Compact Dual Wide Bandstop Filter

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***Abstract*—In this work Dual bandstop filter (DBBSF) using coupled line loaded by a optimum bandstop filter, which consists of stepped impedance resonator. The novel transmission line structure consists of a parallel coupled microstrip line loaded by a modified optimum bandstop filter. The load can be realized by using the uniform characteristic impedance i.e. the total filter can be controlled by using only two characteristic impedances. The wide bandwidth in the stopbands, stopband zero positions can be controlled by using both the coupled line and a shunt stepped impedance open stub (SIOS) unit. Three transmission zeroes in the pass band were created by a mutual coupling between the coupled lines configuration. Design guidelines are derived using loss less transmission line model. The high impedance line required for the series transmission line (TL) sections facilitates convenient meandering that makes the geometry compact. To validate theoretical predictions, a prototype filter operating at two bands 0.74 and 2.2 GHz has been fabricated.**

***Index Terms*—Modified optimum bandstop filter (MOBSF), open ended stepped impedance resonator (OSIR), shorted coupled parallel microstrip line (SCPML).**

I. INTRODUCTION

MODERN trends in wireless communication systems require compact filters with multiband performance for interference suppression. Most of the applications require dualband filters. Several design techniques for single stopband filters have been proposed in literature. However, only a few [1-6] are available for dualband design. Conventionally, the dual-band filter characteristics are obtained by cascading two filter circuits operating at different center frequencies, thus increasing the overall size and the insertion loss [2].

DBBSF was presented in [1] by tapping the OSIR in the middle to the series quarter wave transmission line. In [2] designed by applying frequency-variable transformations to a prototype LPF. However, the performance depends significantly on the couplings between two closely spaced quarter-wavelength short-circuited stubs that achieve the coupled resonant circuit equivalence. Recently lumped element composite shunt resonators have been used to obtain dual-band performance by incorporating parallel-connected open stubs in [2], [3]. However, this method achieves good dual-stopband response at the cost of high out-band insertion loss due to the shunt capacitance effect produced by the parallel-connected open stubs of different lengths and widths. Lumped capacitors loaded tunable resonators (stubs) in combination with parallel-coupled resonators have been proposed in [4] to design multiple stopband filters. However, the stopband response is very narrow and greatly influenced by the lumped capacitors. Composite right/left-handed metamaterial TLs that give two arbitrary frequencies have been proposed in [5] to replace microstrip lines in the conventional design. However, the return loss between the stopbands is high and close to the passband insertion loss between the two stopbands.

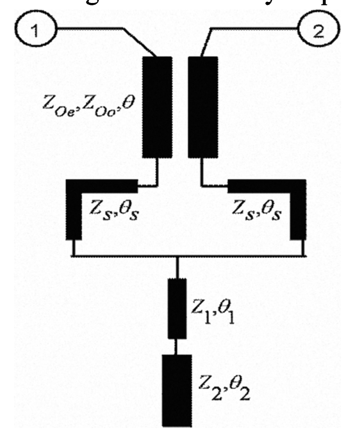

Fig 1 Proposed Dual wide bandstop filter

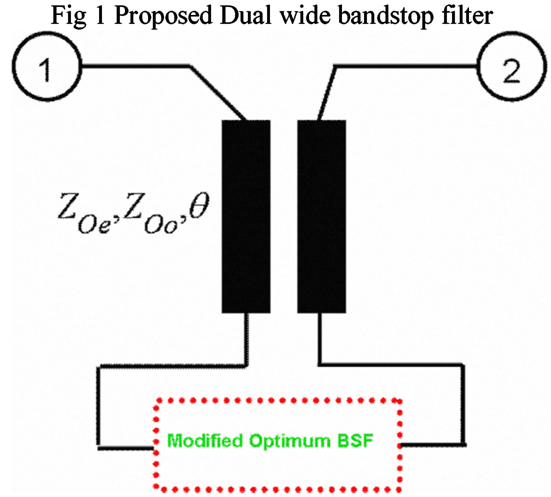

Fig 2 Simplified Schematic of proposed DBBSF

In terms of compactness and control over the dualband frequencies, the use of stepped impedance resonators (SIR) is promising. Variety of designs has been proposed in literature for the dual-band bandpass filters using SIRs. In this work, it is shown that a single SIOS in combination with the coupled line can produce controllable wide dual-stopband frequencies. The high-selective dual stopband effect is generated by the tapped half-wavelength TL structure. A lossless TL model is used to derive the design guidelines. The present filter can be used as a wideband bandpass filter at the operating frequency.

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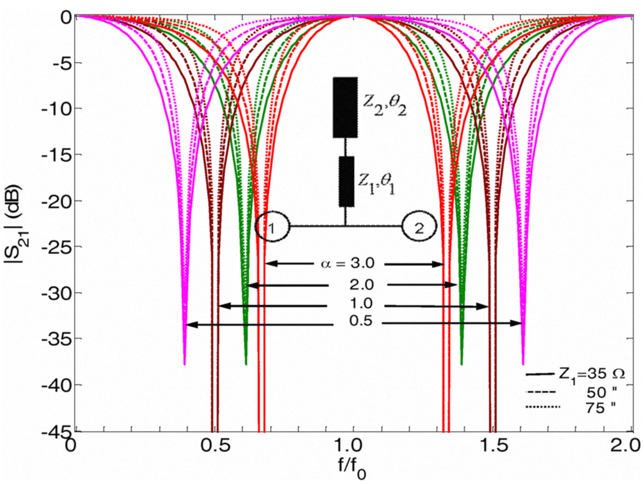

Fig. 3 The transmission response for SIOS (here $\theta_1 = \theta_2 = \pi/2$)

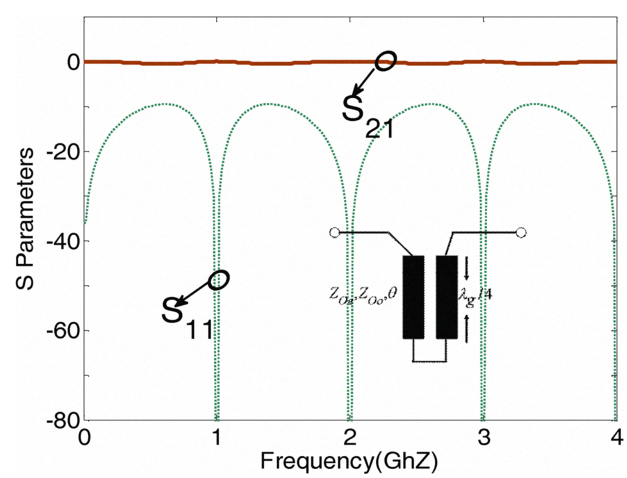

Fig. 4 The all pass response of SCPML (here $\theta = \lambda_g/4$)

II. FILTER DESIGN

Here, a uniplanar DBBSF is presented using parallel coupled microstrip line loaded by a modified optimum bandstop filter where the open stub of a OBSF is got replaced

by a open-ended stepped impedance resonator (OSIR) for realizing stopband transmission zeros. The filter having wide fractional bandwidth (FBW) in the stopbands, pass band between the stopbands, three attenuation poles in the pass band are obtained. The filter design procedure is easy and can be fabricated in a microstrip line.

A. Open ended stepped impedance resonator (OSIR)

The input impedance by looking from the feeding end is given as

$$Z_{in} = jZ_1 \frac{\left(Z_1 \tan\theta_1 - Z_2 \cot\theta_2\right)}{\left(Z_1 + Z_2 \tan\theta_1 \cot\theta_2\right)} \tag{1}$$

Let Z_{in}=0, under the resonance condition, then

$$Z_2 = Z_1 \tan\theta_1 \tan\theta_2 \tag{2}$$

$\theta_1 = \theta_2 = \theta$, the condition (3) further simplifies to

$$Z_2 = Z_1 \tan^2\theta \tag{3}$$

The transmission zeroes are shown in Fig. 3

The OSIR consists of two transmission lines having characteristic impedance of Z_1,θ_1 loaded by another transmission line of characteristic impedance Z_2,θ_2. The variation of zero positions with impedance ratio α = 0.5, 1.0 2.0 and 3.0 are plotted The OSIR resonating two stop frequencies, can be controlled by impedance ratio of α $(=Z_2/Z_1)$ and the fractional bandwidth of the each stopband can be controlled by a varying the impedance Z_1. The separation between the two stop band zeroes is more for α<1(less for α >1), and the pass band separation is more for α<1(less for α >1). Modified optimum bandstop filter (MOBSF)The MOBSF obtained by replacing the open stub of conventional BSF by an OSIR, results in DBBSF having the two stopband zeroes and narrow pass band between the two stopbands.

B. Proposed Filter

The shorted coupled microstrip line (SCPML) is exhibiting an all stop response is shown in the Fig 4.The proposed filter uses the MOBSF in place of a short.

Here the scattering parameters of the filter are derived by using
the even and odd mode analysis.

The impedance parameters of the filter given as

$$Z_{11} = \frac{(2Y_{oe} + 2Y_{oo}) + 0.5(Z_{oe}Y^2 + Z_{oo}Y^2) + Y(1 + 2Z_{oo}Y_{oe} - Z_{oe}Y_{oo}\tan^2\theta - \cot^2\theta)}{(4Y_{oe}Y_{oo}\sin^2\theta - Y^2\cos^2\theta) + Y\sin 2\theta(Y_{oo}\tan\theta - Y_{oe}\cot\theta)}$$

$$Z_{12} = \frac{2i\sin\theta(Y_{oe} + Y_{oo}) + iY\cos\theta(\tan\theta - \cot\theta)}{(4Y_{oe}Y_{oo}\sin^2\theta - Y^2\cos^2\theta) + Y\sin 2\theta(Y_{oo}\tan\theta - Y_{oe}\cot\theta)}$$

where

$$iY = \frac{Z_2\cos 2\theta - Z_1^2 Z_3 - Z_1\tan^2\theta(Z_2Z_3 - \cos 2\theta)}{Z_1^2\cos^2\theta + Y_3Z_2\sin 2\theta + \tan^2\theta(Z_1Z_2\cos^2\theta - Y_3Z_1\sin 2\theta)}$$

The scattering parameters are obtained as [7]

$$S_{11} = \frac{(Z_{11} - Z_o)(Z_{22} - Z_o) - (Z_{12}Z_{21})}{(Z_{11} + Z_o)(Z_{22} + Z_o) - (Z_{12}Z_{21})}$$

$$S_{21} = \frac{2Z_{12}Z_o}{(Z_{11} + Z_o)(Z_{22} + Z_o) - (Z_{12}Z_{21})}$$

C. Analysis

In the Scattering parameters given above Z_1, Z_2 are impedances of the OSIR, Z_3 is series transmission line for loading the parallel coupled microstrip line (PCML) having even and odd mode characteristic impedances as Z_{Oe}, Z_{Oo} respectively.

The filter characteristic impedances are chosen as $Z_2 = Z_1/2$ and $Z_3=Z_1$ such that the load can be realized by using the uniform characteristic impedance Z ($Z = Z_3 = Z_1 = 2\ Z_2$). Here the impedance Z_2 can further be replaced by parallel equivalent of two parallel impedances of Z_1.

D. *Performance*

As shown in the Fig 4 for the transmission coefficient S_{21} by increasing the coupled line characteristic impedances Z_{Oe}, Z_{Oo} the separation between the two stopbands is increasing for a fixed ratio of $R=(Z_{Oe}/Z_{Oo})$ and the distance between the stopband zeroes is decreasing, the Fig 7 shows the rejection in level in the passband is increased by increasing the Z_{Oe}, Z_{Oo} and for fixed uniform impedance Z. The three attenuation poles in the passband for S_{11} are obtained by choosing the impedance Z and coupled line impedance ratio R.In both the cases selectivity increases with the increasing values of Z_{0e} and Z_{0o}. Further control of bandwidth without changing the zero positions is achieved by varying the series TL impedance Z_3.

III. FABRICATION AND MEASUREMENTS

Following the above guidelines, a compact DBBSF operating at two bands 0.74 GHz and 2.2 GHz with 3-dB FBWs of 85.7% and 41.4% respectively is fabricated on a low cost FR4 substrate (thickness = 1.58mm, dielectric constant = 4.3 and loss tangent = 0.022). For these specifications, all electrical lengths θ ,θ_1,θ_2, and θ_s are chosen as $\pi/2$ at f_0=1.5 GHz and for coupled line Zoe=110Ω,Zoo=57Ω and Z_1=130Ω, Z_2=65Ω, and Z_3=130Ω are chosen as the impedance parameters.

All physical dimensions using full wave EM simulator IE3D® are obtained for coupled line as width=1 mm, spacing=0.6 mm and for the load uniform impedance of width=0.3 mm (where $Z_2=2Z_1$). The filter occupies a compact size with rectangular area of $44 \times 20\ mm^2$.

The layout of the proposed filter was shown in the Fig 7.The full wave simulated response of the proposed filter are shown in Fig. 8.Measured stopbands with rejections more than 30 dB appeared at f_{s1} = 0.74 GHz and f_{s2} = 2.2 GHz. The measured 20dB FBWs in the two stopbands are 20.8% and 7.68% respectively, while the return loss in the passband between the stopbands is better than 25dB from 0.97 GHz to 1.193 GHz. Measured passband insertion loss, including connector loss is within 1.2 dB up to 0.7 GHz. The filter has sharp rejection performance. The attenuation rates at the passband to stopband transition knees are 103.33 dB/GHz (measured attenuations being 4 and 35 dB at 0.44 and 0.74 GHz, respectively) and 113.64 dB/GHz (measured attenuations being 7 and 32 dB at 2.44 and 2.2 GHz, respectively) on the lower side of the first and upper side of the second stopbands, respectively.

The comparison of filter with the other designs given in the Table 1.The proposed filter having the wider 3 dB FBW, wider passband between the stopbands and of compact size. Hence the present design can be used as a band pass filter.

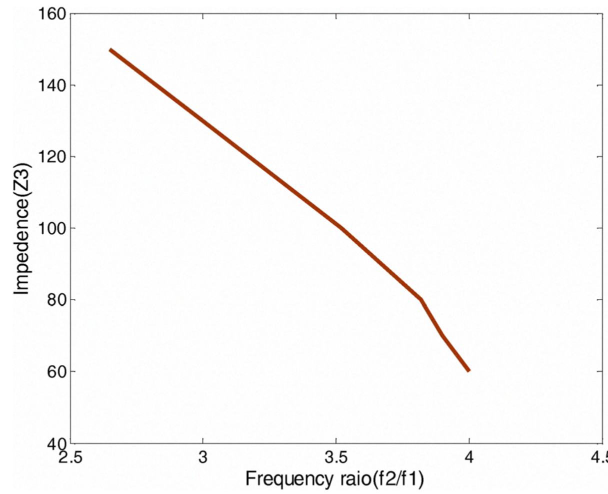

Fig 5 Variation of transmission zeros with impedance Z_3

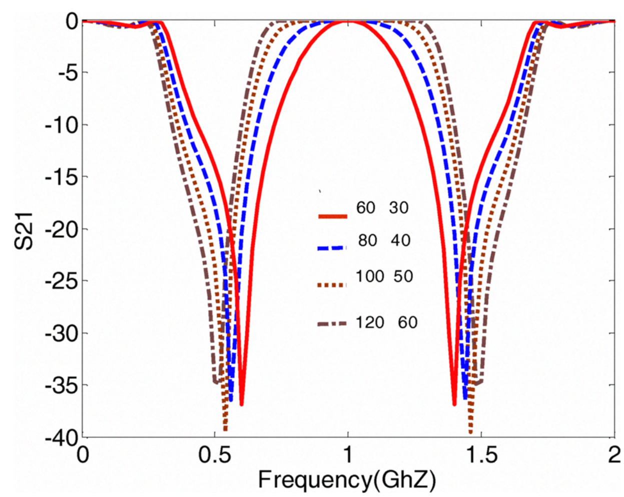

Fig 6 Variation of Transmission zeros and FBW with Z_{Oe}, Z_{Oo}

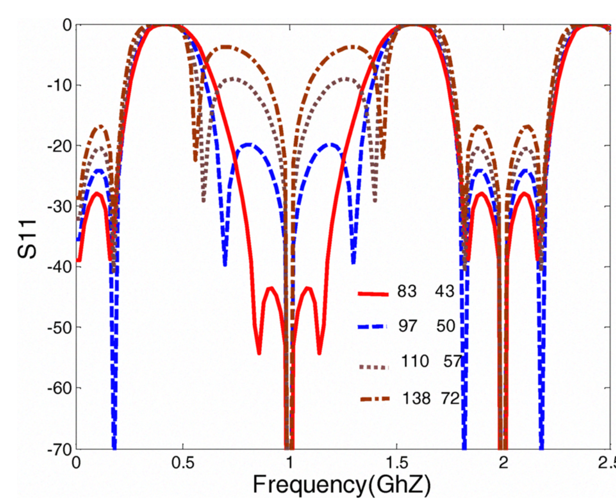

Fig 7 Variation of reflection coefficient in the pass band with Z_{Oe}, Z_{Oo}

TABLE 1 comparison table with the other references

Ref No	3-dB FBW for 1^{st}&2^{nd} bands (In %)	Operating frequency (in GHz)	pass band IL (in dB)	Filter size (in mm^2)	Return loss (in dB)
[1]	80&43	2.5	2	23.5*27.5	25
[2]	-------	5	2	--------	18
[3]	14.9&21.2	2	1	--------	15
[6]	56.7&28.2	1.5	0.9	28*23.8	15
Current Work	**80 &70**	**1.5**	**1**	**44*20**	**25**

IV. CONCLUSION

A compact dual wide bandstop filter is developed using a coupled line loaded with MOBSF. Design guidelines are provided. By varying the impedances of the structure, a simultaneous control over the rejection level in the passband, stopband zero positions and also the fractional bandwidths are achieved. The filter exhibits sharp rejection stopbands with good out-of-band response, which is essential for a bandstop filter design. As the design uses all TL sections only, the filter structure is simple, easy to fabricate and also the geometry is more compact.

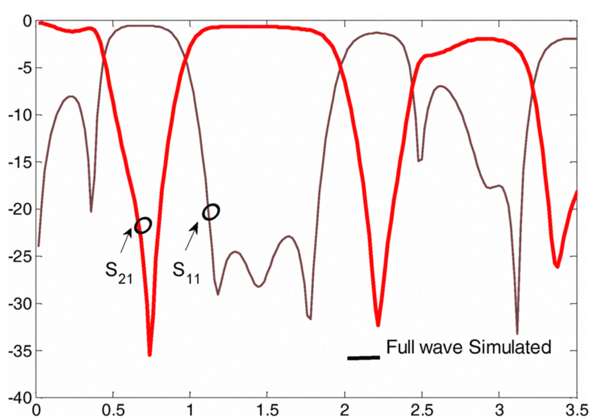

Fig 8 Filter performance in full wave based simulator

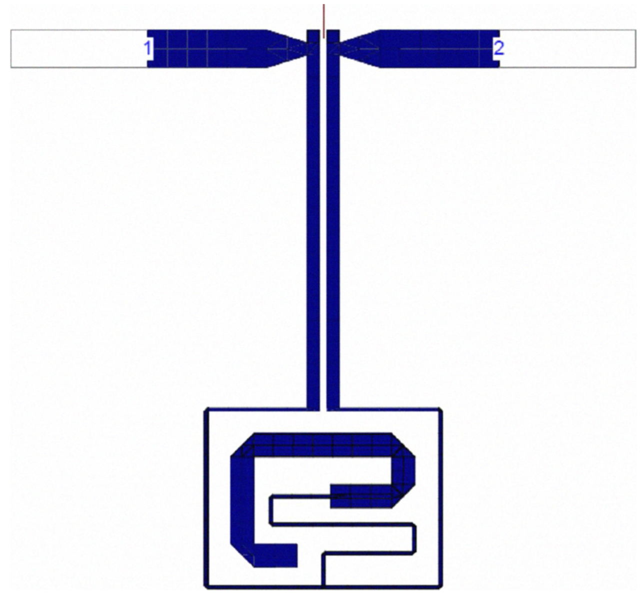

Fig 9 Proposed Filter Lay out in Full wave simulator

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