A Novel Split-Resonator High Power HTS Planar Filter

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Abstract

A novel microstrip filter design employing split-resonators and inserted I/O line coupling structures is proposed for high power high-temperature-superconductive (HTS) thin film filters. The use of split-resonators together with the inserted I/O coupling helps to redistribute the current more evenly over the resonators. The inserted line coupling structure also eliminates the sharp corners and narrow gaps associated with conventional I/O coupling structures. A 3-pole HTS filter was designed and tested. Excellent measurement results were obtained which demonstrate the advantages of the proposed design.

Introduction

The current density is a critical parameter in designing high power thin-film high-temperature superconductor (HTS) filter. Over the past two years, several papers were reported [1]-[4] suggesting the use of HTS patch-type resonators operating at TM_{01} modes. One of the problems associated with the use of such type of resonators is that the attainable spurious performance may not be satisfactory in many applications [5]. Additionally, HTS filters built using TM_{010} patch resonators are considerably large in size compared to conventional planar HTS thin film filter designs.

Using larger resonator size is a natural choice in conventional planar filter design to lower current density, as shown in Figure 1, and hence increase the power handling capability of the resonators. However, the increase of resonator size has its limitations, i.e., the resonant mode along the resonator width direction may become too close to the desired resonator mode which in turn degrades the filter spurious performance. Moreover, the T-shaped I/O coupling structure shown in Figure 1, has a potential weakness when used in designing high power HTS filters: the T-shaped coupling structure has two corners where high current density exists. The gaps between the resonator and the T-shape end strip are typically very small even for narrow band filters.

We present in this paper a novel filter design employing split-resonators and inserted I/O coupling structures for high power thin film HTS filters. With the use of split-resonators, the current becomes more evenly distributed, and the high current density spots and narrow gap associated with T-shaped coupling structure can be effectively eliminated. Therefore, we can significantly improve the filter power handling capability. We have designed and tested a 3-pole thin film HTS filter using this technique. The filter has demonstrated an excellent power handling capability compared to what can be achieved using conventional HTS thin film filter designs.

New Filter Design

The concept of split-resonator can be graphically explained in Figure 2 where cross section views of a conventional microstrip line and sliced microstrip lines are illustrated together with schematic views of their current distributions. A conventional microstrip line has high current concentration close to the outer edges. However, by cutting narrow slots in the microstrip line as shown in Figure 2(b), the current redistributes itself such that the current density at outer edges is reduced while that at the inner edges is increased.

Figure 3 shows a 2-pole filter using the proposed design. Each resonator consists of two (or more) parallel pieces separated by gaps. Full wave EM simulation [6] has shown that the resonant frequency of the split-resonator is very close to that of a similar solid resonator. However, with split-resonator, we can reduce the peak current density at outer edges so that the overall power handling capability of the resonator can be improved. There is another important advantage of applying split-resonator. With the same total resonator width, the resonant frequency corresponding to the width of the resonator, i.e., the mode orthogonal to the desired operating mode, can be moved much higher. In other words, much wider resonator can now be used without the potential interference of the unwanted orthogonal mode.

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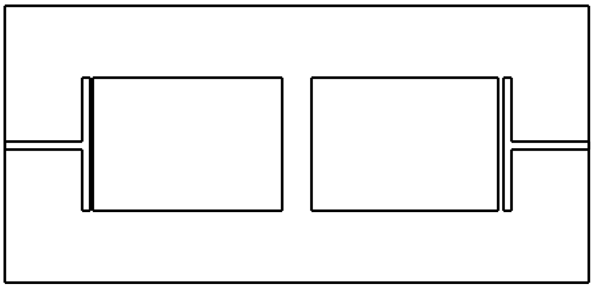


Figure 1, A conventional microstrip filter with wide resonators and T-shaped I/O coupling structures.

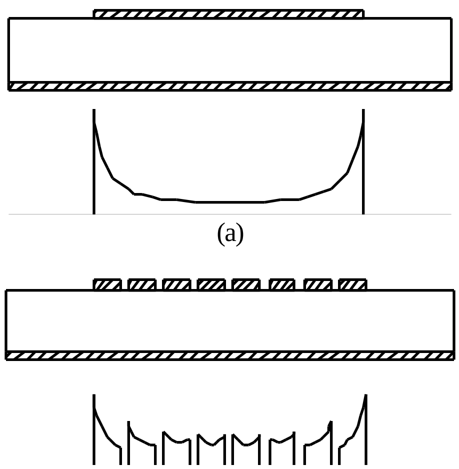


Figure 2, Cross section and current density views of (a) a solid microstrip line, and (b) a microstrip line with narrow slots.

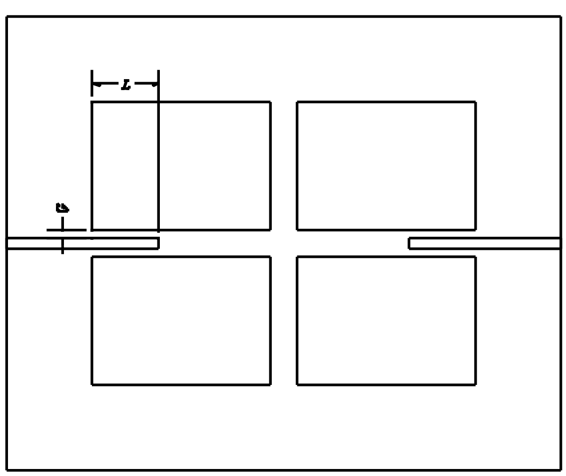


Figure 3, A schematic microstrip filter using split-resonators and inserted line I/O coupling structures.

Having split-resonators, allows extending the microstrip I/O lines into the resonator. Wide range of coupling values can be realized by adjusting the gap width G and inserted line length L. In contrast to the T-shaped coupling structure shown in Figure 1, the new I/O structure can be just a straight line with no high current concentration spots due to discontinuities.

Figure 4(a) illustrates the layout of a 2-pole conventional solid resonator with T-shaped I/O coupling while Figure 4(b) illustrates the layout of a split-resonator filter with inserted I/O coupling structure. The current density plot for the two filters is given in Figure 5. It can be seen that the split-resonator and inserted I/O lines have attracted more current towards the center of the resonator, allowing the current to redistribute more evenly over the resonator cross section.

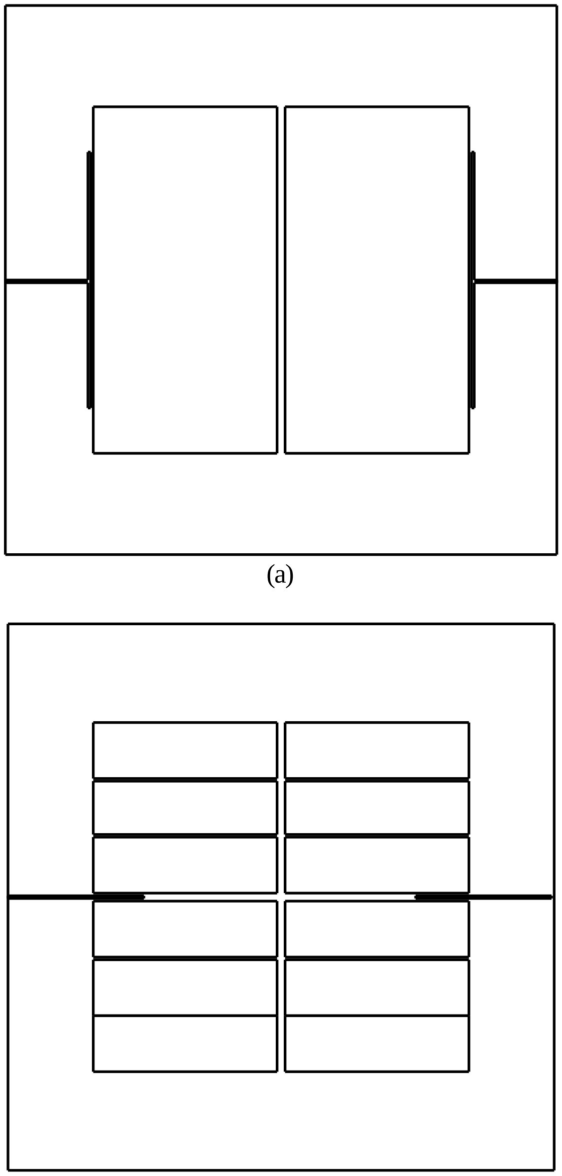
Experimental Results

Figure 6(a) shows a layout of a 3-pole filter employing our new proposed design. The simulated current distribution is given in Figure 6(b). In order to further improve the power handling capability of the filter, gold films were deposited on the high current spots of the input and output lines. It should be mentioned that the gold films deposited on the input/output lines have a little impact on the Q of the resonators which are completely made out of HTS films.

The filter was designed for 20 mil thick $LaAlO_3$ substrate. The resonators are approximately 300 mils by 600 mils. Note that the effective resonator width is approximately twice the resonator length. The inserted I/O coupling line is simply an extension of the 50 Ohm feed line. The gap between the inserted line and resonator is 3.5 mil which was selected due to the uniform grid size limitation of the EM simulator.

The filter was built on a 2 inch TBCCO HTS wafer supplied by DuPont. The measured S-parameter response and high power test results of the 3-pole filter is shown in Figure 7. The HTS filter was tested in LN2 condition and collapsed when input power reached 35W.

Table 1 provides a comparison of the power handling capabilities of three different filters. The first filter is from [1], the second filter is a 4-pole filter we built using a conventional design similar to the one shown in Figure 1, and the third is the 3-pole split-resonator filter shown in Figure 5. In order to compare these three filters with a common reference, we estimate the maximum power of a 4-pole, 1% bandwidth HTS filter derived from each filter's order, bandwidth and measured power [7]. It can be seen that the proposed design demonstrates a considerable improvement in power handling capability.



(a)

(b)

Figure 4, Layout of the 2-pole Chebyshev microstrip filter: (a) using conventional solid resonator and T-shaped I/O coupling structure; (b) using split-resonator and inserted line I/O coupling structure.

Conclusions

We have presented a novel HTS planar filter design using split-resonators and inserted I/O coupling lines. The split-resonator concept can effectively increase the resonator size with the advantage of achieving even current distribution over the resonator cross sections. The design promises to be useful in designing HTS planar thin film filters for high power applications.

Acknowledgment

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References

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Table 1

{PRIVATE }	Bandwidth (%)	Substrate Size (in x in)	Power at 77 K (W)	Estimated maximum Power (W) of a 4-pole 1% bandwidth filter
2-pole from [1]	0.7	1.142 x 0.669	21	9
4-pole conventional	1.0	2.060 x 0.520	6	6
3-pole new design	1.0	1.240 x 0.896	35	20

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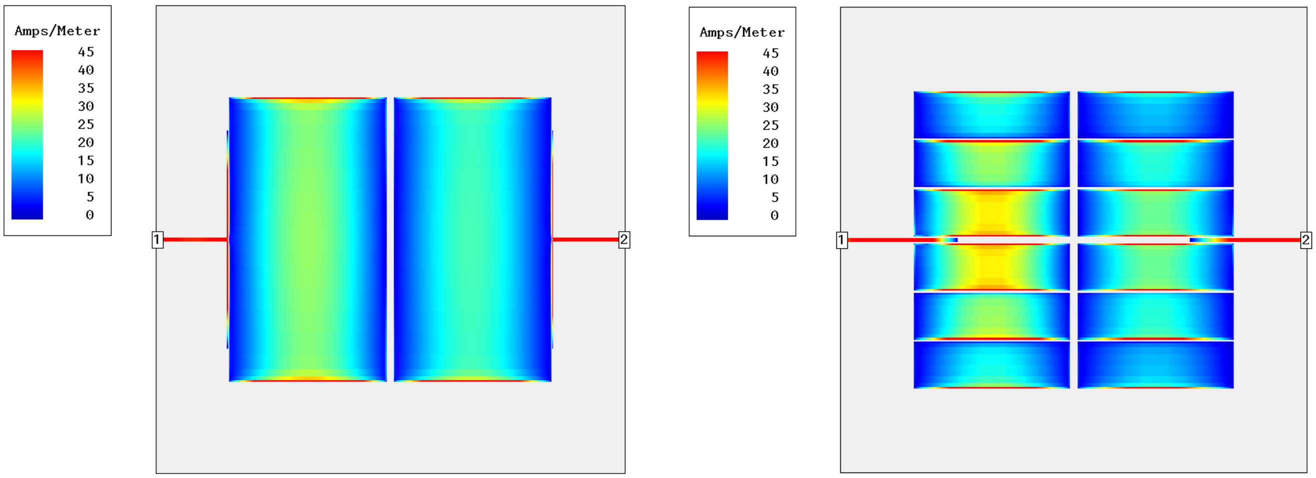
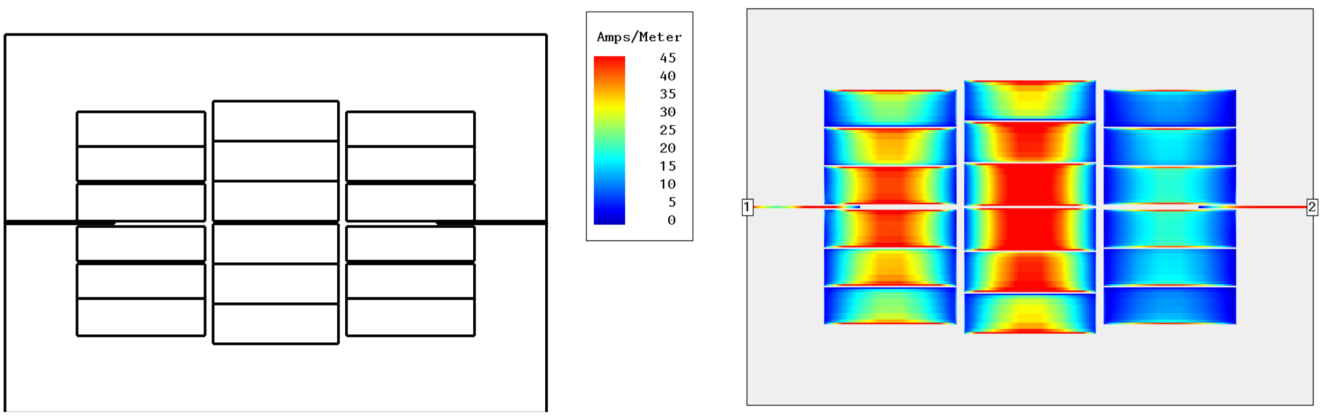


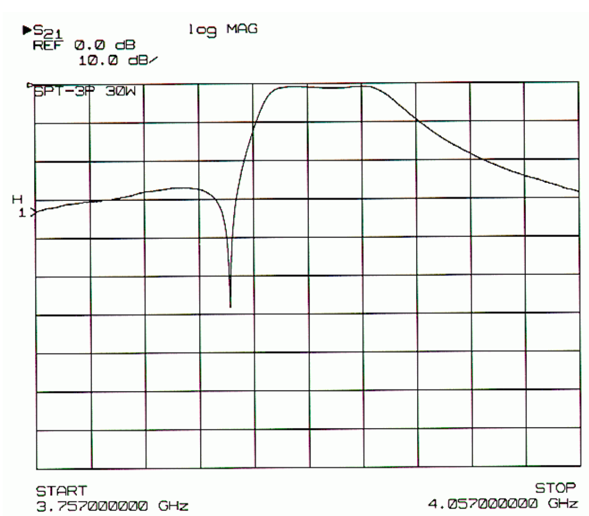
(a) (b)

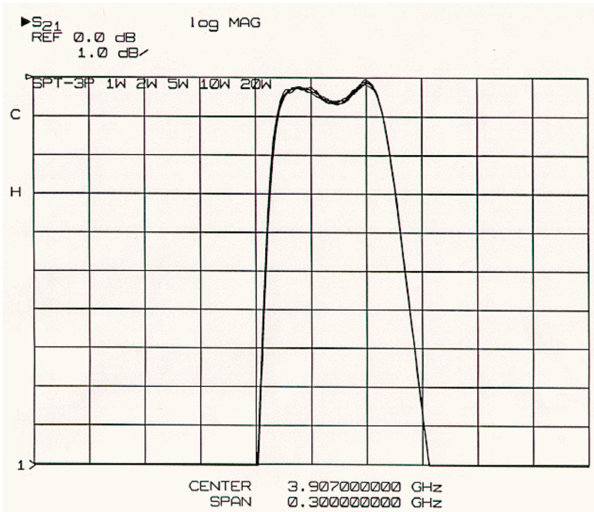
Figure 5, (a) Band edge current density plot of the 2-pole filter shown in Figure 4(a); (b) Current density plot of the 2-pole filter shown in Figure 4(b).



(a) (b)

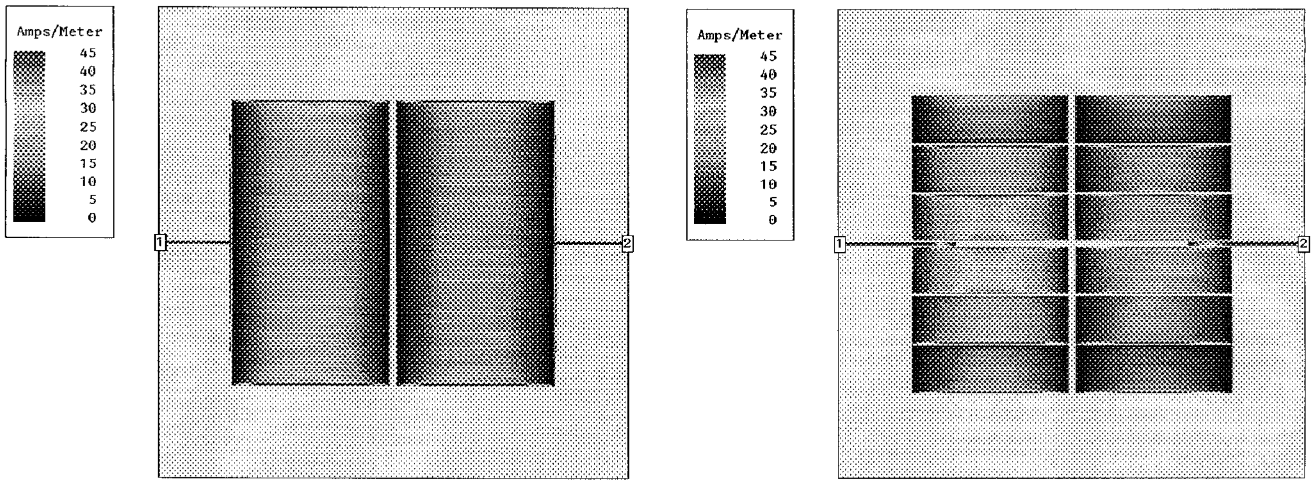
Figure 6, (a) Layout of the 3-pole filter using split-resonator and inserted line I/O coupling structure; (b) band edge current density plot.





(a) (b)

Figure 7, (a) Measured isolation response of the 3-pole filter; (b) insertion loss measured at different input power levels.



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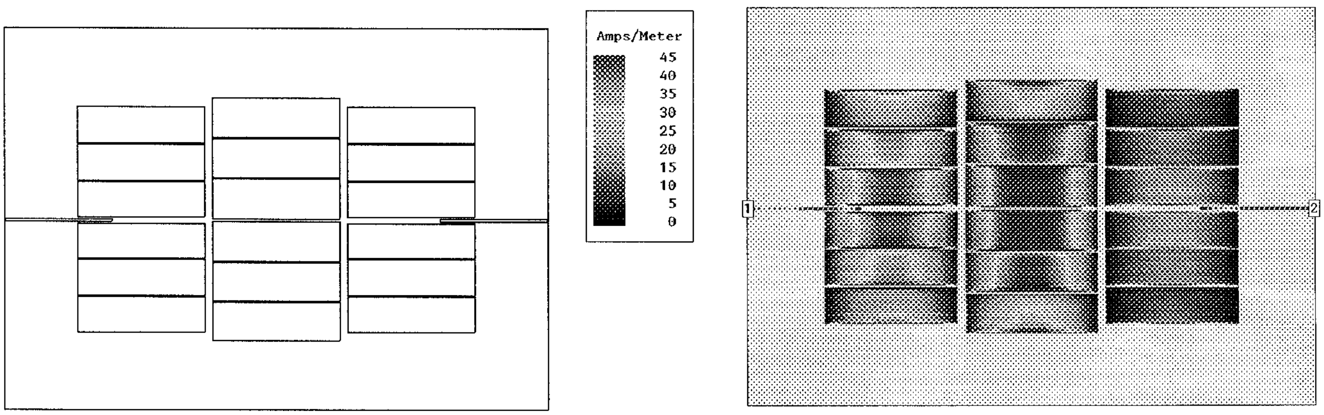

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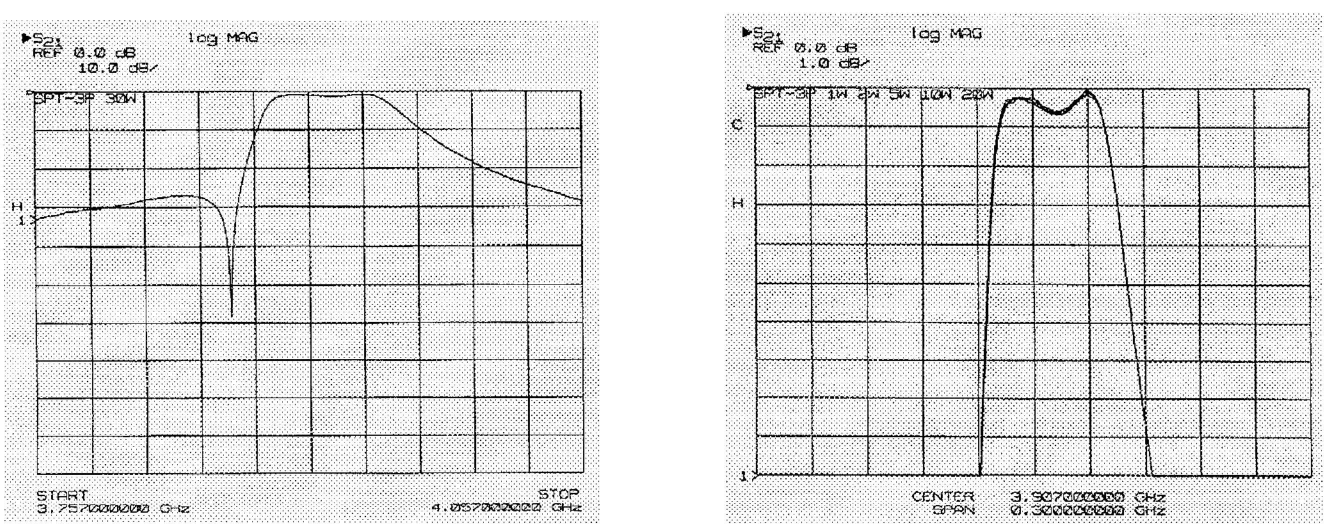

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