Multilayer Combline Bandpass Filter

Nurul Aimi bt Sulaiman
Supervisor: Robi'atun Adayiah Awang
Faculty of Electrical Engineering, Universiti Teknologi MARA Malaysia ,40450 Shah Alam, Selangor, Malaysia.
Email: aimi.sulaiman@yahoo.com

***Abstract* — In this paper, a bandpass filter using combline resonator is presented. The miniaturized band-pass filter is implemented using multilayer technique with broader bandwidth. It operates at centre frequency of 2.58GHz for satellite broadcasting application. The six-pole combline resonators were designed that give 7.9 % of bandwidth with return and insertion losses in the passband are -49.833 dB and -0.7878 dB respectively. The RO3003 substrate was used has 0.75mm thickness and a dielectric constant of 3. The circuit was simulated using Computer Simulation Technology, CST.**

***Keywords*- Bandpass filters, combline, multilayer, digital broadcasting**

I. Introduction

Nowadays, the continued growth in demand for satellite broadcasting systems in sending various types of signal, which are voice, video-conferencing, data, and multimedia applications provide a basis for development of a high performance wideband bandpass filter. The demand for the wide capacity and bandwidth come along with the demand of small size [1].

In order to fulfill this requirement it is recommended to use a combline bandpass filter structure. The combline filter consists of a set of metal bars, spaced, grounded at one end, and loaded by lumped capacitors or open circuited at the other side. The comblines are viewed as coupled TEM-mode transmission lines [2]. As shown in Fig. 1, the combline bandpass filter is comprised of an array of coupled resonators.

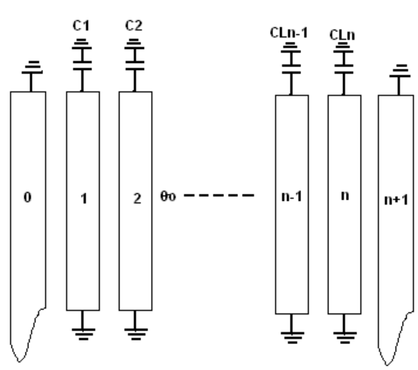

Fig 1. General structure of combline bandpass filter.

The resonators consist of line elements 1 to *n*, which are short-circuited at one end, with a lumped capacitance *CLi* loaded between the other end of each resonator line element and ground. The input and output of the filter are through coupled-line elements 0 and *n* +1, which are not resonators. With the lumped capacitors present, the resonator lines will be less than λ/4 long at resonance, where λ is the guided wavelength in the medium of propagation at the midband frequency of filter [3].

Since most of communication systems end up with a portable device for consumer cenvenience a multilayer approach can be proposed [4]. In [5], spreading all the resonator in a single layer will introduce dificultty in fabrication. This is due to the tight coupling lines between the resonators. Furthermore, multilayer is particularly effective when it comes to a higher order of resonator. In paper [6], the four pole combline bandpass filter was introduced with the bandwidth obtained only 130 MHz. Based on [7], a wider bandwidth can be realized by increasing the number of resonators. Thus, this paper presented six pole resonators of combline bandpass filter. This multilayer combline bandpass filter was designed based on the specifications that are shown in Table I:

TABLE I
DESIGN AND SPECIFICATION

Parameters	Specification
Lower cutoff freq, f_L (GHz)	2.52
Upper cutoff freq, f_U (GHz)	2.65
Center frequency, f_C (GHz)	2.58
Bandwidth (MHz)	>130
Insertion loss, S_{21} (dB)	>-3
Return loss, S_{11} (dB)	<-20

II. Methodology

Fig. 2 shows the overall process of doing multilayer combline bandpass filter.

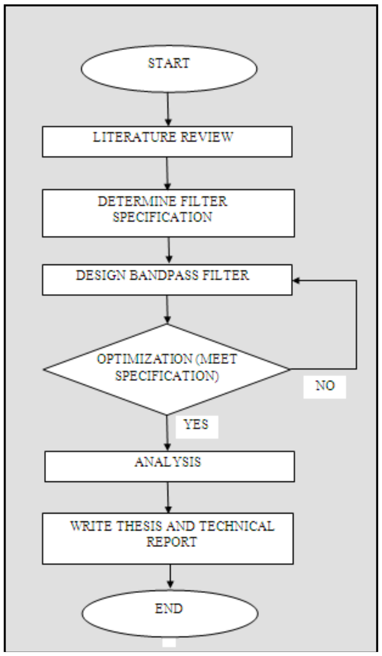

Fig. 2. Design flowchart

In this paper, the substrate used is RO3003 with thickness of 0.75mm, dielectric constant of 3 and loss tangent of 0.0013. The center frequency is 2.58 GHz. Fig. 3 illustrate three of the resonators with feeder was allocated on the upper surface of the dielectric substrate and the other three resonators were placed on the reverse surface of the dielectric substrate. The epoxy below the substrate acted as a glue to combine the multilayer structure. The total thickness is 1.19mm.

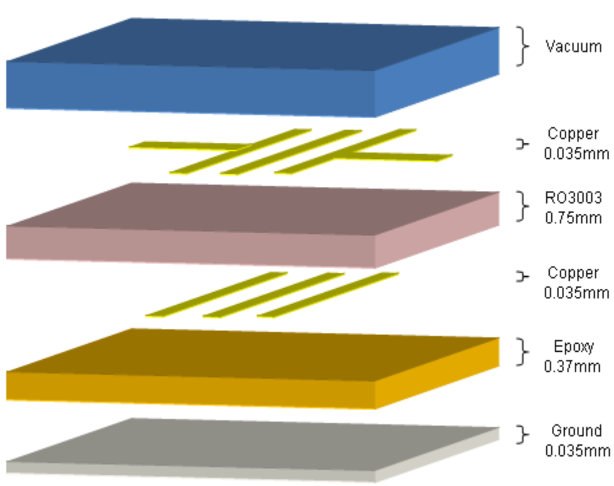

Fig. 3. Multilayer combline bandpass filter

After done with the structure, there are some values need to determine in order to design this multilayer combline bandpass filter. The width of the feeding line on top resonator is calculated using analytical line impedance calculator in CST to obtain 50Ω matching impedance. Quarter wavelength, λ/4 is considered on the length of resonator from outer to minimize the losses that can interfere passes through the copper resonators. Lastly, λ/20 gap between the top adjacent resonators minimized the parasitic effects that can occur between the passive elements of the resonators. However, optimizations still need to be done to obtain desired response to improve the result that obtained. Other than that, overlapping adjacent combline resonator on different layer can give strong couplings between resonator. The lengths, gaps, and position of the feeder also can be varied to modify the result [6].

The dimensions for top layer and inner layer are as shown in Fig. 4(a) and (b). Table II shows the summary for the dimensions layout. The total size of this multilayer combline filter is 43.72mm x 71.1mm.

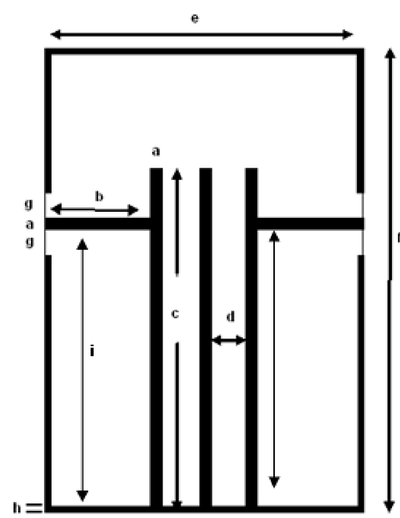

Fig 4. (a). Dimensions of top combline bandpass filter

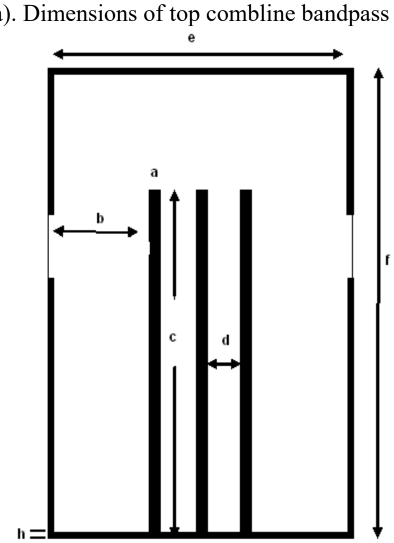

Fig 4. (b). Dimensions of inner combline bandpass filter

TABLE II
DIMENSION OF FILTER DESIGN

Parameters	Length(mm)
a	1.9
b	16.77
c	54.32
d	2.2363
e	43.72
f	71.1
g	3.5
h	1
i	43.5

III. RESULTS AND DISCUSSION

Simulation for the design has been done using CST MWS. It has two solver, which are transient solver, and frequency solver. In this simulation transient solver have been used due to the effect to the overall response as the pulse signal passes through the design filter and considering all the loss material used [4]. Fig. 5 and Table 3 show the simulated frequency response and the parameters obtained.

In order to achieve wider bandwidth, the number of resonators needs to be increased. The bandwidth of the circuit is 203.9 MHz, which is 7.9%. This is increasing 2.9% from the filter proposed by [6]. The bandwidth can be increased by summing up from the response of each dielectric resonator that resonates in a same mode e.g. if the first order of dielectric has a normalized resonant frequency, f1 with bandwidth, b1. The second order dielectric resonator has a normalized resonant frequency, f2 with bandwidth, b2. Next, the combination response of order in resonator could have a bandwidth that is the sum of b1+b2 [7].

The value of S_{11} and S_{21} are -49.8337 dB and -0.7878 dB, respectively as shown in Fig. 5. The overall simulated results are tabulated in Table III. The size of the filter is 43.72mm x 71.1mm. Therefore, all the results have good agreement to the design specification.

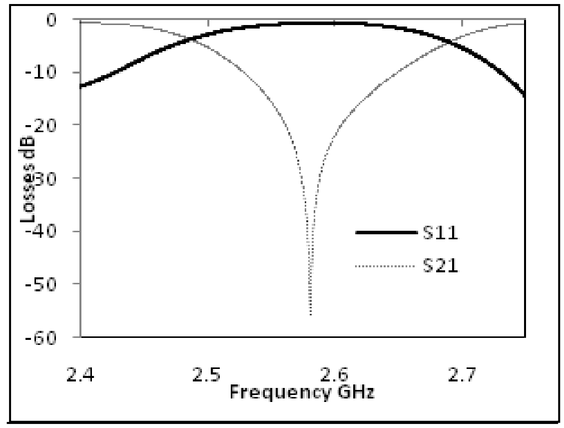

Fig. 5: Frequency response of the combline bandpass filter.

TABLE III
MULTILAYER COMBLINE FILTER

Parameters	Specification
Lower cutoff freq, f_L (GHz)	2.4877
Upper cutoff freq, f_U (GHz)	2.6916
Center frequency, f_C (GHz)	2.5815
Bandwidth (MHz)	203.9 (7.9%)
Insertion loss, S_{21} (dB)	-0.7878
Return loss, S_{11} (dB)	-49.83357

In order to obtain the results, some analyses on certain parameters that contribute major effects on the response were carried out. The length of the resonators, position of the feeder, gap between adjacent resonators on top layer and inner layer have large influence on the performance related to bandwidth, insertion loss, S_{21} and return loss, S_{11}.

Fig. 6 and Fig. 7 show response due to parameter sweeps done on the gap between adjacent resonators on multilayer filter. The response of S_{11} and S_{21} will vary on the coupling strength of the gap. By decreasing the gap between adjacent resonators on multilayer of the filter simultaneously, S_{11} tend to become lower, while S_{21} tends to approach 0 dB. It also produced wider bandwidth. Therefore, gap between the resonators needs to be small compared to first hand design.

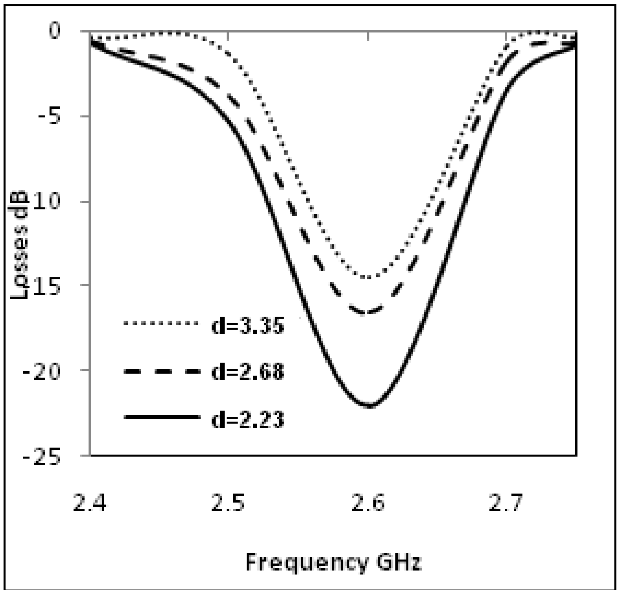

Fig. 6. Parameter sweeps of S_{11} on gap between resonators of the top and inner layer simultaneously

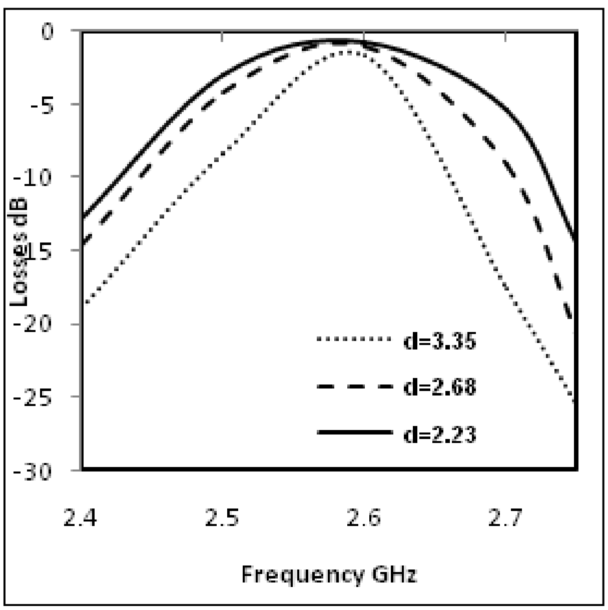

Fig. 7. Parameter sweeps of S_{21} on gap between resonators of the top and inner layer simultaneously

As shown in Fig. 8 and Fig. 9, when the length of the resonators are increased, the S_{11} and S_{21} are shifted to the lower frequency and the size will become bigger. Meanwhile, the value of S_{11} and S_{21} will be affected. The result agreed well with the microwave theory due to the relationship of the wavelength and the frequency, $\lambda = c/f$.

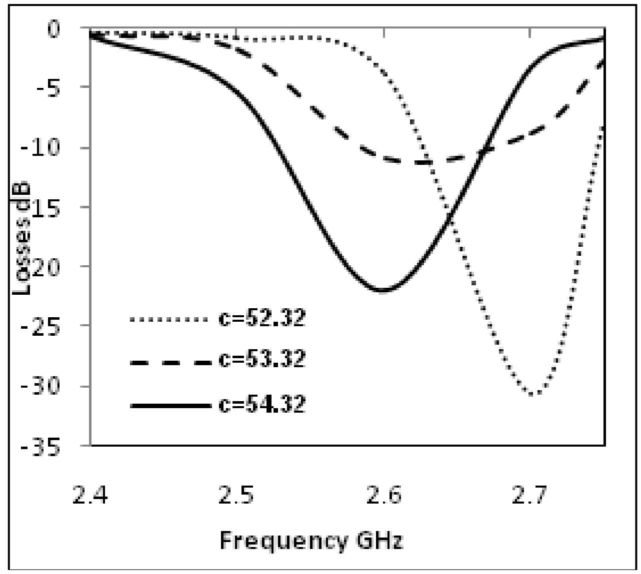

Fig. 8. Parameter sweeps of S_{11} on length of the resonators

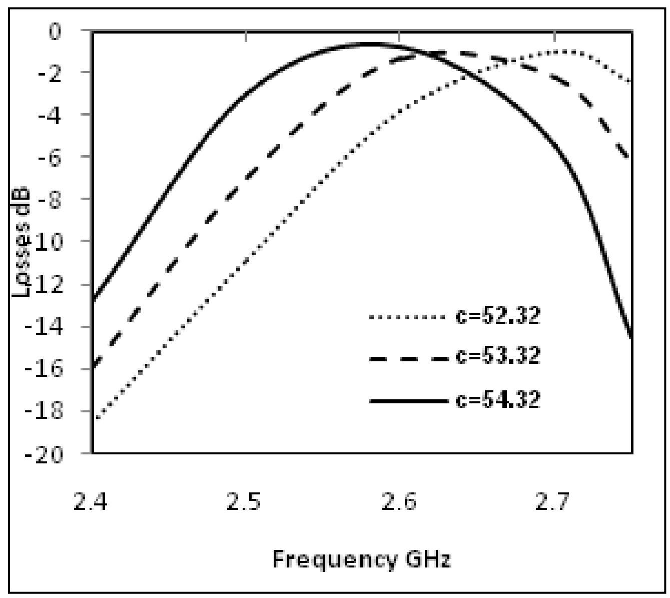

Fig. 9. Parameter sweeps of S_{21} on length of the resonators

Finally, positions of the feeder of the top layer also have been analyzed. The result for S_{11} and S_{21} are portrayed in Fig. 10 and Fig. 11. By adjusting the feeder to the higher position, S_{11} will be increased. This is due the matching between feeder impedance and filter impedance [6]. However, the result for S_{21} has not much different as compared to S_{11}.

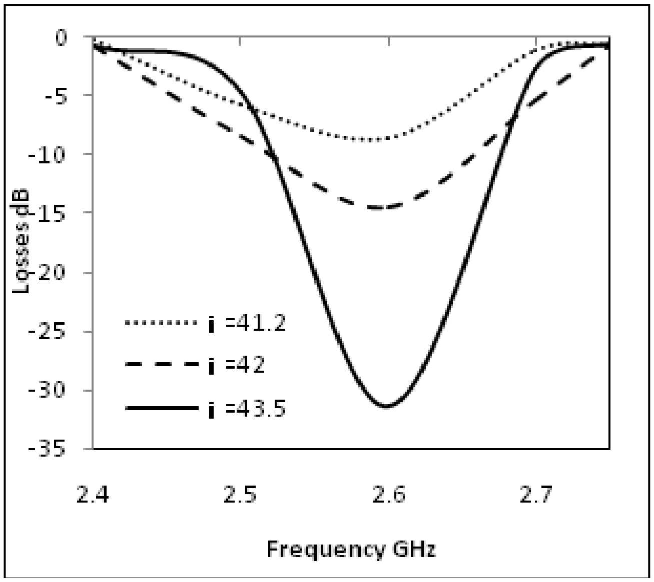

Fig. 10. Parameter sweeps of S_{11} on position of the feed

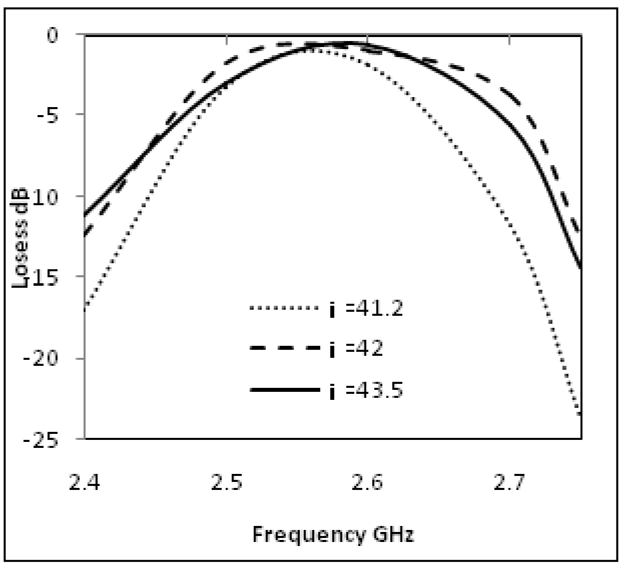

Fig. 11. Parameter sweeps of S_{21} on position of the feed

After the optimization and parameter sweep analyses, the best simulation values were chosen to meet the specification requirement as shown in Table 3.

IV. Conclusion

Miniaturized multilayer combline bandpass filters integrated into RO3003 substrates have been realized and preliminary analysis has been completed. This project presented by designing and analyses of the response on the parameter sweep on resonator of gap, resonator of length, and position of the feeder. A good agreement on value of bandwidth with 7.9% and s-parameters are satisfy and meet the specification.

Recommendation

There are some recommendations, in order to enhance the performance of the filter. One of them is by applying more than two core substrate layers in order to enhance the performance of the filter. Other than that, by changing the structure of the filter is also recommended.

Acknowledgment

The authors would like to thank supervisor, Puan Ro'biatun Adayiah bt Awang for the guidance, senior for the advices and also all the family members for supporting.

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