Dual-Mode L-Band Bandpass Filter with Cross Couplings and Absorbing Resonators

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Abstract- This paper introduces dual-mode bandpass filter with cross couplings and absorbing resonators. The responses of six electrical resonators & two absorbing resonators and eight electrical resonators are simulated. It is shown that the cross coupling and absorbing resonator can improve the cutoffs at the edge of the passband evidently. An L-band filter composed of three physical cylindrical waveguide cavities and one absorbing cavity was made and tuned. The experimental result is in good agreement with the simulation.

I. INTRODUCTION

As the frequency spectrum becomes more and more crowded, specifications for channel filters have tended to become very much more severe. Very high close-to-band rejections are required to prevent interference to or from closely neighboring channels [1]. The filter with the sharp cutoffs at the edge of the passband and high selectivity can meet the demand. In addition to the high selectivity, the items such as the lowest insertion loss, the smallest size and the lowest cost must be taken into account. As we all know that the sharp cutoffs can be improved by adding the number of resonators in the traditional Butterworth and Chebyshev filters, but the insertion loss is also added. The cross-couplings between nonadjacent resonators and absorbing resonators can improve the selectivity without adding the insertion loss. In this paper, the basic theory of cross coupling and absorbing resonator is introduced. The simulation software is designed with Matlab language. The response of direct-coupling and cross-coupling filters is simulated and compared. Besides the simulations, the experiment of dual-mode filters with cross-couplings and absorbing resonators in the L-band is done. The experimental results are in good agreement with the simulation results.

II. BASIC THEORY AND SIMULATION

The equivalent circuit of traditional direct-coupled resonator filter is illustrated in Fig.1. Fig.2 is the simplified schematics of Fig.1. The shunt resonators are shown as circles and coupling elements as heavy lines [2].

Fig. 1. The equivalent bandpass filter with the direct-coupled structure.

Fig. 2. The simplified schematics of direct-coupled structure

The advantage of the direct-coupled bandpass filter appears to be that it is easily tuned and the structure is relatively simple, but its attenuation characteristics sometimes cannot meet the need of the communication systems. Adding cross couplings between nonadjacent resonators and absorbing resonators to the input or output resonators are two main methods to improve the cutoff at the edge of the passband.

Take the six-resonator filter as an example. Fig.3 shows the equivalent circuit of six-resonator bandpass filter with direct-coupled structure. Fig.4 is that of the six-resonator bandpass filter with two cross couplings. One is between resonator 1 and resonator 4; another is between resonator 1 and 6. Fig.5 shows the six-resonator bandpass filter with two cross couplings & two shunt absorbing resonators on resonator 6.

In order to observe and tune the response of filters with different structures, simulation software is designed using the Matlab language. The filters with six resonators and eight resonators are simulated.

Fig.6 is the simulation results of six-resonator filter. Three cases are shown in Fig.6.

Case1: without cross coupling.
Case2: with resonator 1-6 cross coupling.
Case3: with resonator 1-4 cross coupling and 1-6 cross coupling.

Fig.3. Six-resonator bandpass filter with direct-coupled structure

Fig.4. Six-resonator bandpass filter with two cross couplings.

Fig.5. Six-resonator bandpass filter with two cross couplings & two shunt absorbing resonators on resonator 6.

Fig.6. Simulation results of six-resonator filter.
Fig. 7 is the simulation results of eight-resonator filter. Three cases are shown in Fig. 7.

Case A: without cross coupling.
Case B: with resonator 1-8 cross coupling.
Case C: with resonator 1-8 cross coupling and 2-7 cross coupling.

It is clear that the cutoff is greatly improved by cross coupling. The more cross couplings, the sharper cutoff at the edge of the passband.

The frequency response of the filter with absorbing resonators is also studied. The six-resonator filter with two cross couplings & two absorbing resonators is simulated. Fig. 8 shows the response of eight-resonator filter with two cross couplings and that of six-resonator filter with two cross couplings & two absorbing resonators. The cutoff of the six-resonator filter with two cross couplings & two absorbing resonators is slightly sharper than that of the eight-resonator filter with two cross couplings.
III. EXPERIMENTAL RESULTS

As the quality factor of the cylindrical waveguide cavity resonator is much higher than that of the rectangle waveguide cavity resonator, the experimental bandpass filter is constructed with cylindrical waveguide cavity resonators. In order to reduce the size and cost of the filter, the dual-mode structure was used. Both the cross coupling technology and absorbing resonator technology are used. The filter structure consists of four physical cavities, which means 8 electrical resonators due to dual-mode. There are two cross-couplings in the filter. One is between electrical resonator 1 and resonator 4. Another is between resonator 1 and resonator 6. Two absorbing resonators are shunted on resonator 6 (output resonator).

The tuned response is shown in Fig.9. It is found that the response of simulation and experiment are in a good agreement.

IV. CONCLUSIONS

The dual-band filter with cross couplings and absorbing resonators in the L-band demonstrates a significant improvement in the utilization of sharp cutoff at the edge of the passband without adding the insertion loss. The Matlab simulation software is very useful to predict the response of the filters. The simulation result is reliable.

REFERENCES