5.75 GHz Microstrip Bandpass Filter for ISM Band

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***Abstract*- This paper presents on 5.75 GHz bandpass filter based on IEEE802.11a standard for wireless LAN application. The development of bandpass filter includes calculation, simulation, testing and measurement of the filter parameters process has been presented. Simulation software for this project used Ansoft Designer software. The filter operates at center frequency of 5.75 GHz with 100 MHz bandwidth and insertion loss below 10 dB. The bandpass filter contributes to the application of direct conversion front-end receiver for WLAN application at 508 GHz frequency.**

Index term: bandpass filter, microstrip filter, parallel coupled line filter, 5.8 GHz filter, WLAN filter

I. INTRODUCTION

Recently, 5.8 GHz band Wireless Local Area Network (WLAN) is becoming more widely recognized as an economical alternative for short distance voice and data communication. Wireless LANs can provide all the functionality of wired LANs but without the physical constraints of the wire itself [1]. This project is focused on design and development of bandpass filter operating at 5.75 GHz for WLAN application. This band is allocated for the use of outdoor links. The increasing of WLAN applications resulting interference within the 2.4GHz ISM band and it is a major issue [2]. Revolution and demand of WLAN technology have urged development of low cost, low power and small size transceiver by using microstrip technology.

The main idea in this project is to make sure that the filter contributes to the development of suggested new direct conversion receiver for WLAN application as show in figure 1. Superheterodyne architecture is still popular due to high performance in terms of selectivity and sensitivity but lack in term of fully integration solution as reported in [3] and [4]. This is due to passive components such as SAW filter that cannot be integrated into the IC module, which is an active component. The direct conversion architecture is more popular because of its low cost [5], high integration [6] and no problem of image. Instead no RF tuning circuit required for this architecture.

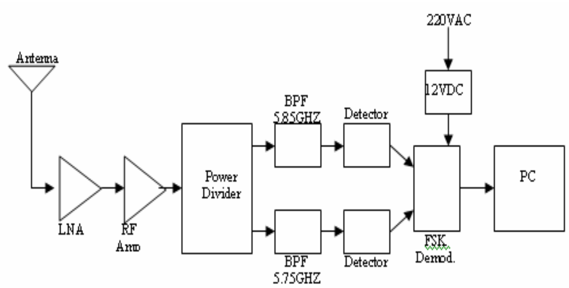

Fig 1: Suggested new direct conversion RF Receiver block diagram

Nonlinear circuit in wireless communication system, such as mixers and amplifiers, usually generate unwanted frequency components in additional to amplified desired signal. The unwanted frequency components are usually harmonic components, image signals and intermodulation distortion components, which will degrade the integrity of the desired signals [7]. Moreover, the drastic growth of new telecommunication system has brought severe constrains to microwave filters [8]. Satellite, radar and others wireless communication systems are use filter as frequency selective network for rejecting unwanted signals, suppressing noise and manipulating output signal characteristics [9].

Filter design method include image parameter method and insertion loss method. Image parameter method is featured by master-slave configuration of simple 2-port filters to represent cut-off frequency and attenuation

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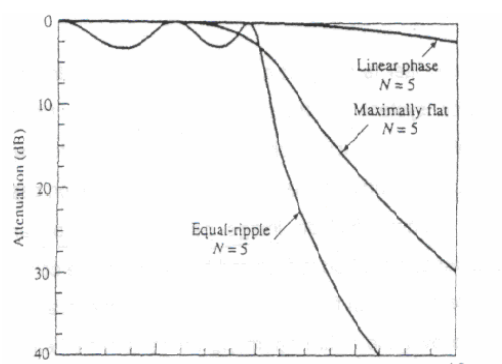
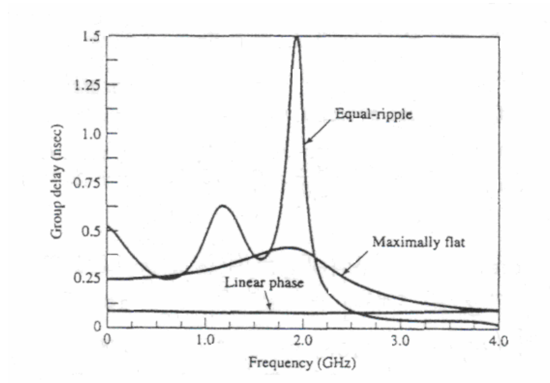
characteristic, but specific frequency response over the entire operating range is not taken into consideration. Therefore, design by image parameter method is comparatively simple but the same process should be repeated several times to get desired result. On the other hand, insertion loss method applies network synthesis technique to design a filter with desired frequency response. In other words, the insertion loss method synthesizes high pass filter, band pass filter or band rejection filter by converting prototype low pass filter normalized with reference to impedance and frequency. Filter types are classified into Chebyshev filter, Butterworth filter, Elliptic function filter and linear phase filter depending on frequency and phase response characteristics [1].

Figure 2 show frequency and phase response characteristics of a filter. Chebyshev (equal-ripple) filter generates some degree of ripple at passband but shows excellent cut-off characteristics at stopband. Butterworth (maximally flat) filter has flat insertion loss at passband but shows slow cut-off characteristics at stopband. Linear phase filter has slow cut-off characteristics at stopband compared with butterworth filter or Chebychev filter but shows linear change in phase at passband. Therefore, it is desirable to design a proper filter according to application. Microstrip line filter, which allow implementation of both compact size and integration, rather than integrated device filter are used for superhigh frequency band. Microstrip line filter types include stub filter, step impedance filter and coupled filter [1].



(a)Attenuation characteristic vs. frequency



(b) Group Delay vs. frequency

Fig 2: Frequency response characteristic of filter [1]

II. FILTER DESIGN

Coupled line band pass filter can be manufactures by connecting the coupled lines. To induce design equation for this type of filter, one coupled line is modelized into the equivalent circuit. Then, image impedance and propagation constant of the equivalent circuit can be calculated from this and it can be seen that these values approach to the values of coupled lines for θ = π/2, which corresponds to the center frequency of band pass response. The parameters of the equivalent circuit can be represented as:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cos\theta & jZ_0 \sin\theta \\ \dfrac{j\sin\theta}{Z_0} & \cos\theta \end{bmatrix} \begin{bmatrix} 0 & -j/J \\ -jJ & 0 \end{bmatrix} \begin{bmatrix} \cos\theta & jZ_0 \sin\theta \\ \dfrac{j\sin\theta}{Z_0} & \cos\theta \end{bmatrix}$$

$$= \begin{bmatrix} \left(JZ_0 + \dfrac{1}{JZ_0}\right)\sin\theta\cos\theta & j\left(JZ_0^2 \sin^2\theta - \dfrac{\cos^2\theta}{J}\right) \\ j\left(\dfrac{1}{JX_0^2}\sin^2\theta - J\cos^2\theta\right) & \left(JZ_0 + \dfrac{1}{JZ_0}\right)\sin\theta\cos\theta \end{bmatrix}$$

Therefore, image impedance of the equivalent circuit is given by:

$$Z_i = \sqrt{\frac{AB}{CD}} = \sqrt{\frac{JZ_0^2 \sin^2\theta - 1/J\cos^2\theta}{\left(1/JZ_0^2\right)\sin^2\theta - J\cos^2\theta}}$$

At the center frequency θ = π/2, this reduces to:

$$Z_i = JZ_0^2 = \frac{1}{2}\left(Z_{0e} - Z_{0o}\right) \quad (3.3)$$

Propagation constant is:

$$\cos\beta = A = \left(JZ_0 + \frac{1}{JZ_0}\right)\sin\theta\cos\theta = \frac{Z_{0e}+Z_{0o}}{Z_{0e}-Z_{0o}}\cos\theta \quad (3.4)$$

Therefore, it is assumed that sin θ = 1, if θ = π/2. These equations can be analyzed to give even and odd mode line impedance:

$$Z_{0e} = Z_0\,[1 + JZ_0 + (JZ_0)^2] \quad (3.5)$$
$$Z_{00} = Z_0\,[1 - JZ_0 + (JZ_0)^2] \quad (3.6)$$

First, order of filter to be designed should be determined through attenuation graph for the normalized frequency. Then, parameter value (gn) of LPF prototype should be determined using the table of parameter value of LPF for Chebyshev filter. Based on this parameter value, admittance conversion constant (Jn) is calculated using the formula (3.6) and (3.10) and even mode and odd mode impedances are calculated using the formula (3.5) and (3.6) respectively. After obtaining even mode and odd mode, the filter can be manufactured by connecting coupled line. Further attenuation graphs and parameter value (gn) of LPF prototype can be easily found in textbooks describing microwave electronics.

$$Z_0 J_1 = \sqrt{\frac{\pi\Delta}{2g_1}} \quad (3.7)$$

$$Z_0 J_n = \frac{\pi\Delta}{2\sqrt{g_{n-1}g_n}} \quad (3.8)$$

For n = 2, 3, 4, N

$$Z_0 J_{N+1} = \sqrt{\frac{\pi\Delta}{2g_N g_{N+1}}} \quad (3.9)$$

For n = N + 1

$$\Delta = (\omega 2 - \omega 1)/\ \omega o \quad (3.10)$$

Based on the calculation, the filter is 9^{th}-order bandpass filter. The order of the filter can be determine from plotting the normalized frequency versus attenuation. After the desired specifications have been defined, a schematic of the bandpass filter will be generated in Ansoft Designer software. Figure 3 shows the schematic layout of the filter.

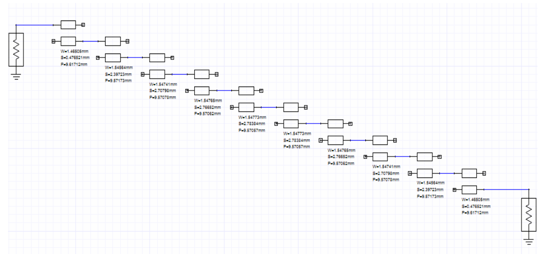


Fig 3: Schematic layout of the 9^{th} order bandpass filter

III. SIMULATION RESULT

In this project, Ansoft Designer software is used to generate schematic circuit of bandpass filter. Duroid 5880 is being used as the microstrip substrate and the characteristic of this substrate is shown in Table 1. The advantages of microstrip technology include simple, small size, light weight and durable finish as compared to conventional design [10]. These advantages are significant to smaller size RF components design, nowadays.

Table 1 shows the parameter value of the substrate Duroid 5880 that had been used in this project. While figure 4, 5 and figure 6 shows the simulated S-parameter of the filter.

Table I:
Duroid 5880 TLY-5A-0200-CH/CH substrate parameters

Dielectric	*Metalization*			
H = 0.508mm ε_r = 2.17 TAND = 0.0018 (5.8GHz)	*Material*	*Resistivity*	*Thickness*	*Unit*
	Cooper	1.72414	0.0175	mm

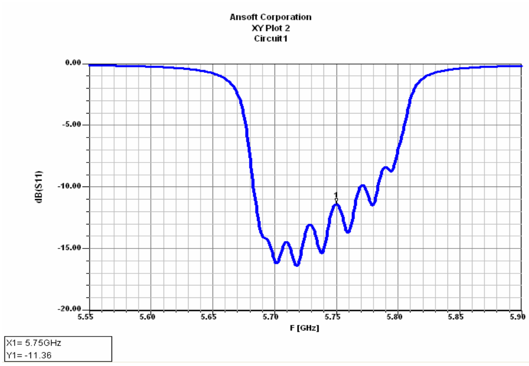


Fig 4: S-parameter (S11)

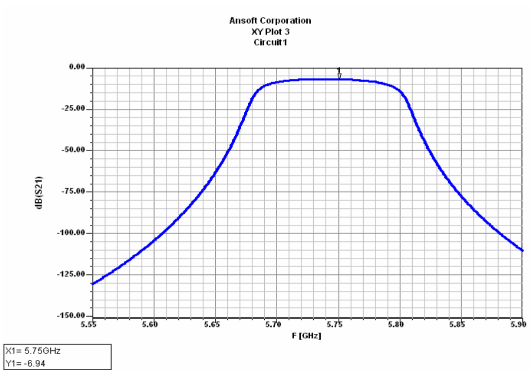


Fig 5: S-parameter (S21)

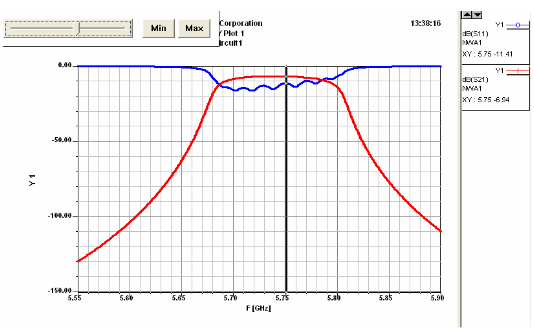


Fig 6: S-parameter (S11&S21)

IV. FABRICATION AND MEASUREMENT RESULT

Fabrication was accomplished by a manufacturer because lack of technology and instrument for this purpose. The designed circuit was also tuned and optimized by the manufacturer in order to get an optimum layout. Somehow, the performances of the simulated circuit are remained.

Figure below (figure 7, 8, 9 and 10) show the measurement results for S-parameter. The measurement results are then had been compared with simulation results and concluded in table 2.

During measurement process, losses took place. So the measurement result not the same as the result in simulation. The comparison between simulation result and measurement result is shown in table 2.

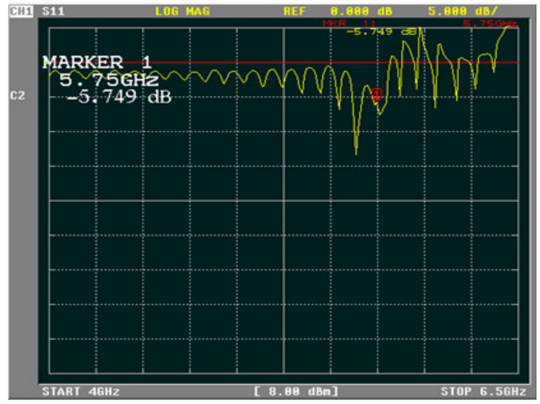


Fig 7: S-parameter (S11)

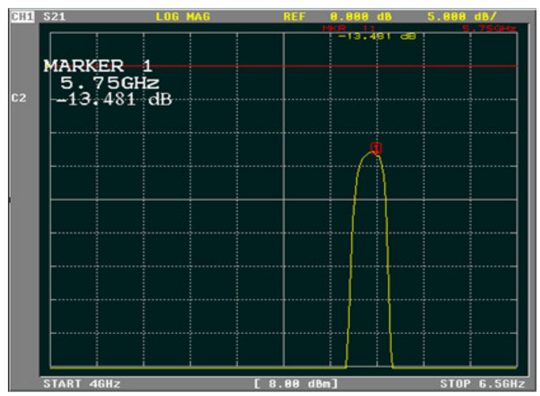


Fig 8: S-parameter (S21)

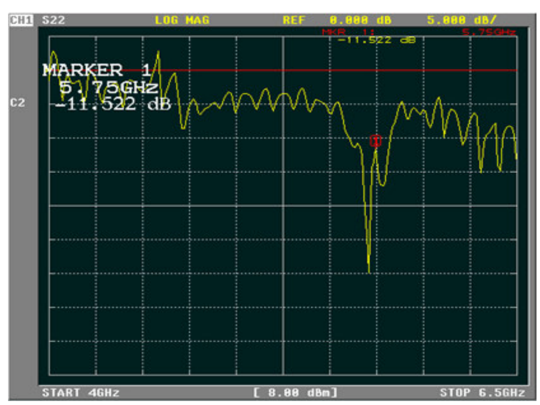


Fig 9: S-parameter (S22)

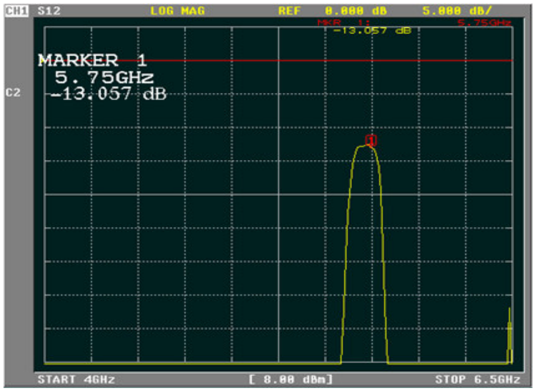


Fig 10: S-parameter (S12)

Table II:
Comparison of expected result, simulation result and measurement result of bandpass filter

	Expected Results	Simulation Results	Measurement Results
Center Frequency	5.75 GHz	5.75 GHz	5.75 GHz
Insertion Loss	10 dB	4.86 dB	7.73 dB
Bandwidth	100 MHz	100 MHz	103 MHz

Fig 11: Fabricated bandpass filter

V. CONCLUSION

This paper has presented the design and development of ninth order parallel coupled microstrip line bandpass filter that has been built on the Duroid5880 substrate. The filter operates at center frequency of 5.75 GHz with 103 MHz bandwidth. The filter has insertion loss of 7.73 dB and stopband attenuation 63.21 at 5.85 GHz.

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