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Design of 12-14.1 GHz Bandpass Filter with Stub Loaded

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ABSTRACT
This paper presents the design, fabrication, and measurement of 12-14.1GHz microstrip multi-mode bandpass filter. The fabricated microstrip bandpass filter has a compact size of 15.785mm×5mm and good filtering characteristics. In the frequency range of 12-14.1GHz, the insertion loss varies between 1.565dB and 2.051dB with about 0.5dB ripple. The measured results show excellent out-of-band rejection above 40dB in 0.02-10GHz, but much poorer rejection performance in upper stopband due to the existence of spurious passband. To solve the problem, a DC-14.1GHz LC low pass filter is supplemented after the microstrip bandpass filter.
Keywords: Stopband rejection, insertion loss, low pass filter

I. INTRODUCTION

Bandpass filter (BPF) is a passive component capable of selecting a signal inside a specific bandwidth with a certain centre frequency known as passband and rejecting signals in another frequency region known as stopband. In practical application, receivers have to provide enough second harmonic rejection, and rejection to intermediate frequency (IF) and mirror frequency. These demands are generally met by designing a proper out-of-band rejection of BPF in switch filtering banks. Compared with conventional parallel coupled-line BPF, a filter with a multi-mode resonator (MMR) has outstanding advantages, such as wide passband, miniature size, and high performance. Stub-loaded MMR-based filter has been confirmed to have a sharp out-of-band rejection, but usually suffers from a narrow upper stopband due to the resonant mode in the MMR filter [1]. The open-circuited stubs can be applied to adjust the high resonant modes generated from the MMR into desired passband, which deepens the upper stopband [2] and improves the rejection near $2f_0$ simultaneously. However, according to our previous study [3], like conventional parallel coupled-line BPF, MMR filter still suffers from a spurious passband at $2f_0$[4] when operating at high frequencies.

In this work, to sharpen the skirt and out-of-band rejection level in the upper stopband of MMR filter, we cascade a LC low pass filter. Thus, the designed MMR bandpass filter within 12-14.1GHz frequency range presents low insertion loss (*IL*), high selectivity, and excellent rejection. The initial physical dimensions of filters are calculated and optimized using ADS, and then the optimized sizes are tuned slightly using the fullwave electromagnetic simulator HFSS. After that, final filter schematic is obtained.

II. PROPOSED FILTER

In this paper, the design specifications are as follows:
1dB bandwidth: 12-14.1GHz
Insertion loss: ≤3dB
Rejection:≤-30dB@0.02-7.1GHz&16-18GHz
&24.28-28.2GHz
≤-75dB@19-21.9GHz
Input and output *VSWRS*: ≤2

The chosen substrate is Rogers 6010, which has a permittivity ε_r =10.2, thickness *h*=0.635mm, and dielectric loss $\tan\delta$ =0.0023. The reason for choosing this relative high substrate ε_r is to have a circuit of smaller size, compared with those on substrates with lower ε_r. Fig. 1 illustrates the geometrical sketche of the designed filter using three cascaded MMR proposed in Ref.[3]. The filter shows a compact size of 15.785mm×5mm. When the length of stub is equal to quarter-wavelength at a resonant frequency f out of the desired passband, a transmission zero is generated, sharpening the roll-off skirt in stopbands. The up-loaded stub in the central MMR relocates the transmission zero near $2f_0$ and enlarges the rejection, while the MMRs at two sides flatten the fluctuation of insertion loss and increase the reflection loss by creating a new transmission pole in the passband. Identical parallel coupled lines connected to input and output feeds are stretched longitudinally so as to raise the frequency-dispersive coupling degree with a coupling peak near the lower passband. By adjusting the length of the coupled lines, the frequencies of passband and stopband can be varied.

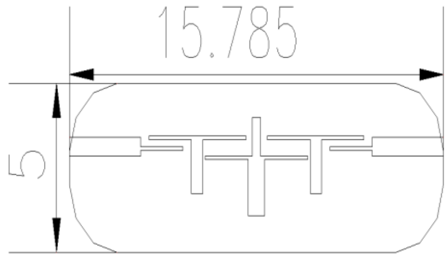

Fig.1 The designed MMR bandpass filter.

The width of the input and output feeds are determined using ADS Line-Calc to be kept as 0.614mm with 50 ohms impedance and the dimensions of other lines are optimized to balance the different specifications. To have a degree of freedom in tightening the coupling degree and achieve a coupling peak in the lower passband, the strip and slot widths in the coupled lines should be chosen carefully. On the other hand, the strip and slot widths can not be too small to be fabricated. Increasing the bandwidth means less loss in the passband but reduced selectivity. However, the selectivity can be improved by flattening the ripple but at the cost of decreased return loss [5]. Therefore, the tradeoff among these specifications should be balanced. In practice, the actual bandwidth of the filter appears to be always less than the value assumed in the design. Therefore, it would be desirable in calculating the parameters of a given filter to use a somewhat larger bandwidth than actually is required.

III. SIMULATION AND MEASUREMENTS

The *IL* and *VSWRs* are measured with R&S ZVK Vector Network Analyzer, and the test results are present in Fig. 2. Four transmission poles and three transmission zeros at 12.73GHz, 13.74GHz, and 14.58GHz are formed in the passband. The first resonant frequency at 12.18GHz is attributed to the parallel coupled lines, while the resonant mode at 14.02GHz can be explained by the introduction of stubs in the MMRs at the two sides. The down-loaded stub in the central MMR brings about the resonances at 13.39GHz and 14.88GHz, respectively. The up-loaded stub in the central MMR moves the first and fourth transmission poles close to passband.

The maximum 2.051dB of *IL* is achieved at 12.8GHz, and the *ILs* at low and high cut-off frequencies are 1.773 and 1.721, respectively. In addition, input and output *VSWRs* are better than 1.8 in the desired frequency range. The measured results show good out-of-band rejection above 40dB at 0.02-10GHz, and the rejection at 16-18GHz is also more than 30dB. However, much poorer rejection performance in further upper stopband is witnessed. Only more than 39.4dB rejection is achieved in 19-21.9GHz, and the requirements of rejection≥30dB @ 24.28-28.2GHz and ≥75dB@19-21.9GHz can not be satisfied. The reason is that the achieved structure suffers from the existence of second spurious response around -7.943dB at 18.36 GHz.

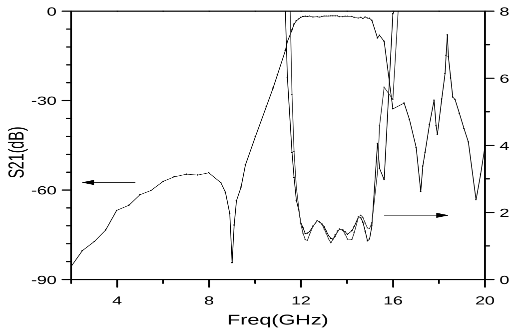

Fig.2 Frequency response of the fabricated.BPF.

To deepen the rejection in the upper stopband, we can add a DC-14.1GHz low pass filter (LPF) after the BPF. The 9 order Chebyshev low pass filter of DC-14.1GHz can be designed using Genesys easily. Fig. 3 shows the topology of 9 order Chebyshev LC LPF, and the values of inductors and capacitors can be realized in practice.

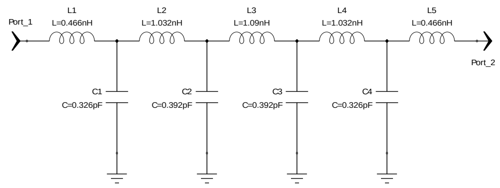

Fig.3 Schematic of DC-14GHz low pass filter.

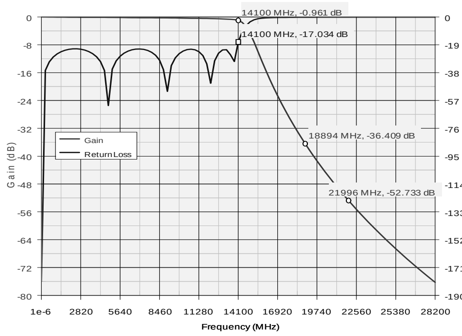

Fig.4 Frequency response of DC-14.1GHz low pass filter.

From Fig. 4, the *IL* of LPF up to 14100 MHz is less than 0.961 dB, and the return loss is no more than -17dB. The attenuation increases from 36.409dB at 19GHz to 52.733dB at 21.996GHz. Therefore, BPF consisting of the circuits in Fig. 1 and Fig. 4 can meet the all design specifications before.

IV. CONCLUSION

In this paper, 12-14.1GHz microstrip multi-mode bandpass filter is designed, fabricated, and measured. The fabricated microstrip bandpass filter has a compact size of 15.785mm×5m and good filtering characteristics. In the frequency range of 12-14.1GHz, the insertion loss varies between 1.565dB and 2.051dB with about 0.5dB ripple. The measured results show excellent out-of-band rejection above 40dB in 0.02-10GHz, but much poorer rejection performance in further upper stopband due to the spurious passband. To solve the problem, a DC-14.1GHz LC low pass filter is introduced after the microstrip bandpass filter. Thus, the final circuit constituted of MMR BPF and LC low pass filter has performances satisfying the specification.

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