.40 GHz, and 5.30 GHz. While six transmission zeros are 0.6 GHz, 1.3 GHz, 2.37 Gz, 4.0 Ghz, 4.8 GHz, and 5.7 GHz. However, compare to the simulation results, the centre frequencies of the fabricated BPF are shifted, in average to 5–10 MHz lead to simulation results. This is because in the ADS simulation, the value of dielectric constant of FR4 is set to 4.3 and loss tangent of 0.0002 for all frequencies. It is known that the value of the dielectric constant and loss tangent of FR4 are dependent to the operating frequency. Meanwhile in the fabricated BPF, the exact value of dielectric constant and loss tangent are not known clearly, so, the performances of the fabricated BPF are shifted to the simulation results. Other parameters that caused error in measured result of the fabricated BPF are fabricated process, including imperfect dimension of fabricated BPF, soldering between connector to substrate and cable losses. Therefore, the fabricated BPF is need to be tuned to satisfy to the design BPF.

4. CONCLUSION

Multiband BPF based on folded DCOS has been designed, fabricated and analyzed. The proposed multiband BPF generated six frequencies at center frequencies of 0.950 GHz, 1.85 GHz, 2.65 GHz, 3.35 GHz, 4.375 GHz, and 5.25 GHz. The simulation and fabricated results of insertion loss, return loss, VSWR, and group delay of the proposed BPF satisfied the design requirements. However, the center frequencies of fabricated proposed multiband are shifted in average to 5–30 MHz because of some errors in fabricated process including imperfect dimension of fabricated BPF, soldering between connector to substrate and cable losses.

5. ACKNOWLEDGEMENT

This research is supported by International Collaboration Research Grant from Directorate Research and Community Development (DRPM) University of Indonesia, 2012, No. 1165/H2.R12/HKP 05.00.Perjanjian/2012.

6. REFERENCES

Chu, Q.-X., 2008. Advanced Triple-Band Band Pass Filter using Tri-Section SIR, *Electronic Lett*. Volume 44(4).

Chu, Q.-X., Chen, F.-C., Tu, Z.-H., Wang, H., 2009. A Novel Crossed Resonator and its Applications to Bandpass Filters, *IEEE Trans. Microw. Theory Tech.*, Volume 57, pp. 1753–1759

Hosein, H., 2005. Integrated Concurrent Multiband Radios and Multiple Antenna System. *Ph.D. Dissertation*. California Institute of Technology. California. September 2005

Ministry of Communication and Information Republic of Indonesia, 2009. Table of Indonesia Radio Spectrum Frequency. Ministry of Communication and Information Republic of Indonesia Decree No. 29/PER/M.KOMINFO/07/2009, 30 July 2009

Packiaraj, D., Ramesh, M., 2006. Design of a Tri-section Folded SIR Filter, *IEEE Microw. Wireless Component. Lett.*,Volume 16(5), pp. 317–319

Wenjie, F., Tan, D.M., Wenquan, C., 2010b. Compact Tri-band Bandpass Filter based on Short Stubs and Crossed Open Stubs, *Int'l Conf on Advanced Technologies for Communications 2010*. Ho Chi Minh City, Vietnam, 20–22 Oct 2010. pp. 213–216

Wenjie, F., Wenquan, C., Quan, X., 2010a. Novel Tri-band Microstrip Bandpass Filter using Open Stub with Different Length, *The 15th Int'l Symp on Antennas and Propagation 2010 (ISAP 2010)*, Macao, China. pp. 267–270

Xue, M.-L., Chu, Q.-X., 2009. Design of Triple-band Bandpass Filter using Tri-section Stepped-Impedance Resonators, in: *Proc. Int. Conf. Microw. Milli. Tech., 2009*, pp. 1261–1263

Zhu, H., Gao, L., 2011. Design of Quad-band Bandpass Filter using Open- and Short-stub-Ioaded Resonators, *Cross Strait Quad-Regional Radio Science and Wireless Technology Conference*, 26-30 July 2011