Multilayer Bandpass Filter Using Hairpin Resonator for Digital Broadcasting

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*Abstract*__**This paper presents 12.2-12.75 GHz bandpass filter using multilayer hair-pin resonator for digital broadcasting applications. The multilayer coupled resonator RF filter shows a significant size reduction and increase the bandwidth have been designed with the five-pole resonator centered at 12.475 GHz with bandwidth of 550 MHz This filter is simulated on RO3003 substrate with dielectric 3 using Computer Simulation Technology software (CST) .**

***Index term*__multilayer structure, bandpass filter, digital broadcasting.**

I. INTRODUCTION

TV can be broadcast by satellite, terrestrially or through cable. These three delivery methods have been for many years using analogue transmission. Recently, TV broadcasting is now undergoing a revolutionary change to digital broadcasting. Many countries worldwide including Malaysia are already using Digital Broadcasting by satellite. Satellite television like other communication relayed by satellite starts with a transmitting antenna located at an uplink facility and finally received radio wave from satellite transponder at downlink facility. Nonlinear circuit in satellite broadcasting system such as mixer and amplifier usually generate unwanted frequency components in additional to amplified desired signal. The unwanted frequency components usually harmonic components, image signal and intermodulation distortion components, which will degrade the integrity of the desired signals.

In recent years, the demand for small-size and high performance microwave filters is growing rapidly in various communication systems. Conventional design theory and circuitry of microwave filters are meeting new and exciting challenges in realizing unprecedented demands and applications.

This project is focused on design and development of two port network bandpass filter operating at 12.475 GHz for digital broadcasting. Bandpass filter restrict the passband between specific lower and upper frequency points where the attenuation is either low (bandpass) or high (bandstop) compared to remaining frequency band [3][9][10]. Filtering technology still focusing on how to operate in higher performance requirement, smaller size, lighter weight and lower cost. To meet these requirements, several types of planar microstrip filters, such as resonator filters, open loop resonator filters, and stepped impedance resonator filters have been proposed. However, planar microstrip filters are implemented on a single microstrip substrate layer which takes often a large size. To overcome this problem there has recently been increasing interest in multilayer bandpass filters. Recently multilayer structure approach has been proposed for reducing the size and increasing the bandwidth of the microstrip filters [2].

Based on stripline design approach, the parallel coupled lines model is chosen and used to demonstrate the performance of the filter on multilayer substrate. The filter is one of the filter structures that use parallel coupled lines. In this case, each pair of parallel coupled lines is connected to the next pair, not directly, but via a λ/4 impedance transformer. The multilayered architecture is primarily of two types: Core material (RO3003) and an epoxy material is used to fill the spacing between core material and ground. The physical layout for multilayer construction is depicted in Figure 1. Using a 3 layers PCB, the multilayer construction is created this way: Copper foil is laid down as Layer 1 of the PCB followed by layer 2 (epoxy). The core material that contains the upper and the lower resonators is applied on top as layer 3. The filter model is simulated using CST Microwave Studio (CST MWS) simulator to achieve the target specification as publicized in Table 1.

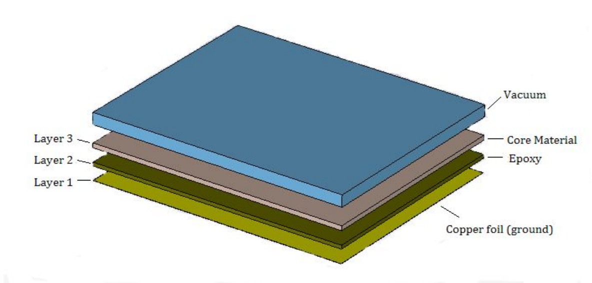

Figure 1: Multilayer construction

TABLE I
Filter Design Specifications

Filter Specification	Values
Center frequency	12.475 GHz
Lower cut-off frequency	12.2 GHz
Upper cut-off frequency	12.75 GHz
Insertion loss, *S21*	< -3 dB
Return loss, *S11*	> -20 dB
Bandwidth	550 MHz

Table 2 shows the properties of RO3003 material that are used to model the filter response.

TABLE II
RO3003 Substrate Properties

Parameters	Values
Dielectric constant, ε_r	3
Substrate height, ***h***	0.75 mm
Loss tangent, ***tan δ***	0.0013
Cooper thickness	0.035 mm

II. METHODOLOGY

Figure 2 described all the methodology involved in designing the filter. The alternately formed resonator may be spaced in overlapping style to obtain coupling that was physically impossible in microstrip application where the resonators were located on a single surface [2][10]. The dimension are then adjusted a number of times in order to improve the response of the filter.

Since the filter is operating at high frequency, the length of hairpin resonators become very short, thus, the "U" turn hairpin type is the optimum shape for designing this filter[2].

The proposed filter design method is simply derived from microstrip resonator design. By overlapping adjacent resonator on different layer, strong couplings between resonators can be achieved. Figure 3 illustrate the structure of the multilayer filter which resonator 1, 3 and 5 are arranged on the surface of the third layer of dielectric, while resonator 2 and 4 on the reverse surface of the dielectric. Since the resonator is implemented in two layer structure, adjacent resonator lines are placed on different variation of overlapping to obtained filter requirement.

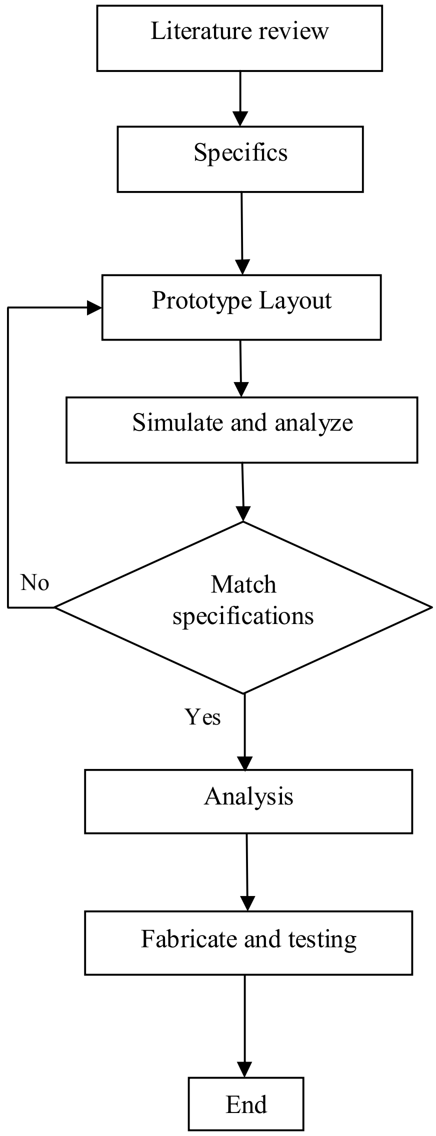

Figure 2: Design process flowchart

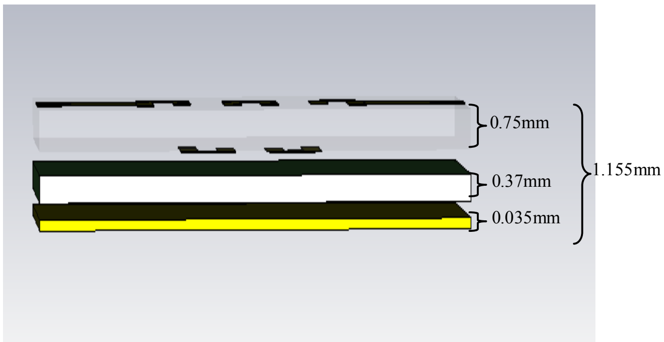

Figure 3: Fifth order multilayer bandpass filter

The tuning process was performed. The detailed resonator pattern on the third layer is described in Figure 4 and 5. The overall dimension of the filter is 9.585 × 14.935 × 1.155 mm^3.

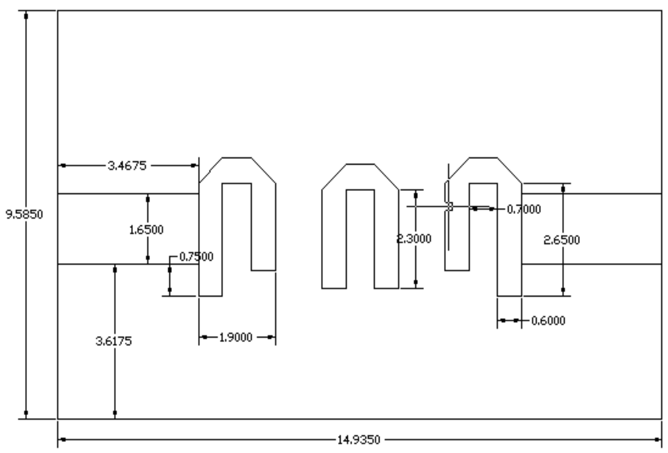

Figure 4: Dimension of resonators at the upper side

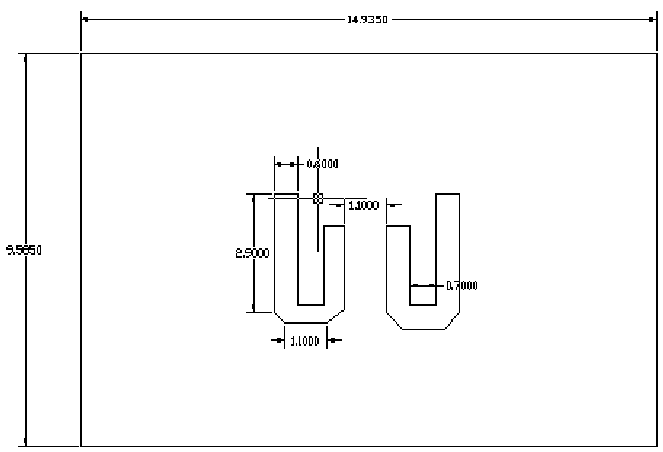

Figure 5: Dimensions of resonators at the bottom side

III. RESULTS AND DISCUSSION

The simulation has been done by using CST to compute the required S-parameter. The bandwidth is very good. Some further tuning need to be performed to achieve a better return loss and the exact bandwidth. Other factors that caused the error were due to the material loss, loss tangent and the adhesive epoxy that is used to join between the filter layers. However this loss is still good in multilayer filter since return loss is still better than -20dB, insertion loss less than -3dB and the measured center frequency nearly the same with the desired one. Figure 6 shows a simulated frequency of the targeted filter specification.

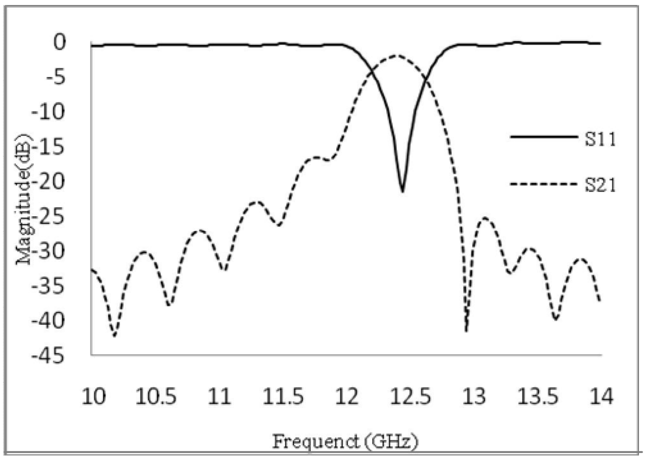

Figure 6: S-parameters of the simulation process

Table 3 shows the simulation results of the filter that has been designed, there is slightly different between the specific values and the simulation values of the filter, and nevertheless it is still acceptable.

TABLE III
Simulation results

Parameters	**Values**
Lower cut-off frequency (f_C), GHZ	12.206
Upper cut-off frequency (f_L), GHZ	12.629
Insertion loss (*S21*), dB	-2.297
Return loss (*S11*), dB	-21.51
Bandwidth, MHz	0.429
Center frequency	12.449

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If we compare the simulation results by using RO3003 and FR_4, we can observe the advantage of using a substrate with smaller dielectric constant and loss tangent.
Figure 8 and 9 show the simulating result of using RO3003 and FR-4 respectively.

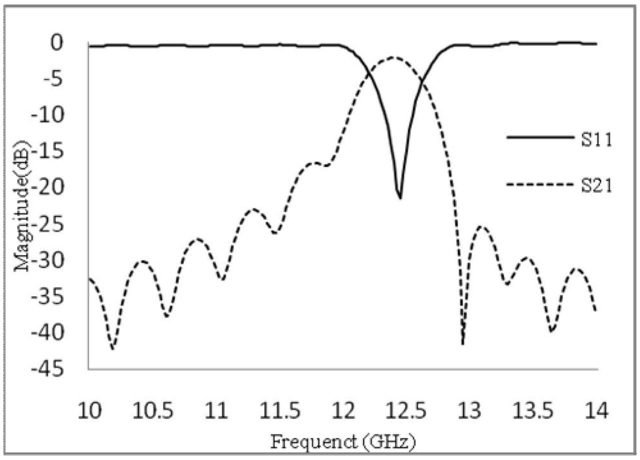

Figure 8: S-parameters by using RO3003

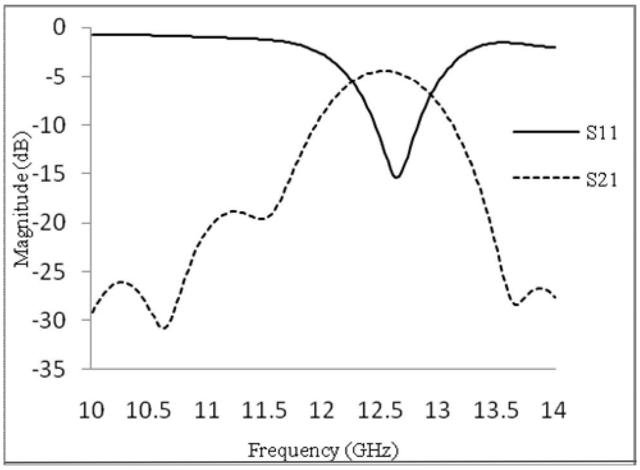

Figure 9: The S-parameters by using FR4

By increasing the length of the resonators, the bandwidth will be shifted to the left and vice versa.
Figure 10 and 11 will illustrate the effect of increasing the length of the resonators on the location of the bandwidth.

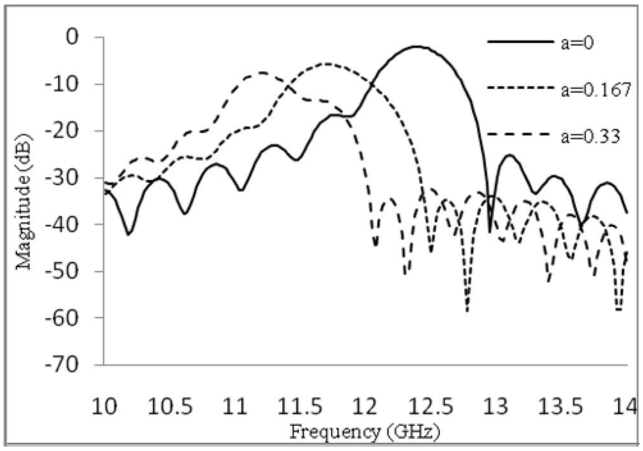

Figure 10: Insertion loss shifting (S_{21})

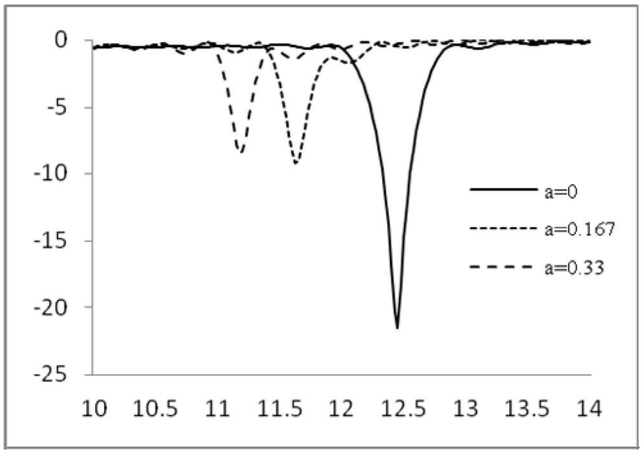

Figure 11: Return loss shifting (S_{11})

Increasing the width of the resonators will cause decreasing in both of the insertion loss (S_{21}) and return loss (S_{11}) with shifting in bandwidth. Both figures 12 and 13 show the effect of increasing the width of the resonators on S_{21} and S_{11} respectively.

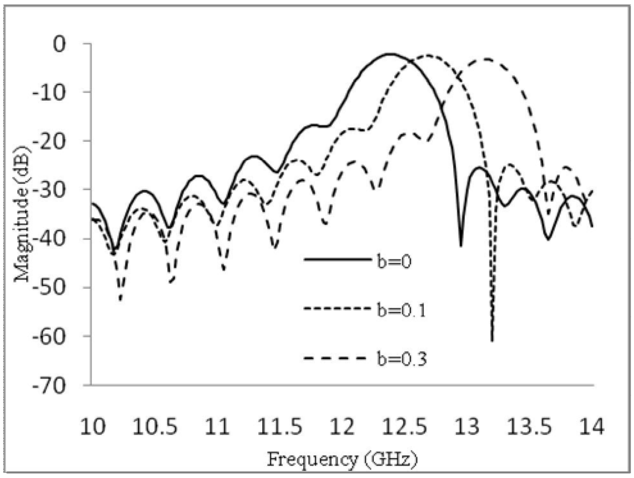

Figure 12: Insertion loss (S_{21})

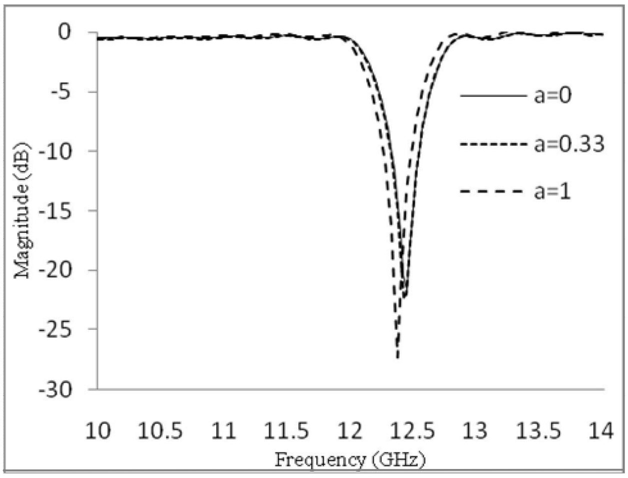

Figure 14: Return loss (S_{11})

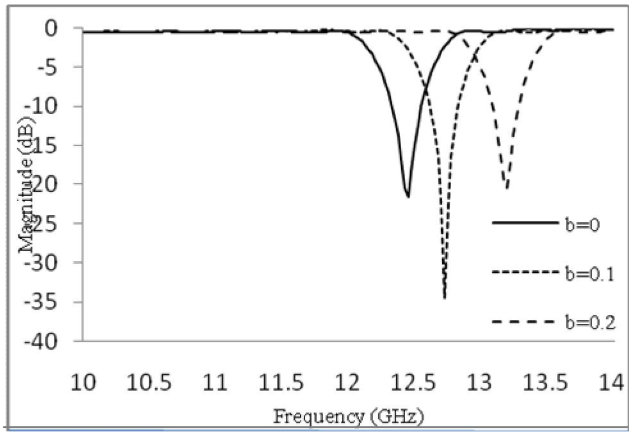

Figure 13: Return loss (S_{11})

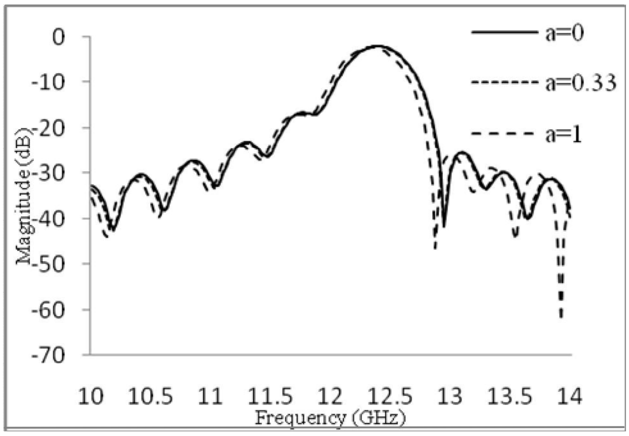

Figure 15: Insertion loss (S_{21})

By increasing the wavelength (λ), the physical size of the filter will increase because it has been considered that the length of the feeders is $\lambda/4$ and the distance between the resonators and the edge of the filter on the upper and the bottom sides is $\lambda/4$ as well.

Another effect of increasing the wavelength is decrease the magnitude of the return loss (S_{11}) and not much change in the magnitude of the insertion loss (S_{21}). Figure 14 and 15 show the effect of increasing the wavelength and its effect on both the return loss and the insertion loss respectively.

All these analysis has been done by using the sweep parameter function in the simulation software (CST) to ease study the effectiveness of changing one of the parameters of the filter rather than using the normal method (change the dimension one at a time and simulate).

IV. CONCLUSION

The multilayer bandpass filter has been presented. The multilayer structure can not only reduce the size of the filter greatly, but also introduce transmission zeros in the stop band to improve the frequency selectivity of the filter.

V FUTURE DEVELOPMENT

In future, this project can be improved by change the core material with another that has smaller dielectric constant or smaller loss tangent to improve the response at the passband and extend the range of the filter to cover the whole range of the digital broadcasting in Malaysia.

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