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Design of 4th Order Parallel Coupled Microstrip Bandpass Filter at Dual Frequencies of 1.8 GHz and 2.4 GHz for Wireless Application

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ABSTRACT: Design of a parallel-coupled microstrip bandpass filter is presented in this paper. The aim of this paper is to present the design technique, parameter analysis, real prototype fabrication and measurement results at dual simulation frequencies of 1.8GHz and 2.4GHz. Half wavelength long resonators and admittance inverters are used to design the filter. The filter is simulated using AWR Microwave Office software (Advanced Wave Research).

KEYWORDS: Bandpass filter; Microstrip; 1.8 GHz & 2.4GHz; Parallel Coupled Line; Microwave Engineering; AWR Simulator.

I.INTRODUCTION

The microwave filter is a two port network which used to control the frequency response by providing transmission at frequencies within the passband and attenuation in the stopband of a filter. Filters are an essential part of telecommunications and radar systems. Of its low-cost fabrication, easy integration and simple designing procedure, the parallel coupled-line/edge-coupled filters are widely used in microwave microstrip circuits with a required bandwidth up to 20 % of central frequency . A bandpass filter only passes the frequencies within a certain desired band and attenuates others signals whose frequencies are either below a lower cutoff frequency or above an upper cut-off frequency. The range of frequencies that a bandpass filter let's to pass through is referred as passband. A typical bandpass filter can be obtained by combining a low-pass filter and a high-pass filter or applying conventional low pass to bandpass transformation . The architecture demonstrated here is a coupled line type filter, since this is among the most practical and common filter types which can meet the stated specifications. In Coupled Transmission Lines, coupling between two transmission lines is introduced by their proximity to each other. Coupling effects may be undesirable, such as crosstalk in printed circuits, or they may be desirable, as in directional couplers where the objective is to transfer power from one line to the other . Another of their major use is using them in filtering the Microwave range frequencies.

The filter response will be based on the Chebychev transfer function. Chebychev type filters are popular for their high selectivity, i.e., they have a relatively fast signal cut off between pass and stop band. Filters operating in gigahertz frequency ranges rely on distributed transmission line structures to obtain the desired frequency response. Dimensions of the coupled transmission lines can be derived with published formula or minimal simulation software capability.

II.RELATED WORK

This paper presents the design of a parallel-coupled microstrip bandpass. The design is based on the use of half wave long resonators and admittance inverters. The dual center frequencies of 1.8 GHz & 2.4GHz are selected, the bandwidth (BW) is about 5%, the minimum attenuation amounts to -30 dB and the pass-band ripple is obtained equal to 0.5 dB. The design technique, parameter analysis, real prototype fabrication and measurement results of a 4th order coupled line bandpass filter at a dual simulation frequencies of 1.8GHz & 2.4GHz is presented in this paper.

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III. THEORY

A general layout of a parallel coupled microstrip bandpass is shown in figure 3.1 . The filter structure consists of open circuited coupled microstrip lines . These coupled lines are quarter wavelength , ($\lambda/4$) long and are equivalent to shunt resonant circuits. The coupling gaps correspond to the admittance inverters in the low-pass prototype circuit. Even- and odd- mode characteristic impedances of parallel-coupled half-wave resonators are computed using admittance inverters. These even- and odd- mode impedances are then used to compute physical dimensions of the filter. Now consider a bandpass filter composed of a cascade of $N + 1$ coupled line sections, as shown in Figure 3.1. The sections are numbered from left to right, with the load on the right, but the filter can be reversed without affecting the response. Since each coupled line section has an equivalent circuit of the form, the equivalent circuit of the cascade is as shown in Figure 3.2.

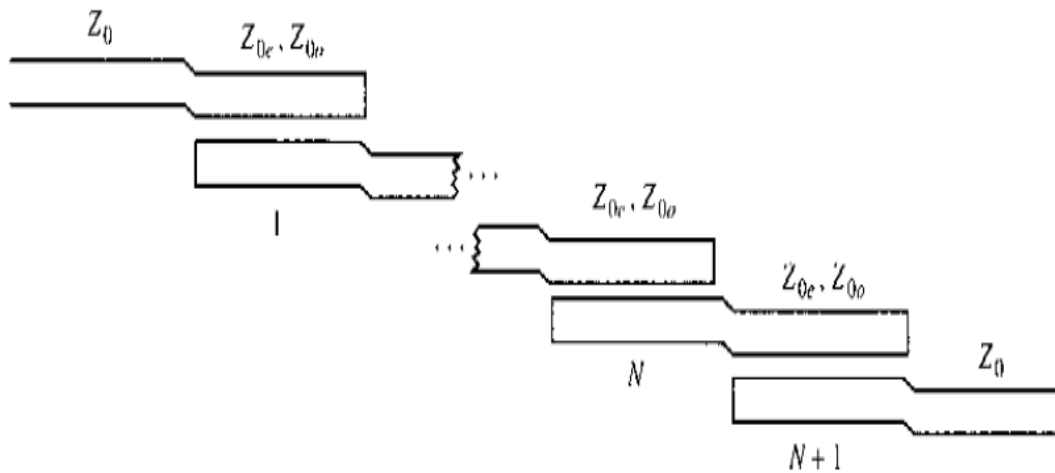


Figure 3.1 : Layout of an (N + 1)-section coupled line bandpass filter.

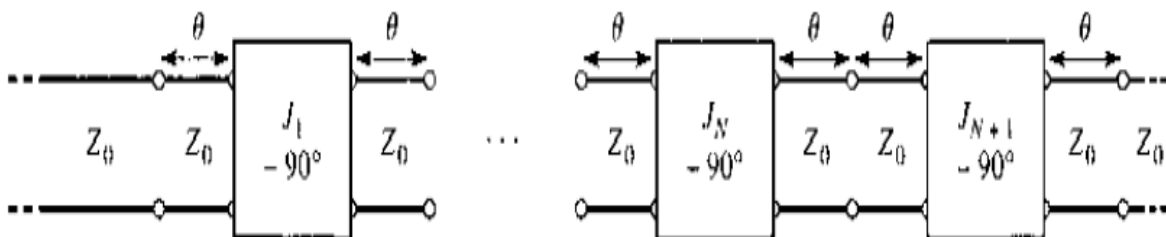


Figure 3.2 : Using the equivalent circuit of Figure 3.1 for each coupled line section.

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IV. IMMITANCE INVERTER

Immittance inverters play a very important role in filter design. They are used to transform a filter circuit into an equivalent form that can be easily implemented using various microwave structures. Immittance inverters are either impedance or admittance inverters. Making use of the properties of immittance inverters, bandpass filters may be realized by series (L-C) resonant circuits separated by impedance inverters (K) or shunt (L-C) parallel resonant circuits separated by admittance inverters (J). To design a bandpass filter, first of all a low-pass prototype circuit is modified to include immittance inverters. These low pass structures are then converted to bandpass circuits by applying conventional low-pass to bandpass transformation.

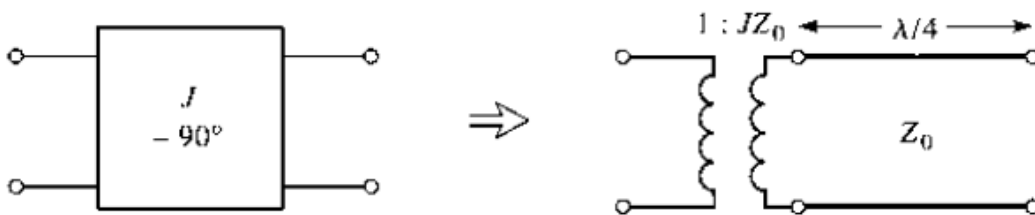


Figure 4.1 : Equivalent circuit of the admittance inverters.

V. SIMULATION MODELING AND DISCUSSION

The design equations for the coupled line are as follows:

The order of the filter was calculated assuming an equi-ripple (Chebyshev type 1) response with an insertion loss (L) of 30dB at the center frequency of 1.8GHz and 2.4GHz and the passband ripple amplitude (G) of 0.5dB. The fractional bandwidth $\Delta = 5\%$.

Hence the upper and lower cutoff frequencies of the passband are 2.52 GHz and 2.28 GHz respectively. Using the standard Chebyshev model:

$$n = \frac{\cosh^{-1} \sqrt{(10^{\frac{L}{10}} - 1) / (10^{\frac{G}{10}} - 1)}}{\cosh^{-1} \left(\frac{f}{f_c} \right)}$$

This gives us $n = 4$. Now, we get the lowpass prototype values from the standard Chebyshev table:

| |
|----------------|
| $g_0 = 1$ |
| $g_1 = 1.6704$ |
| $g_2 = 2.3662$ |
| $g_3 = 0.8419$ |
| $g_4 = 1.9841$ |
| $g_5 = 1.6704$ |

Now, we use the following design equations to get the inverter constants for a coupled line filter with $N+1$ sections:

$$Z_0 J_1 = \frac{\sqrt{\Pi \Delta}}{\sqrt{2g_1}}$$

$$Z_0 J_n = \frac{\Pi \Delta}{2\sqrt{g_{n-1} g_n}} \quad ; n = 2, 3, 4 \dots N$$

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$$Z_0 J_{n+1} = \sqrt{\frac{\Delta \Pi}{2g_n g_{n+1}}}$$

Using these equations, we get:

| |
|--------------------|
| $Z_0 J_1 = 0.2168$ |
| $Z_0 J_2 = 0.0556$ |
| $Z_0 J_3 = 0.0467$ |
| $Z_0 J_4 = 0.0556$ |
| $Z_0 J_5 = 0.2168$ |

Now, the even and odd mode impedances can be calculated as follows:

$$Z_{oe} = Z_0 [1 + JZ_0 + (JZ_0)^2]$$

$$Z_{oo} = Z_0 [1 - JZ_0 + (JZ_0)^2]$$

The results of these calculations are tabulated below:

| N | $Z_{oe}(\Omega)$ | $Z_{oo}(\Omega)$ |
|---|------------------|------------------|
| 1 | 63.191 | 41.512 |
| 2 | 52.934 | 47.378 |
| 3 | 52.446 | 47.778 |
| 4 | 52.936 | 47.377 |
| 5 | 63.192 | 41.514 |

The substrate used is a standard FR4 substrate (MSUB) with $\epsilon_r = 4.4$, $H = 1.58\text{mm}$, $T = 0.036\text{mm}$ and $T_{and} = 0.005$. Using a coupled line calculator, the width, length and line spacing for each coupled line was calculated:

| Line | W(mm) | L(mm) | S(mm) |
|------|---------|----------|----------|
| 1 | 2.70182 | 69.11613 | 0.794745 |
| 2 | 2.98623 | 68.10692 | 3.450721 |
| 3 | 3.0021 | 68.05937 | 3.948424 |
| 4 | 2.98624 | 68.10694 | 3.450725 |
| 5 | 2.70188 | 69.11616 | 0.794743 |

Based on the above values and taking standard port impedances as $Z_0 = 50\Omega$, the design was simulated.

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V.SIMULATION DESIGN, RESULTS & DISCUSSION

The design was simulated using AWR Design Environment (9.00.4847) and a response was generated. The coupled line design used for simulation was MCFIL which is a non-floating line. This is a coupled line model with the end effect included for the open ended line. One side of each coupled line is the ground plane.

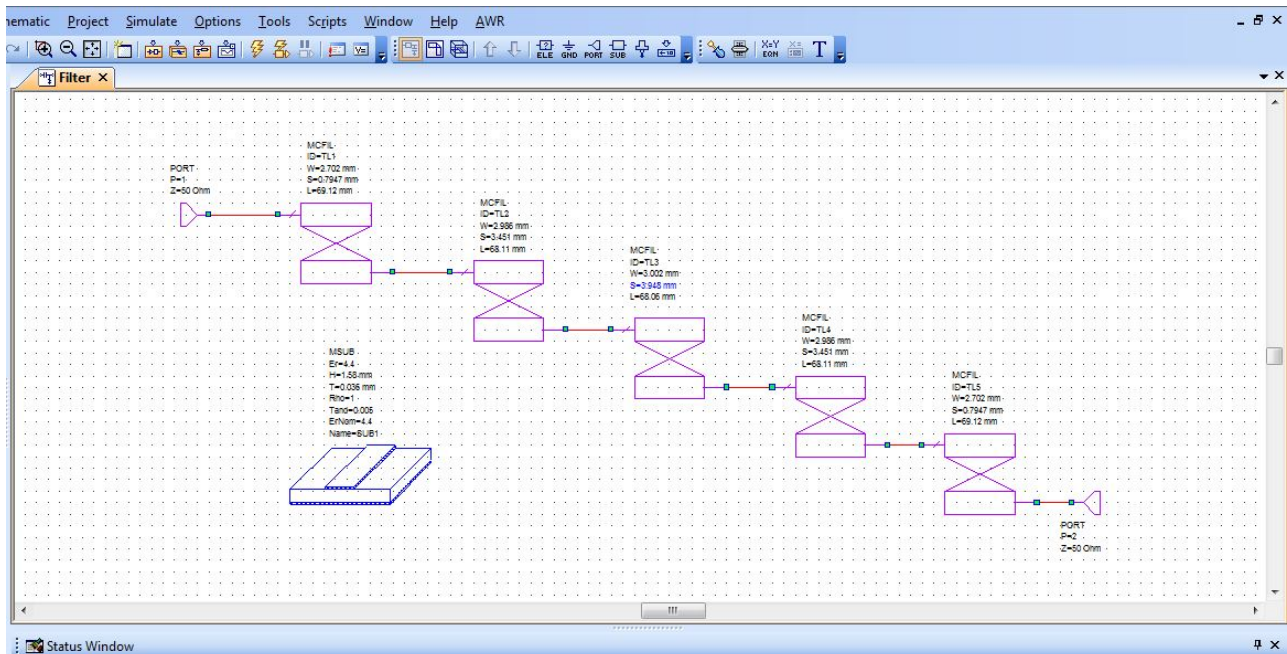


Figure 5.1 : Layout of the proposed 4th order filter design in AWR Software

Here, the parameter S_{11} (dB) represents the insertion loss at port 1 and this parameter which has a value of -6.521dB at the center frequency of 2.4 GHz while -6.587dB at the center frequency of 1.8GHz

The parameter S_{21} (dB) represents the insertion loss from port 1 to port 2 which has a value of -2.633dB at the center frequency of 2.4GHz while -6.375dB at the center frequency of 1.8GHz.

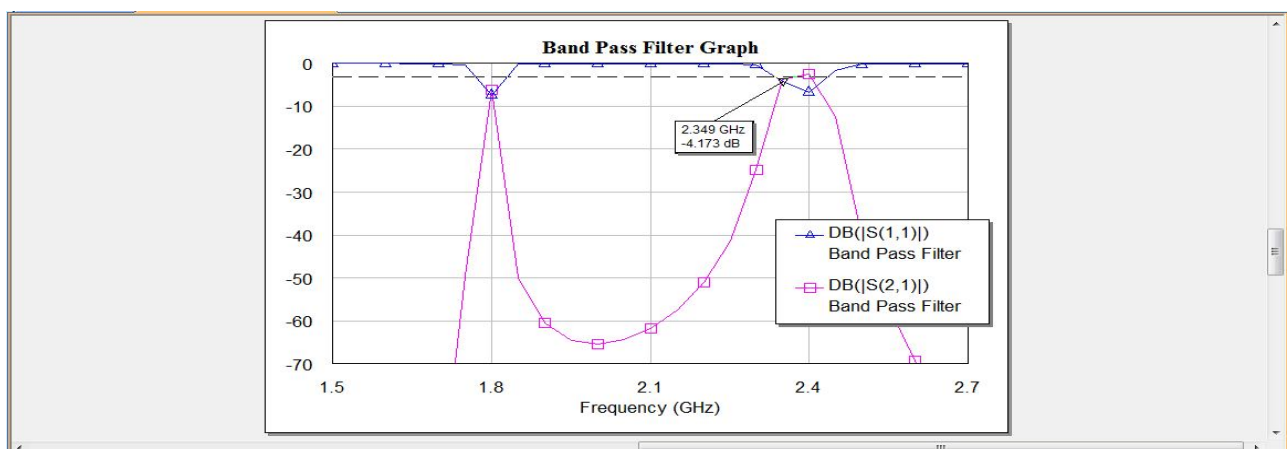


Figure 5.2 : Coupled Line Bandpass Filter at Dual Frequencies Result

The first design discussed above was simulated in AWR. The same was simulated using EM simulation. The schematic diagram for the same is given below:

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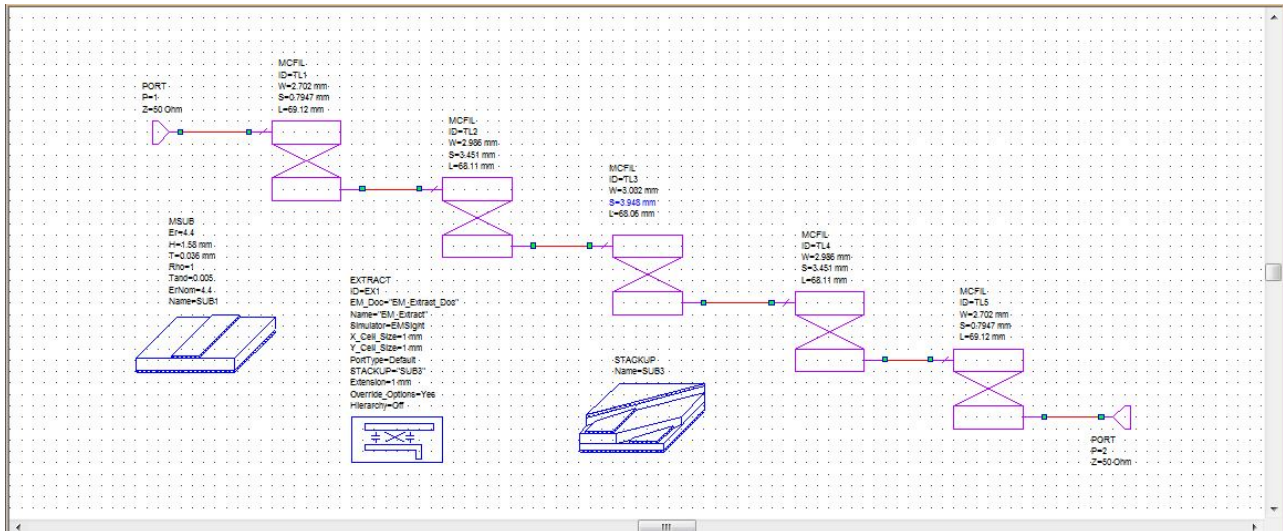


Figure 5.3 : Layout of the proposed 4th order filter design in AWR Software using EM simulation

Here, the parameter S_{11} (dB) represents the insertion loss at port 1 and the parameter which has a value of -2.606dB at the center frequency of 2.4 and 1.8GHz

The parameter S_{21} (dB) represents the insertion loss from port 1 to port 2 which has a value of -16.87dB at the center frequency of 2.4GHz while -31.55dB at the center frequency of 1.8GHz.

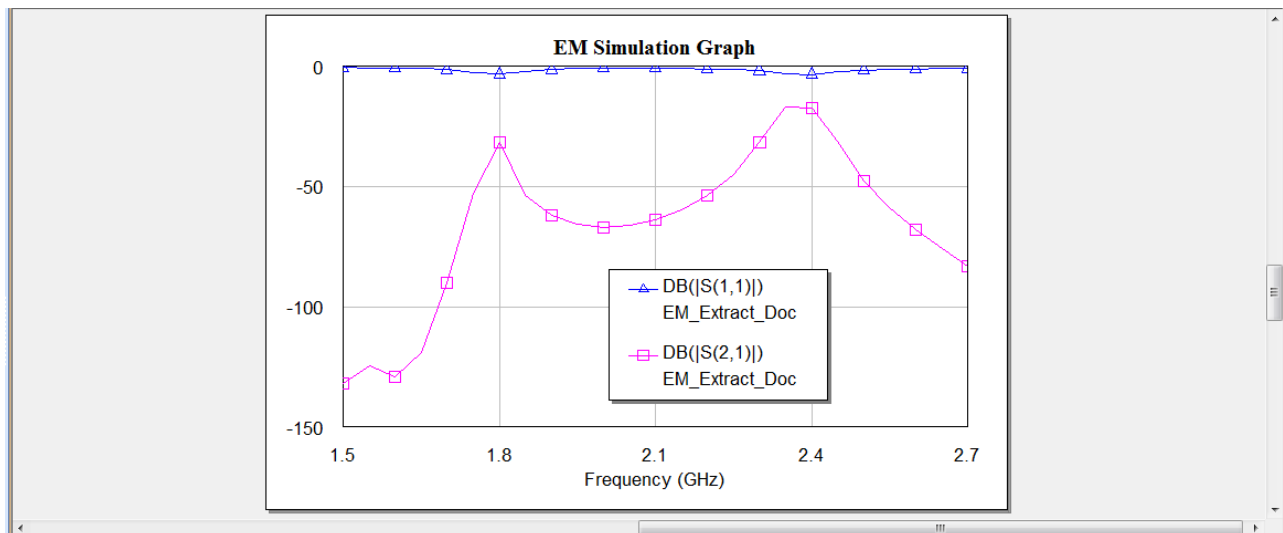


Figure 5.4 : Coupled Line Bandpass Filter at Dual Frequencies EM Simulation Result

For the Stackup, the dielectric used is FR4 and the conductor is copper. The transmission lines used in the design are MCLIN which are essentially similar to MCFIL lines with their remaining ends left open. The thickness of the dielectric layer is taken as 1.58mm and air thickness is taken as 24mm.

The simulation is done on EMSight with X and Y cell resolution of 0.5mm and an extension of 1mm. The extracted EM schematic is given below:

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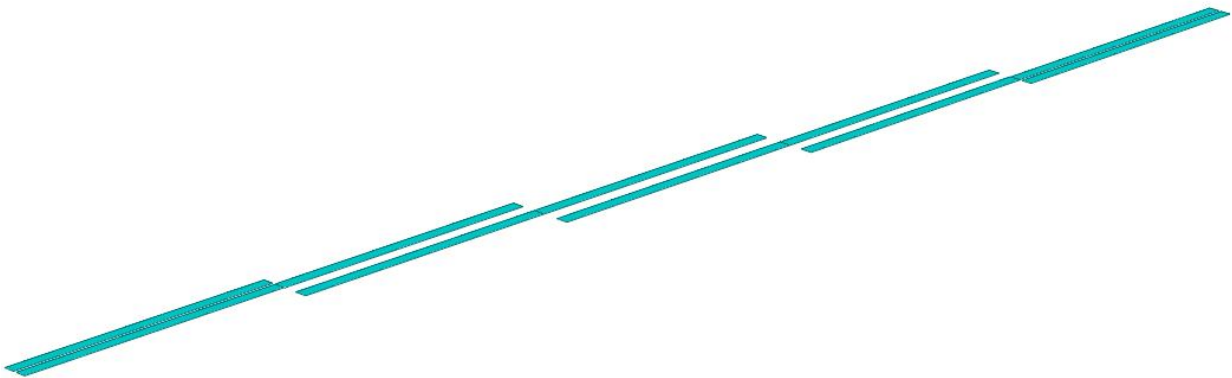


Figure 5.5 :3D View of the Coupled Line Bandpass Filter

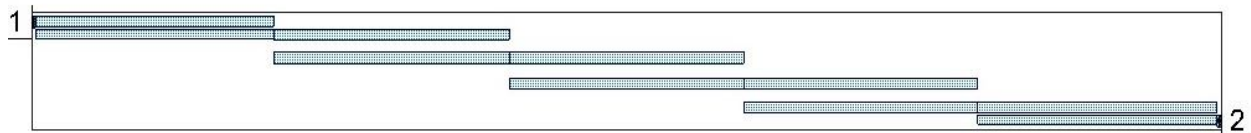


Figure 5.6 :3D View of the Extraced EM Strucure

VI.CONCLUSION

On a substrate with a dielectric constant of 4.4, with the dual center frequencies of 1.8 GHz & 2.4 GHz, a coupled line bandpass filter was simulated with the bandwidth of about 5%, with the minimum attenuation of 30 dB and with the pass-band ripple equal to 0.5 dB. Thus the design technique, parameter analysis, real prototype fabrication and measurement results at dual simulation frequencies of 1.8GHz and 2.4GHz of a 4th order coupled line bandpass filter was presented in this paper.

VIII.ACKNOWLEDGEMENT

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BIOGRAPHY



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