DUAL MODE COMBINED DIELECTRIC AND CONDUCTOR LOADED CAVITY FILTERS

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ABSTRACT

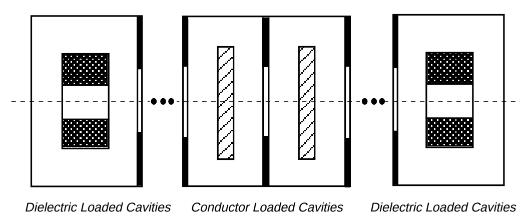
A new configuration of dual mode combined dielectric and conductor loaded cavity filter is presented. Using one or two conductor loaded cavities with dielectric loaded cavities, both low loss and excellent spurious performance are achieved. Resonant frequencies, unloaded Q and the fields of both resonators are rigorously computed by mode matching method. The coupling between two resonators is computed by small aperture approximation theory. Three different types of 4-pole elliptic function filters under same condition are constructed. Insertion loss and spurious performance of the filters are compared. Experimental results verify the theory.

I. INTRODUCTION

Dielectric loaded cavity filters are finding increasing applications in the satellite and mobile communication systems, due to many of their unique properties, such as lower loss, small size and excellent temperature satability [1-4]. Two types of DR filters are most commonly used. One is the single mode DR filter which is operating in TE_{01} mode, the other is the dual mode filter operating in HE_{11} mode. Dual mode DR filter is more favorable among the two type filters, because it has less volume and elliptic function responses can be realized. The drawback of the DR filters is their too close spurious, especially for the dual mode filters.

A large amount of effort has been spent on improving the spurious free performance of the DR filters in the past decade. For single mode DR filters operating in TE_{01} mode, the spurious performance of the filter can be improved by using ring shape dielectric resonator [3], and suitable design of the coupling and DR structure [6][7]. Quarter-cut of DR can further improve the spurious performance [5], but the structure of the filter becomes too complicated and is at the cost of large degradation of the unloaded Q of the cavity. For dual mode DR filter, using two TE_{01} mode DR cavities at both end of the filter can improve the spurious performance of the filter while maintaining the advantages of elliptic function filters [8]. A lateral offset between TE_{01} mode and HE_{11} mode DR cavities increases the complexity of the filter. The inferior spurious performance is still the major drawback of the DR filters.

In this paper, a new configuration of the dual mode cavity filter maintaining the advantages of the dual mode DR filters with excellent spurious performance is introduced. Using one or two conductor loaded cavities with dielectric loaded cavities, the filter has the advantages of low loss, simple structure, elliptic function realization and good spurious performance. Resonant frequencies, unloaded Q and the fields of both resonators are rigorously computed by mode matching method. The coupling between two resonators is computed by small aperture approximation theory. Three different types of 4-pole elliptic function filters including one combined filter, one DR filter and one conductor loaded filter with the same center frequency, band-



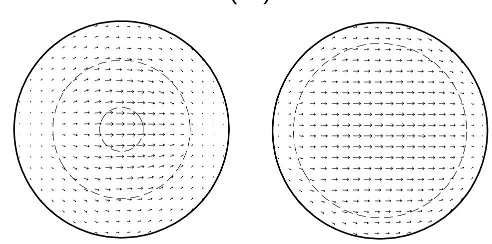


Fig. 1. (a) Configuration of the new type of filter; (b) Magnetic field distributions of two types of resonator

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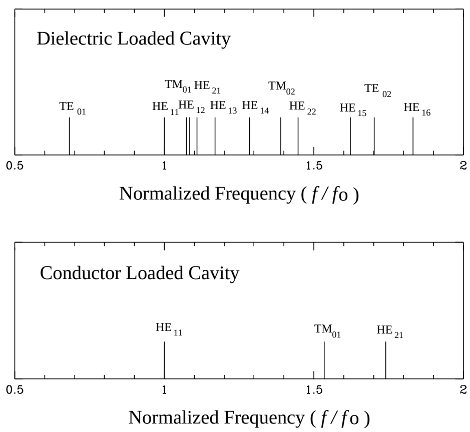

Fig. 2. Typical resonances of the dielectric and the conductor loaded cavities versus the normalized frequency

width, coupling matrix and enclosure are constructed and compared. Experimental results verify the theory.

II. ANALYSIS

The configuration of the dual mode cavity filter is shown in Fig. 1(a). One or two conductor loaded cavities are used in the middle of the filter, where rest of the cavities are using HE_{11} mode dielectric loaded resonators. Since the two types of resonators have similar field distribution at the ends of the cavity as shown in Fig. 1(b), the structure of the filter is same as the conventional dual mode filter. Conductor loaded resonators have slightly less unloaded Q than dielectric loaded resonators but also have much better spurious mode separation [9]. This is illustrated in Fig. 2, which shows the resonant frequencies in both types of resonators. The proposed type of filter can significantly suppress the spurious of the DR resonators and has low loss at same time.

The resonant frequencies, unloaded Q and field distributions of both types of resonators are obtained by mode-matching method. For dielectric loaded resonator, the cavity is divided into three regions in the radial direction. Each region can be treated as a multilayer parallel plates bounded waveguide of which the eigen function of the waveguide can be solved analytically [4]. Then the boundary conditions of the radial regions are forced to be satisfied. This procedure leads to a characteristic equation. Searching for the zeros of the determinant (characteristic equation) gives the resonant frequency of the resonator. The field coefficients of the resonant modes can be obtained by solving the equation at the resonant frequency. The unloaded Q of the cavity can be computed analytically by integrating the superposition of the eigenmode fields for stored

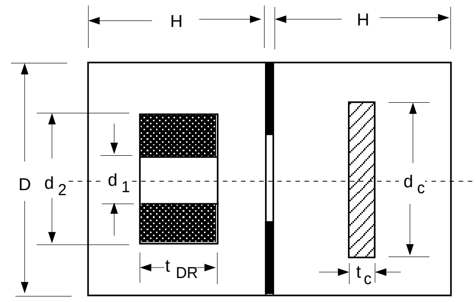

Fig. 3. Configuration of the tested 4-pole elliptic function filter

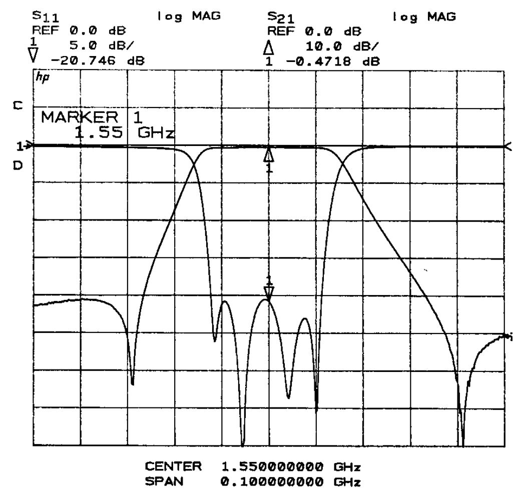

Fig. 4. Measured frequency responses of the 4-pole new type filter

energy, conductor loss and the dielectric loss. Similar procedure can be applied to analyze the conductor loaded cavity [9] in which the structure is partioned into several regions in accordance with the spatial discontinuity boundaries and the eigen functions of each region are known.

The coupling between two resonators of the same type can be calculated by small aperture approximation theory [10]-[12]. The coupling between two different types of resonators is obtained by taking the geometric mean of two couplings between two resonators of the same type [8].

III. RESULTS

To demonstrate the theory, three 4-pole elliptic function filters with center frequency of 1.55 GHz and bandwidth of 22 MHz, are designed, constructed and tested. The first filter has one dielectric loaded cavity and one conductor loaded cavity. The second filter has cavities both dielectric loaded, and the third filter has both

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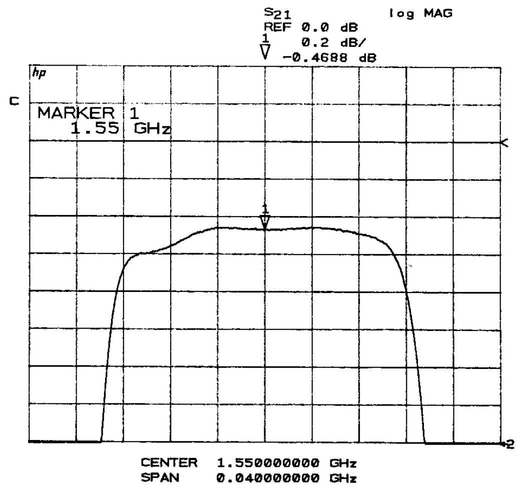

Fig. 5. Insertion loss of the 4-pole new type filter

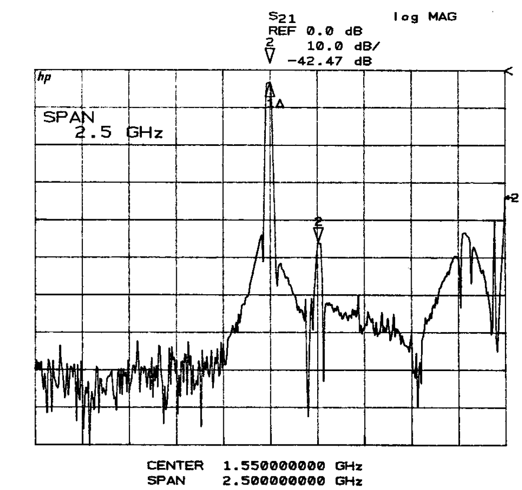

Fig. 6. Measured spurious response of the 4-pole new type filter

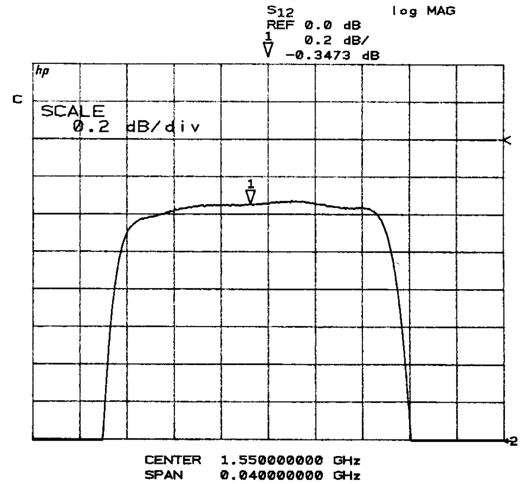

Fig. 7. Insertion loss of the 4-pole dielectric loaded resonator filter

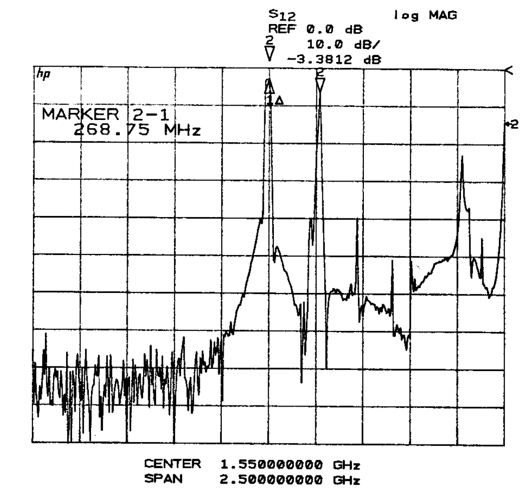

Fig. 8. Measured spurious response of the 4-pole dielectric loaded resonator filter

cavities conductor loaded. The measured insertion loss and spurious performance of the three filters are compared. The input/output resistances and the coupling matrix element of the filters are: $R_1 = R_2 = 1.2535$, $M_{12} = M_{34} = 0.9799$, $M_{23} = 0.7875$, $M_{14} = -0.1095$. Fig. 4 shows the measured frequency response of the 4-pole new type filter. The in-band return loss of all the filters is better than 20 dB. The in-band insertion loss and the wide band frequency response of this filter shown in Fig. 5 and Fig. 6 respectively. The insertion loss and the wide band response of the dielectric loaded cavity filter are shown in Fig. 7 and Fig. 8 respectively. The performance of the 4-pole filter using all conductor loaded cavities are given in Fig. 9 and Fig. 10 respectively. The measured in-band insertion loss of each of the three filters includes additional 0.15 to 0.20 dB of loss from two 3.5 mm to N-type adapters. It is shown that in the new mixed resonator filter the spuriouses of the DR are all suppressed to below -40 dB up to 2.8 GHz. In comparison, the first spurious of the DR filter is only -3 dB at 270 MHz from the center frequency. The insertion loss of the new filter is slightly larger than DR one and less than conductor loaded cavity one.

The advantages of the new type filter is more significant for higher order filters. Table 1 shows the estimated performance of the 8-pole filter assuming the realized unloaded Q of the DR is 10000, and the unloaded Q of the conductor loaded resonator is 6000. It is expected that two conductor loaded cavities are enough

TABLE I
ESTIMATED PERFORMANCE
OF AN 8-POLE ELLIPTIC FUNCTION FILTER

# of conductor loaded cavity	attenuation of nearby spurious	equivalent unloaded Q
1	≤ -40 dB	8600
2	≤ -80 dB	7500

to suppress the spurious to a very low level (-80 dB). The two conductor loaded cavities are cascaded next to each other to prevent the leakage between two adjacent DR cavities. The conductor loaded cavity can be at any place, but it is recommended to place it in the middle of the filter from the power handling point of view.

IV. CONCLUSION

A new configuration of dual mode filter using one or two conductor loaded cavities together with dielectric loaded cavities is presented. The filter has the advantages of low loss of the DR filter and the excellent spurious performance of the conductor loaded cavity filter, and maintaining all the merits of the dual mode filter and simple structure. Three different types of 4-pole elliptic function filters with same center frequency, bandwidth, coupling matrix and enclosure are constructed and compared. Excellent experimental results verify the theory.

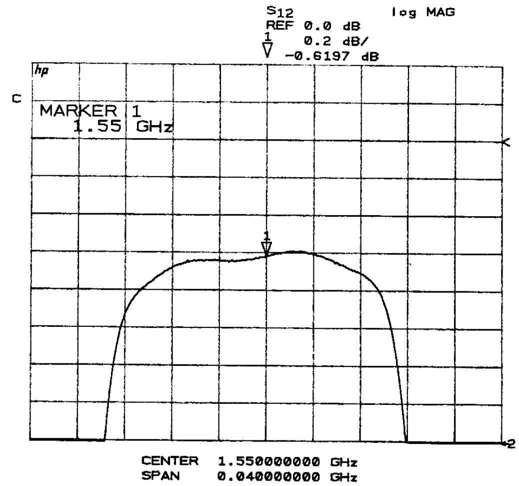

Fig. 9. Insertion loss of the 4-pole conductor loaded resonator filter

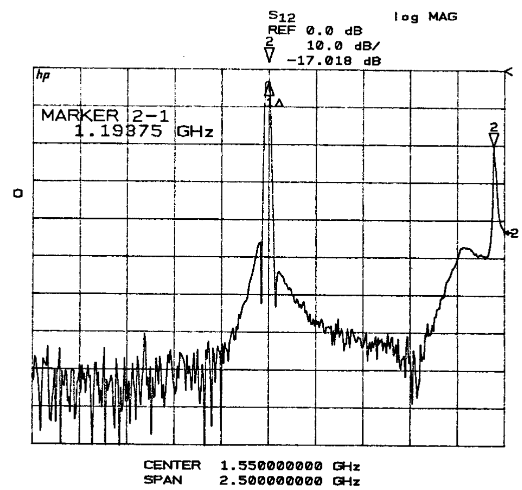

Fig. 10. Measured spurious response of the 4-pole conductor loaded resonator filter

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