Folded Dual-Mode HTS Microstrip Band Pass Filter

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Abstract — **A novel dual-mode HTS microstrip resonator is presented. Interdigitated capacitive networks replace the usual distributive coupling. Also, a novel symmetrically folded technique is used that reduces the physical size of the structure while minimizing unwanted coupling and maintaining well defined transmission zeros.**

I. Introduction

Compact dual-mode microstrip resonators utilizing a ring structure have been studied [1]-[3] that can have size advantages over dielectric resonator designs for narrow-band quasi-elliptic filters. Patch dual-mode microstrip patterned structures, like circles and squares, take up more area when operated at the same frequency as a microstrip ring structure. At lower frequencies, however, even these ring structures can become quite large because resonance occurs when the ring is approximately a full electrical wavelength long. When coupling multiple resonators to make a band pass filter, the area required to accommodate the filter can grow undesirably large in order to minimize unwanted parasitic coupling between resonators and to the test package. This is particularly an issue for narrow bandwidth filters, where the desired coupling between resonators is very small, making the spacing between resonators greater and thus the overall size of the filter becomes even larger. For very high Q structures, like thin film HTS, significant Q degradation can occur due to the normal metal housing. The dual-mode resonator described in this paper is made from thin film HTS that possesses very high Q, low far-field radiation, integral resonator coupling (between resonator pairs), small size and a pair of transmission zeros (one on the high and one on the low side of the passband) for each dual-mode structure. In making the dual-mode structure as small as possible, care has to be taken in the folding process to preserve these attractive properties. In addition, external coupling as well as the coupling between dual-mode resonator structures, has to be done appropriately to maintain good filter characteristics.

II. Discussion

Figure 1 shows the layout of a novel dual-mode HTS microstrip resonator. Two key innovations are the point contact interdigitated coupling and the symmetric folded ring.

The dual-mode resonator structure was analyzed using a full-wave electromagnetic simulator [4]. This structure was split into 2 analysis efforts: the basic structure as shown in Fig. 2 and the interdigitated capacitor external loading (see Fig. 3 for a view of this circuit area). Figure 2 shows the various de-embedded tap points used in the simulation to determine the excitation locations necessary to create the desired bandwidth from the two modes [5] of the ring resonator. In addition, due to the two path lengths from the input to the output tap positions, two transmission zeros can be created in the stop band.

Computer models of dual-mode microstrip resonators often use ideal capacitors for external coupling. Because of the parasitic nature of physical capacitors, low quality factor, and effects of mounting, they often become undesirable when fabricating state-of-the-art HTS microstrip circuits. In order to eliminate the physical capacitors when realizing high performance HTS dual-mode filters, the computer capacitor models are often replaced by distributed structures (i.e. by using the coupling between a length of the resonator structure and an input/output line running parallel to it).

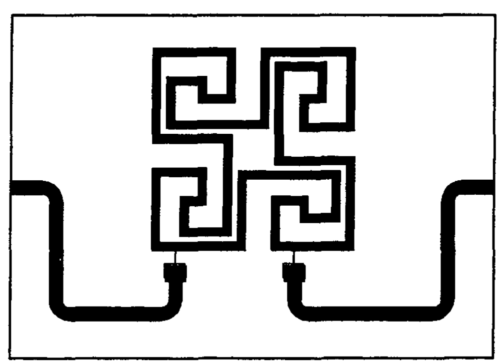

Fig. 1. Physical layout of a novel dual-mode HTS microstrip resonator with interdigitated couplings and field suppression folded arms.

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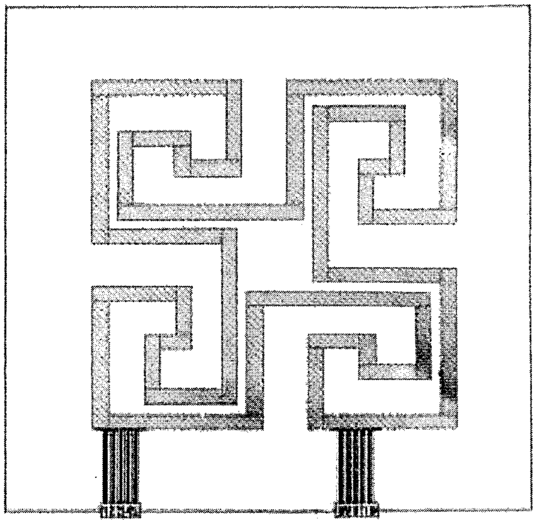


Fig. 2. Resonator layout in electromagnetic circuit simulator with ten de-embedded tap points.

This replacement usually introduces degradation in frequency response. This degradation is most noticeable in the shape and depth of the transmission zeros and poor alignment of the filter poles.

To minimize this degradation from the physical realization of dual-mode HTS microstrip structures, we have replaced the distributed external coupling with a planar interdigitated capacitor. The capacitive network essentially provides a point contact with the HTS microstrip ring resonator. Figure 3 is a magnified view of the interdigitated external capacitive network. This point contact more accurately represents an ideal lumped element capacitor connection from the computer modeling than the distributed coupling structures. It has been found that the resonators need to be loaded in this manner in order to preserve optimum frequency performance. Using the full-wave electromagnetic simulator [4], the interdigitated capacitors were analyzed to give the appropriate susceptances needed to couple to the dual-mode resonator and create the desired frequency response. These interdigitated capacitors can also be used to couple between dual-mode resonators to create higher order filters.

The position of the tap location plays a key role in coupling to the orthogonal modes of the resonator as well as defining the transmission zeros [6].

Our analysis has also shown that in order to maintain well defined transmission zeros the microstrip ring resonator must also maintain four-quadrant symmetry. It is usually desirable to minimize the size of an HTS dual-

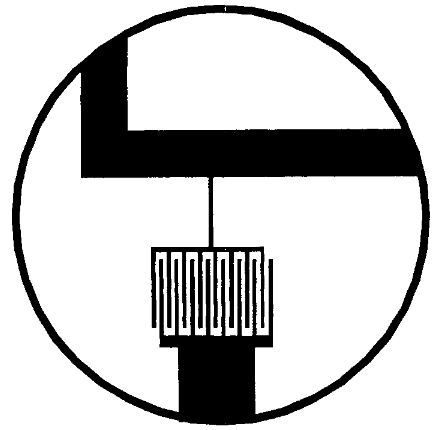
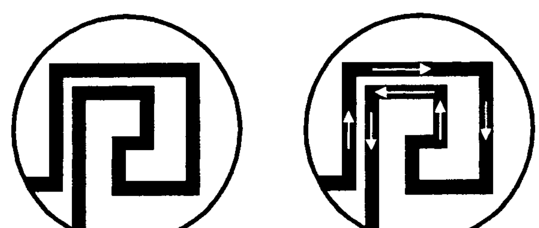


Fig. 3. Magnified view of HTS microstrip interdigitated external coupling capacitive network.

mode microstrip structure in order to utilize the available circuit real estate to its maximum. However, potential unwanted parasitic couplings can occur as circuits are squeezed into smaller spaces.

To overcome these issues, we have adopted a novel technique used in the design of the dual-mode HTS microstrip resonator to create a four quadrant symmetric folded structure. This technique overcomes some of the undesirable features of commonly reported dual-mode microstrip resonators. The folded design incorporates four-quadrant circuit symmetry needed to maintain good frequency response. The footprint of the resonator is greatly reduced as a result of the folded sections. Also, because the electrical currents in adjacent HTS patterned paths of the folded resonator are essentially in opposite direction, far-field radiation is minimized allowing for tighter packing of the resonators and minimum performance degradation due to the packaging. Figure 4(a) shows a magnified view of a folded section of the resonator and Figure 4(b) shows a snapshot of the current direction in the HTS dual-mode microstrip structure.



(a) (b)

Fig. 4. (a) One quadrant of the folded dual-mode HTS microstrip resonator. (b) Snapshot of current flow in the HTS circuit.

Another feature of this structure is that the two modes of the structure can be tuned nearly independently by positioning tuning elements over adjacent quadrants of the structure where the peak electric fields are located. This tuning can be done using low loss dielectric rotors in order to preserve the quality factor of the resonators.

The measured and modeled frequency responses of a single dual-mode HTS resonator structure are shown in Figure 5. As can be seen, there is very good agreement between the measured and modeled responses. In order to measure the unloaded quality factor of the dual-mode resonator, the input and output couplings were greatly decoupled allowing the natural modes of the resonator to be measured. This was accomplished by scribing away part of the HTS input and output transmission lines. The measured unloaded Q at 77K and 2.14GHz was approximately 36,000 which included the effects of the normal metal package and lid (Figure 8 shows a photograph of the package used in this measurement.)

The dual-mode HTS microstrip resonator is a building block that can be utilized to create more complex filters. Figure 6 is the circuit layout of a 4-pole HTS microstrip bandpass filter composed of two dual-mode HTS microstrip resonators coupled together in a similar manner as the external coupling was derived. The measured frequency response of a 4-pole bandpass dual-mode HTS microstrip filter at 77K is shown in Figure 7. The well defined poles illustrated by Figure 7 are a result of the implementation of the coupling technique and four-quadrant symmetrical layout. Figure 8 is a photograph of the 4-pole HTS microstrip bandpass filter implemented using TBCCO on a 20 mil thick MgO substrate. The HTS circuit is 12mm by 34mm and the lid is 0.508mm above the circuit.

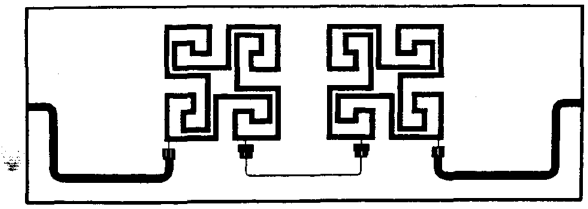


Fig. 6. Circuit layout of a 4-pole bandpass filter comprised of 2 dual-mode HTS microstrip folded resonators and interdigitated couplings.

V. Conclusion

It has been shown that by utilizing the novel coupling and folding features of the dual-mode resonators described here, a much more useable building block for practical high order, high selectivity, planar HTS thin film bandpass filters results. These techniques allow for better correlation with computer models, less undesirable electromagnetic radiation, practical tuning and tighter packaging of bandpass filters.

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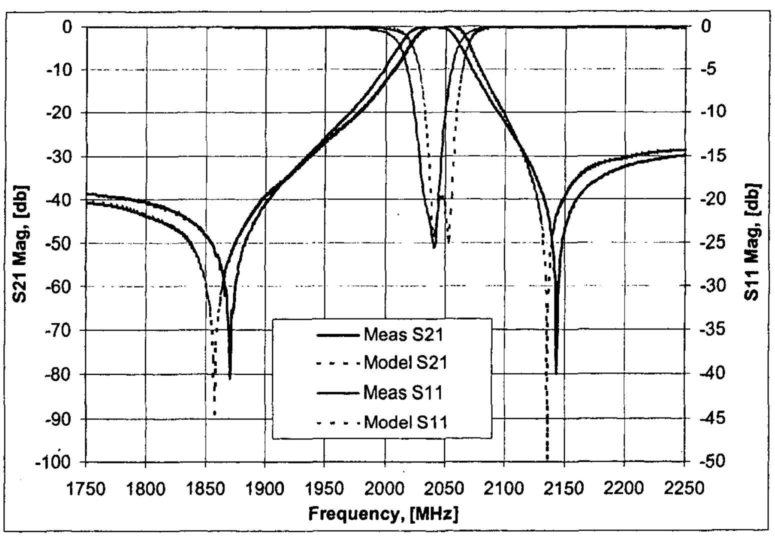

Fig. 5. Measured and modeled frequency response of a 2 GHz 2-pole HTS dual-mode microstrip resonator.

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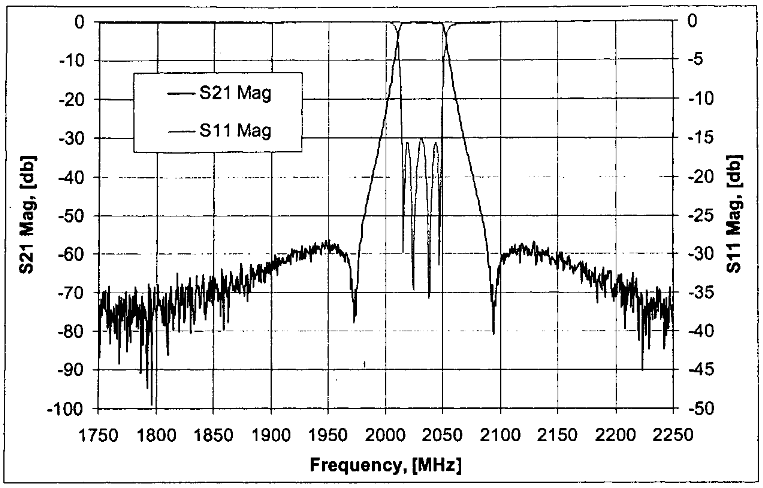

Fig. 7. Measured frequency response of a 2 GHz 4-pole dual-mode HTS microstrip filter at 77K.

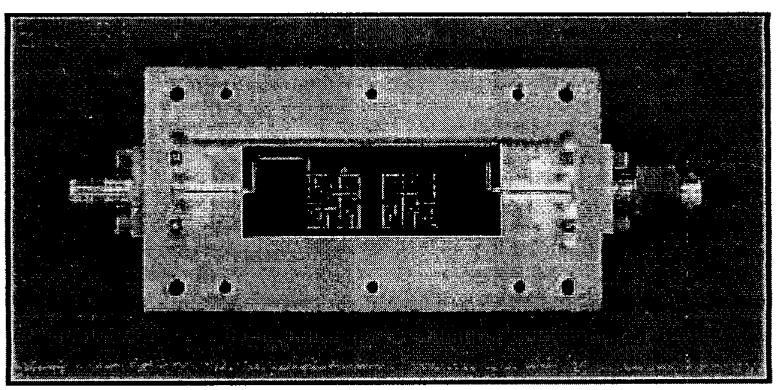

Fig. 8. Photograph of the 4-pole HTS microstrip bandpass filter implemented using TBCCO on a 20 mil thick MgO substrate.