Design of S-Band Interdigital Band Pass Filter

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Abstarct:
A Band Pass Filter is one of the key components in the receive chain of any Transmit-Receive Module of an Active Array Radar. The critical parameter for the design of a BPF for a TR module is the form factor,insertion loss and rejection. Hence a microstrip based interdigital (tapped) BPF for S-Band TR Module (3.1-3.5 GHz) was designed. The filter was designed to achieve a typical insertion loss of 2.0 dB in the passband and a rejection of 50 dB on either side at 1.2 GHz away from centre frequency. The filter was realized and tested successfully on a 25 mil thick Rogers's substrate having a dielectric constant of 10.2. Further development is under progress to suppress the harmonics.

I. INTRODUCTION

Interdigital and parallel-coupled-line filters are traditional coupled-line structures to implement bandpass filter. Interdigital filter have compact size compared to coupled line filter hence more popular. Due to the unequal even and odd mode velocity, one of the intrinsic limitations of this filter is the spurious passband which occurs at third harmonic of fundamental frequency. A novel approach is used to suppress the spurious band as discussed in following paper.

II. DESIGN AND SIMULATION

A conventional five order microstrip interdigital filter is implemented as shown in fig.1.The electrical length of all elements is $\lambda_g/4$. The filter input and output use tapped lines which is at Θ_t distance from short circuit end. The tapped lines are having characteristic impedance of 50 Ω. This filter is compact but needs grounding(resonators) alternately which is accomplished using via holes.

The design equations for calculating physical dimensions are as follows:

$$C_i = \frac{Y_1 - Y_{i-1,i} - Y_{i,i+1}}{v} \qquad \text{for } i = 2 \text{ to } n-1$$

$$C_{i,i+1} = \frac{Y_{i,i+1}}{v} \qquad \text{for } i = 1 \text{ to } n-1$$

$$Y_{i,i+1} = J_{i,i+1}\sin\theta \qquad \text{for } i = 1 \text{ to } n-1$$

$$C_1 = \frac{Y_1 - Y_{1,2}}{v}, \; C_n = \frac{Y_1 - Y_{n-1,n}}{v}$$

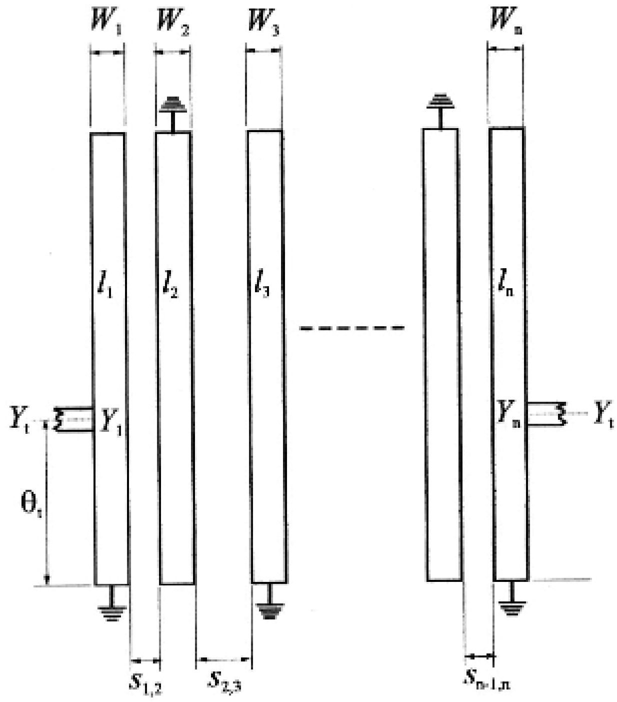

Fig 1: Conventional interdigital filter

$$\theta_t = \frac{\sin^{-1}\left(\sqrt{\frac{Y\sin^2\theta}{Y_0 g_0 g_1}}\right)}{1 - \frac{FBW}{2}}$$

$$Z_{0oi,i+1} = \frac{1}{2Y_{i,i+1} + 1/Z_{0ei,i+1}} \qquad \text{for } i = 2 \text{ to } n-2$$

$$Z_{0en-1,n} = \frac{1}{Y_1 - Y_{n-1,n}}, \qquad Z_{0on-1,n} = \frac{1}{Y_1 + Y_{n-1,n}}$$

Where,
$Z_{0ei,i+1}$, $Z_{0oi,i+1}$: even- and odd-mode impedances of coupled lines associated with resonators i and i + 1.

C_i (i = 1 to n) :Self-capacitances per unit length.

$C_{i,i+1}$(i= 1 to n– 1) : mutual capacitances per unit length between adjacent line elements.

The filter is EM simulated(layout in fig2) in Agilent ADS and results(dB(S2,1),dB(S1,1)) are shown fig3,fig4 and fig5 which meets given spec.

Passband: 3.1-3.5 GHz
Rejection:
@2700 and 3900 MHz: 25 dB min
@DC to 2000 MHz: 50 dB min.
@4.5 GHz: >50 dB

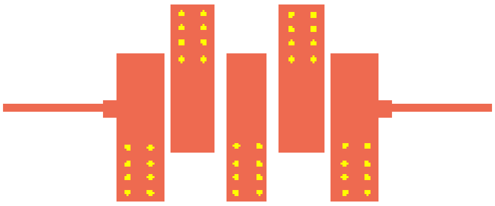

Fig2: Layout of conventional filter

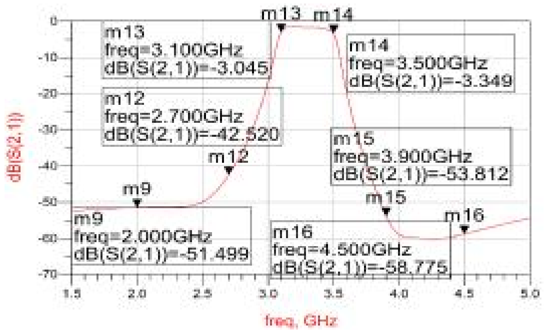

Fig3: simulation result of Insertion loss

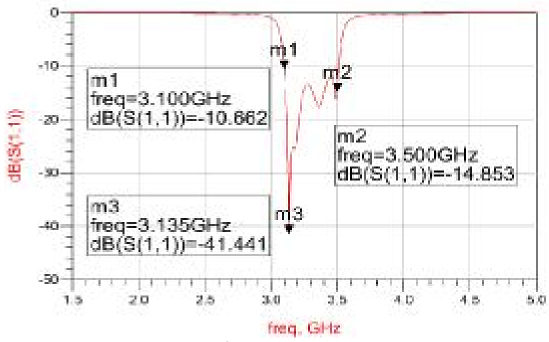

Fig4: simulation result of input return loss

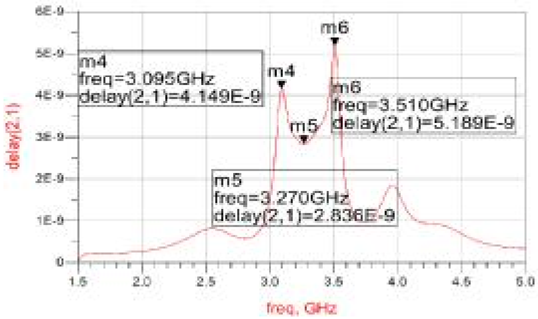

Fig5: simulation result of group delay

The broadband simulation of filter is shown in fig6 which indicates spurious passband at third harmonic.

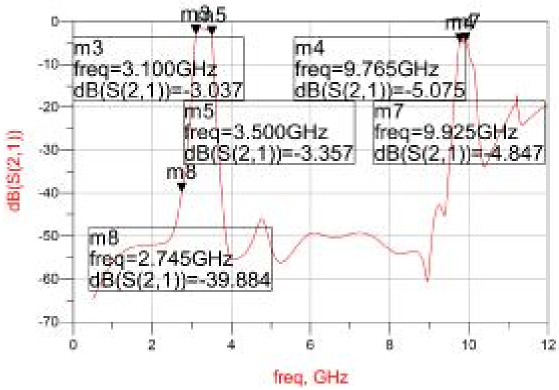

Fig6: simulation result of Insertion loss(wide band)

The unwanted passband or third order harmonic appears due to unequal odd mode and even mode phase velocities. Therefore spurious passband can be suppressed by equalizing the even and odd mode phase velocities.

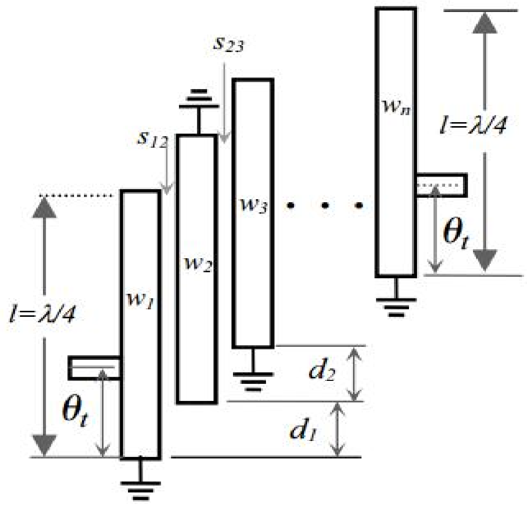

Fig7 : optimum edge coupled interdigital filter

The new proposed structure is shown in fig7 . This is implemented by shifting resonator by some distance, which will vary the odd mode capacitance keeping even mode capacitance constant. Finally when even and odd phase velocity will be equal, suppression of spurious passband occur.

The EM simulated result of above proposed filter is shown in fig 9 and fig 10 and corresponding layout shown in fig8.

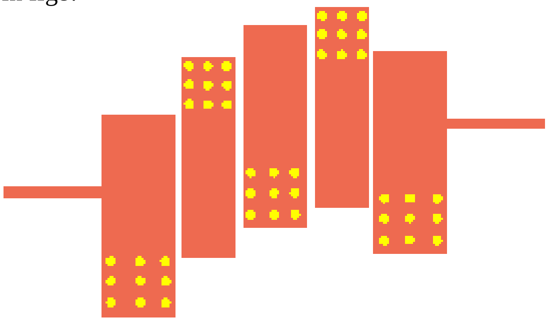

Fig8: Layout of optimally coupled interdigital filter

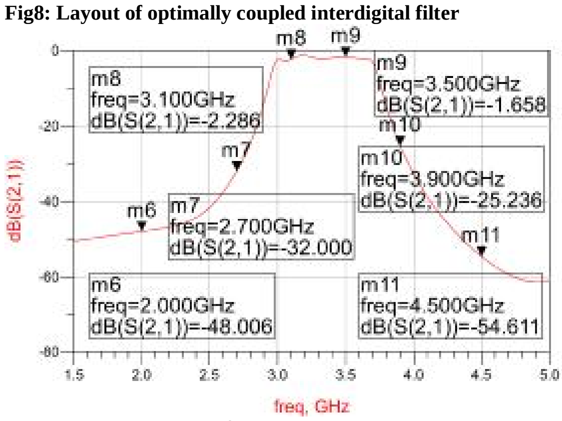

Fig9: Simulation result of Insertion loss

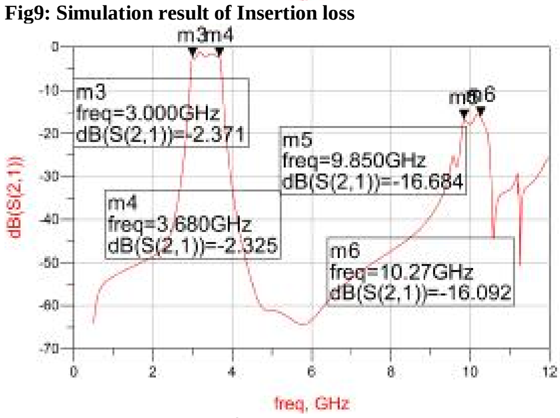

Fig10: simulation result of Insertion loss(wideband)

It is very clear from graph(fig 9 and fig 10) that spurious passband is suppressed by 13 dB(typ) without affecting insertion loss. The main advantage of optimum coupled filter it suppress harmonics without adding extra space.

III. MEASUREMENT AND ANALYSIS

The conventional interdigital filter is fabricated in Rogers 6010 substrate having $\mathcal{E}_r$=10.2 and H=25 mils. Fig 11 and Fig12 shows the photograph of connectorized (SMA) filter module having size(30×20 mm).

Higher dielectric constant material offers advantage of size reduction and hence preferable for filter design. Measured S parameter results(Fig 13) are having good correlation with simulated result but there is slight drift of centre frequency (80 MHz typ).Adjusting the length of resonators, centre frequency can be readjusted to 3.3 GHz. Also it shows 55 dB rejection(Fig 14) at 1GHz away from either side of passband. Groupdelay performance shows(fig 15) two peaks at start and stop frequency.

The wideband measured result confirms the spurious passband at 9.36 GHz as shown in fig 14.

Fig11: Photograph of fabricated filter

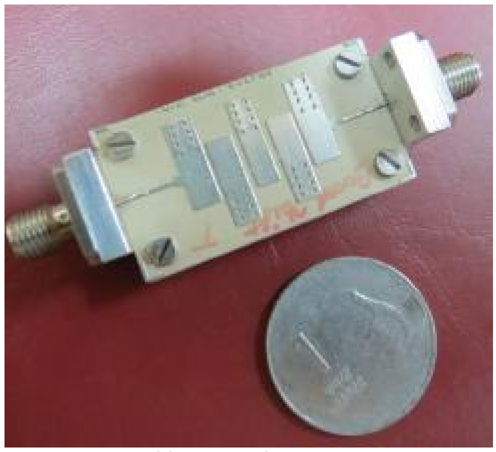

Fig12: photograph of fabricated filter compared to coin.

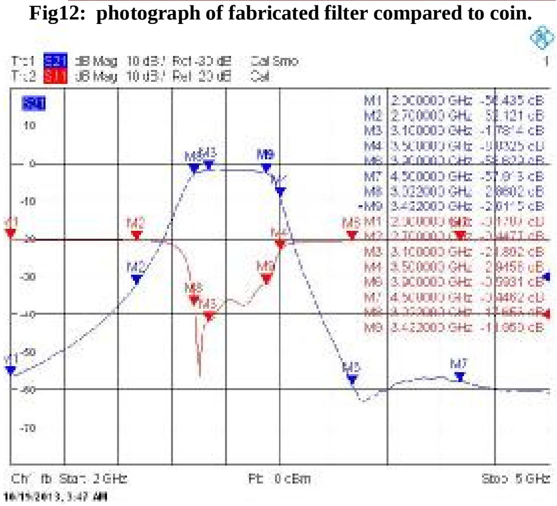

Fig13: VNA measured result of insertion loss

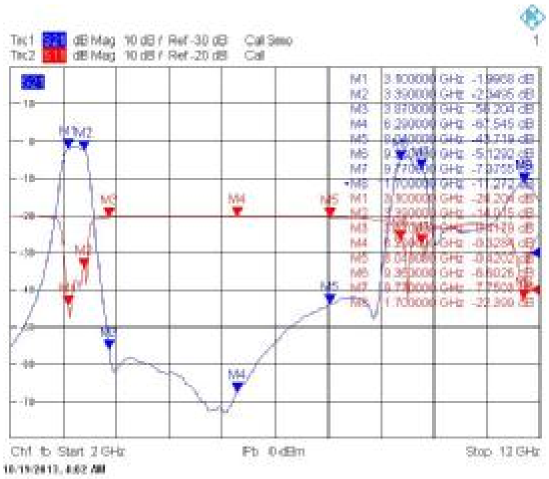

Fig14: VNA measured result of insertion loss(wideband)

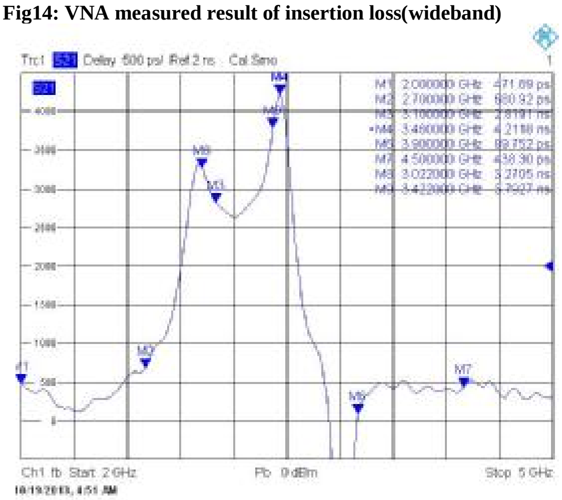

Fig15:VNA measured result of group delay

IV. CONCLUSION

In this paper simple design of interdigital filter(tapped) is briefly explained and fractional bandwidth of 12.12% is achieved. A design concept of optimum edge coupled band pass filter has been investigated in order to suppress harmonics. Simulation results good improvement in terms of spur reduction(13 dB). Adjusting the spacing between resonators we will able to increase coupling bandwidth/passband, but spacing need to be retuned to achieve required spurious reduction. This new technique offers additional advantage of size utilization compared to conventional interdigital filter.

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Rahul Sadhu completed his M.Tech in Microwave Electronics from Delhi University ,South campus. He joined Bharat Electronics in January 2011, and currently working in PA Design projects in D&E-Microwave Components group. Prior to this he was design engineer in Nokia Siemens networks and Sr Engineer in Mindtree Wireless in the RF domain.

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