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DESIGN OF MULTIBAND MATCHED BAND-STOP FILTER USING T-SHAPE RESONATOR NETWORK SYSTEM

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ABSTRACT

Wireless communication system is a system that transfer information among two or more points that are not connected by an electrical conductor while microwave filter is the elementary element in each radio frequency (RF) front-end telecommunication structure, moreover as band reject or band select components for transceivers and receivers. In designing a complicated wireless communication system or any other system that is working at microwave frequencies, noise is one of the big challenges. One of the techniques that can be used to avoid noise, or any other interference signal is by applying filtering techniques. For microwave communication front-end system, a band-stop filter can separate frequency band positioned inside a wide-ranging pass-band. Firstly, a single-band matched band-stop filter using T-shape resonator. Two different design had been done at 1.0 GHz and 1.5 GHz with S_{21} center frequency at – 16.063 dB and – 14.059 dB, respectively. Then, the combination of the multiband matched band-stop filter using T-shape resonator will be design at center frequencies of 1.0 GHz and 1.5 GHz with two S_{21} center frequency at – 16.281 dB and – 16.962 dB, respectively. The simulation process for this design is using Advanced Design System (ADS) simulation software and fabricated using FR-4 board. In real situation, this project will be able to isolate the signal of interest from interference signals at desired frequencies.

Keywords: *Wireless Communication System, Multiband Matched Band-Stop Filter, Band-Stop Filter, T-Shape Resonator*

1. INTRODUCTION

The demand from the user, industries players of the microwave filter in radio frequency (RF) communication system area effect to create a powerful and enhanced performance design that can used in Wireless LAN, WiMAX, and other applications. In cellular radio area, this microwave filters are located at base station and telephone center that differential the desired and undesirable frequency over network system [1]. Radio frequency or microwave filter is a passive device with a combination of the two-port network with

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functioning to passes the desired signals while to block the undesired signals.

Figure 1 shows the block diagram of RF front end of the cellular base station system with transmitter filter and receiver filter located after the antenna. The other component in this system is antenna, power amplifier, low noise amplifier and up-down converter. Performance of telecommunication system might be tarnished meanwhile the interference may be occur due to the occurrence of signals from other present wireless communication systems. Band-stop filter is the important elements that in microwave design since it used to suppress undesired signals in the complete front-end communication system.

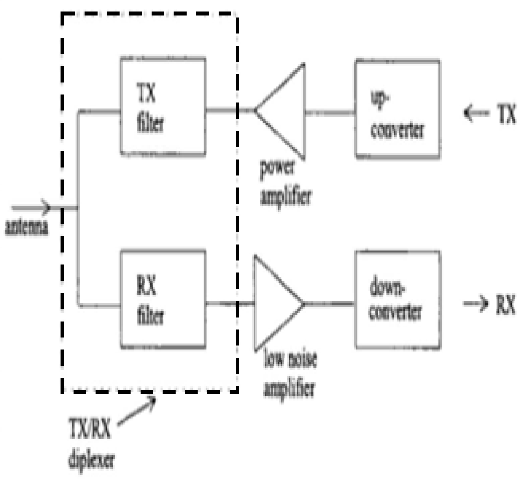

Figure 1. RF front end of the cellular base station system [1]

There are several techniques that used by the researcher such as using metamaterial structure like split ring resonator, defected ground structure (DGS), defected microstrip structure (DMS), ring filter, impedance resonator structure or using photonic crystal filter [2-11].

Much research has been agreed out in order to develop multiband matched band-stop filter. Multiband matched band-stop filter is designed for applications such as advanced communication and electronic warfare systems by basically cascading two single-band matched band-stop filter [12]. Microwave or radio frequency (RF) band-stop filters are extremely chosen for their actual suppression of unwanted signals in wireless telecommunication applications.

The band-stop filter was practical in an active component circuit design. From the previous work, it shows that the example of active component are a mixer and oscillator to eliminate higher order harmonics and another counterfeit signal [13]. Essentially, the tand-stop filter (band-rejection filter) will insulate frequency band situated inside a wide pass-band. For a perfect band-stop filter, an attenuation of frequencies will occur between the range of frequencies between the lower cut-off frequencies, f_1 and upper cut-off frequencies, f_2. The frequencies that is not in the range between f_1 and f_2 is permitted to pass and is recognized as a pass-band region. Figure 2 illustrate the fundamental frequency response for band-stop filter with lower cut-off frequencies, f_1 and upper cut-off frequencies, f_2.

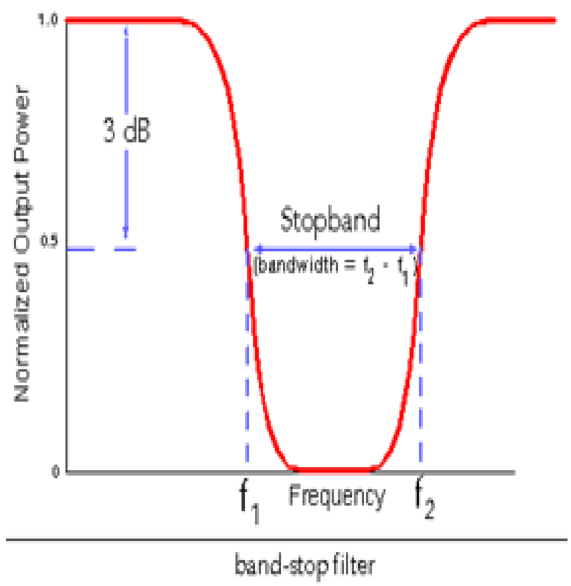

Figure 2. Band-stop frequency response with lower cut-off frequencies, f_1 and upper cut-off frequencies, f_2

Many techniques on band-stop filter had been used previously such as frequency selective surface, defected ground structure (DGS), and others. There is example on the band-stop filter design such as in Sarika [14] that design a band-stop filters for X-band and Ku-band applications using fractal frequency selective surface (FSS) structure. In this case, 10 mm width x 10 mm length of FSS element had been used at 8.6 GHz, 11.9 GHz and 17.5 GHz with bandwidth of 1.6 GHz, 1.4 GHz and 1.7 GHz, respectively. Kumar [15-16] also used the DGS in his band-stop filter design. In his case a dumbbell-shaped DGS effect at 4.3 GHz of resonant frequency and 3-dB cutoff frequency is 4.0 GHz and Q-factor of 0.93. This DGS also effect to miniature the size of the filter design.

In other design, Matoug [17] had been design tunable band stop filter using thin film bulk acoustic wave resonator (FBAR) of Barium Strontium Titanate. This filter effect at 4.76 GHz with 13.5 dB insertion loss when applied voltage of 10 V. When there is no voltage apply or 0V, there are no frequency switching with high insertion loss. Rahman [18] describe on his paper on the multiband effect on the compact ultra-wide band (UWB) antenna that act as band-stop filter. Five range of frequency had been attained at 3.30 GHz - 3.60 GHz, 5.150 GHz - 5.350 GHz, 7.0 GHz - 7.40 GHz, 8.10 GHz - 8.50 GHz for WiMAX, lowe WLAN, upper WLAN, downlink X-band and uplink X-band, respectively.

Besides that, in the paper of Verma [19], a square shaped defect etched defected ground structure (DGS) had been applying to create a small size of the band stop filter. This 14 mm width x 14 mm length filter operate 300 MHz of frequency. BalaSenthilMurugan [20] in his paper stated that modified L-resonator band stop filter achieve – 60.0 dB attenuation at 2.45 GHz for microwave application. It also shows the bandwidth improvement of 6.3 % from 0.56 GHz to 0.71 GHz, effect of cascaded structure filter.

In this work, the matched band-stop microwave filter using T-shape resonator with multiband effect with center frequency at 1.0 GHz and 1.5 GHz. Before that, a several examples of the literature review on the band-stop filter that using T-shaped resonator had been present.

2. LITERATURE REVIEW ON BAND-STOP FILTER DESIGN USING T-SHAPED RESONATOR

Basically, there are many researchers that focus to using T-shape resonator structure for their band-stop filter design. This structure had a capability to improve or enhanced the microwave filter with different effect. Different structure used in the design will effect the performance of the microwave filter.

For the first design for review, Tantawy [21] had been applied this effective performance with small size design of T-shape resonator to create two different band notches in ultra-wideband (UWB) band pass filter (BPF). This filter is using RT Duroid substrate with dielectric constant of 3.38. In this case, the band notches are effected by a shunt series resonator branch of T-shaped resonator that connected to the rectangular middle patch. This filter is operating at UWB frequency range between 1.8 GHz to 10.6 GHz. The two band notches are located at two different frequencies at 7.25 GHz to 7.745 GHz for down link X-satellite band while 7.9 GHz to 8.395 GHz for uplink X-satellite band application. This T-shaped capability to control the resonate frequency by changes the dimension of its T-shaped length. This band notches are functioning to avoid the unwanted frequency range that effect the interference to the radio communication system.

Xiao [22] in his paper is design inner T-shaped defected microstrip structure (DMS) to create multiband effect of band-stop filter. There three different varieties of inner T-shaped that apply in his work, first is inner T-shaped at the center, second is inner T-shaped at the edge part, while the third consist two same size of the inner T-shaped that located at the left and right part of the filter design. This two pair T-shaped filter with 32 mm length x 1.2 mm width design is effect to operate three different frequencies at 2.16 GHz, 3.98 GHz and 5.96 GHz. It shows 1.2 dB and 1.4 dB of the insertion loss at between first-second stopband and second-third stopband, respectively. This combination technique creates the transmission zeros that basically expand the filter frequency selectivity significantly.

In other hand, Wang [23] in his paper introduced a novel band-stop filter (DBBSF) with the combination of T-shaped defected microstrip structures (DMS) and the U-shaped defected ground structures (DGS) technique. This combination technique effect to create dual band frequency at 3.49 GHz (Bandwidth between 3.33 GHz and 3.63 GHz) and the other one at 4.95 GHz

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(Bandwidth between 4.73 GHz and 5.16 GHz). The stopband rejections for both stopband are 57.7 dB and 46.4 dB, respectively. This structure successfully to miniaturize the microwave filter with only using 66.7 % size compared with the previous design of Ning [24]. In Ning paper, he designs a planar dual and triple narrow-band band-stop filter with the meandered slot defected microstrip structure (MS-DMS) and the simplified spiral microstrip resonator (SSMR).

Besides that, Shuang [25] had been designs a microstrip bandpass filter with dual-mode open-loop resonators with the combination of folded T-shaped stub and a W-shaped stub. This microwave filter is design for 2.4 GHz application with the return loss performance of – 20.9 dB with 3 dB bandwidth of 400 MHz. This microwave filter effect the wide bandwidth of 16.7 % at resonant frequency with the miniaturized size effect.

Lee [26] in his paper had been introduces T-shaped stepped impedance resonator (SIR) and L-shaped open stub for band-stop filter. It shows the insertion losses of 1.28 dB, 1.43 dB, 1.36 dB, with 2.12 dB, 23.7 dB, 16.1 dB, 25.2 dB, and 16.7 dB at frequencies of3.3 GHz, 7.3 GHz, 16.5 GHz, and 23.6 GHz, respectively. This combination technique effect to reduce the size of the band-stop filter.

JinLing [27] describe in his paper on his band-stop filter design that using a T-shape resonator. This filter is design for terahertz communication system using a metallic resonator on high-resistivity silicon wafer. It shows that a center frequency for this design are at 0.436 THz and 0.610 THz with performance of – 42.0 dB and – 28.0 dB, and with 0.2 THz and 0.8 THz of bandwidth, respectively.

Liu [28] in his work had been design a triband frequencies band-stop filter using T-shaped structure with dimension of 78.3 mm width x 64.7 mm length. In his work, three passbands are creating at the frequencies range of 1.05 GHz – 1.3 GHz, 1.85 GHz - 2.05 GHz and 2.75 GHz - 2.9 GHz. From his experiment, it can see that the lowest insertion losses at three passbands are 0.5 dB, 1.3 dB and 1.3 dB with return loss of 15 dB, 15 dB and 10 dB, respectively. It also stated in his paper that high isolation of 28 dB and 50 dB between three passbands range.

In other work, Yechou [29] had been design a T-inverted shaped open stubs for band-stop filter. In this work, a wideband effect from the design while it also effect to reduce the size of the filter with 23.25 mm x 2.2 mm of L-shaped stubs and 43.4 mm x 34.5 mm for overall size of the band-stop filter. It shows performance below 20 dB with a sharp and wide rejection at resonance frequency with bandwidth is 890 MHz at 1.8 GHz of frequency.

Another technique is use metamaterial structures split ring resonator (SRR) structure in the band-stop filter, such as in Mishra [30] works. In his design, the SRR are located at band-stop filter that applied at frequency range 3.24 GHz to 4.78 GHz with center frequency at 4.01 GHz and bandwidth performance of 38.4 %.

Lastly, in Jose [31] paper, he successfully to design a tunable coplanar waveguide (CPW) band-stop filter by manipulating the T-shaped DGS and combined with the switches. In his design, four MEMS series switches are encumbered ended each of the four branches of a T-shaped DGS structure and effect to increase the resonant frequencies of the band-stop filter from 22.0 GHz to 20.0 GHz. The bandwidth of this band-stop filter can be control from the embedded 0.1 µm MEMS switches.

3. BAND-STOP FILTER DESIGN

A basic design of the microstrip bandpass filter is the side-couple filter, that constructed based on the transmission line theory. This section focusses on the lossy all-pass network in a band-stop limiter and a perfect notch concept.

3.1 Lossy All-pass Network in A Band-stop Limiter

A micro-strip technology has a natural lossy that effect it difficult to realize a high Q-factor [32]. Higher Q designates a lesser rate of energy loss relative to the kept energy of the resonator. The perfect matched band-stop filter is the design created depends on the K-inverter topology for lossy resonator that contain of a similar coupled $\lambda/2$ short circuit transmission line that formed a

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supposedly 90° phase shift component among the resonator couplings in one designed [33].

Figure 2 represents the two equal lossy resonators that are tied to a 3-dB 90° hybrid coupler with right coupling factors [3] improve the Q factor of band-stop limiter. This technique can produce a higher stop-band attenuation, compact in size and matched at the input and output port of band-stop filter [34].

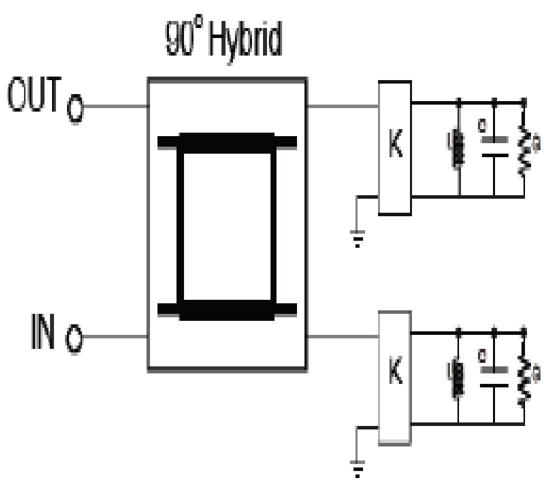

Figure 2. Implementation of a hybrid circuit in a perfectly-matched notch filter [35, 36]

Deliberate an equal two-port network definite by even an odd-mode admittance Y_e and Y_o. The S-parameter are then given by:

$$S_{11} = \frac{1 - Y_O Y_E}{(1 + Y_O)(1 + Y_E)}$$
$$S_{12} = \frac{Y_O Y_E}{(1 + Y_O)(1 + Y_E)}$$

if $Y_O = {}^{1}/_{Y_E}$, henceforth $S_{11} = 0$ for all ω. The system is then impeccably matched.

$$S_{12} = \frac{Y_O - Y_E}{(1 + Y_O)(1 + Y_E)} = \frac{(1 - Y_E)(j + 1)}{(1 + Y_E)(j - 1)} = \frac{(1 - Y_E)}{(1 + Y_E)}$$

if the network is lossless, then Y_E is a reactance function,

$$Y_E = j\frac{N(\omega)}{D\,(\omega)}, \text{ given } S_{12}(j\omega) = \frac{D - jN}{D + jN}$$

and $|S_{11}|^2 = 1$ for all ω (an all-pass work).

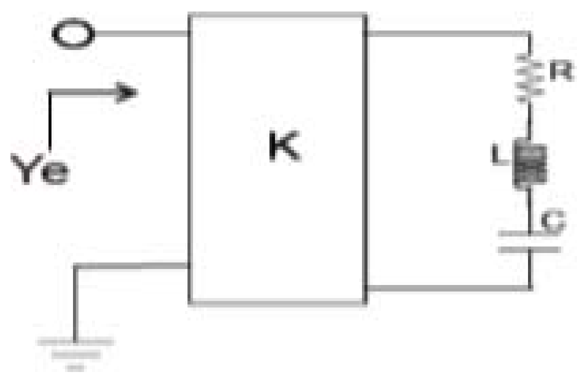

Figure 3. Even-mode admittance of a lossy resonant circuit [35,36]

By considering Y_E is a lossy resonant circuit,

$$\text{Let, } Y_E = L_P + \frac{1}{C_P} + R$$

Pretentious $Y_O = {}^{1}/_{Y_E}$, then

$$|S_{11}(j\omega)|^2 = \frac{(1 - R)^2 + (\omega L - {}^{1}/_{\omega C})^2}{(1 + R)^2 + (\omega L - {}^{1}/_{\omega C})^2}$$

If $R = 1$,

$$|S_{12}|^2 = \frac{1}{1 + \frac{4}{Qu^2\left[\frac{\omega}{\omega_O} - \frac{\omega_O}{\omega}\right]^2}}$$

Which is the transfer function of ideal lossless band-stop resonator, Q_U is the unloaded Q.

$$Q_U = \frac{\omega_O L}{R} \rightarrow (8)$$

3.2 Perfect Notch Concept

Once the narrow stop-band is founded, it is named a band notch filter [2]. Two lossy low Q resonator will be used to demonstrate the perception and design of perfect matched band-stop filter, so a high notched depth and selectivity of matched band-stop filters can be produced [2,5]. To produce a

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maximum attenuation and to enhance the Q factor of band stop limiter as shown in Fig. 4, notch concept of filter is applied.

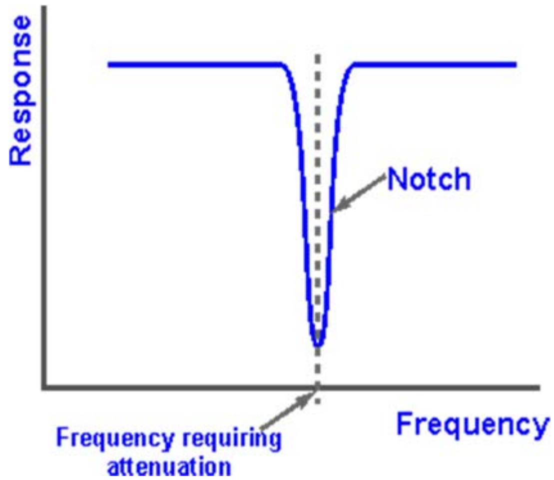

Figure 4. Notch band-stop frequency response

A multiband matched band-stop filter is calculated by basically cascading the two single matched band-stop filters at center frequency of 1.0 GHz and 1.5 GHz. This simulation work is to demonstrate that the impeccably matched band-stop filter allows the structure of a multiband matched band-stop filter. The structure apparatuses a narrow band of single frequency response and matched at all frequencies.

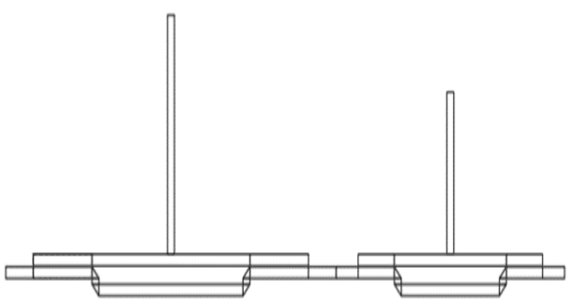

Figure 5. Shape of Multiband Matched Band-stop Filter Design

4. RESULT

This section displays the result of the single-band matched band-stop filter and multiband matched band-stop filter. The important main result is the resonant frequency (center frequency) and insertion loss performance of the several band-stop filters.

4.1 Single-band Matched Band-stop Filter

The project of multiband matched band-stop filter will be done both software and hardware. In this case, the multiband matched band-stop filter will be using the one type of resonator, and the resonator that being used is T-shape resonator.

The ADS software was used in designing this project. The first thing that needs to be fixed was the center frequency. For this multiband matched band-stop filter, the center frequency being fixed to 1.0 GHz and 1.5 GHz. Perfect multiband matched band-stop filter can be done by cascading the two perfect single matched band-stop filters.

Figure 6 shows the layout of single band matched band-stop filter at center frequency of 1.0 GHz and 1.5 GHz respectively. T-shaped structure patch is contained of two rectangular lines. The width of the lines is W and W_1 and the height is L and L_1.

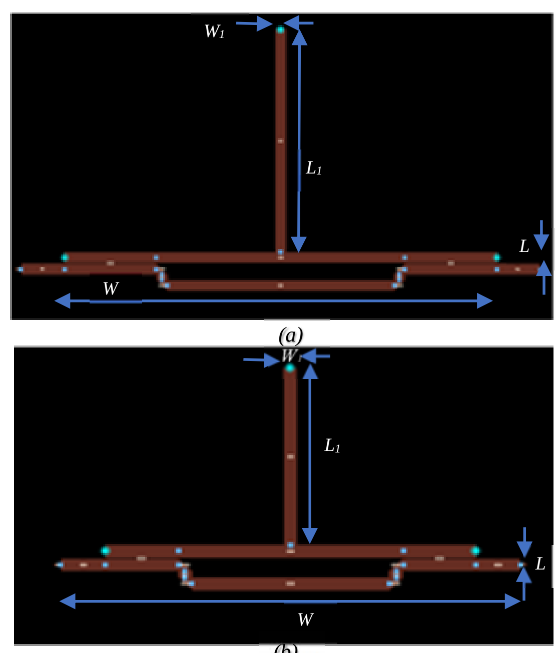

Figure 6. Single band matched band-stop filter at center frequency, (a) 1.0 GHz and (b) 1.5 GHz

Figure 7 shows the simulation result obtained for 1.0 GHz and 1.5 GHz for single band matched band-stop filter. In this work, the different

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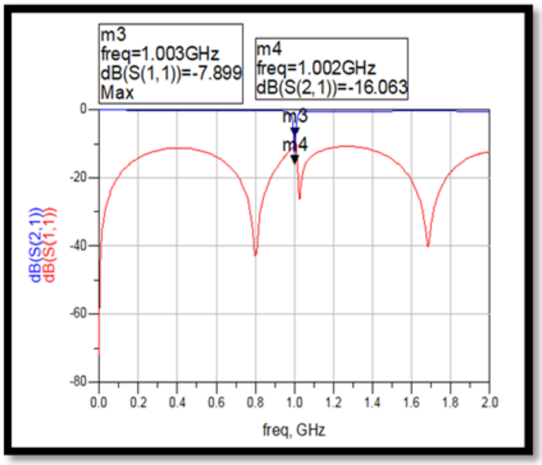
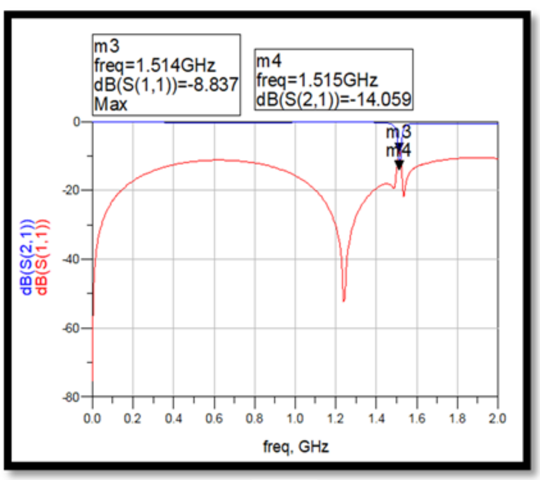
dimension of the band-stop filter can be effect to the location of the S_{21}. Both band-stop shows a single frequency range of performance. The S_{21} result for 1.0 GHz and 1.5 GHz are – 16.063 dB and – 14.059 dB, respectively.



(a)

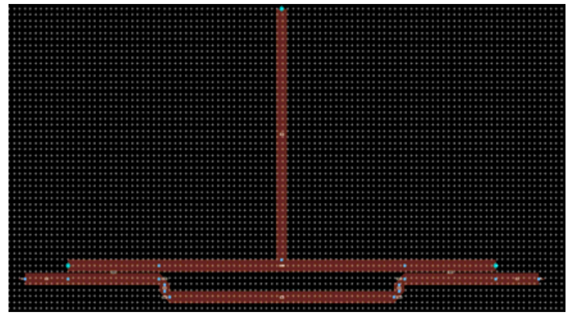


(b)

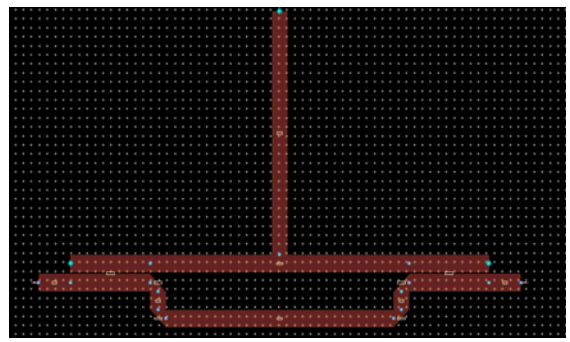
Figure 7. S_{11} and S_{21} results of single band matched band-stop filter at center frequency, (a) 1.0 GHz and (b) 1.5 GHz

4.2 Multiband Matched Band-stop Filter

Figure 8 expressions the layout of single matched band-stop filter and the multiband matched band-stop filter, respectively. This both singles matched band-stop filter is same as the previous while the multiband matched band-stop filter is the combination of both single matched band-stop filter.



(a)



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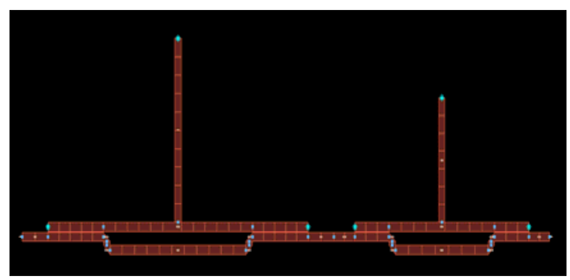

(c)

Figure 8: Layout of matched band-stop filter, (a) single-band of 1.0 GHz, (b) single-band 1.5 GHz and (c) multiband matched band-stop filter

Figure 9 shows the simulation result obtained for 1.0 GHz and 1.5 GHz for single-band matched band-stop filter and multiband matched band-stop filter. The S_{21} result for 1.0 GHz and 1.5 GHz are – 16.063 dB and – 14.059 dB, respectively. For multiband matched band-stop filter, the S_{21} is located at the same frequencies at two different location at 1.0 GHz and 1.5 GHz with – 16.281 dB and – 16.962 dB, respectively.

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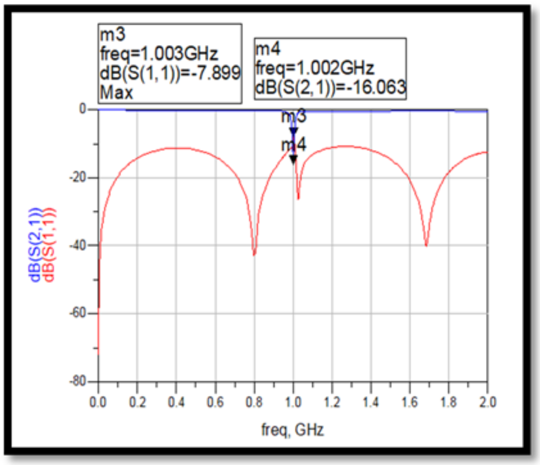
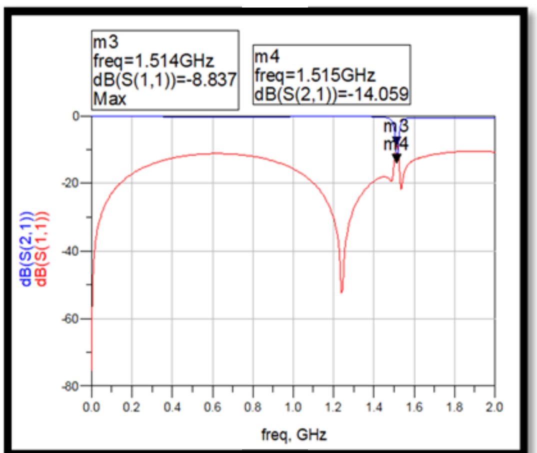
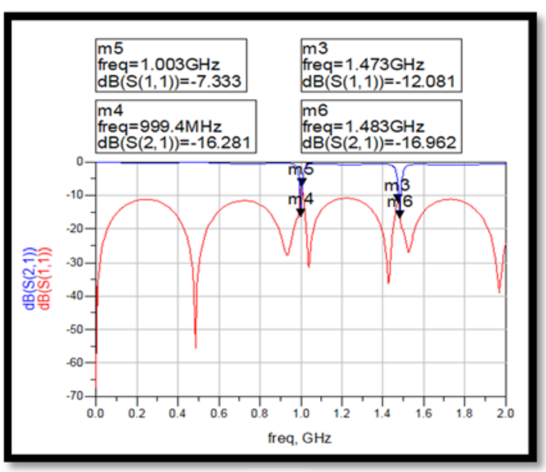


(a)



(b)



(c)

Figure 9. ADS simulator result for matched band-stop filter, (a) single-band of 1.0 GHz, (b) single-band 1.5 GHz and (c) multiband matched band-stop filter

Figure 10 represent the simulation and the measurement result for multiband matched band-stop filter. It shows that the differential result for both simulation and measurement but with the acceptable values. In the fabrication issue, the human error slightly may reflect the sensitivity of coupling gap is very critical. This will effect the performance of the measurement microwave filter results.

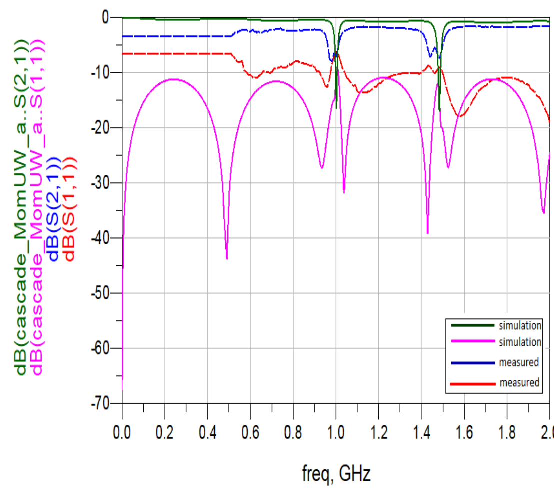


Figure 10. Multiband matched band-stop filter simulation and measurement result

After this simulation and measurement works had been done, this microwave filter had been capability to connect into the full system of front-end communication with several devices such as antenna, amplifier and other devices. The best performance of this microwave filter is effect to the right value and best performance to the complete system.

Compare with the current available filter that design by several researcher before, it shows that this filter is used the different size of double T-shaped resonator structure that compose two different resonant frequency. In other work by other researcher had been choose another frequency, but in this work two different resonant frequency at 1.0 GHz and 1.5 GHz had been chosen. Beside that, some modification technique also had been considering to design, and this design is did not same with previous work of other researcher.

For the future work, there are many techniques that can be used to enhance the performance of the microwave filter. The combination technique such as the embedded metamaterial structure into the design with the defected ground structure (DGS), defected microstrip structure (DMS). The example metamaterial structure that can be apply are split ring resonator (SRR), artificial magnetic conductors (AMC), electronic band gap (EBG) or photonic band gap (PBG). This metamaterial is effect to decrease the size and advance performance of the microwave filter.

5. CONCLUSION

The multiband matched band-stop filter work had been done in this paper. The theory, design, development and application of singleband and multiband matched band-stop filters using lossy resonators have been reported in this paper. The literature review, assumption theory and measurement investigation are proven which confirmation that the perfectly matched topology agrees the construction of multiband matched band-stop filter by basically cascading the two single band matched band-stop filter at center frequency of 1.0 GHz and 1.5 GHz. It shows the frequency performance at 1.0 GHz and 1.5 GHz with S_{21} of –16.281 dB and – 16.962 dB, respectively. By considering an even-mode and odd-mode analysis, the theory of matched band-stop filters using lossy resonator is derived from all-pass network. There is a design challenge in obtaining a perfectly matched band-stop filter, where it requires tuning or manual-optimization to optimize the attenuation or notch performance.

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