MINIATURE DUAL MODE MICROSTRIP FILTERS

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ABSTRACT

Dual mode cavity and dielectric resonator filters are the mainstay of satellite communications. In this paper, a new generation of planar dual mode filters is introduced which offers significant size, weight, and cost advantages over these previous designs. All currently used elliptic function, self equalized, etc. filter designs can be implemented in microstrip using this new concept. The proposed filter structures are ideally suited for implementation using the recently discovered high temperature superconductors. Basic dual mode resonator and filter structures are discussed, and experimental data for proof of concept filters implemented using both normal and superconducting microstrip are presented.

INTRODUCTION

Design techniques for single mode microstrip filters such as broad side edge coupled filters have long been established. However, these filters are of limited utility for most high performance microwave applications due to their typically high insertion loss and impracticality for filter pass bands of less than 5%. The high performance requirements for communication satellite frequency multiplexers typically require the use of dual mode cavity or dielectric resonator filters to realize self equalized, quasi-elliptic responses having pass bands often less than 1%. Cavity and dielectric resonator filters have the the drawbacks of relatively large size and high cost.

In this paper, we introduce a new class of dual mode planar filters that are ideally suited for the realization of narrow band, quasi-elliptic, and self equalized responses and offer significant size, weight and cost reductions as compared to cavity and dielectric resonator designs. This new class of filters, based on (1), is especially well suited for implementation using extremely low loss, thin film, high temperature superconductors. Here we present a variety of dual mode microstrip resonator and filter structures as well as measured data for proof of concept filters based on this concept.

DUAL MODE MICROSTRIP RESONATOR STRUCTURES

Figure 1 illustrates three dual mode microstrip resonator structures that are the building blocks of a new class of dual mode planar filters. In each of these structures, a perturbation has been added to a previously single mode resonator at a point that is 45 degrees from the axes of coupling to the resonator. The perturbation in the symmetry of the resonator at the 45 degree offset location facilitates coupling between two orthogonal modes within the resonator. The axes of coupling to the resonator are orthogonal, so each couples energy independently to and from only one of the orthogonal modes within the resonator as is required to realize dual mode filters of more than two poles. The perturbations can take on any number of forms, and the extent to which they disturb the resonant fields, determines the coupling coefficient between the two orthogonal modes. The perturbations shown in Figure 1 were chosen because of their repeatability, symmetry, and tunability.

The square resonator of Figure 1 is an adaptation of a single mode resonator commonly used for microstrip patch antennas and previously used as a discriminator (2,3). The circular resonator is an adaptation of a single mode disk resonator that is also used in microstrip antennas and has been used previously to realize single mode microstrip filters (2,4). The dual mode ring resonator is an adaptation of the single mode resonator commonly used for a variety of

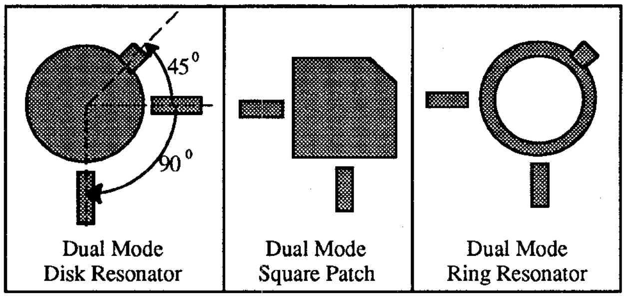

Figure 1: Three dual mode microstrip resonators that are the building blocks for a new class of planar dual mode filters.

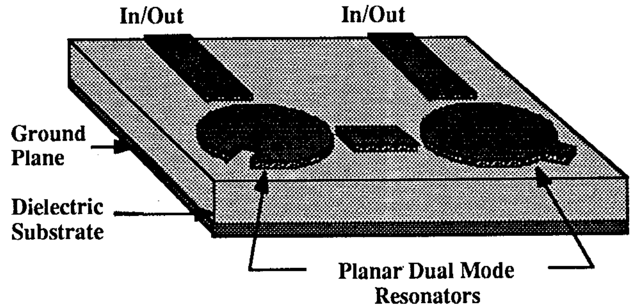

Figure 3: Realization of a dual mode, four pole, Chebyshev, microstrip filter using disk resonators.

purposes including microstrip transmission line evaluation. Perturbations in ring resonators have been used previously to excite degenerate modes, but to our knowledge have not previously been used to to realize multi-pole (n>2) dual mode filters (5,6).

DUAL MODE MICROSTRIP FILTER CONFIGURATIONS

The resonators described in the previous section can be arranged in a number of ways to realize dual mode microstrip filters. In this section, we present a few of the feasible configurations. The sketch in Figure 2 illustrates a dual mode, four pole, Chebyshev filter realized using two square patch resonators. The arrows represent the dual orthogonal modes facilitated by the asymmetric "cut away" corner geometry. Coupling to and from the resonators is facilitated by capacitive microstrip gaps, and the coupling between the orthogonal modes is a result of the asymmetry. A similar four pole filter realized using dual mode microstrip disk resonators is illustrated in Figure 3.

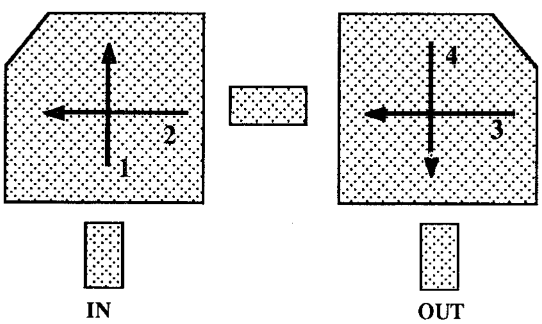

Figure 2: Sketch of a dual mode, four pole, microstrip filter. The arrows represent the orthogonal modes within the resonators.

One of the principle advantages of this new class of planar filters over other classes of microstrip filters is that it facilitates the practical realization of elliptic and quasi-elliptic function responses. Figures 4 and 5 illustrate two dual mode microstrip realizations of elliptic function filters. The required cross coupling is implemented using short sections of microstrip.

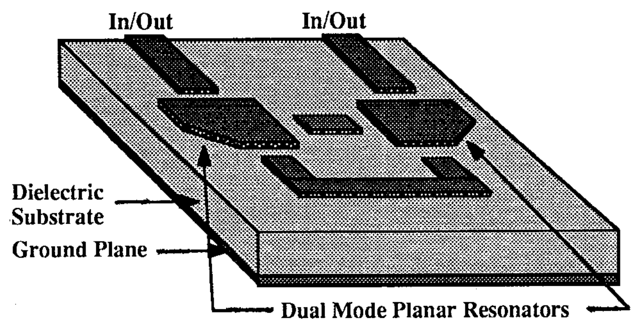

Figure 4: Four pole, dual mode, elliptic function microstrip filter using square patch resonators.

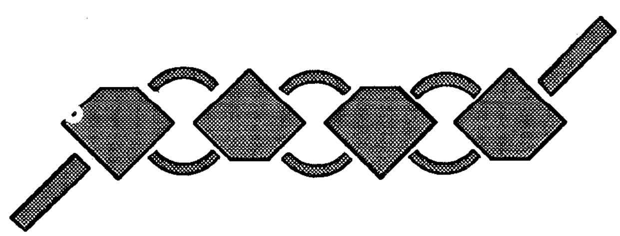

Figure 5: Realization of an eight pole, dual mode, elliptic function, microstrip filter.

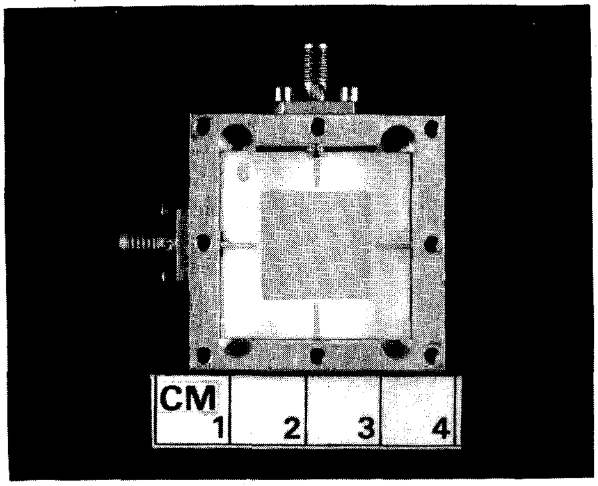

Figure 6: Photograph of two pole, dual mode POC filter.

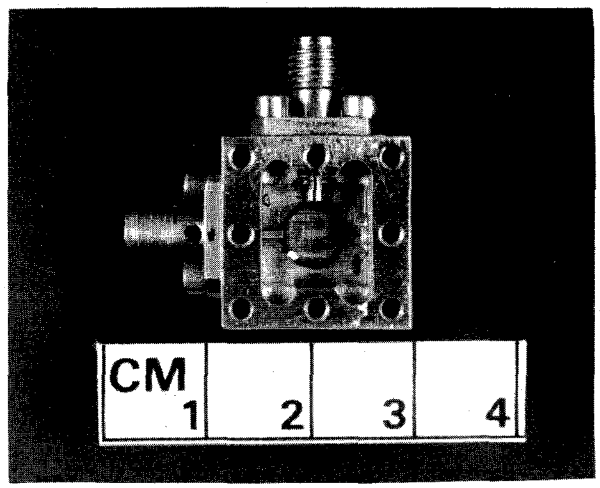

Figure 8: Photograph of a dual mode, superconducting, ring resonator filter.

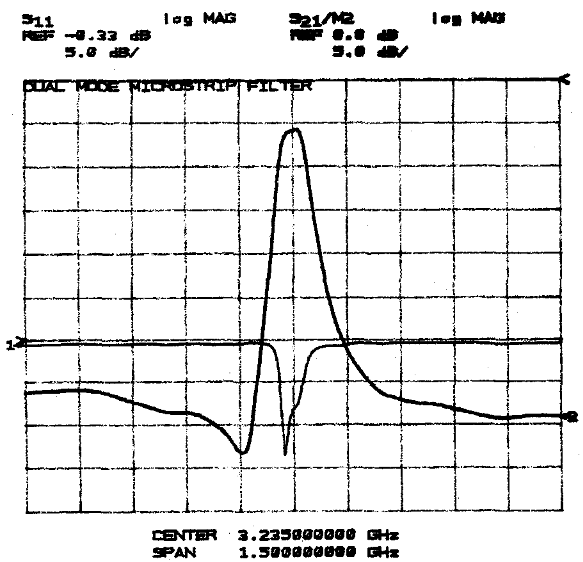

Figure 7: Measured performance of the filter shown in Figure 6 illustrating two well defined poles.

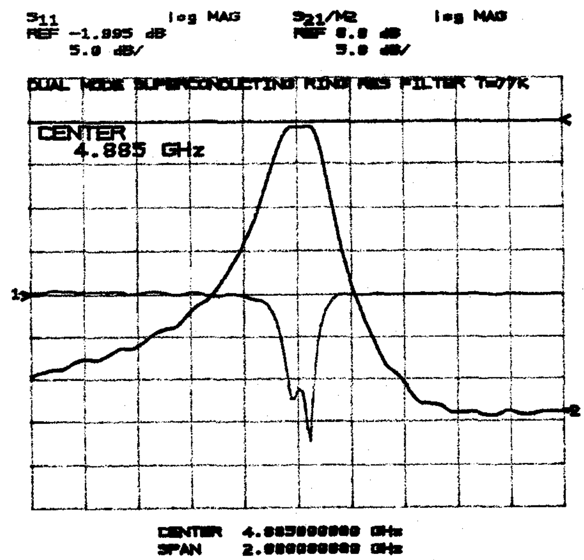

Figure 9: Measured performance of the filter shown in Figure 8 at 77K. Superconductors may be used to fabricate high Q, dual mode, microstrip filters.

EXPERIMENTAL RESULTS

Proof of concept (POC) filters using both normal (copper/gold) and thin film superconducting microstrip have been fabricated to demonstrate this concept. Figure 6 is a photograph of a dual mode, POC, two pole filter realized using a square patch resonator, and Figure 7 is a plot of its measured performance. In this filter, the asymmetrical perturbation is implemented by using a checker board pattern in the metallization at one corner of the patch.

Figure 8 is a photograph of a 2 pole, dual mode, ring resonator filter that was implemented using the high temperature superconductor YBCO on a lanthanum aluminate substrate. Coupling between the orthogonal modes is implemented by the silver stub on the ring. Figure 9 is a plot of the performance of this POC filter measured at at 77 Kelvin. As compared with an identical

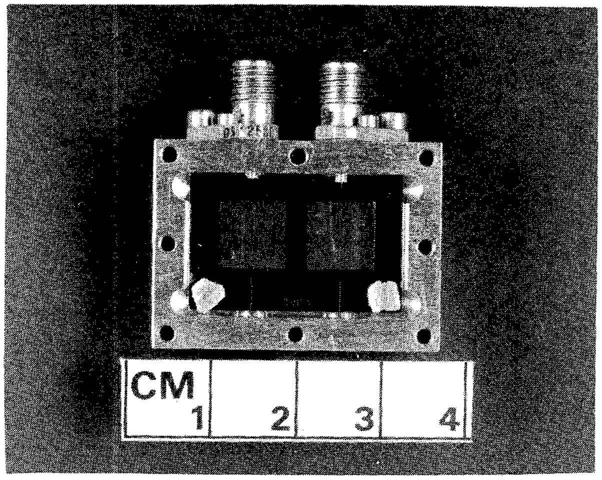

Figure 10: Photograph of a four pole, dual mode microstrip filter that is currently being optimized.

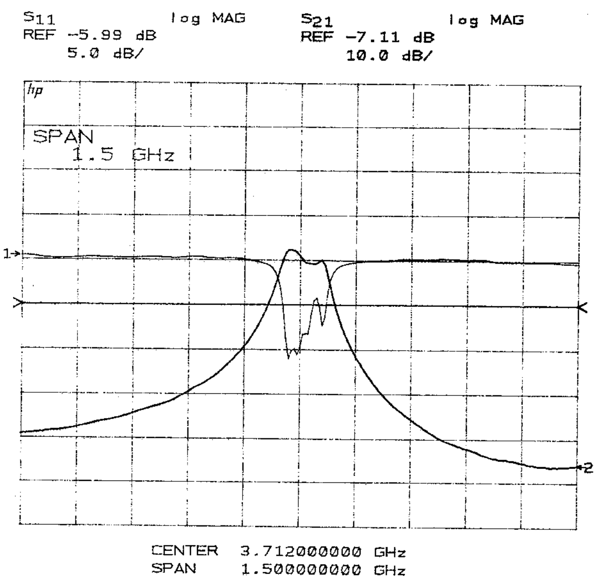

Figure 11: Measured performance of the filter shown in Figure 10. The four well defined poles illustrate the dual mode behavior of the device.

circuit fabricated from a normal metal microstrip, this superconducting filter exhibits more than a 3 dB improvement in insertion loss.

Figure 10 is a photograph of a 4 pole, dual mode microstrip filter on lanthanum aluminate that is currently being optimized. Figure 11 illustrates the initial performance of this filter showing 4 well defined poles. The lanthanum aluminate substrate was chosen so the optimized filter can ultimately be realized using high temperature superconductors. The asymmetrical perturbations required for dual mode behavior were implemented using dielectric tuning elements.

CONCLUSIONS

In this paper we have introduced a new generation of planar dual mode filters. These filters can be used to implement the elliptic function, self equalized, narrow band responses required for satellite communications, but are significantly smaller, lighter, and potentially less expensive than the dual mode cavity and dielectric resonator filters currently used. This new class of filters is ideally suited for fabrication from thin film high temperature superconductors to achieve high Q performance. A variety of these filters has been demonstrated using both normal metal and superconducting microstrip. Superconducting realizations of this new class of filters may be used to replace bulkier, heavier filters currently used for satellite communications.

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