MODELING OF CONDUCTOR LOADED RESONATORS AND FILTERS IN RECTANGULAR ENCLOSURES

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ABSTRACT

Full wave modeling of conductor loaded resonators in rectangular enclosures and associated coupling structure is presented. The generalized scattering matrices of the planar conductor loaded resonator in rectangular waveguide are obtained. By applying short condition and cascading procedure, resonant frequency, field distribution of the resonator, and coupling between two cavities through an iris are obtained. The computed results are compared with the measured data and both are in good agreement. A 4-pole dual mode elliptic function filter using planar structure cavity is designed, constructed and tested. Excellent measured frequency responses of the filter are obtained.

I. INTRODUCTION

High performance, small size microwave resonators and filters are finding increasing applications in modern communication systems. Tremendous progress on miniaturization of both resonator and filter has been achieved in the past three decades [1]-[3]. Dual mode technique cuts the size of the filter by half. Dielectric loaded resonator decreases the volume of the cavity greatly. Recently, a counterpart of the dielectric loaded resonator, *i.e.* conductor loaded resonator, was introduced [11]. The resonator has both high quality and wide spurious free performance. For the conventional cylindrical dual mode filter structure, it is difficult to support the resonator in the cavity when the number of cavities is more than two. The planar structure, shown in Fig. 1(a) (*i.e.* resonator with dielectric support mounted in a rectangular enclosure) can solve above difficulty, and increase the mechanical stability of the resonator [7].

Full wave modeling of cylindrical objects in a rectangular waveguide is not an easy task, because the problem involves two kinds of coordinate systems. Although point matching method [5] and the moment method [6] can be applied, the accuracy of the results is not as good as mode matching method. The integrals in the inner products of the mode matching method can not be evaluated analytically and directly. By expanding the fields in the rectangular waveguide into cylindrical wave function using Bessel-Fourier series, the integration for each term of the series can be obtained analytically [8]-[10].

In this paper, the discontinuity in the cylindrical region, i.e. planar conductor loaded resonator, is modeled by radial mode matching method, and the approach using the Bessel-Fourier series as [8]-[10] is used to solve the cylindrical region to rectangular waveguide discontinuity. As a result, the generalized scattering matrices of the planar conductor loaded resonator in rectangular waveguide are obtained. By applying short condition at both ends of the cavity, resonant frequency and field distribution of the resonator can be obtained. Using cascading procedure[4], coupling between two cavities

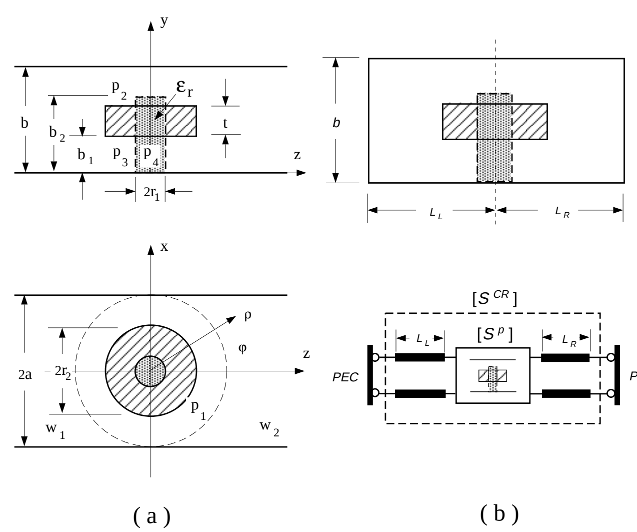

Fig. 1. (a) Configuration of a generalized conductor loaded resonator with support in a rectangular waveguide; (b) Configuration of a conductor loaded rectangular cavity and its Network representation

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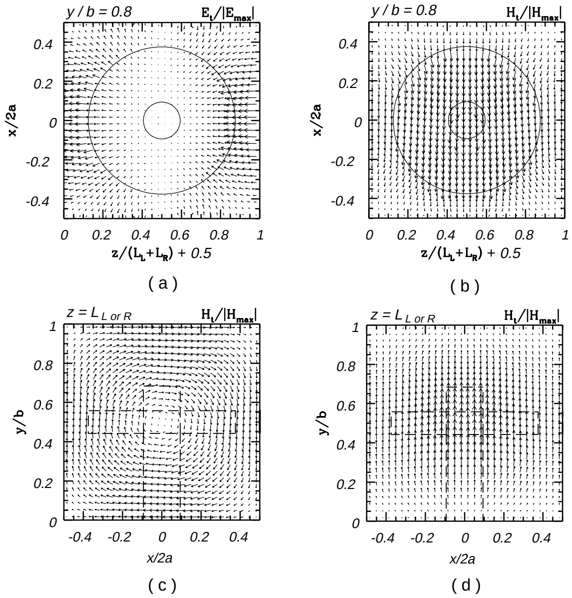

Fig. 2. Field distributions of a conductor loaded rectangular cavity with $2a = 1.2$", $b = 1.0$", $r_1 = 0.0$, $r_2 = 0.45$", $t = 0.1$", $b_1 = 0.45$", (a) Electric field distribution at $y = 0.8$" plane with PMC at $x = 0$ plane; (b) Magnetic field distribution at $y = 0.8$" plane with PMC at $x = 0$ plane; (c) Magnetic field distribution at $z = \pm 0.6$" plane with PMC at $x = 0$ plane; (d) Magnetic field distribution at $z = \pm 0.6$" plane with PEC at $x = 0$ plane

through an iris is calculated. The computed results are compared with the measured data and are shown to be in good agreement. A 4-pole dual mode elliptic function filter using planar structure cavity is designed, constructed and tested. Excellent measured frequency responses of the filter are obtained.

II. ANALYSIS

The configuration of a conductor loaded resonator in a rectangular waveguide under consideration is shown in Fig. 1. A conductor ring resonator of thickness t, radius r_1, r_2, is supported by a dielectric rod of height b_2 through the resonator. Since two conductor loaded cavities with a rectangular coupling iris in their common wall can be viewed as a shorted conductor loaded waveguide and two shorted conductor loaded cavities connected through an iris, solving the scattering of the conductor loaded resonator in a rectangular waveguide, the conductor loaded cavity and its coupling structure can be solved.

A. Scattering Parameters of the Conductor Loaded Resonator in a Rectangular Waveguide

The structure of Fig. 1(a) is divided into two main regions: cylindrical region, defined as $\rho \leq a$; and the rectangular waveguide region, defined as $x^2 + z^2 > a$. The cylindrical region is further divided into three one layer regions and one two layer region along radial direction, while the waveguide region is divided into left region w_1 and right region w_2.

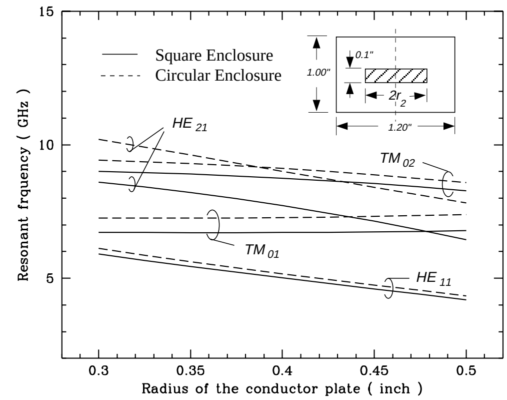

Fig. 3. Mode chart of a conductor loaded rectangular cavity with $2a = 1.2$", $b = 1.0$", $r_1 = 0.0$, $t = 0.1$", $b_1 = 0.45$" versus radius r_2

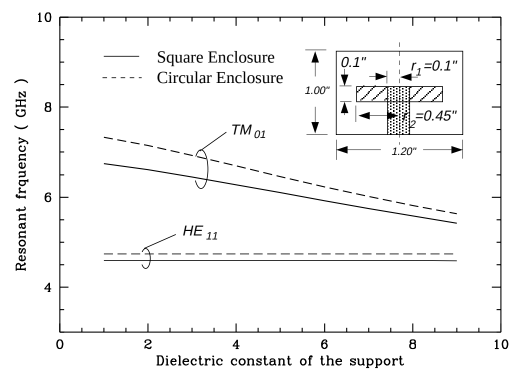

Fig. 4. Effect of the dielectric constant of the support on the resonant frequencies of the first two modes of a conductor loaded rectangular cavity with $2a = 1.2$", $b = 1.0$", $r_1 = 0.1$", $r_2 = 0.45$", $t = 0.1$", $b_1 = 0.45$"

The fields in the cylindrical regions are expressed by the summation of the two parallel plate waveguide's eigen functions in each region in cylindrical coordinates (ρ, ϕ, y). The field coefficients of the inner cylindrical regions can be related to the field coefficients of the outer region P_1. Then applying the boundary conditions at the artificial boundary at $r = a$ as [9][10], the fields in cylindrical region P_1 are related to the fields in waveguide regions w_1 and w_2. The generalized scattering matrix of the conductor loaded resonator in a rectangular waveguide can then be obtained.

B. Conductor Loaded Rectangular Cavity

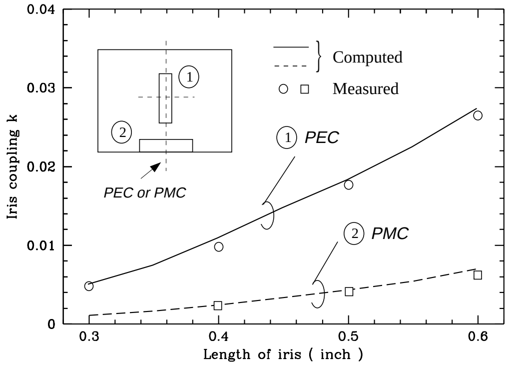

Fig. 5. Coupling coefficients between two identical conductor loaded rectangular cavities with $2a = 1.2$", $b = 1.0$", $r_1 = 0.0$, $r_2 = 0.45$", $t = 0.1$", $b_1 = 0.45$" versus the length of the iris of 0.1" width

Having obtained the generalized scattering matrix of the conductor loaded resonator in a rectangular waveguide, the conductor loaded rectangular cavity can be modeled by moving the reference planes of the two port network with distance L_L and L_R from the center of the resonator and applying the short condition at the ports as shown in Fig. 1(b). A characteristic equation for the resonant frequency of the cavity can be obtained. The zeros of determinant of the matrix are the resonant frequencies of the cavity. Solving the matrix equation at each resonant frequency gives the field coefficients of the resonant mode in the waveguide region. All the other field coefficients in the cylindrical regions can be calculated from the continuity equation at the boundaries. The field distribution of the resonant mode can then be computed.

C. Slot Coupling Between Two Identical Cavities

To compute the coupling between two identical cavities through an iris, property of the symmetrical network can be used to simplify the computation. By applying PEC and PMC boundary conditions at the symmetrical plane, the coupling structure can be modeled as a conductor loaded cavity connected with an evanescent mode waveguide whose length is half the iris thickness. The coupling coefficient can be computed from two resonant frequencies f_e and f_m of PEC and PMC boundary condition at symmetrical plane.

III. RESULTS

Computer program has been developed to compute the resonant frequency, field distribution and coupling coefficient of the conductor loaded rectangular cavities. The field distributions of HE_{11} mode of a cavity is shown in Fig. 2. The fields satisfy the boundary conditions and this ensures the correctness of the fields. Fig. 2(a) gives the electric field distribution, and Fig. 2(b) shows the magnetic field distribution of the cavity with PMC at $x = 0$ plane. The field distributions of the cavity with PEC at $x = 0$ plane have the same shape but 90^o angle difference. Fig. 2(c) shows the magnetic field distribution in $x-y$ plane at the ends of the cavity with PMC at $x = 0$ plane. It is shown that magnetic field is strong at top and bottom of the plane. Fig. 2(d) presents the magnetic field distribution in $x-y$ plane at the ends of the cavity with PEC at $x = 0$ plane. Strong magnetic field is in the center region of the plane in y direction.

TABLE I
COMPARISON OF THE CALCULATED AND MEASURED RESONANT FREQUENCIES IN GHz

	HE_{11}	TM_{01}	HE_{21}	TM_{02}	HE_{12}
computed	4.555	6.672	7.066	8.461	10.631
measured	4.549	6.631	7.082	8.478	10.575

$2a = 1.2$", $b = 1.0$", $r_1 = 0.0$, $r_2 = 0.45$", $L_L = 0.6$", $L_R = 0.6$", and $\epsilon_r = 1.02$

The resonant frequencies of a conductor loaded rectangular cavity of different modes are computed and compared with the measured results shown in Table I. Both results are in good agreement. Fig. 3 shows the resonant frequencies of first five modes in a cavity with a solid conductor plate loaded resonator versus the radius of the plate. The resonant frequencies of the rectangular cavity are also compared with that of the cylindrical enclosure of $r = a$. It is shown that the resonant frequency of the rectangular enclosure is lower than that of cylindrical enclosure, especially for HE_{21} mode, but have the same trends for both kinds of enclosures. Fig. 4 shows the resonant frequencies of the cavity versus the dielectric constant of the support. It is seen that the dielectric constant of the support has strong effect on the resonant frequency of the second mode (TM_{01}) of the cavity.

The coupling coefficients between two identical conductor loaded rectangular cavities through an iris with PEC and PMC boundary conditions at $x = 0$ plane are also computed and compared with the measured results and shown in Fig. 5. It is shown that strong coupling can be achieved with PEC at $x = 0$ plane. Both calculated and measured couplings are in good agreement.

As an application of the modeling, a 4-pole elliptic function filter with center frequency of 4.40 GHz, bandwidth of 48 MHz is designed, constructed and tested. The input/output resistances and the coupling matrix

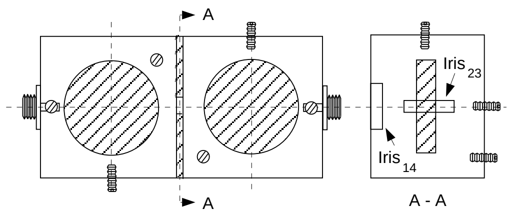

Fig. 6. Configuration of the test dual mode 4-pole elliptic function filter using the planar structure conductor loaded rectangular cavities

element of the filter are: $R_1 = R_2 = 1.2535$, $M_{12} = M_{34} = 0.9799$, $M_{23} = 0.7875$, $M_{14} = -0.1095$. The configuration of the filter is shown in Fig. 6. The vertical iris is used to obtain M_{23} and the horizontal iris is used to achieve the negative coupling M_{14}. Fig. 7 shows the measured frequency responses of the test filter. Fig. 8 presents the wide band frequency response of the 4-pole filter.

IV. CONCLUSION

Conductor loaded resonator in rectangular enclosure and its coupling structure are modeled by rigorous mode matching method. The computed resonant frequencies and coupling coefficients of the cavity are compared with the measured data and shown to be in good agreement. A 4-pole dual mode elliptic function filter using planar structure cavity is designed, constructed and tested. Excellent measured frequency responses of the filter are obtained. Dual mode conductor loaded resonator filters have far superior out-of band spurious response to the corresponding dielectric loaded resonators.

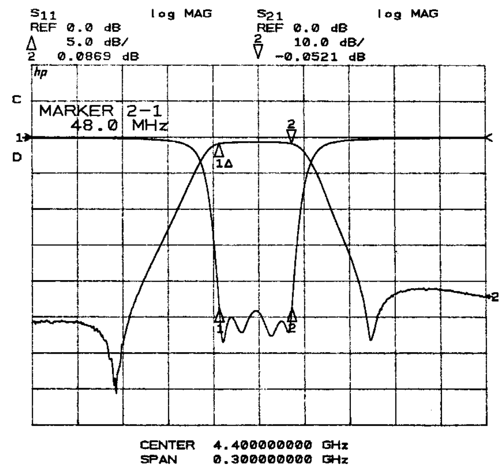

Fig. 7. Measured frequency responses of the test 4-pole filter

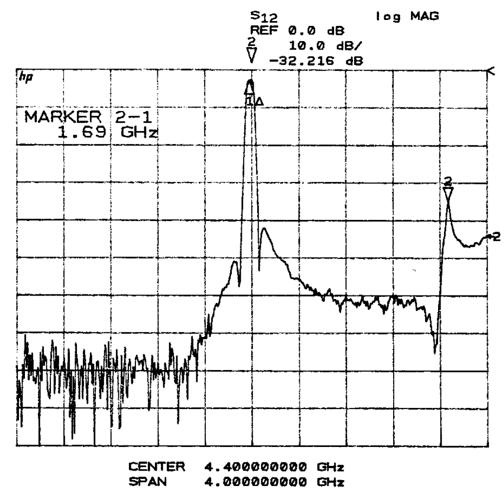

Fig. 8. Measured wide band response of the 4-pole filter

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