Microstrip Interdigital-Hairpin Bandpass Filter

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Abstract — **This paper deals with a microstrip single layer of inter-digital hairpin. The concept of the filter is the combination of interdigital and hairpin types of filter, which the designed used the fundamental idea of coupled lines. The filter was designed with four sections (four-pole) of U-shaped, hairpin types, which one of each feeds is touching ground via holes such the interdigital filter type. Based on the concept and to illustrate the various possibilities, the circuit layout, simulations, and calculation are presented in this paper.**

***Index Terms*—Bandpass filters, resonator filters, coupled lines.**

I.INTRODUCTION

THE microstrip filters are to be discovered widely used in many RF/microwave circuits applications and systems. The phenomenon is induce by the rapidly growing wireless communications, emerging high-temperature superconducting (HTS), and micromachining technologies [8]. In that case, the interdigital-hairpin bandpass filter (BPF) is well-known for its attractive features like low loss, and compact structure [2]. Theoretically, in the broadest sense, all microwave components can be considered as filters, since each will exhibit some band-limiting behavior when used in a system. Sometimes filters are also used for impedance matching [10].

The microwave bandpass filter once before appeared as one of the most complicated device created since they required hardened constraints in terms of selectivity, out-of-band rejection, insertion loss, and size reduction [8]. Hence a recent research has discover and approved that the interdigital line structures also have very interesting properties of band-pass filter. In that study, various image-impedance and image-propagation phase properties of interdigital line structures were determined, and the results were verified by experimental tests on an interdigital line structure. [9]. However for in this paper the experimental result is not presented as the process of fabricating is still ongoing. Hence the result presented is focuses on the simulation designed.

There have been numerous reports on the development of small-sized microwave filters. In miniaturized microstrip interdigital-hairpin filters filters using folded quarter-wave or quasiquarter-wave resonators were proposed. The filter consists of parallel-coupled quarter wavelength or 90^0parallel-coupled lines, which alternate between the short- and the folded open-circuited ends [2], [10], which same as the hairpin structure. Electric coupling was realized by placing the open-end of two microstrip resonators alternately with the close-end, while magnetic coupling was got through the connection of the short-circuited ends of two microstrip resonators [2]. Interdigital band-pass filters have an interesting feature of compactness [9].

II. DESCRIPTION OF THE FILTER STRUCTURE

As the filter proposed used the fundamental concept of combination of hairpin and interdigital filter structure, there is the basic structure of single layer interdigital bandpass filter as shown in figure 2, and the hairpin type in figure 1. Then there is the figure 3 shows the combination of the both filter to call as interdigital-hairpin filter.

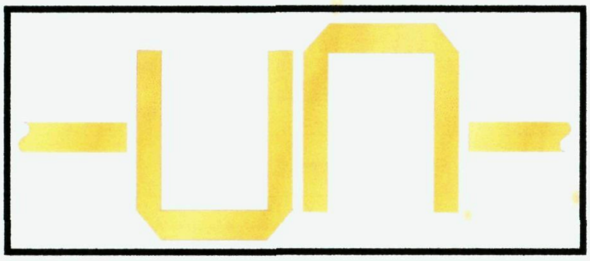

Figure 1: Basic structure of hairpin bandpass filte

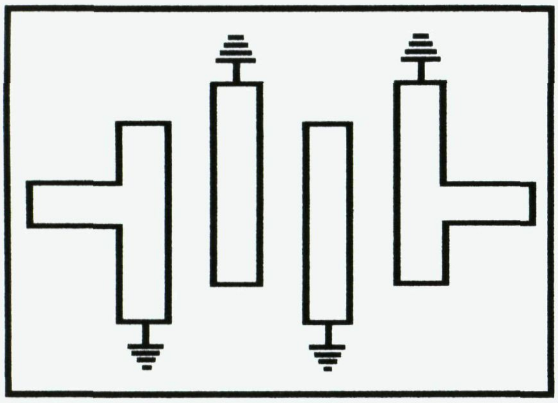

Figure 2: Basic structure of interdigital bandpass filter.

Such the figure 2, the designed filter is with 4 elements or called as four transmission lines, which every resonator are short-circuited at one end and open-circuited at the other end. It is arranged coupled alternately between the short end and open-end resonator.. However the designed then was modified to be the interdigital-hairpin, where the open-end is fold to be U-shape resonator. The conceptual idea by folding the resonators of parallel-coupled, half wavelength resonator filters into a "U" shape called hairpin filter. It is widely used due to its advantages on providing flexible coupling variation and produce compact filter with simple design procedure [3].

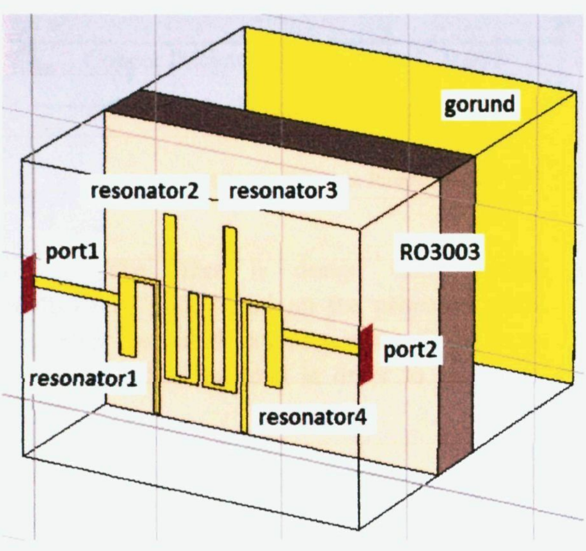

Figure 3: the simulation designed filter.

Based on figure 3, there are four elements of the resonator with the two ports to be connected to the connector after fabrication process. The first layer of the filter in the simulation is the copper resonator with height of 0.035mm. The next down layer is the substrate of RO3003 with height of 0.75mm, while the last layer is the copper as ground with height of 0.035mm down. There is figure 4 shows the height of each layer as designed in the CST.

1st layer **The fouer elements resonator**
2nd layer **Substrate RO3003**
3rd layer **Ground**

Figure 4: the layer of the filter

III.DESIGN PROCEDURE

The filter is designed simulation using CST software. The four pole interdigital-hairpin bandpass filter centered at a frequency of 2.585 GHz and the desired bandwidth is 140 MHz's. In order to make it a compact filter, it is then been folded as a hairpin filter, but still stick with the interdigital concept as each of the resonator is short-end which means it it grounded. The overall size of the filter is 35.9 mm × 52.1 mm. There is a figure 5 show the dimensions of the resonators.

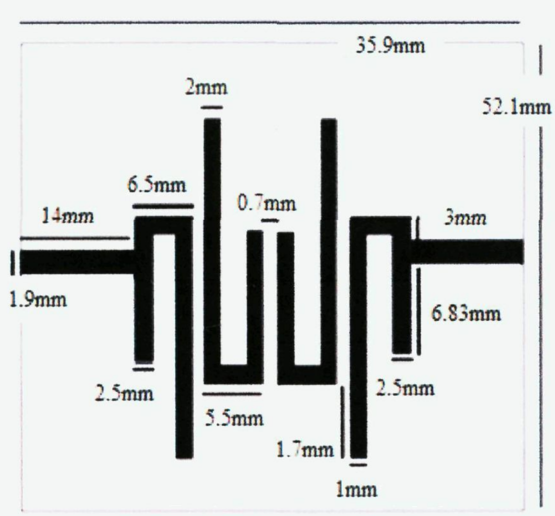

Figure 5: the dimension of designed filter

Initially before start to designed, all parameters have to calculate such the quarter wavelength (λ/4), the width (d), and so the wavelength over ten ratio (λ/10). The purposed of λ/10 is in order to be the gap between the resonator, and the impedance would go far from 50Ω (Z=50 Ω) as the tuned process is done. The wavelength can be calculated using the function in the CST.

The substrate used for the filter is RO3003 with dielectric constant of 3 and thickness of 0.795mm. Before starting to design, the dielectric constant of substrate was studied first in order to obtained better efficiency. The hypothesis state that the thinner and lower the dielectric constant, the better the efficiency [5]. The properties of the material used in designing the filter, RO3003 is as showed in Table I below.

TABLE 1

Properties	RO3003
Dielectric constant, ε_r	3
Substrate height, h (mm)	0.75
Loss tangent, $tan\ \delta$	0.0013
Copper thickness (mm)	0.035

Rogers RO3003 Substrate Properties

The filter is design using simulation software of CST based on the proposed structure. However the initial structure is not fit as the tuned process need to be done in order to get the better result.

IV.SIMULATION RESULT

Below is the result of the simulation (Figure 6) which shows the response of the designed interdigital-hairpin bandpass filter. Analysis from the response, it is known that the lower cut-off frequency (fc) obtained is 2.5112 GHz and the high cut-off frequency 2.6588 GHz. While the center frequency obtained is 2.5856 GHz and the bandwidth is 147.6 which is not far from the specification of 130MHz. the insertion loss obtained is 0.1137 dB and the return loss is 26.332 dB.

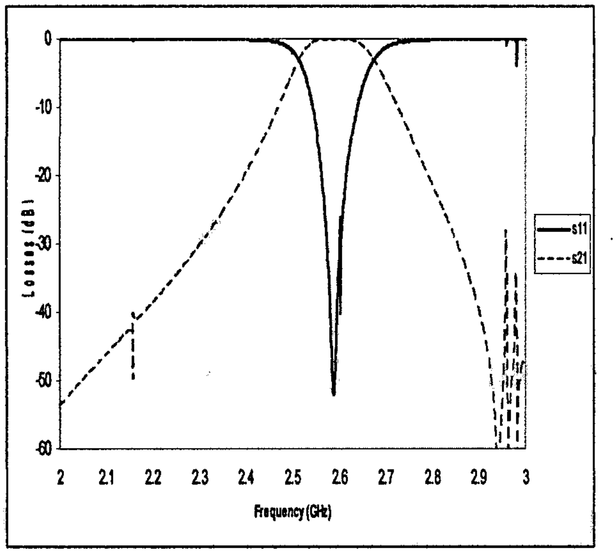

Figure 6: The simulated response of the proposed filter.

There are methods used to tune the graph which are manually varies one or many variable at a time or using the parameter sweep function. In the initial designed, the parameter sweep was used to determined better width of resonator. The parameter is such figure 7(a) to (d) below.

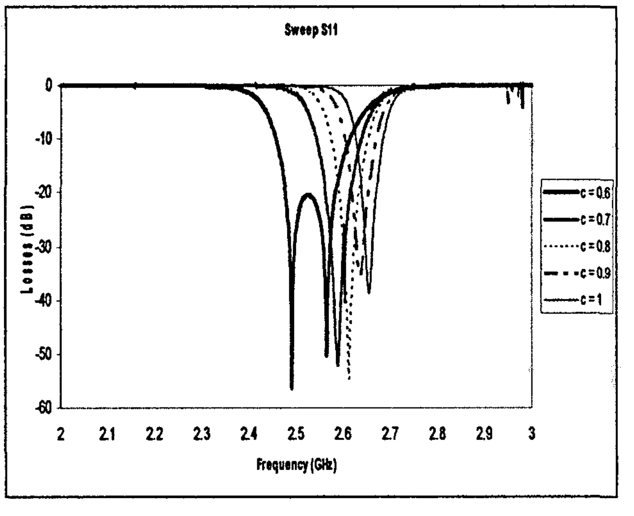

Figure 7(a): The S11 simulated response using the parameter sweep function as variable c varied.

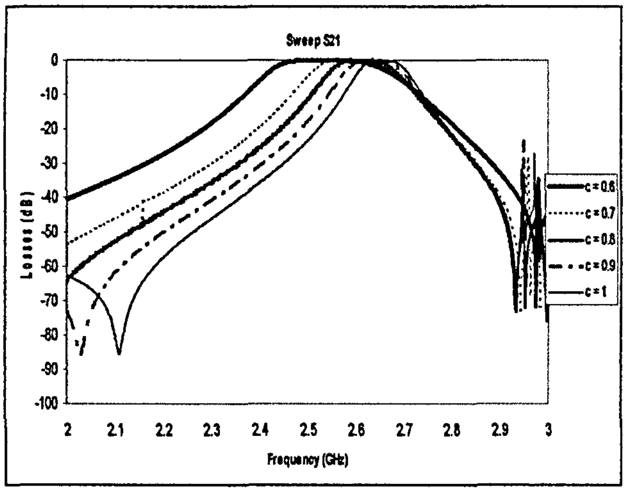

Figure 7(b): The simulated S21 response using the parameter sweep function as variable c varied.

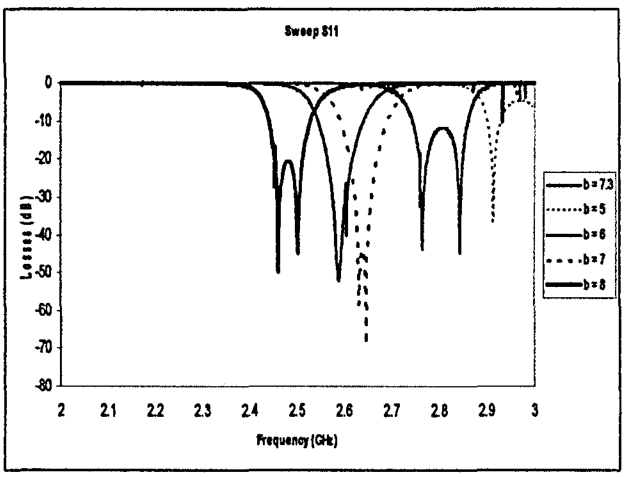

Figure 7(c): The simulated S11 response using the parameter sweep function as variable b varied.

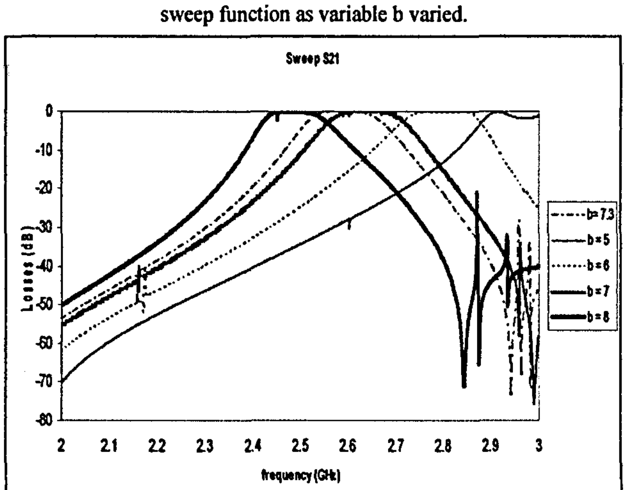

Figure 7(d): The simulated S21 response using the parameter sweep function as variable b varied.

In the figures (a) and (b), variable c, which is declared as length of the feed was varied. It can be observed that the graph shift from the right to the left as the value of the variable is increased. While in the figures (c) and (d), variable b is varied which declared as wavelength over ten. But then however, the tuning still can be done manually by varying one of the variables until the graph is obtained.

V.DISCUSSION

At first, the tuning process is done in order to obtain the proposed graph of frequency range 2.52GHz – 2.65GHz. The tuning process are included varying the variables that had been declare while creating the brick of resonator. This varying process is trying and error until graph is fit well into the range.

From observation after several simulation were done, it is known that there are some shift and change of graph. If width is increased, the graph will shift to the left, the return loss will close to 20dB and vice versa. Variable that declared as $\lambda/10$ value also had been varied. It shows that as the value is decreased, the graph will shift to the right. Another variable is the feed length that use for the hole connected to the ground..

It is known that from the formula of $c=f/\lambda$, as there is increased of wavelength in the tuning process, there will be decreased value of frequency and vice versa, which meant that they are inversely proportional to each other.

There are also some analyses done in order to determine and discover the type or behavior of different number of element (U-shaped) resonator on the filter. As the paper initially proposed the four element analysis, then there are three element analyses. Figure 8 show the related designed filter.

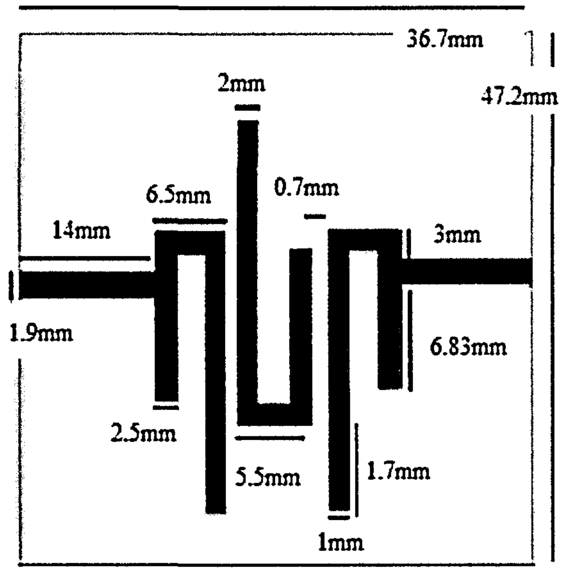

Figure 8: the 3 element filter.

Below is the result of 3 elements respectively.

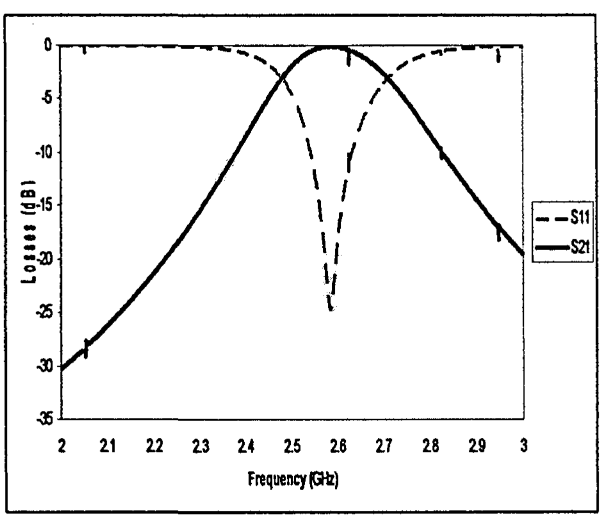

Figure 9: result of 3 element resonator.

Based on the result simulation obtained, there are differences between the two designed. For the three elements, the bandwidth obtained is wider which 220MHz is. Therefore the more elements is used, the narrow bandwidth would be obtained.

Another comparison made for the value of 50Ω line which the value are such the table below.

TABLE 2

Number of elements	Value of impedance
Five (5)	45.90 Ω
Three (3)	46. 01 Ω

Comparison of 50 Ω impedance line value

The size of three elements however is more compact compared to the four elements, but there is increased of length from 35.9mm to 36.7mm.

VI.CONCLUSION

The Microstrip Interdigital-Hairpin RF bandpass filters integrated into RO3003 based single layer substrates have been realized and the necessary analysis had accomplished. The aim of designing is focuses on its compact realization, therefore more effort on the reducing size were done. Besides, the performance of the filter that related to insertion loss, S21 and return loss, S11 also had been discussed and improve. Based on the simulation result, it's obviously show relatively low loss and good attenuation for some RF application. In a nutshell, the single layer technique used to reduce the size achieved, which is 35.9mm x 52.1mm size filter was realized. Besides of compactness, the filter designed also introduce transmission zeros in the stopbands to improve the frequency selectivity of the filters. To conclude, the simulated results of the filter with the four pole bandpass filter show an excellent agreement.

V. RECOMMENDATION

For future improvement, the project of single layer still can be edit or modified in order to obtained better filter perfomance. Besides there are also other features can be add or been analyses in the filter. In fact, there are some other higher relative permittivities of substrates which can be used to improve the filter performance.

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REFERENCES

[1] M. K. Mohd Salleh, G. Prigent, O. Pigaglio, R. Crampagne, "Quarter Wavelength Side-Coupled Ring Resonator for Bandpass Filters," *Microwave Theory and Techniques, IEEE transactions* on, vol. 56, pp 156-162, 2008.

[2] Yani Mu, Zhewang Ma, Member, IEEE, and Deming Xu, Senior Member, IEEE for "A Novel Compact Interdigital Bandpass Filter Using Multilayer Cross-Coupled Folded Quarter-Wavelength Resonators," *IEEE Microwave and Wireless Components Letters*, vol. 15, no. 12, December 2005.

[3] H. Adam, A. Ismail, M. A. Mahdi, M. S. Razalli, A. Alhawari and B. K. Esfeh, "X-Band Miniaturized Wideband Bandpass Filter Utilizing Multilayered Microstrip Hairpin Resonator", *Progress in Electromagnetics Research, PIER* 93, pp. 177-188, 2009.

[4] M.E. Mayercik, "Resonant microstrip rings and dielectric material testing, Microwaves", *IEEE Trans. Microwave Theory Tech*, Apr. 1991, 95- 102.

[5] L.H. Hsieh and K. Chang, "Tunable microstrip bandpass filters with two transmission zeros," *IEEE Trans Microwave Theory Tech.*, vol. 51, 2004, pp.520-525.

[6] John W. Bandler, Radoslaw M. Biernacki, Shao Hua Chen, and Ya Fei Huang, "Design Optimization of Interdigital Filters Using Aggressive Space Mapping and Decomposition", *IEEE Trans. Microwave Theory Tech.*, vol. 45 May 1997. 761-769.

[7] Y. X. Guo, L. C. Ong, M. Y. W. Chia and B. Luo, "Dual-band bandpass filter in LTC," *Microwave Symposium Digest, 2005 IEEE MTT-S International*, June 2005

[8] Elena Semouchkina, Amanda Baker, George B. Semouchkin, Michael Lanagan and Raj Mittra, "New Approaches for Designing Microstrip Filters Utilizing Mixed Dielectrics",*IEEE Trans. Microwave Theory Tech.*, vol. 52, No.3, February 2005.

[9] J. T. Bolljahn and G. L. Matthaei, "A study of the phase and filter properties of arrays of parallel conductors between groundplanes, Interdigital Band-lPass Filters," *PROC. IRE*, vol. 50, pp. 299-311, March, 1962.

[10] Yuen Yoon Ming," Design of Single Layer Interdigital Band Pass Filter With Elliptical Response," A Project Report of The Requirements for The Award of The Degree of Master of Engineering (Electrical – Electronics and Tlecommunications), *Faculty of Electrical Engineering, Universiti Teknologi Malaysia*, November 2005.