DUAL MODE PATCH SUPERCONDUCTOR CAVITY FILTERS

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ABSTRACT

A new kind of dual mode filter consisting of high temperature superconductor(HTS) patch loaded circular cavity resonators is presented. The resonator is analyzed using full wave mode matching method. The generalized scattering matrices of the HTS patch loaded circular cavity are obtained. After performing cascading procedure and applying boundary conditions, resonant frequencies, field distribution, unloaded Q of the resonator and the coupling between two cavities through irises are obtained. Two 4-pole dual mode elliptic function patch conductor loaded cavity filters are designed, constructed and tested. Excellent measured frequency responses of the filter are obtained.

I. INTRODUCTION

Dual mode filters have many advantages in applications which require small size, high quality narrow or medium bandwidth filters. Dual mode filters introduced in the early 1970's [1], consisted of empty circular cavity resonators. The introduction of dielectric loading in dual mode resonators [2] reduces the size of the cavity, but the dielectric resonator filters tend to have too close spurious response. Recently introduced conductor loaded resonator dual mode filters [3] have wider spurious separation but lower unloaded Q.

The rapid development of high temperature superconductor(HTS) materials provides opportunities in the applications of high performance filters. During the past decade, filters employing HTS have been developed successfully [4]-[6]. Replacing the dielectric or conductor resonator loading with superconductor loading in the dual mode filter, will overcome the disadvantages of the close spurious response of the dielectric loaded resonators and the low quality factor of the conductor loaded resonators.

This paper introduces a new class of dual mode filters using HTS printed circuits resonators loaded in cavities. Some possible resonator structures are presented. Numerical analysis of printed circuit patch loaded cavity resonators are performed from which the resonant frequency, coupling coefficients and unloaded Q's are obtained. Experiment results of dual mode filters consisting of such resonators are presented. The printed circuit loading can be made of thin film superconducting material on $LaAlO_3$, and the resulting superconducting filters would have ideal performance.

II. ANALYSIS

Four possible configurations of printed circuit loaded circular cavity resonators are shown in Fig.1. A conductor patch can be plated on one or both sides of the substrate which is in the middle of the circular waveguide cavity. The diameter of the conductor patch is d_1, the diameter of the substrate is d_2, the thickness of the substrate is t, the diameter of the cavity is D, and the length of the cavity is H.

The scattering matrices of each discontinuity can be

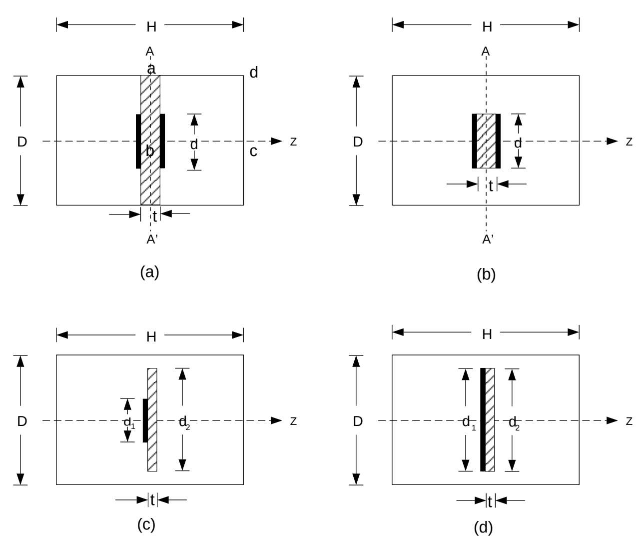

Fig.1. Configurations of print circuit loaded circular waveguide cavity resonators

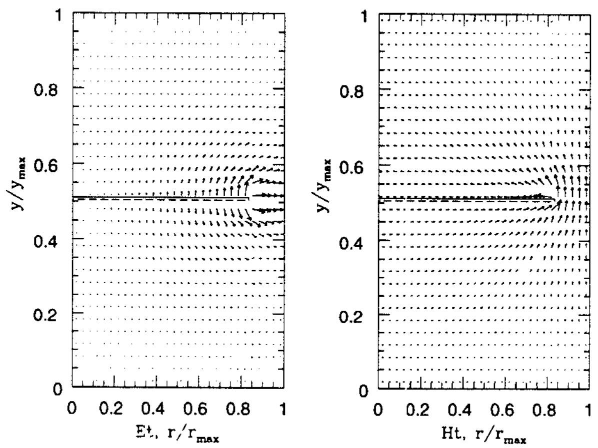

Fig.2. Field distribution of HE_{11} mode of structure in Fig.1(d)

obtained with full wave mode matching analysis. The electromagnetic fields at each side of the discontinuity can be expressed as linear combinations of the eigen mode fields, which are orthogonal and constitute a complete set of basis functions. By applying the boundary conditions (i.e. the continuity of the tangential fields in both regions) and performing proper inner products of these eigen mode fields, the scattering matrices of the discontinuities are obtained. The scattering matrices of different regions can be cascaded to form the scattering matrix of the whole cavity after applying certain boundary conditions at the two ends of the cavity. This process yields a set of linear homogeneous equations. The solution of the characteristic equation of these set gives the resonant frequencies of the cavity resonator. After the resonant frequencies of the cavity are determined, the field distribution, energy stored in the whole cavity, the power loss due to the conducting walls, the substrate and the printed patch as well as the unloaded Q of the cavity resonator can be obtained. The coupling coefficients between two cavity resonators are also calculated by cascading the scattering matrices of the cavity with the scattering matrices of the discontinuity of the circular and rectangular waveguide.

III. RESULTS

Computer programs were developed to accomplish the above analysis. Using the computer simulation programs, the field intensity in the cavity is computed. Due to the symmetry of the structures shown in Fig.1 (a) and (b), there are two basic kinds of field distribution: the symmetric plane between two conductor patches is PEC (HE_{11e} mode) or PMC (HE_{11m} mode). For HE_{11e} mode, both the electric fields and magnetic fields are mostly concentrated in the region between the conductor patch plates. Since the field intensity at the ends of the cavity is extremely weak, it's impossible to couple two cavities by irises. In that case, the HE_{11m} mode should be used. Since there is no symmetry in the structures shown in Fig.1 (c) and (d), HE_{11} should be used. In the following calculation and filter design, structure (d) will be used due to its simplicity and easy to made. The field distribution of HE_{11} mode of structure (d) is shown in Fig.2.

For structure (d), the relationship between the resonant frequencies and the radius of the conductor patch (r_1) and the radius of the cavity (R) is shown in Fig.3 and Fig.4 respectively. The relationship between un-

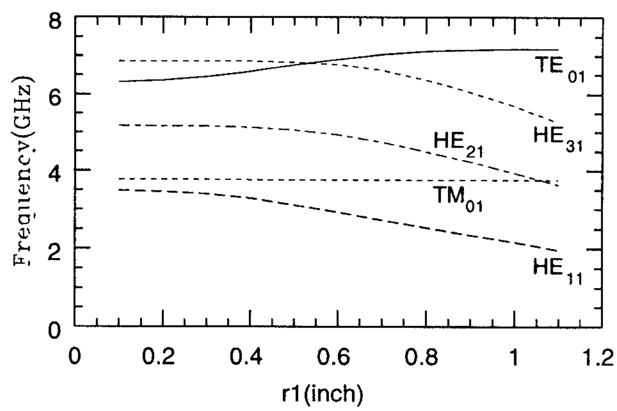

Fig.3. Resonant frequencies of a patch conductor loaded cavity (structure (d)) with $D = 2.4'', H = 3.0'', t = 0.02''$ as a function of radius of conductor patch

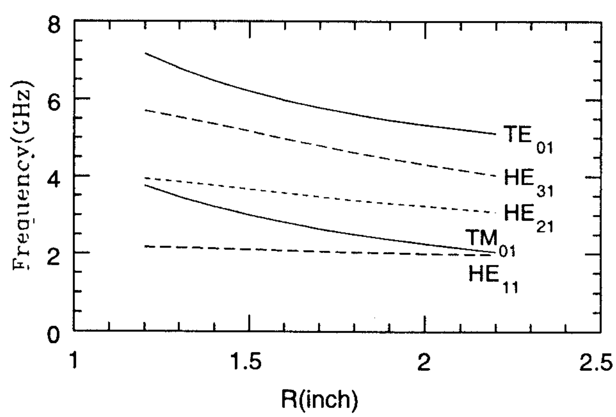

Fig.4. Resonant frequencies of a patch conductor loaded cavity (structure (d)) with $r_1 = 1.0'', H = 3.0'', t = 0.02''$ as a function of radius of cavity

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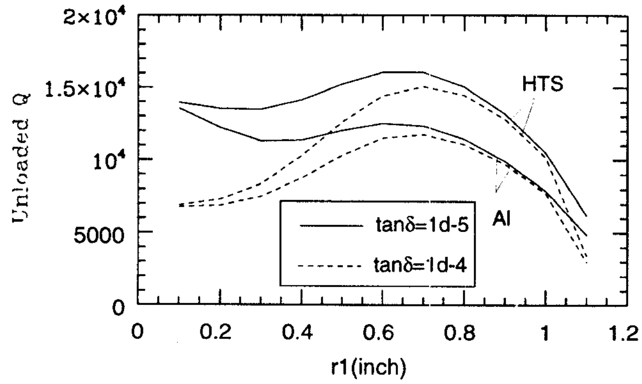

Fig.5. Unloaded quality factor of a patch conductor loaded cavity (structure (d)) with $D = 2.4'', H = 3.0'', t = 0.02''$ as a function of radius of conductor patch

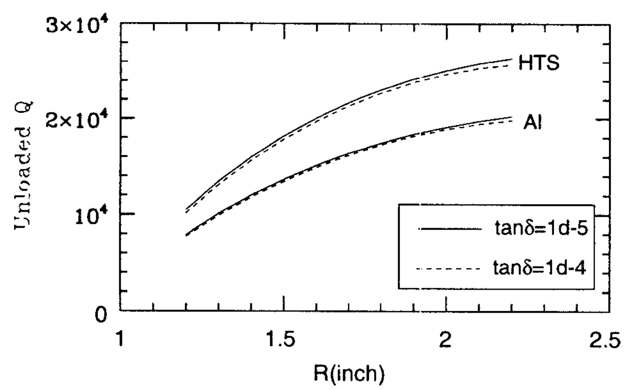

Fig.6. Unloaded quality factor of a patch conductor loaded cavity (structure (d)) with $r_1 = 1.0'', H = 3.0'', t = 0.02''$ as a function of radius of cavity

loaded quality factor of HE_{11} mode and r_1, R is shown in Fig.5 and Fig.6 respectively, for resonators with aluminum enclosure and aluminum or superconductor patch loads. The loss tangent of the substrate is assumed to be 10^{-4} or 10^{-5}. Proper dimensions of the resonator can thus be obtained to get the least spuriousness and lowest loss.

Two 4-pole elliptic function filters are designed using HE_{11} dual mode patch conductor loaded cavities coupled by rectangular irises. Since it's easier to plate the conductor on one side of the substrate, structure (c) and (d) are used. The cavities are made of aluminum, with $D = 2.4''$ and $H = 3.0''$. The substrate is $LaAlO_3$, with $d_2 = 2.0''$ and $t = 0.02''$. The conductor patch is 0.8" gold and 2.0" aluminum, respectively. Measured results of the frequency response of the insertion loss and return loss of test filters under uncooled condition are shown in Fig.7 and Fig.8.

Fig.9 and Fig.10 show the measured wide band response of the test filters. The first higher order mode spurious response occurs at 1.035GHz and 1.455GHz away from the center frequency for structure (c) and (d), respectively. Structure (d) gives larger separation of the spurious frequencies.

IV. Conclusion

Dual mode patch cavity filters are presented, which have very promising applications in high performance superconductor filters. The resonators are analyzed with full wave mode matching method. The measured results of the test filters verify the theory.

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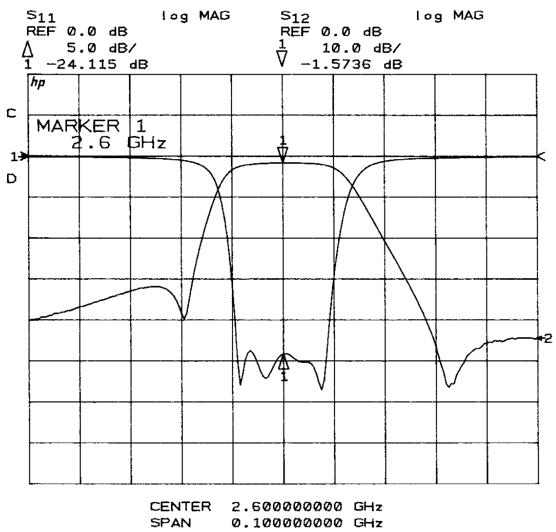

Fig.7. Measured frequency response of the test filter with structure (c)

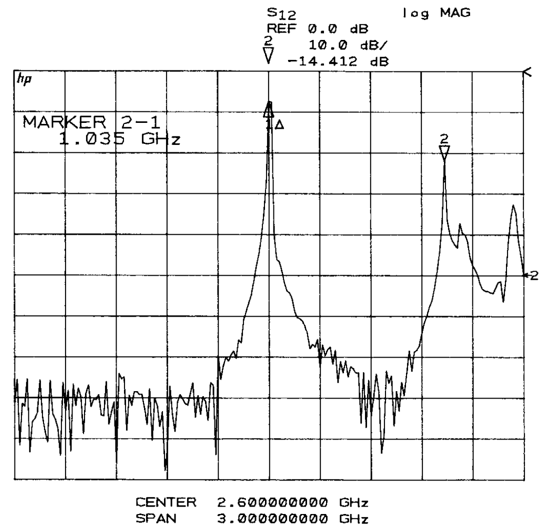

Fig.9. Measured wide band freq. resp. of the test filter with structure (c)

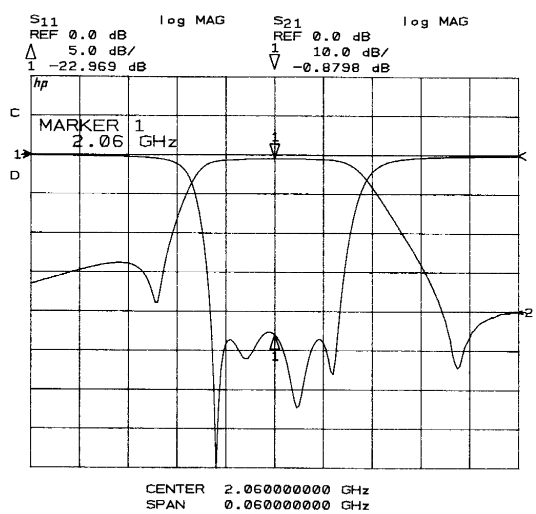

Fig.8. Measured frequency response of the test filter with structure (d)

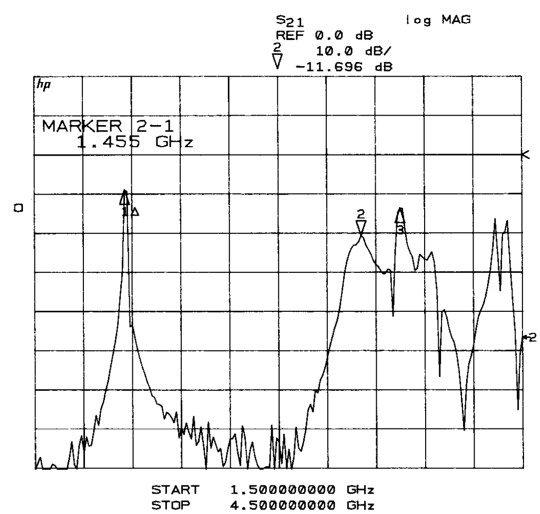

Fig.10. Measured wide band freq. resp. of the test filter with structure (d)