Multi-Layered Planar Filters Based on Aperture Coupled, Dual Mode Microstrip or Stripline Resonators

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ABSTRACT

High temperature superconductivity has created a great deal of interest in replacing dual mode cavity and dielectric resonator filters with printed circuits which are dramatically smaller, lighter, and less costly. Recently, a set of dual mode filters was introduced which facilitates the realization, in a planar configuration, of the elliptic function and self-equalized responses required for satellite applications. In this paper, a new class of planar filters is introduced that is based on a multi-layered stack of dual mode stripline or microstrip resonators coupled through irises. This new filter configuration offers extremely small size and mass and is ideally suited to fabrication using thin film superconductors. All filter types that are currently implemented using dual mode cavities or dielectric resonators can be realized using this new filter structure. Novel, multi-layer, planar filters are introduced, and experimental results are presented.

INTRODUCTION

The discovery of high temperature superconductivity has caused a renewed interest in planar filter structures for high performance applications. Design techniques for single mode microstrip filters such as edge coupled and interdigital have long been established for the realization of Chebychev filters having bandwidths greater than 3 percent. However, these structures are impractical for many applications because of the inherent difficulties they present for very narrowband designs and designs requiring elliptic function and/or self-equalized responses.

Recently, a class of dual mode microstrip filters was introduced which makes practical the realization of very narrowband, elliptic function, and/or self-equalized designs in a planar configuration [1,2]. In this paper, we present a new class of planar filters based on a multi-layered stack of dual mode stripline or microstrip resonators. In this new stacked configuration, coupling between the dual mode resonators is controlled through coupling apertures or irises similar to those used for the realization of cavity and dielectric resonator filters. Similar coupling apertures are also used in planar antennas [3,4]. The new stacked filter configuration has advantages over the previously introduced dual mode microstrip filters in that it is somewhat smaller and lighter, but more importantly, it offers the potential for tunability through the selection of iris and resonator dimensions during the testing stages of development.

This new planar stack configuration can be used to realize any of the filter types that are currently implemented using dual mode cavities or dielectric resonators including elliptic function and/or self-equalized responses. The stacked planar structure offers dramatic reductions in size, mass, and potentially cost as compared to the currently used cavity designs. This new class of filters is ideally suited for fabrication using thin film, high temperature superconductors for high Q performance.

FILTER CONFIGURATIONS

The stacked planar filters described in this paper can be based on a variety of dual mode, planar resonator structures similar to those used in dual mode microstrip filters [1,2]. These include square patches, circular disks, and rings as illustrated in Figure 1. Basic field configurations for these resonators in single mode form can be found in [5,6]. Coupling between the dual orthogonal modes supported by these resonators is accomplished by introducing a perturbation to the symmetry of the previously single mode resonator at a location that is offset 45 degrees from the axes of coupling to and from the resonator. Figure 1 illustrates some possible perturbations that can be used to control the coupling between the orthogonal modes supported by a resonator.

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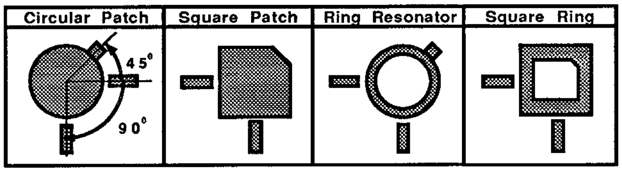

Figure 1: Illustration of 4 dual mode, microstrip or stripline resonators. Perturbations in the previously single mode resonators facilitate coupling between dual, orthogonal modes.

In the novel filter configurations introduced in this paper, the dual mode stripline resonators of Figure 1 are stacked as shown in Figures 2 and 3. Coupling energy between the resonators is implemented by including a coupling aperture or iris in the ground plane shared by the two resonators. These figures illustrate both square and circular dual mode resonators coupled together by either round coupling holes or orthogonal slots. In each of these figures, a four pole filter is realized by stacking four patterned substrates directly on top of each other. This concept can obviously be extended to realize filters of any number of poles.

For the configurations illustrated in Figures 2 and 3, each resonant mode couples only to one mode in the adjacent resonator. In the case of the round aperture, the coupling between the resonators is equivalent for each pair of dual modes. For the case of the slot apertures, the coupling between each pair of modes can be controlled independently by varying the length of the slots.

The size and mass of the filters based on this multi-layer concept is extremely small in comparison to cavity and dielectric resonator designs and is also significantly smaller than that required for the previous dual mode microstrip designs [1,2]. Each dual mode resonator is approximately one half wavelength (at Fc) long and each resonator requires the thickness of 2 substrates. Assuming a substrate thickness of .020", each dual mode resonator requires a thickness of only .040".

A similar multi-layer design can be applied to microstrip filters. This is illustrated in Figure 4. The multi-layer microstrip configuration has a disadvantage as compared to the multi-layered stripline structure in that it is more difficult to extend the concept for filters with more than four poles.

An important aspect of the multi-layered filters introduced in this paper is tunability. For these filters, tuning can be achieved by a combination of select at test substrates containing resonators or irises of varying dimensions and the introduction of tuning screws which perturb the field configurations of the resonant modes.

EXPERIMENTAL RESULTS

In order to demonstrate the feasibility of the aperture coupled, dual mode stacked filters described in this paper, proof of concept filters have been built and tested. Figure 5 is a photograph of a

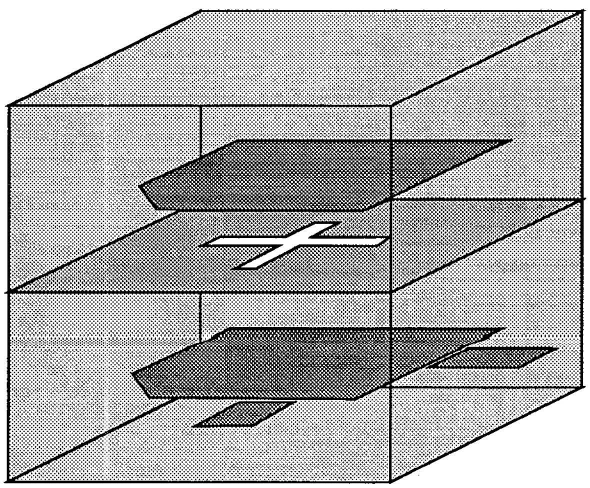

Figure 2: Illustration of a stacked, planar filter constructed from rectangular, dual mode resonators coupled through slot irises. This filter is made from a stack of 4 patterned substrates.

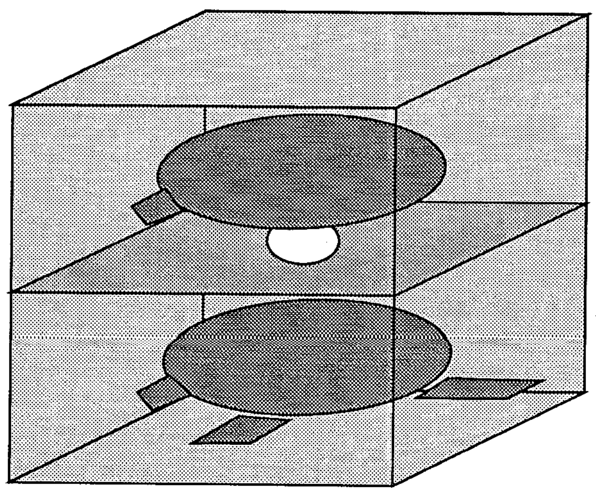

Figure 3: Illustration of a stacked, planar filter constructed from dual mode disk resonators coupled through circular irises. This filter is made from a stack of 4 patterned substrates.

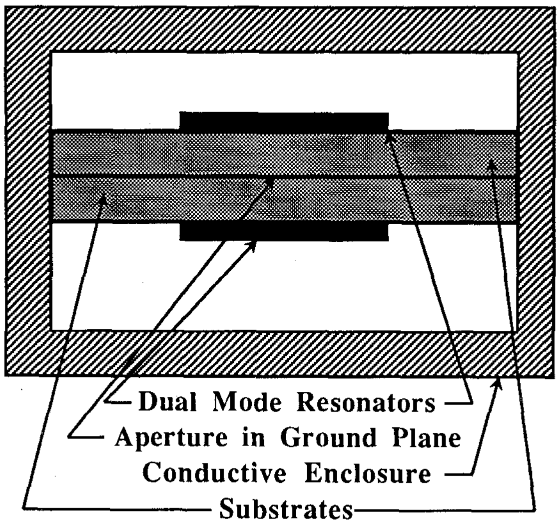

Figure 4: Illustration of 4-pole filter constructed from a stack of two dual mode microstrip resonators. The resonators are coupled together through an aperture in the ground plane they share.

4-pole, elliptic function, stacked stripline filter similar to the one illustrated in Figure 2. In the case of this filter, input and output couplings were implemented by inserting coaxial coupling probes into holes drilled into the substrate in a direction perpendicular to the plane of the resonators. Tuning screws were also introduced in the same way.

Coupling between the resonators was controlled using two orthogonal irises as in Figure 2, and coupling between the dual modes of a single resonator was accomplished through a combination of notches in the corners of the resonators and tuning screws introduced into the substrates beneath the notches.

The measured performance of the filter in Figure 5 is shown in Figure 6. The experimental results clearly indicate the feasibility of the stacked planar filter concept.

CONCLUSIONS

A new and novel printed circuit filter concept has been introduced that is based on a multi-layered stack of dual mode microstrip or stripline resonators. The coupling between the resonators is controlled by coupling apertures in the ground plane commonly shared by the two resonators. This new type of filter facilitates the realization of any of the filter designs currently implemented in dual mode cavity or dielectric resonator configurations and offers dramatic reductions in size and mass as compared to these currently used designs. The multi-layer stacked filters introduced here are ideally suited for realization using thin film superconductors for high Q performance.

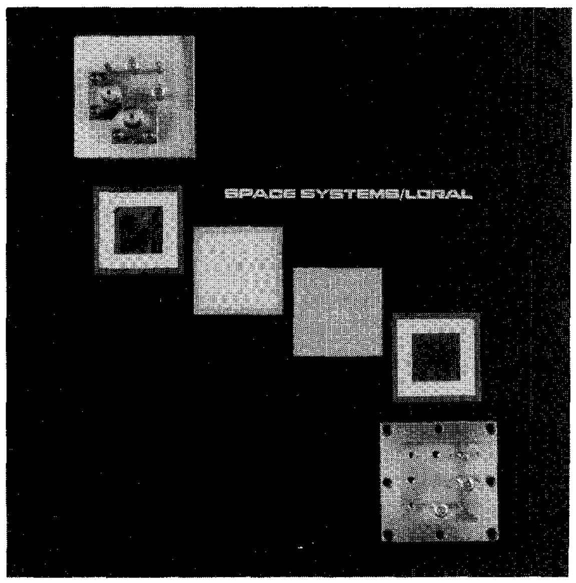

Figure 5: Photograph of a 4-pole, proof of concept, multi-layer, planar filter based on aperture coupled, dual mode stripline resonators.

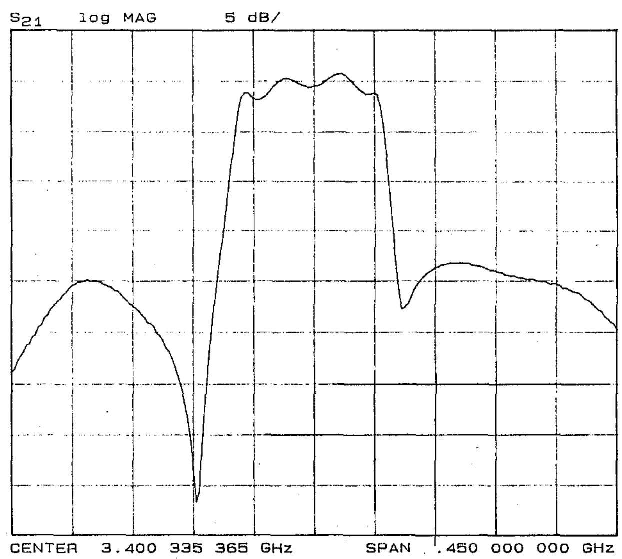

Figure 6: Measured performance of the proof of concept filter shown in Figure 5. This plot clearly demonstrates the feasibility of the multi-layered, aperture coupled, dual mode filter concept.

REFERENCES

1. J.A. Curtis and S.J. Fiedziuszko, "Miniature Dual Mode Microstrip Filters", *Proceedings IEEE MTT-S*, pp. 443-446, June, 1991.

2. J.A. Curtis and S.J. Fiedziuszko, "Dual Mode Microstrip Filters", *Applied Microwave Magazine*, pp. 86-93, Fall 1991.

3. D.M. Pozar, "A Microstrip Antenna Aperture Coupled to a Microstripline", *Electron. Lett. U.K.*, vol. 21, no. 2, pp. 49-50, January, 1985.

4. Frederic Croq and Albert Papiernik, "Stacked Slot-Coupled Printed Antenna",*IEEE Microwave and Guided Wave Letters*, vol. 1, no. 10, pp. 288-290, October, 1991.

5. I. Wolff and N.Knoppik ., "Rectangular and Circular Microstrip Disc Capacitors and Resonators", *IEEE Trans. on Microwave Theory and Tech.*, MTT-22, pp.857-864, October 1974.

6. R.R. Bonetti and P.Tissi , "Analysis of Planar Disc Networks", *IEEE Trans. on Microwave Theory and Tech.*, MTT-26, pp.471-477, July, 1978.