Design and Realization of Coupled Line Bandpass Filter Using Compact Structure at Frequencies of 3300 MHz – 3400 MHz for WiMAX Application

Perancangan dan Realisasi *Bandpass Filter Coupled Line* dengan Metode *Compact Structure* Pada Frekuensi 3300 MHz – 3400 MHz Untuk Aplikasi WiMAX

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Abstract

In this paper, the design of microstrip BPF (Bandpass Filter) for WiMAX (Worldwide Interoperability for Microwave Access) application has been presented. The frequency band allocations for BWA (Broadband Wireless Access) in Indonesia are 2.3; 3.3 and 5.8 GHz. This microtrip BPF is designed using parallel coupled line in compact form and it has spesific parameter, i.e. 3.35 GHz center frequency, 400 MHz bandwidth, VSWR ≤ 2, -3 dB insertion loss and matching impedance between two port is 50 Ω. The Advanced Design System (ADS) software has been used during simulation and optimization. The simulation results show that return loss S_{11} and insertion loss S_{21} are -15.31 dB and -2.2 dB at 3.35 GHz respectively. For the design verification, the prototype of the proposed design wasfabricated and measured.The results of the fabrication approach of simulation results, which have return loss value S11and insertion loss S_{21} of the proposed microstrip filter are -18.20 dB and -2.91 dB at 3.35 GHz respectively. The result shows that the proposed design can be implemented forWiMAX communication system applications.

Keywords : *WiMAX, Coupled Line, Compact BPF, ADS.*

Abstrak

Pada tulisan dibuat desain BPF (*Bandpass Filter*) mikrostrip untuk aplikasi WiMAX *(Worldwide Interoperability for Microwave Access)*. Indonesia memiliki alokasi pita frekuensi BWA (*Broadband Wireless Access*) yaitu 2,3 ; 3,3 dan 5,8 GHz. *Bandpass filter* ini didesain menggunakan *parallel coupled line* dan dimodifikasi dengan bentuk yang *compact* dengan frekuensi tengah 3,35GHz, bandwidth sebesar 400 MHz, VSWR kurang dari 2, *insertion loss* sebesar -3 dB dan impedansi pada kedua port sebesar 50 Ω. Desain ini telah disimulasi dan dioptimasi menggunakan *software* ADS 2011. Hasil simulasi pada frekuensi 3,35 GHz didapatkan nilai return loss S_{11}adalah -15,31 dB dan nilai *insertion* loss S_{12} adalah -2,2 dB. Pada tahap verifikasi, desain awal difabrikasi dan diukur. Hasil fabrikasi mendekati spesifikasi hasil simulasi yang telah ditentukan yaitu nilai *return loss* S_{11} adalah -18,20 dB dan nilai *insertion loss* S_{12} adalah -2,91 dB. Berdasarkan hasil pengukuran, BPF hasil desain dapat digunakan untuk aplikasi sistem komunikasi WiMAX.

Kata kunci : WiMAX, *Coupled Line*, *Compact BPF*, ADS.

I. INTRODUCTION

WiMAX (Worldwide Interoperability for Microwave Access) is a the IEEE 806.16 standard for wireless technology. The Indonesian Government allocate frequency band of BWA (Broadband Wireless Access) in 2.3 , 3.3 , 5.8 GHz. WiMAX systems supported by the device on the side of the BTS (Base Transceiver Station) and the receiver side, bandpass filters are used on every transmitter and receiver devices which areavailable on the BTS and the receiver side.

Filters can be designed in various ways and components. It can be created using lumped element, with capacitors and inductors are connected using a line printed on the printed circuit board (PCB). Filters with lumped element are usually used for low frequencies, very difficult to design filters for high frequency using lumped element. While this type of filter for high frequency uses microstrip line. Bandwidth is the frequency range that the signal current can be passed through the filter with a small attenuation where the

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return loss is the ratio between the power source that is reflected back by the load [1].

There are various kinds of materials and manufacturing technology for making filters. They are : lumped-element LC filters, planar filters, coaxial and dielectric filters. Each filter has their advantages and disadvantages. LC filter is the simplest and has the smallest filter size, but the quality factor is very low, so the performance will be poor. Planar filter is a filter that is quite simple and easy to fabricate. It is bigger than the LC filter and will be bigger if the working frequency decreases but the quality factor is better than LC filter [2]. Most of the researches on microstrip coupled line filter are made for frequencies above 1 GHz. Coupled Line microstrip filters have been studied and were designed for various applications [3] - [6], thus development of the filter is focused on the operating bandwidth, the narrow band , wideband or ultra wideband of bandwidth filter are chosen according to their applications. The coupled line BPF have been studied and were designed for the conventional form [7] - [8]. The conventional parallel coupled line is a simple method to be applied but does not indicate a compact form so it requires more substrate material to be fabricated and causes high costs. Therefore, it needs a compact form of a coupled line filter.

In this paper, we have been proposed a microwave planar filter using coupled line resonators at a Roger substrate for WiMAX applications. The proposed filter is composed of 5 resonators with compact coupled line structures and designed with 500 MHz bandwidth in 3.35 GHz operational frequency. Calculation methods using simulation software and results of the characteristics are discussed and reported. The proposed device is analyzed using ADS 2011.11 software where the substrate with dielectric constant of 2.2 and thickness of 0.8 mm is used. The designed device has a simple and compact structure, easy in fabrication, and compatible with integrated microwave circuit.

II. FILTER DESIGN AND SIMULATION

The bandpass filter was designed using couple line compact resonator. The resonator is made using couple lineswith the length is λ/2. In this design, the bandpass filter has the center frequency of 3300 MHz - 3400 MHz. In this frequency, filter acquires quite a long resonator line. It causes the dimension of filter becomes quite large. Therefore, the compact filter is needed.

A. Effective Dielectric Constant

The microstrip is influenced by the dielectric substrate caused by air and so the structure is not homogeneous, it is necessary relative dielectric constant as a substitute, to determine the resistance characteristics. Relative dielectric constant of the dielectric constant can be considered as a homogeneous medium and substrate replacement air medium with h (substrate thickness), dielectric constant (ε_r), the microstrip line can be determined by using the equation Hammerstedt and Jansen [9].

$$\mathcal{E}_{eff} = \frac{\mathcal{E}r+1}{2} + \frac{\mathcal{E}r-1}{2}\left(1+\frac{10}{u}\right)^{-(ab)} \quad (1)$$

$$a = 1 + \frac{1}{49} ln\left[\frac{(u)^4+\left(\frac{u}{52}\right)^2}{(u)^4+0.432}\right] + \frac{1}{18.7} ln\left[1+\left(\frac{u}{18.1}\right)^3\right] \quad (2)$$

$$b = 0.564\left(\frac{\mathcal{E}r-0.9}{\mathcal{E}r+3}\right)^{0.053} \quad (3)$$

B. Impedance Characterized

Characteristic impedance is a function of the width of the strip conductor, dielectric material thickness from the surface to the ground plane and the homogeneity of the dielectric material ε_{eff} [10]. On microstrip transmission characteristics are determined by the dielectric constant and characteristic impedance. To determine the impedance characteristics, the following equation can be used:

$$Z_c = \frac{60}{\sqrt{\epsilon_{eff}}} ln\left[\frac{8}{w/h} + 0.25\frac{w}{h}\right] \quad (4)$$

$$Z_c = \frac{120\pi}{2\pi\sqrt{\epsilon_{re}}}\left\{\frac{W}{h} + 1.393 + 0.677 ln\left(\frac{W}{h} + 1.444\right)\right\}^{-1} \quad (5)$$

C. Dimension of Bandpass Filter

The concept of parallel coupled is half wavelength resonator filters. In order to reduce the dimension of filter, the resonant of filter arranged series with compact structure line. Furthermore, the substrate which has higher dielectric constant is used. The filter simulated and realized on RT/duroid 5880 substrate with the typical values as follows :

- Dielectric constant ε_r = 2.2
- Dissipation factor tan δ = 0.0009
- Thickness of substrate =0.8 mm
- Copper cladding = 35 µm

The values of parameter in this filter design shows in Table 1.

TABLE 1
THE DIMENSION OF RESONATOR

Resonator Name	Resonant Dimension		Gap (mm)
	Width (mm)	Length (mm)	
A1	3	11,85	-
A2	2,75	11,85	0,1
B1	2,75	11,85	
B2	3	11,85	0,8
C1	3	11,85	
C2	2.75	11,85	0,15
D1	2.75	11,85	
D2	2.75	11,85	0,15
E1	2,75	11,85	
E2	3	11,85	0,8
F1	3	11,85	
F2	2.75	11,85	0,1
G1	2,75	11,85	
G2	3	11,85	-

The proposed design of BPF module with 5 resonators is depicted in Figure 1. The resonator is coupled line that is formed in compact form in order to accommodate a lot of resonator. Resonator filter shown in each section (A, B, C, D, E, F and G) and each resonator has a different width and spacing gap. The result of this simulation contains graphs of the insertion loss and return loss of the proposed design BPF.

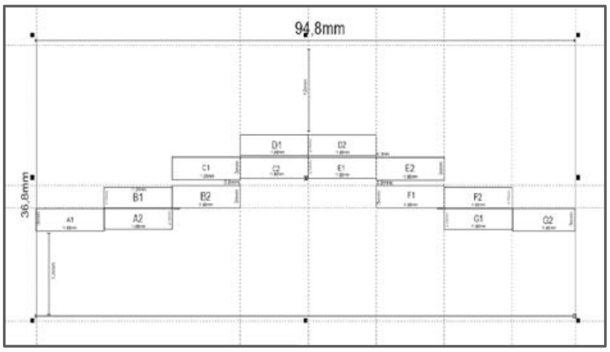

Figure 1. Layout for Simulation Bandpass Filter.

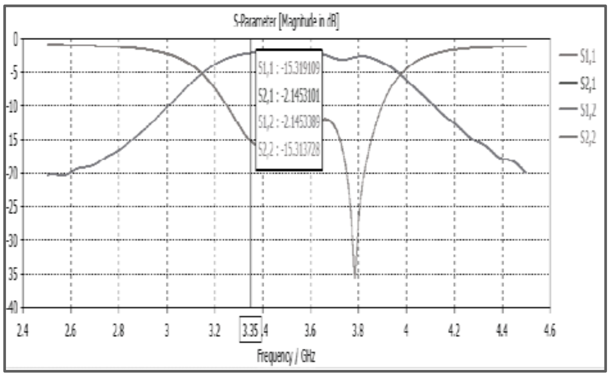

Figure 2. Simulation Result of Compact Coupled Line BPF.

The simulation of proposed design is produces a bandwidth about 1.2 GHz shown by the value under -15 dB (< -15 dB) is depicted on Figure 2. The cutoff of filter (-3 dB down) at the frequency of 3.2 GHz to 3.9 GHz and the bandwidth of pass band is 700 MHz. The value of return loss on each port (S_{11} - S_{22}) at 3.35 GHz is -15.31 dB.

III. RESULT AND DISCUSSION

For the fabrication we use RT/duroid 5880 and using the SMA (Sub Miniature version A) connector. The photograph of the fabricated bandpass filter is shown in Figure 3.

Figure 3. The Photograph of Fabricated Bandpass Filter.

The measurement results were taken using an advantest vector network analyzer. For the measurement, a microstrip feed line of 12mm was added at both input and output sma connector. The dimension of the filter is 95 × 36 mm; there are some important parameters to consider in this design such as return Loss, insertion loss and narrow bandwidth.

Figure 4 shows the measurement result of S_{11} return loss and S_{22} insertion loss characteristic in one graph. The insertion loss at the center frequency 3.35 GHz is about -2.91 dB. The return loss at the center frequency 3.35 GHz is about -18 dB. The measurement of BPF produces bandwidth about 1.1 GHz shown by the value under -15 dB (< -15 dB) is depicted on Figure 4. The cutoff of filter (-3 dB down) at the frequency of 3.1 GHz to 3.5 GHz and the bandwidth of pass band is 400 MHz. The value of return loss on each port (S_{11} - S_{22}) at 3.35GHz is -18.2 dB. It indicates that only 1.513% of the power is reflected and reflection coefficient is 0.123.

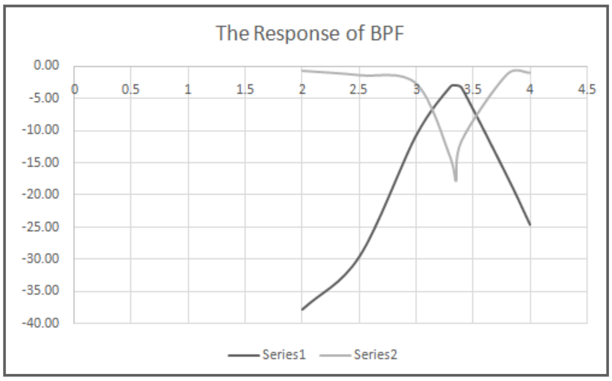

Figure 4. Measurement Result Response ($S_{11}$and S_{21}) of BPF.

Figure 5 shows the S_{11} characteristic. The VSWR at the center frequency 3.35 GHz is about 1.163 and the VSWR at pass band frequency 3.3 GHz and 3.40 GHz is about 1.354 and reflection coefficient 0.144. It indicates that only 2.08% reflected power.

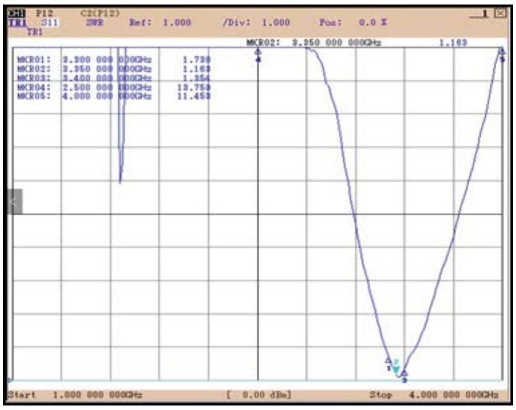

Figure 5. The S_{11}VSWR Characteristic of The Bandpass Filter.

The phase characteristic of the bandpass filter is shown in Figure 6. At the center frequency 3.35 GHz, the phase is -80.31 deg. We can tune the phase by changing the length of transmission line if we want the phase with another value.

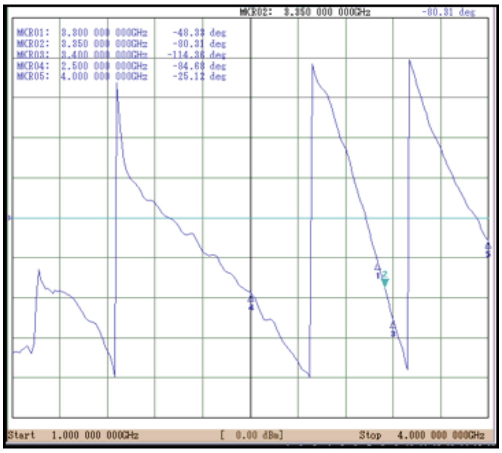

Figure 6. The S_{21} Phase Characteristic of BPF.

From the simulation and fabrication, we obtain that the characteristic of S_{11} and S_{21} are approximately similar. The measurement results show the insertion loss from S_{21} is -2.5 dB and the bandwidth of the filter is 400 MHz from 3.1 GHz MHz to 3.5 GHz. Both simulation and measurement results showed that the designed filter can be used for the 3.35 GHz WiMAX application. The slight difference between simulation and measurement results occured due to soldering process of SMA connector.

CONCLUSION

The results of measurement and simulation show a good filter performance. On the other hand, the result of fabrication shows differences with the simulation, which depends on the number of mesh during the simulation run. There is little different bandwidth response between simulation and realization, based on the ADS simulation results, the designed has an operational bandwidth of 700 MHz from 3.20 GHz to 3.90 GHz, otherwise on the realization bandpass filter, the designed has an operational bandwidth of 400 MHz from 3.10 GHz to 3.50 GHz. The compact coupled line BPF replace conventional coupled line BPF and compact coupled line BPF more simple and small compared to the Hairpin BPF. The results of the filter measurement were close to the values in required specifications. Both simulation and measurement results show the proposed filter design can be used for the 3300 MHz – 3400 MHz frequencies WiMAX application.

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