

DESIGN OF PARALLEL COUPLED MICROSTRIP BAND-PASS FILTER

Ghasan Ali Hussain

Assist Lecturer in Dept. of Electrical Eng., College of Engineering, University of Kufa
ghasan.alabaichy@uokufa.edu.iq

ABSTRACT

Filters occupy important acts in several Radio Frequency microwave applications. Several applications such as wireless communications still challenge RF/microwave filters with strict requirements such as smaller size, higher performance, lighter weight, and lower cost. Microstrip Filters for RF/Microwave Applications offers a unique and comprehensive treatment of RF/microwave filters based on the microstrip structure. One of the most common methods in designing microwave filters is using of parallel-coupled microstrip. In this paper simulate and fabricate by using Ansoft Designer a two resonator microstrip band-pass filter suitable for Wi-Fi applications. The results of simulation were quite good.

Indexing terms / Keywords: Band-Pass-Filters; Microstrip; Ansoft Designer; Transmission line; Fabricate.

1. INTRODUCTION:

Filters occupy important acts in several Radio Frequency microwave applications. It is used to separate or combine different frequencies. Filters are employed to select or confine the Radio Frequency microwave signals within assigned spectral limits due to the electromagnetic spectrum is limited and has to be shared [1].

The traditional design of parallel-coupled line filters, however, suffers from the spurious response at twice of the design frequency, which not only degrades pass band symmetry but also deteriorates rejection levels in upper stop-band. It is due to that phase constants of the even and odd modes of each coupled stage are not identical [2]. It has been shown that a micro-strip coupler filter may have more bandwidth and better isolation characteristic. The equalization can be achieved by using capacitor compensation, suspended substrates, corrugated coupled lines and an overlay dielectric. Furthermore, both of [3,4] used parallel-coupled microstrip filters and considered one of the best and common approaches for implementing a planar filter.

The band pass filter with suppression of spurious responses has been designed by using a flat dielectric overlay. For a single-stage coupler with an overlay, the thickness of the overlay dielectric can be easily determined by a full-wave transmission line program, e.g., the spectral domain approach. The thickness of the overlay dielectric, however, generally depends on material constants and geometric dimensions of the coupled micro-strips.

A multi-order filter consists of several cascade coupled stages. If the overlay dielectrics for these stages have different dimensions, fabrication of the whole filter will be tedious and difficult. Our objective is thus to design a filter with a uniform overlay dielectric, so that each stage is suppressing the spurious responses.

2. BAND-PASS FILTER BY PARALLE COUPLED LINES

This filter or as it known as parallel-coupled filter as shown in Figure 1. The strips are arranged parallel beside each other, where they are coupled with certain coupling factors[5].

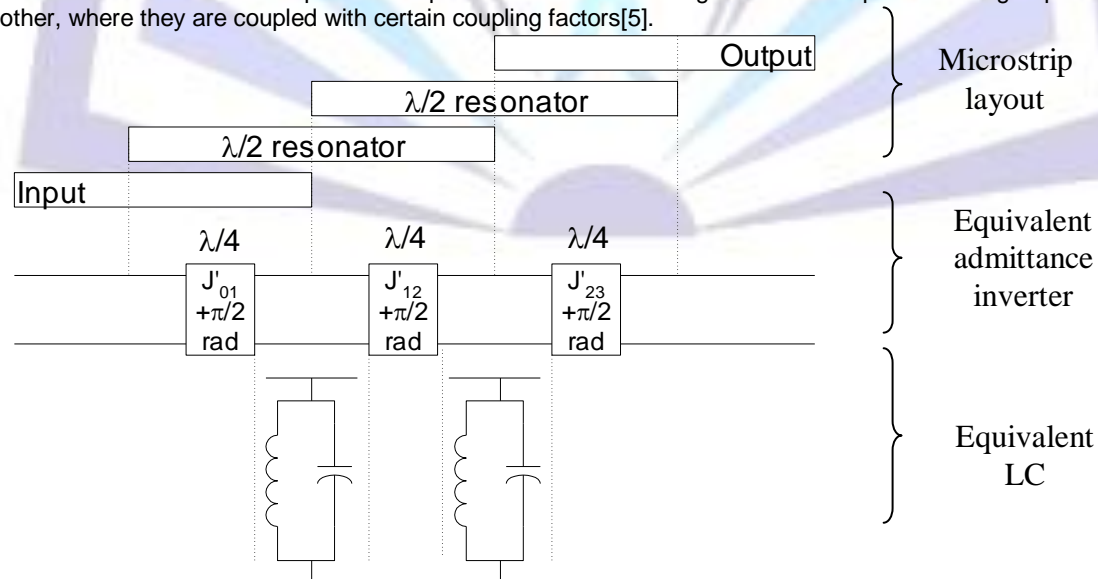


Figure (1): Band Pass Filter

• **Required admittance inverter parameters**

The normalized admittance inverter is given by [6,7]:

$$J'_{01} = \left\{ \frac{\pi \Omega}{2g_0g_1} \right\}^{\frac{1}{2}} \quad \text{where} \quad \Omega = \frac{\omega_2 - \omega_1}{\omega_o}$$

$$J'_{k,k+1} = \frac{\pi \Omega}{2} \times \frac{1}{\sqrt{g_k g_{k+1}}} \quad \text{for } k = 1, 2, \dots, n-1$$

$$J'_{n,n+1} = \left\{ \frac{\pi \Omega}{2g_n g_{n+1}} \right\}^{\frac{1}{2}} \quad n = \text{no. of sections}$$

$$Z_{oe,k,k+1} = Z_o \left[1 + J'_{k,k+1} + J'_{k,k+1}{}^2 \right]$$

$$Z_{oo,k,k+1} = Z_o \left[1 - J'_{k,k+1} + J'_{k,k+1}{}^2 \right] \quad \text{where} \quad J'_{k,k+1} = J_{k,k+1} Z_o$$

3. Filter design:

In this part the filter design will be explained, simulate, fabricate and testing a coupled line band-pass filter that be suitable for Wi-Fi applications with 100MHz bandwidth. Our aim is also to design it as small as possible so we are using 2 or 3 resonator by the given 'g' values for a Gaussian filter.

In this paper we use the CER substrate with properties $\epsilon_r=10$ and 0.64 mm thickness and $\tau_{gs}=0.0035$. By having the substrate information and applying previous equations on them we can get the values of even and odd characteristic impedance (Z_{oe} , Z_{oo}). then we use the figure 2 to find S/h and W/h for each stage.

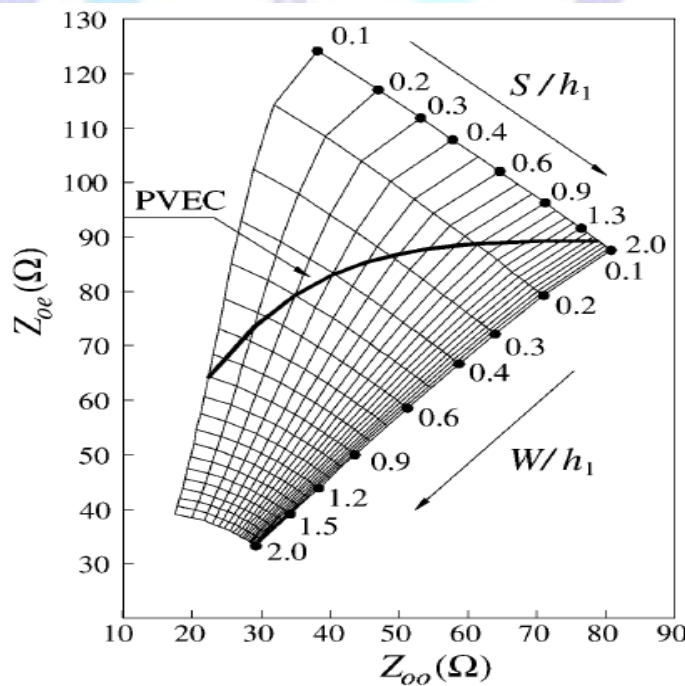


Fig. 2 Even- and odd-mode characteristic impedance design data for coupled Micro-strips with an overlay dielectric [8].

After getting the S/h and W/h and by knowing the thickness of substrate, $h=0.64$ mm for substrate we can calculate the W and S , where:

S: is the spacing distance between two resonators

W: the thickness of resonator

These results are verified using any simulator software as in figure 2 to see the expected results before fabrication.

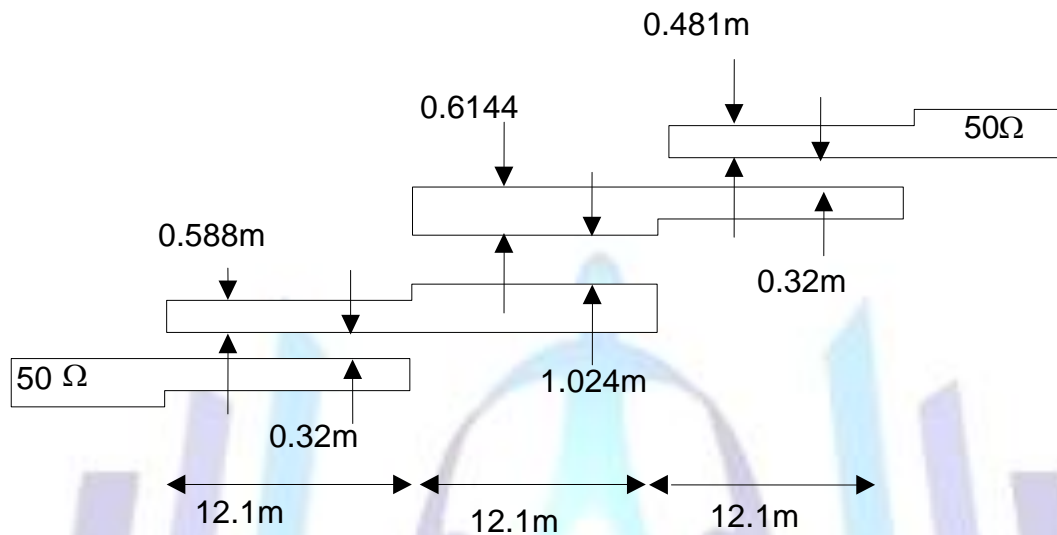


Fig. 2 Micro-strip Band-Pass Filter Calculations

4. SIMULATION AND FABRICATION

For simulating the designed template, Ansoft Designer has been selected [9]. First the selected substrate data for it are defined. Now, substrate is Taconic CER-10™ by :

- Relative permittivity =10
- Dielectric loss tangent =0.0035
- Dielectric height = 0.64 mm

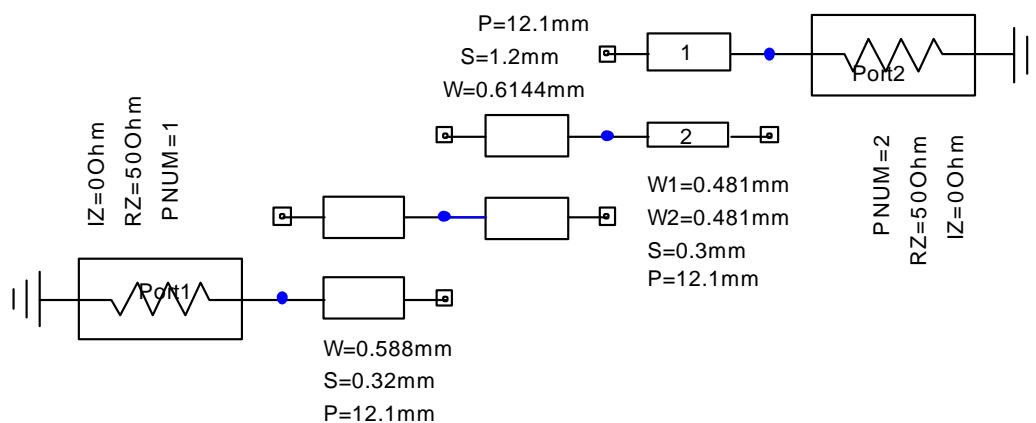


Fig. 3 Micro-strip Band-Pass Filter Design

For designing the circuit, designing tools are used. In this environment we can simply put our resonators, connect them together and also connect the microwave ports into its ends. The schematic would be as bellow:

Then the simulation parameters are defined and simulate it. The desired part is around 2.4GHZ, and in this area it can see the result as:

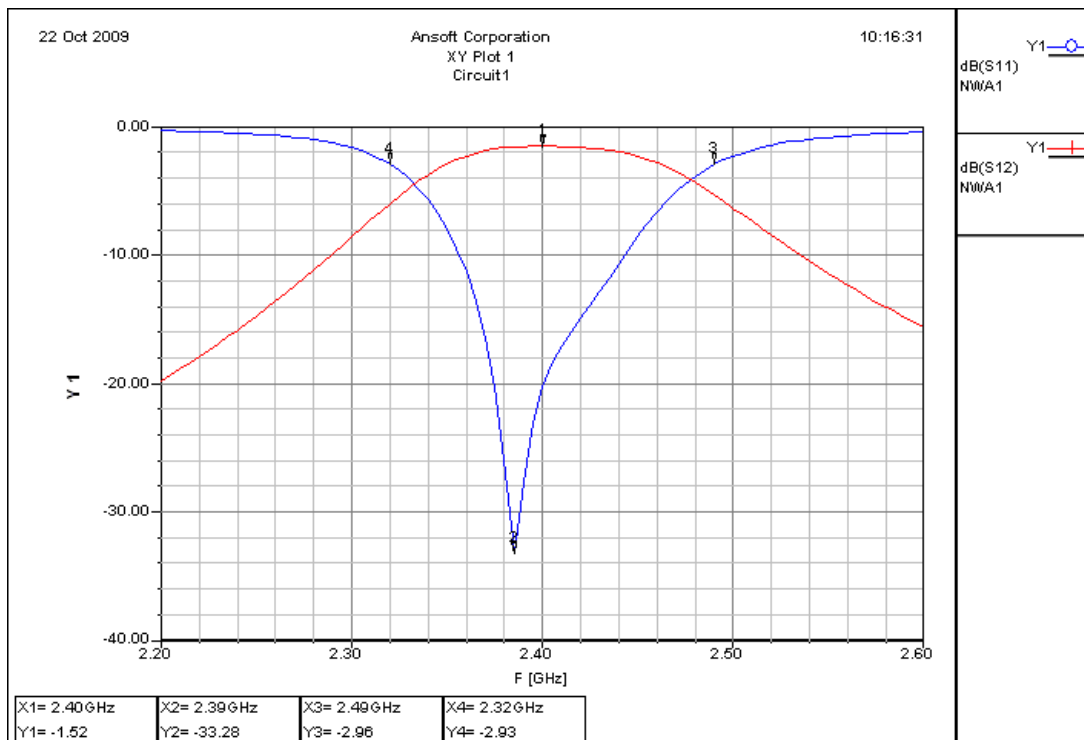


Fig. 4 Ansoft Result

As shown, the simulation results are near to expected results, because its center frequency is very near to 2.4, the S12 peak is -1.52 dB at 2.4GHz and the bandwidth is around 160 MHz. Although some verification is needed to improve the bandwidth we postponed it now and try to fabricate a prototype to see what will happen in fabrication.

In this part it should make its layout and save it in Gerber format so that be compatible with CNC machine software. The 2D and 3D layout is as below:

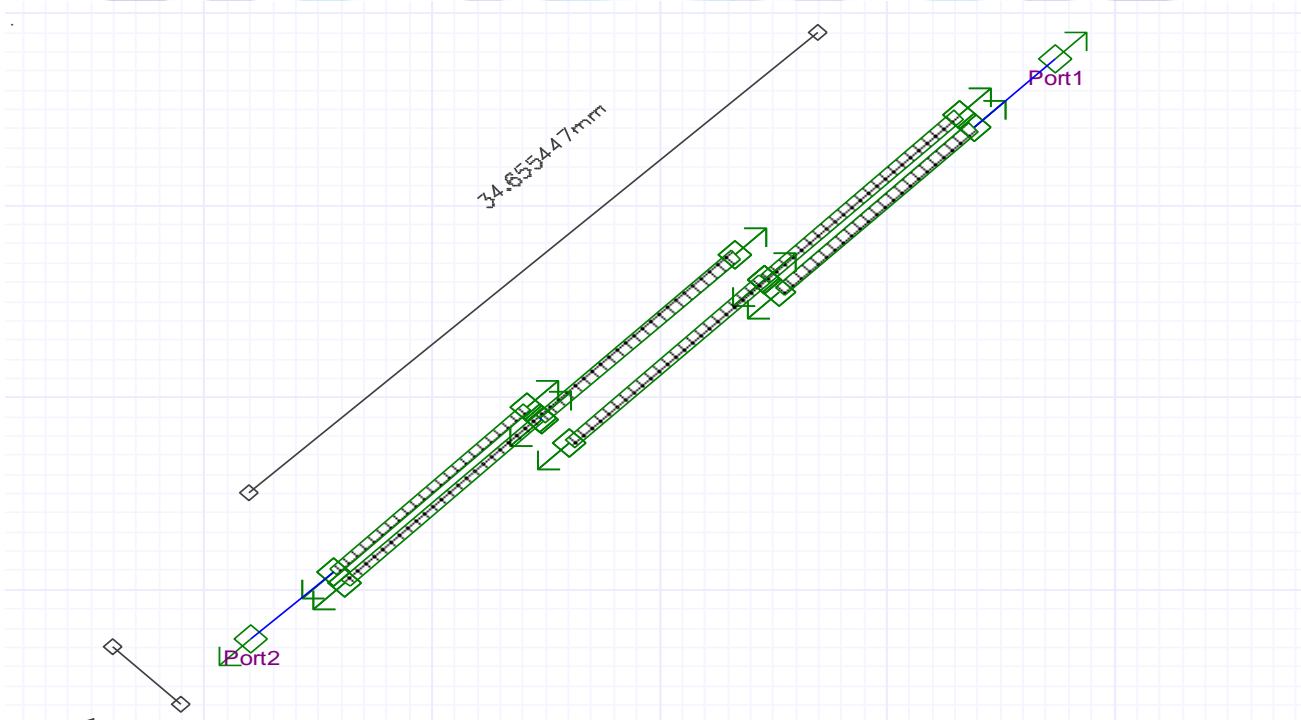


Fig. 5, 2D Layout of Ansoft Result

Everything was looking good and fabricated, but after fabrication the experimental result was quite different to simulation result. The problem that doesn't mentioned in the fabrication is impedance matching between 50 ohm connectors and resonators. This effect would be big in small cases as ours.

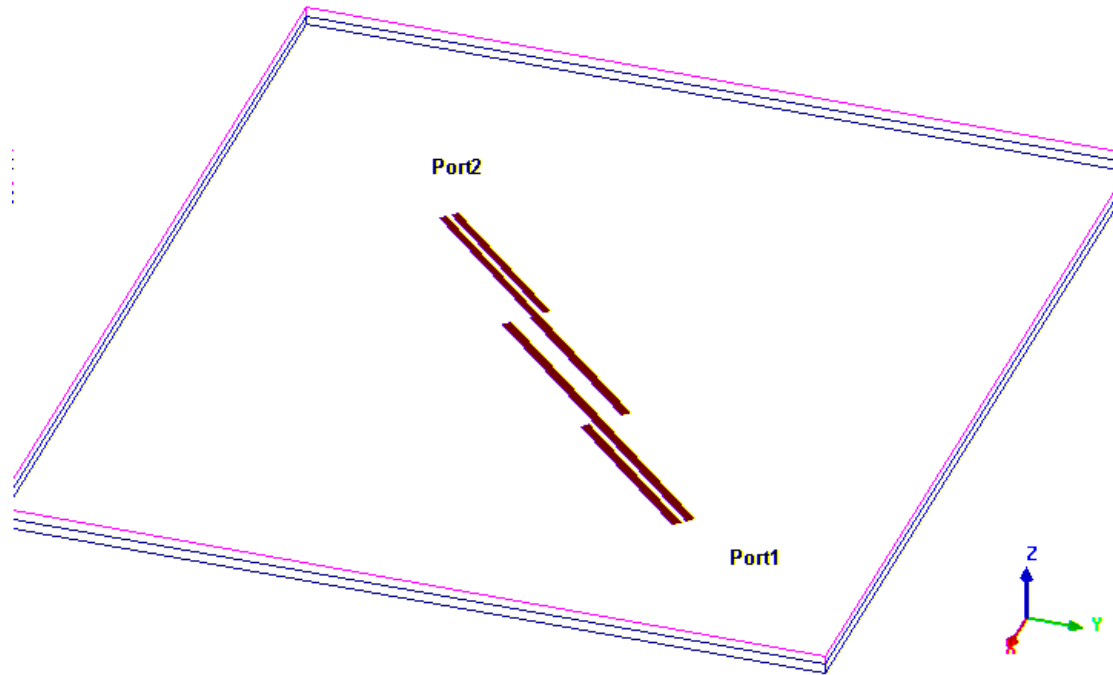


Fig. 5, 3D Layout of Ansoft Result

Impedance Matching

In this section, it should add two 50 ohm transmission lines to the ends of the circuit. The aims are as following:

- Provide impedance matching
- Provide a suitable area for soldering the connectors

For calculating the size of transmission line it can use TX line calculator software. The substrate data entire in it and let it calculate the size of transmission line as below:

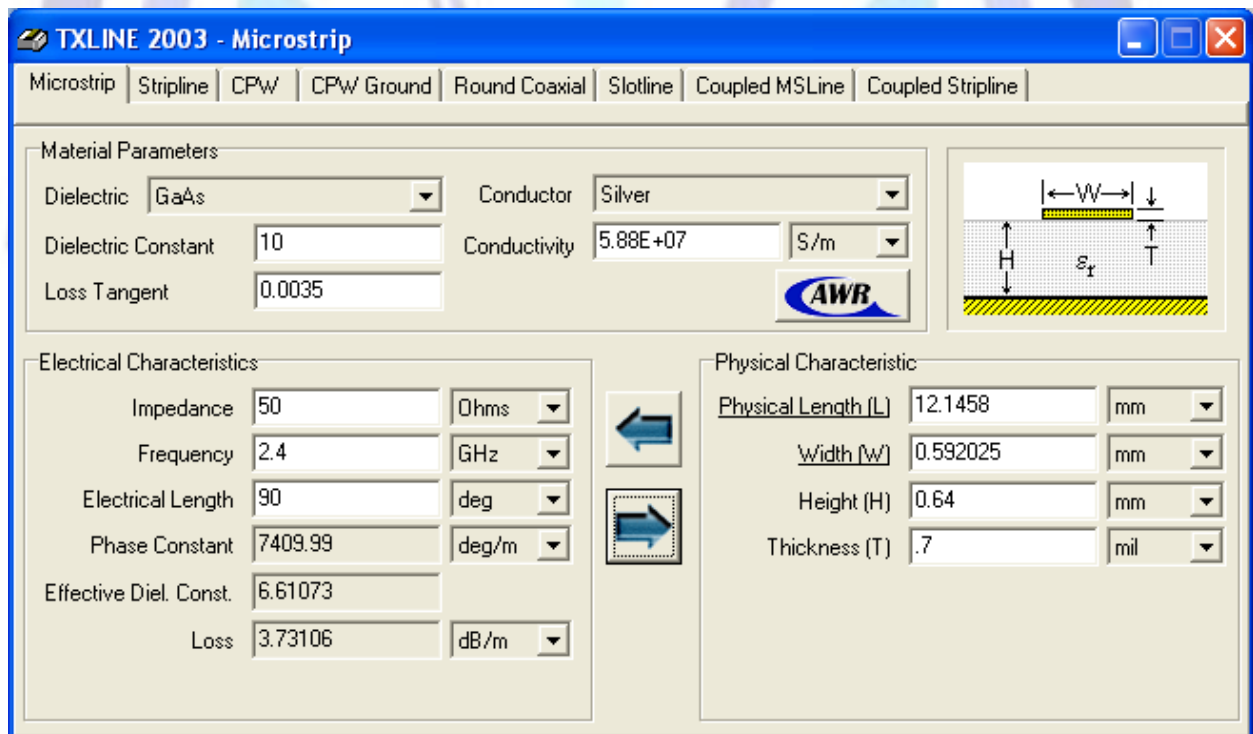


Fig.6 Material Parameters

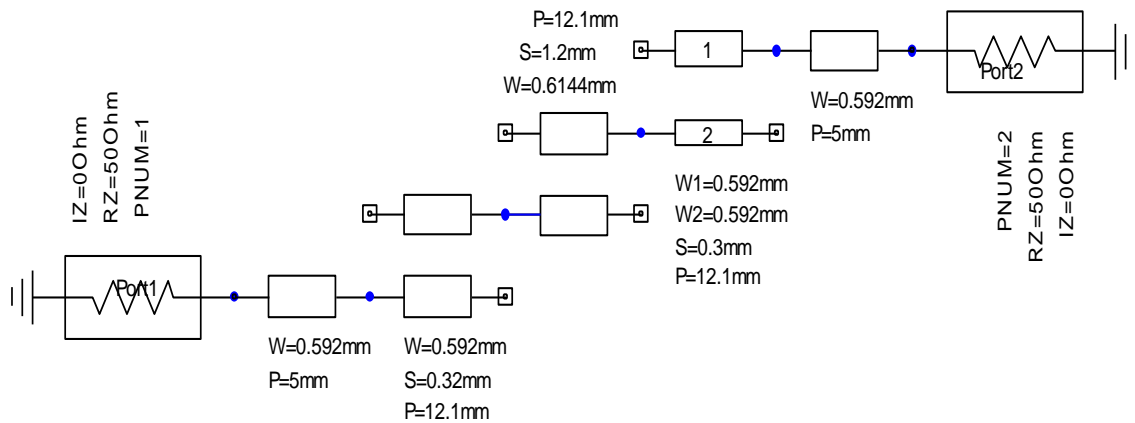


Fig.6 Filter Design

As known, the transmission line width is most important and its physical length has less effect, the samples prototype proof this idea, so it is added two 5 mm length transmission line to our design. By this act the simulation result is changed thus we have to do some improvements also including bandwidth improvement that we forgot it last time. The new schematic is as below:

And its result as following picture:

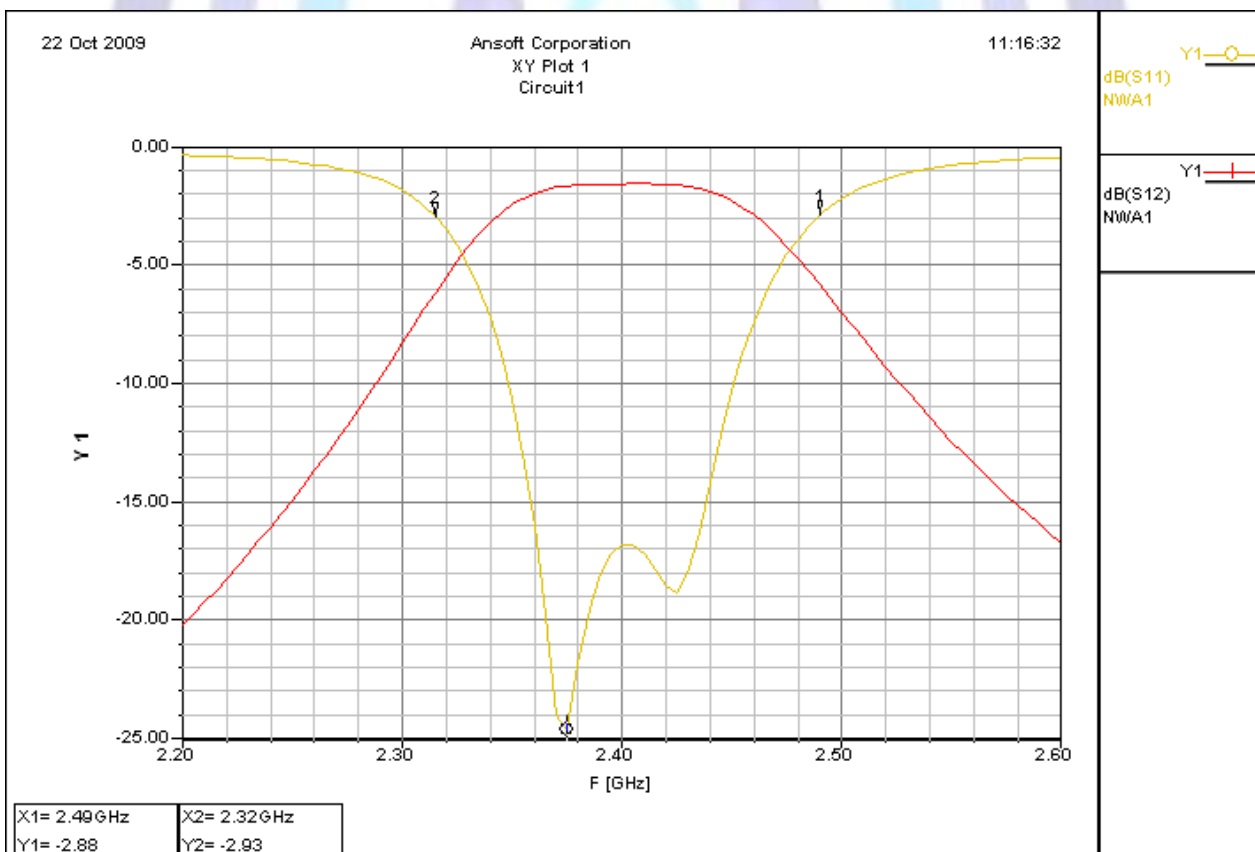


Fig. 7 Ansoft results

Everything was good expect bandwidth. For improving the bandwidth it has to do some verification in the design. It can see below the improved schematic by small changes to width and space between resonators:

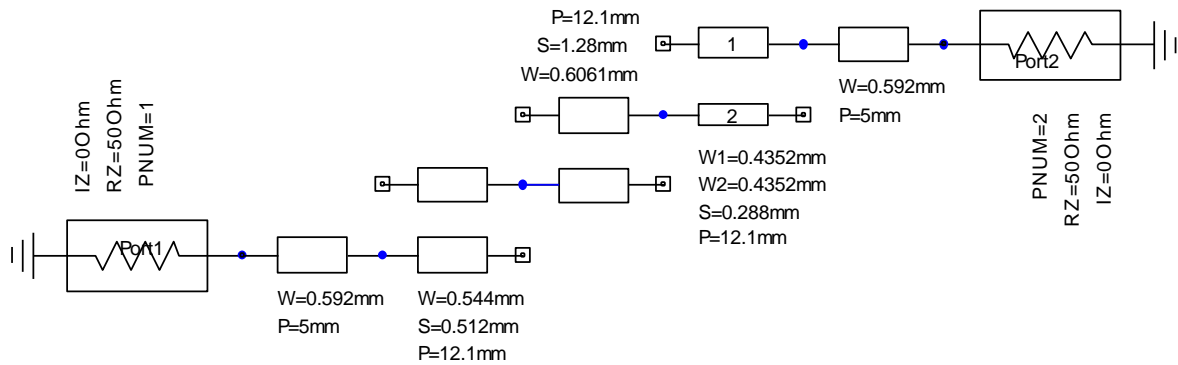


Fig.8 Filter Design

And the result below is satisfied the qualification:

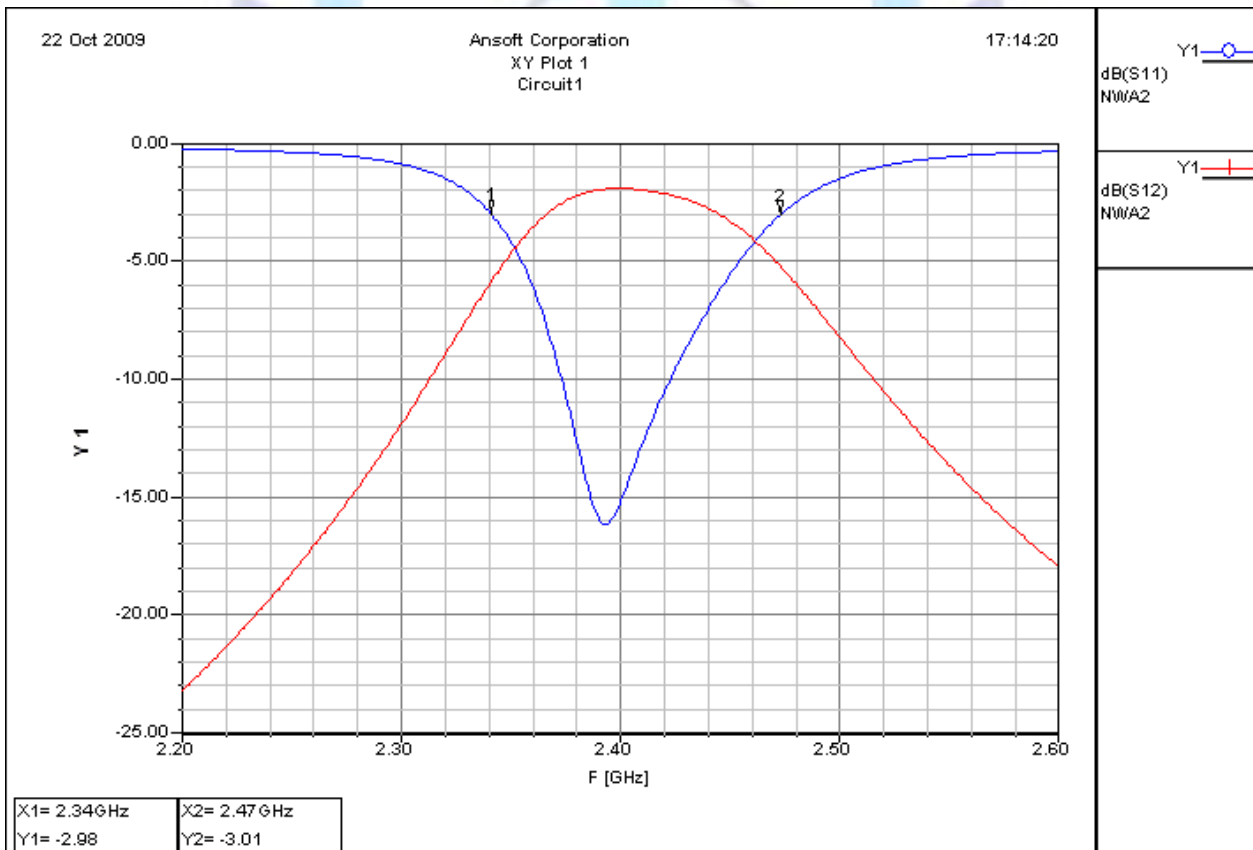
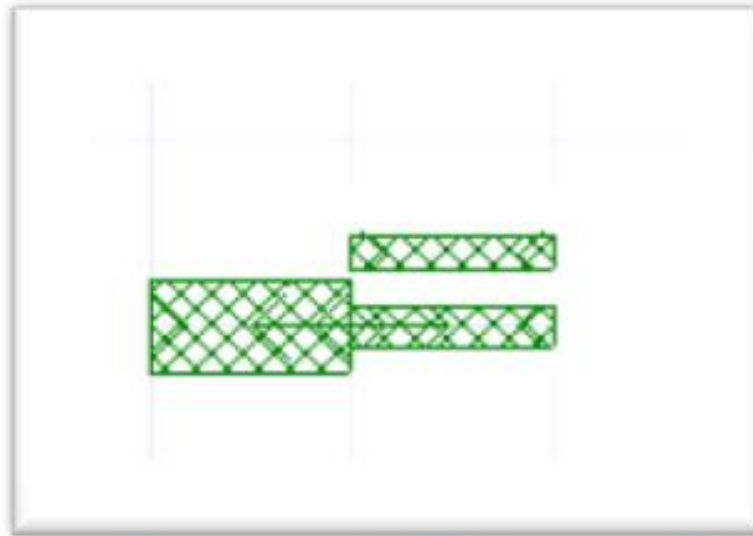


Fig. 9 Ansoft Result

As shown, the center frequency is around 2.4 GHz, the bandwidth is around 130 MHz and the S12 max value is -2dB at 2.4GHz.

5. CONCLUSION AND FUTURE WORK

In this paper, the two resonator microstrip bandpass filter suitable for WIFI applications has been simulated and fabricated. The simulation results are quite good with some of difficulties occurred in fabrication. One of them is impedance matching and soldering part. Others maybe the limitation of CNC machine in fabricating narrow lines so that although of respecting its limitations some prototypes were corrupted. Ansoft Gerber file output so that if the differences between two consequent resonators are high as figure bellow, the distance between corners become very small and although it has no effect on simulation result it will corrupt the real result.



Due to this limitation, the design changing so that having less effect of these limitations, for instance different shapes needing narrower lines neglected and proceed with simple linear shape with big enough lines.

Another problem that faced after fabrication was changing the center frequency and bandwidth of the filter. After investigation, this effect would be due to difference between substrate characteristics in datasheet and real that is quite common in sample substrates normally used in used student projects. For instance although its copper thickness in datasheet is considered around 18 microns in some parts it was more than 70microns so that it reached CNC machine surface cleaning limitation and can not be removed by machine. If considered its copper thickness equal to 18micron –as in its datasheet- the physical length of resonators should be 12.1mm that mentioned it in simulation and fabrication, but when increasing the thickness to 70micron –as in real- the resonators length should be increasing to 12.41mm.

Another effect that didn't considered in our design was this fact that the substrate dissipation factor is measured in 10GHZ while we was using it in 2.4GHZ, so further compensation should be done to improve the result.

To overcoming this problem we have to use standard substrate instead of sample substrate, and making several prototypes to achieve the exactly desired results.

REFERENCES

- [1] JIA-SHENG HONG M. J. LANCASTE, "Microstrip Filters for RF/Microwave Applications", ISBN 0-471-22161-9, Copyright © 2001 by John Wiley & Sons, Inc.
- [2] Jen-Tsai Kuo, Meshon Jiang, "Enhanced Microstrip Filter Design With a Uniform Dielectric Overlay for Suppressing the Second Harmonic Response", IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS, VOL. 14, NO. 9, SEPTEMBER 2004
- [3] D. M. Pozar, *Microwave Engineering*, 2nd ed. New York:Wiley, 1998.
- [4] C.-Y. Chang and T. Itoh, "A modified parallel-coupled filter structure that improves the upper stopband rejection and response symmetry," IEEE Trans. Microwave Theory Tech., vol. 39, pp. 310–314, Feb. 1991.
- [5] Mudrik Alaydrus, "Designing Microstrip Bandpass Filter at 3.2 GHz", International Journal on Electrical Engineering and Informatics - Volume 2, Number 2, 2010.
- [6] M. Kirschning, and R.H. Jansen, "Accurate wide-range design equations for parallel coupled microstrip lines", IEEE Trans. MTT-32, Jan. 1984, pp. 83-90. Corrections in IEEE Trans. MTT-33, March 1985, p. 288.
- [7] R..Mongia, P. Bhartia and I.J.Bahl, RF and Microwave Coupled-line Circuits, 2nd ed., Artech House, Boston, 2007.
- [8] Jen-Tsai Kuo, and Meshon Jiang, "Enhanced Microstrip Filter Design With a Uniform Dielectric Overlay for Suppressing the Second Harmonic Response", IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS, VOL. 14, NO. 9, SEPTEMBER 2004.
- [9] www.ansys.com