Cross-Coupling Hairpin Bandpass Filter with Periodic Grooves

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Abstract

This paper introduces a miniaturized bandpass filter with high out-of-band rejection for 5G communication systems. The proposed method includes directly connecting the non-adjacent resonant units of the filter with a section of 1/2 wavelength transmission line to form a special cross-coupling structure, thereby introducing a pair of transmission zeros, and the out-of-band suppression is below -30dB, which improves the performance and the out-of-band rejection capability of the filter. At the same time, periodic square grooves are used on the outer edge of the coupled resonator to achieve phase velocity compensation between odd-mode and even-mode to suppress parasitic passband.The 1dB bandwidth of this filter is 4.8GHz~ 5GHz, the center frequency is 4.9GHz, and the bandwidth is 4%. The minimum insertion loss in the passband is 1.6dB and the insertion loss in the band is less than 3dB, and the return loss in the band is less than -11dB. Rejection level is -32.7dB around $2f_0$ and -34.2dB around $3f_0$,and more than 20dB rejection level is achieved in the out-of- band 5.1GHz ~ 25GHz frequency range.

Filter Design

Based on the hairpin microstrip filter, the parallel characteristic impedance between non-adjacent resonator units is 50 Ω， a transmission line with an odd multiple of length ($l1 + 2l2 = \lambda 0/2$). The filter produces a pair of transmission zeros near the passband, which greatly improves the filter's band selection characteristics. After HFSS parameter optimization simulation, l1+2l2=22.9mm.

The odd-mode field is mainly distributed outside the microstrip coupling filter, while the even-mode field is mainly distributed inside the microstrip coupling filter.In order to keep the same phase velocity of the two modes at the port, it is necessary to increase the phase velocity of the even-mode to perform phase velocity compensation to prevent the distortion of the scattering parameters.In this regard, a periodic groove is introduced into the coupling edge of the parallel resonator to realize the phase velocity compensation of the odd-even mode. As shown in the figure, fx and fy represent the length and width of the periodic square groove respectively. After the HFSS parameter optimization simulation, it obtains fx=0.5mm, fy=1.6mm, and the distance between the two square grooves is 0.35mm.

Fig.1 shows the layout of the cross-coupling hairpin band-pass filter with grooves. The overall size is 30mm*21mm.Table1 shows the parameter values of the cross-coupling hairpin filter with grooves.

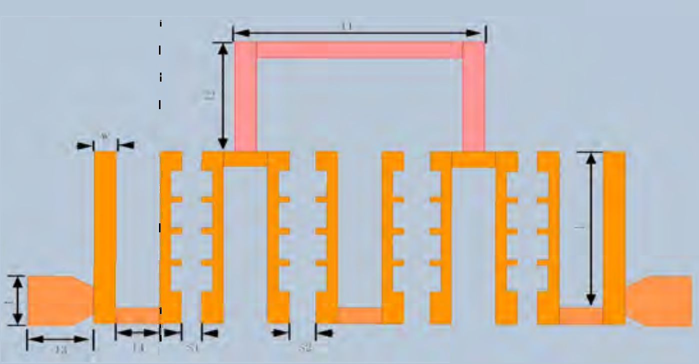

Fig. 4. The structure of the Cross-Coupling hairpin filter with grooves.

t	w	l	S_1
1.4mm	1mm	10.7mm	0.9mm
S_2	l_1	l_3	l_4
1.2mm	6.75mm	3mm	0.35mm

TABLE I. PARAMETER VALUES OF THE CROSS-COUPLING HAIRPIN FILTER WITH GROOVES.

Conclusion

The present article proposes the effect of the 1/2 wavelength cross-coupling structure on the out-of-band suppression capability introduced by the transmission zero and the inhibitory effect of periodic square grooves on parasitic passbands. Compared with the traditional increase of the order of the microstrip filter to enhance the out-of- band suppression, the design of structure ensures miniaturization. The center frequency is 4.9GHz, and the passband insertion loss is guaranteed to be less than 3dB and the return loss is less than - 11dB, obtained from 5.1GHz to 25GHz wide stopband with rejection level lower than -20dB. The filter meets the requirements of 5G communication system for high performance and miniaturization of the filter, and has certain engineering practical significance for promoting the development of 5G communication technology.

Results

In Fig.2,it can see the minimum insertion loss in the passband is 1.6dB, the insertion loss in the passband is less than 3dB, and the return loss in the passband is less than -11dB.It can be seen from the Fig.3 that the traditional fifth-order hairpin filter has a general out-of-band selectivity, and it has parasitic passband around $2f_0$ and $3f_0$ .Fig.4 shows the result of comparison of the two filters. It introduces two sharp transmission zeros at 4.7GHz and 5.1GHz through cross-coupling, increasing the out-of-band selectivity. However, there is still parasitic passband around integer multiple of center frequency, the four square grooves on the edge of each coupled resonator can suppress the spurious passband very well, with -32.7dB at $2f_0$ and -34.2dB at $3f_0$ .From 5.1GHz to 25GHz, the suppression level of more than -20dB is achieved.

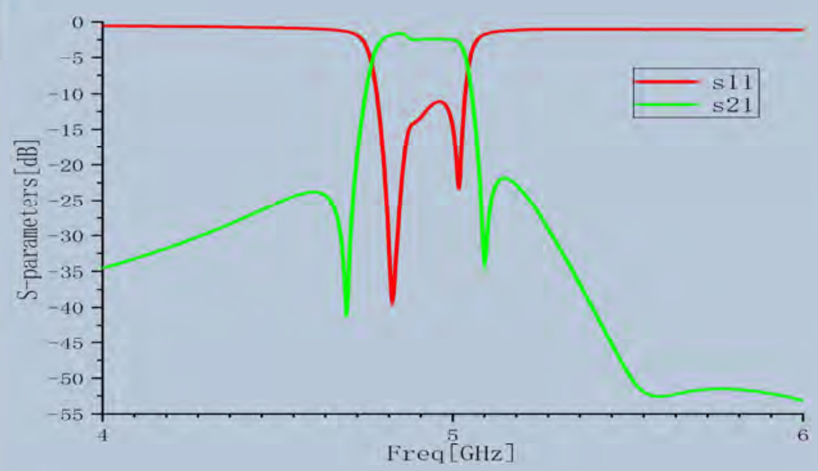

Fig. 2. S-parameters of the Cross-Coupling hairpin filter with grooves from 4GHz to 6GHz.

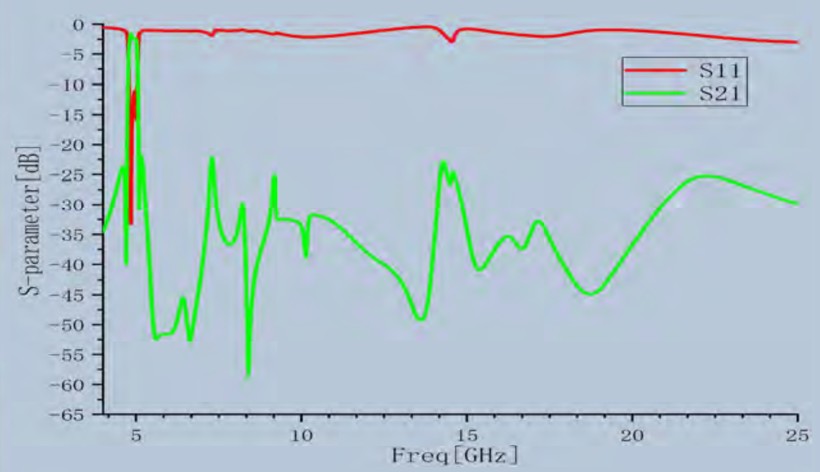

Fig. 3. S-parameters of the Cross-Coupling hairpin filter with grooves from 4GHz to 25GHz.

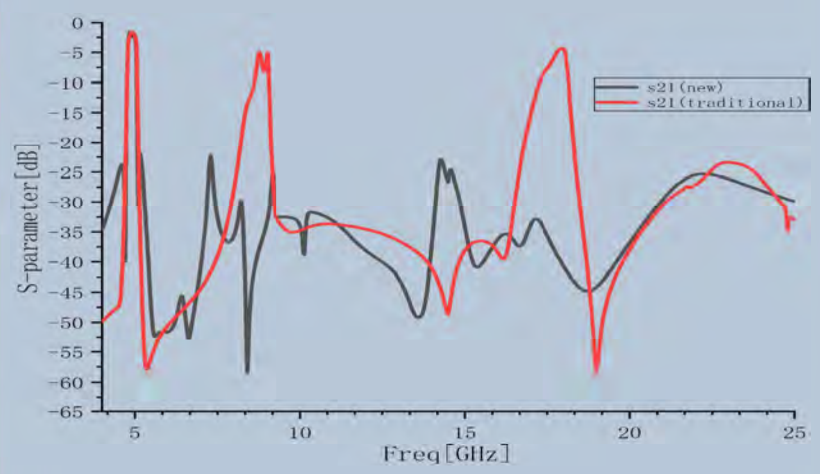

Fig. 4. S-parameters comparison between the new filter mentioned above with traditional microstrip hairpin filter.