CONDUCTOR LOADED RESONATOR FILTERS WITH WIDE SPURIOUS FREE STOP BAND

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ABSTRACT

A new configuration of conductor loaded resonator filters using two different sized conductor loaded resonators is presented. The spurious performance of the conductor loaded resonator filters are significantly improved. Rigorous mode matching method is used to compute the resonant frequency, unloaded Q and the field of the resonant mode of the conductor (solid or ring) loaded resonators. The coupling coefficients between two resonators are computed using small aperture theory by Levy's approach. An 8-pole elliptic function filter is designed, constructed and tested. Experimental results verify the theory.

I. INTRODUCTION

The newly opened personal communication system market demands a large number of base station filters with extraordinary strict requirements on both in-band and out-of-band performances. High selectivity, high rejection, low loss and extremely wide spurious free performance are required for both transmitter and receiver channels. Furthermore, the filters are desired to have small size and low cost in order to be accepted by the market.

The strict requirements on the filter makes it difficult to be realized. Resonators with high unloaded Q and the elliptic function response of the filter have to be used to satisfy the loss and the high rejection requirements [2]. Resonators with good spurious free performance are needed to meet the out-band requirements. Although dielectric loaded resonators have higher unloaded Q, they have too close spurious responses [3][4]. To satisfy the out-of-band requirements using dielectric loaded resonator filter, a low pass filter with very high rejection response is needed to be connected with the dielectric loaded filter. Thus the size, loss, cost and complicity of the filter assembly will increase significantly. Coaxial and combline filters have very good spurious performance, but not very high unloaded Q [1][10]. They can not satisfy the loss requirement of the systems. The conductor loaded resonator filter which has both high unloaded Q and relatively good spurious performance is the desired filter type for the systems [11].

In this paper, a new configuration of a conductor loaded resonator filter is proposed. By using two different sized conductor loaded resonators, the resonant frequencies of the spurious modes of two coupled resonators are shifted apart, thus the spurious response close to the filter's center frequency are completely suppressed. Rigorous mode matching method is used to

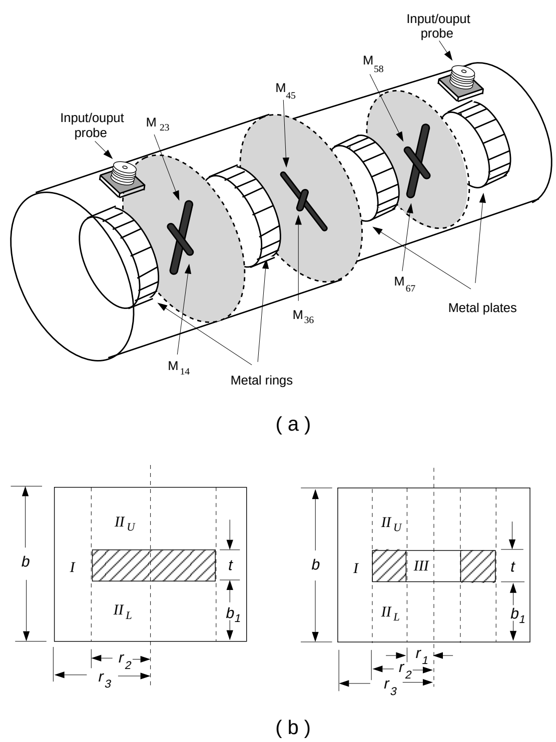

Fig. 1. (a) Configuration of an 8-pole different sized conductor loaded resonator filter; (b) Solid and ring loaded resonators

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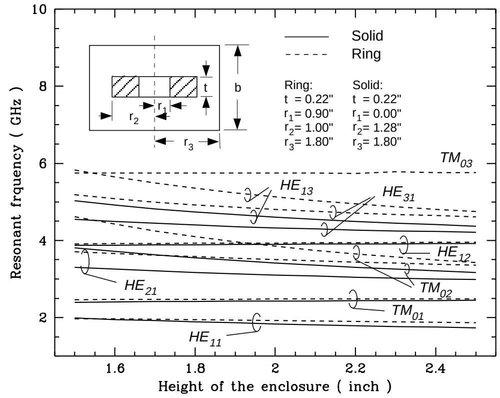

Fig. 2. Mode chart of the conductor loaded resonators versus the height of the enclosure

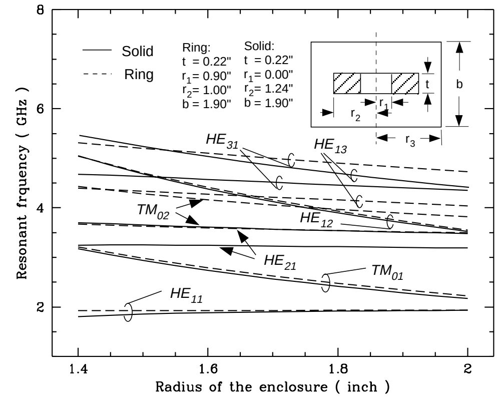

Fig. 3. Mode chart of the conductor loaded resonators versus the radius of the enclosure

compute the resonant frequency, unloaded Q and the fields of the desired resonant mode as well as the spurious higher order modes of the conductor (solid or ring) loaded resonators. The coupling coefficients between two resonators are computed efficiently using small aperture theory. The mode charts and the unloaded Q of the resonators are presented and studied. An 8-pole elliptic function filter is designed, constructed and tested to verify the theory.

II. CONFIGURATION AND ANALYSIS

The configuration of an 8-pole dual mode elliptic function conductor loaded resonator filter is shown in Fig. 1(a). Different sized conductor loaded resonators both operating in HE_{11} mode are used in the filter for differentiating the resonant frequencies of the spurious modes of the resonators. Because the spurious modes of the resonators have different resonant frequencies, the spurious response of the filter near the center frequency will be significantly suppressed. Thus better spurious performance of the filter can be achieved.

To be able to design the proposed type of filters successfully, the dimensions of the resonators have to be accurately determined by computer simulation program. The configuration of the conductor loaded resonators both solid and ring types are given in Fig. 1(b). Rigorous mode matching method is used to compute the resonant frequency, unloaded Q and the fields of the resonant modes. In this method, the resonators are divided into several regions in radial direction as shown in Fig. 1(b), where solid case can be considered as a special case of the ring case. The mode fields in each region are expressed as the summations of their own waveguide eigenmodes. Then the tangential electric and magnetic fields are forced to be continuous at the interfaces between region I and II, and between region II and III if the resonator is the ring case, respectively. By taking the proper inner products, a characteristic matrix for resonant frequency can be obtained. Searching the frequency which gives the zero determinant of the matrix, resonant frequency and the field coefficients of the resonant mode can be obtained.

Once, the field expansion coefficients in each region are obtained, the unloaded Q of the cavity can be computed analytically by integrating the superposition of the eigenmode fields as:

$$Q_u = \omega_o \frac{W_s}{P_{l,c}} = \omega_o \frac{\frac{1}{2}\mu_o \int_V |H|^2 dV}{\frac{1}{2} R_s \oint_S |H_t|^2 dS} \tag{1}$$

where W_s is the stored energy in the cavity at the resonant frequency ω_o, $P_{l,c}$ is the power loss on the structure.

The coupling coefficient between two identical cavities can be obtained, by small aperture approximation [5]-[8], using the following equation:

$$k = \mathbf{c}_l \mathbf{c}_t M \frac{\int_{S_a} |H_t|^2 dS}{S_a \int_V |H|^2 dV} \tag{2}$$

where M is the magnetic polarizability of the aperture, c_l is the large aperture correction factor, c_t is the thickness correction factor.

The coupling coefficient between two different sized cavities is obtained from the coupling coefficients between two identical cavities as [9]:

$$k_{12} = \frac{M_{12}}{\sqrt{L_1 L_2}} = \sqrt{k_1 k_2} \tag{3}$$

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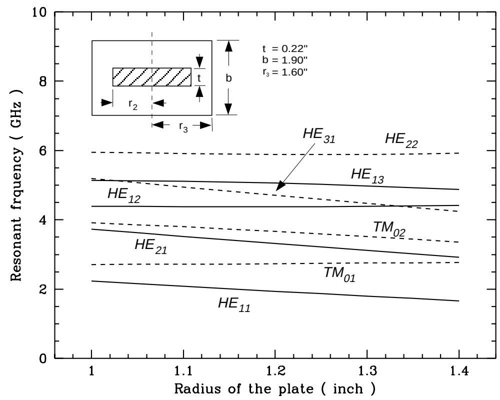

Fig. 4. Resonant frequencies of a solid loaded resonator versus the radius of the conductor

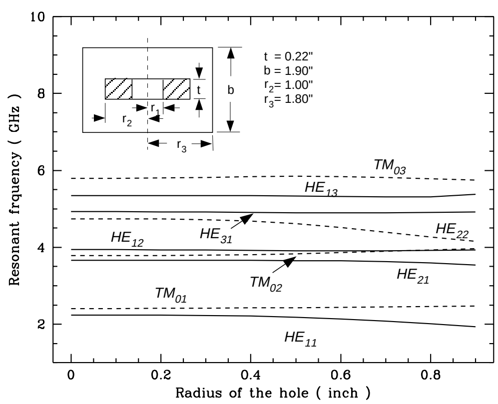

Fig. 5. Resonant frequencies of a conductor loaded resonator versus the radius of the hole

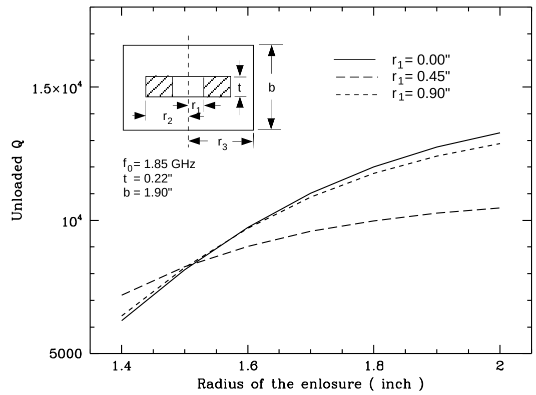

Fig. 6. Unloaded Q of the solid and ring resonators versus the radius of the enclosure (silver plated)

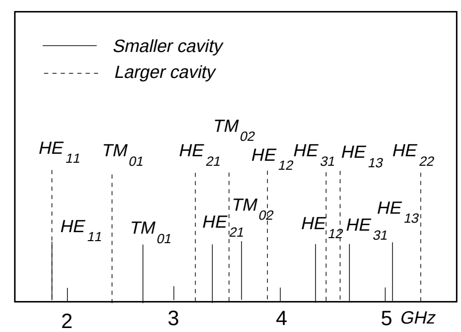

Fig. 7. Spectrum of the designed two conductor loaded resonators for the 8-pole test filter

III. RESULTS

A computer program has been developed to compute the resonant frequency, unloaded Q, field distribution and coupling coefficient of the conductor loaded resonator for the design of the presented dual-mode filters. Fig. 2 shows the mode chart of both solid and ring resonators versus the height of the enclosure. Fig. 3 gives the resonant frequencies of solid and ring resonators versus the radius of the enclosure. It is shown that the resonant frequencies of the first several modes, except TM_{02} mode, are not very sensitive to the height of the enclosure for both resonators, but most of the modes, except HE_{11} and HE_{21}, are very sensitive to the radius of the enclosure. The resonant frequencies of the HE_{11} and HE_{12} modes are very close to each other for solid and ring resonators. But the resonant frequencies of the HE_{21} and TM_{02} modes are quite different for both types of the resonators. The resonant frequency of the operating mode (HE_{11} mode) is nearly constant to the radius of the enclosure.

Fig. 4 shows the resonant frequencies of a solid resonator versus the radius of loaded conductor. It is seen that the resonant frequencies of the HE_{n1} mode is more sensitive to the radius of loaded conductor than other modes. Fig. 5 gives the resonant frequencies of a ring resonator versus the radius of the hole. It is shown that the resonant frequencies of the resonator are not sensitive to the radius of the hole, especially when the hole is not large. The unloaded Q of the conductor loaded resonators versus the radius of the enclosure is given in Fig. 6. It is shown that the unloaded Q of the ring resonator is very close to that of the solid one when the hole is small. The unloaded Q of the ring resonator with large hole is smaller than solid resonator when enclosure is large, but is larger than solid one when enclosure is small.

An 8-pole elliptic function filter with center frequency of 1.8575 GHz, bandwidth of 15.5 MHz for PCS base station application is designed, constructed and tested.

The input/output resistances and the coupling matrix element of the filter are: $R_1 = R_2 = 1.2101$, $M_{12} = M_{78} = 0.8153$, $M_{23} = M_{67} = 0.8465$, $M_{34} = M_{56} = 0.4292$, $M_{45} = 0.5408$, $M_{14} = M_{58} = -0.4119$, $M_{36} = -0.0109$. Based on previous analysis and computer simulation, the dimensions of the cavities are determined. Solid conductors are loaded into the cavities of different radius. The unloaded Q of the designed cavities are 9500 and 12000 with both inner conductor and enclosure silver plated. Fig. 7 shows the spectrum of the two designed resonators. It is expected that the TM_{01}, $HE21$ and TM_{02} modes of the resonators can be significantly suppressed. Fig. 8 shows the measured frequency responses of the test filter. The insertion loss of the filter at the center frequency is 0.72 dB. The corresponding realized unloaded Q of the filter is larger than 6000. Fig. 9 gives the wide band frequency response of the 8-pole filter. It is shown that the spurious free performance of the filter is upto 4.2 GHz or $2.26f_0$. The spurious performance of the filter is much better than that of the HE_{11} mode DR filter of $1.2f_0$, TE_{01} mode DR filter of $1.5f_0$, and same sized conductor loaded resonator filter of $1.9f_0$.

IV. CONCLUSION

A new configuration of the dual mode filters using different sized conductor loaded resonators are presented. By differentiating the resonant frequencies of the two kind of resonators, the spurious level of the nearby modes is significantly suppressed. Rigorous mode matching technique is used to compute the resonant frequency, unloaded Q and the fields of the resonators. The coupling coefficients between two resonators are obtained by small aperture approximation. An 8-pole test filter is designed, constructed and tested. Measured results verify the theory.

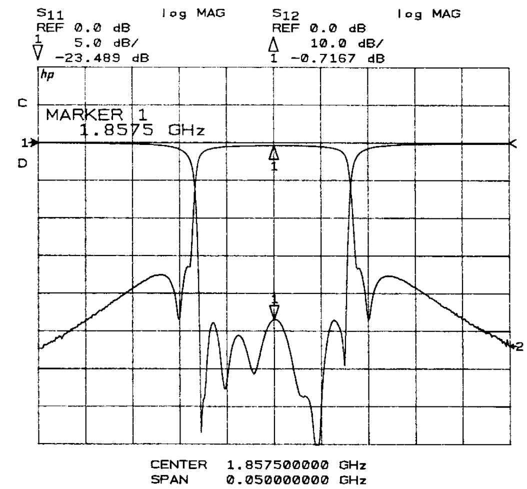

Fig. 8. Measured frequency responses of the test 8-pole filter

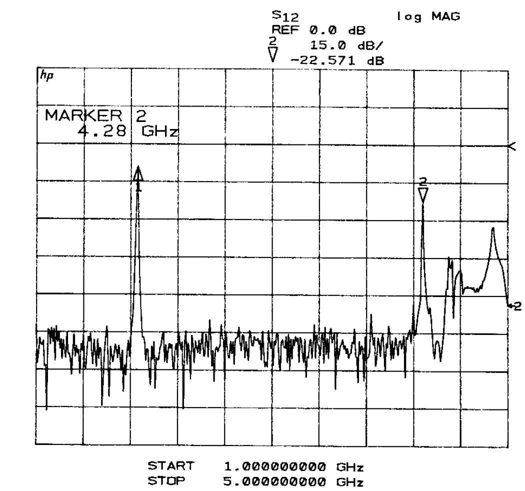

Fig. 9. Measured spurious response of the 8-pole filter

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