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5-POLE HIGH-TEMPERATURE SUPERCONDUCTING BANDPASS FILTER AT 12 GHZ USING HIGH POWER TM_{010} MODE OF MICROSTRIP CIRCULAR PATCH

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This paper presents a five pole Chebyshev bandpass filter using high temperature superconducting (HTS) thin films which employed the symmetrical TM_{010} mode of a circular patch resonator. The filter is designed with centre frequency of 12 GHz with fractional bandwidth of 0.45%. The design is fabricated using double sided YBCO thin films on a sapphire wafer of size $(0.33\times22.5\times39.0)mm^3$. The achieved unloaded Q-factor of the resonators in the fabricated filter is about 6,500 giving the filter an insertion loss of about 0.8 dB at centre frequency of 12.14 GHz..

1 Introduction

Low power HTS filters [1-4] have been widely reported since the discovery of HTS materials [5] in 1986. The low power HTS filters give very promising performance for receive filters in communication systems working at frequencies ranging from 800 MHz to 5 GHz. The HTS thin films are not very popular for high power handling devices because of the limited surface current density on HTS thin films. To increase the power handling of HTS filters, Chaloupka [6] has proposed the TM_{010} mode of circular patch resonator to eliminate the edge current. A 2-pole [7] and 4-pole [8] have been previous reported which employed the edge-current free, TM_{010} mode, resonators. Here, we show that a higher order filter using the TM_{010} can be achieved. We demonstrated this by designing a 5 pole Chebyshev filter with centre frequency of 12 GHz on a double sided YBCO on sapphire substrate.

2 Filter Design, Fabrication and Measurement

Fig. 1 shows the layout of the designed 5-pole HTS bandpass filter which comprises of high power TM_{010} mode resonators. The number in resonators denotes the resonators sequence. The first and the fifth resonators are rotated by 68° from the centre coupling line of the 2^{nd}, 3^{rd} and 4^{th} resonators. This rotation will reduce the length of the filter significantly. Because the TM_{010} mode is a symmetrical mode, the charge and current distributions of the TM_{010} are symmetrical about the centre of the disk. Therefore, the coupling between the 1^{st} and 2^{nd} resonators is the similar type of coupling between the

2^{nd} and 3^{rd} resonators even though they are rotated by 68°.

The input and output couplings are achieved by tapping the input and output lines into the circular disk. More discussion about this input/output coupling will be presented in the next section. The coupling spacing between resonators are obtained through full-wave electromagnetic (EM) [9] simulator.

The filter was fabricated using $YBa_2Cu_3O_7$ thin film material deposited onto a sapphire substrate. The sapphire substrate has a dimension of $(0.33\times22.5\times39.0)mm^3$ with dielectric constant of 9.6 at the principle axis plane. The fabricated filter is mounted onto a gold plated titanium carrier which is then assembled into a test housing. The housing lid accommodates seven tuning screws.

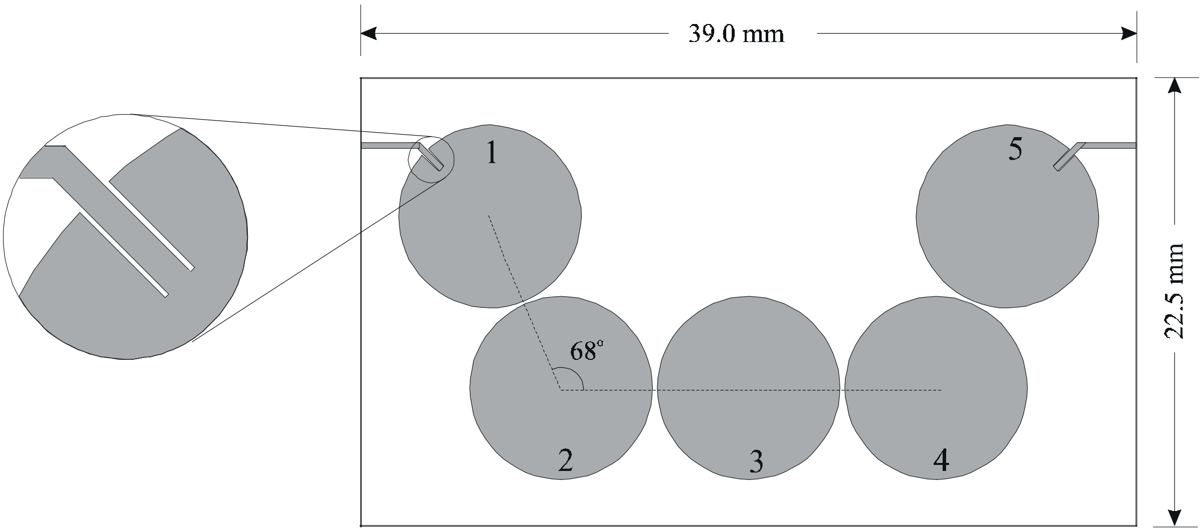

Figure 1: Layout of a high power HTS using TM_{010} resonators on a Sapphire substrate with a thickness of 0.33mm.

The filter was cooled down to 60K using closed cycle cryostat and the performance of the filter was measured using HP8720 network analyser. Fig. 2 shows the measured results after tuning. The measured centre frequency of the filter is at 12.14 GHz with fractional bandwidth of about 0.55%. The passband minimum insertion loss is measured at 0.8dB which corresponds to an unloaded Q-factor of 6,500.

The measured results show a slight increase in the bandwidth. This can be accounted for by the slight inaccuracy of the EM simulation used to determine the coupling coefficients. A single real frequency transmission zero is obtained in the measured response. This transmission zero is due to unwanted cross-coupling between non-adjacent resonators. This unwanted cross-coupling is yet to be modelled. Due to the present of this unwanted transmission zero, the filter response is not symmetrical. It has also cause the low side band to roll off at much slower pace than the theoretical response as shown in Fig. 2.

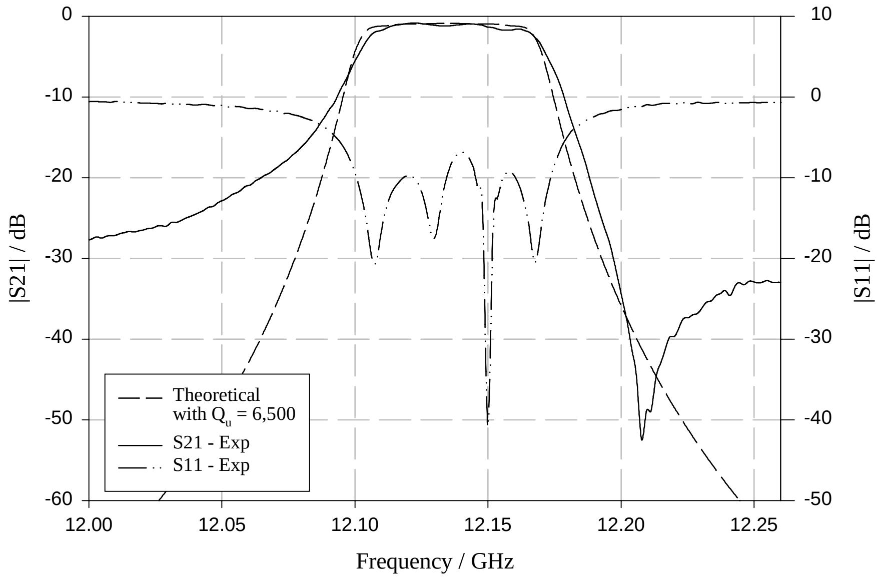

Figure 2: The measured |S21| and |S11| of the tuned HTS five pole filter at about 60K and the theoretical |S21| with unloaded Q-factor of 6,500.

3 Input/Output Coupling

The input/output of this filter is achieved by tapping into the circular patch microstrip resonator. Fig. 3 shows the normalised surface current distribution of the TM_{010} mode of a circular patch microstrip resonator with radius of 9.2mm. The maximum (short circuit) surface current are found at about one half of the radius of the disk and minimum (open circuit) are at the edge and the centre of the disk. Therefore, by varying the tap location from the edge to the half radius of the disk, an increasing external Q-factor can be obtained.

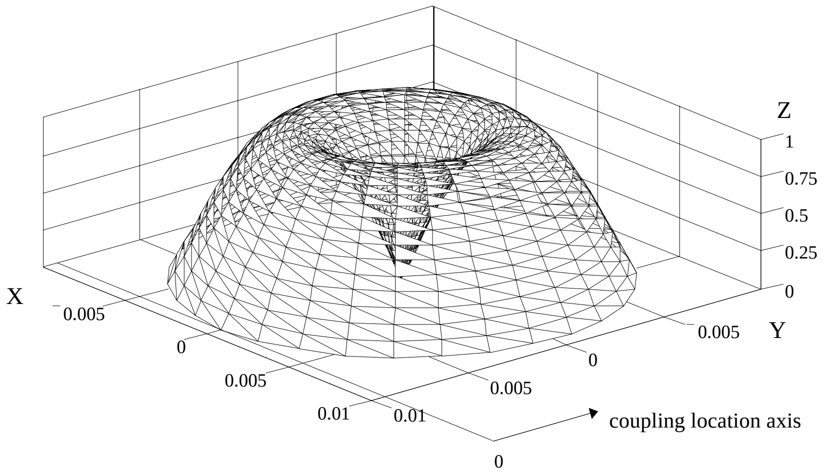

Figure 3: 3D plot of the normalised surface current for TM_{010} mode of circular disk.

The advantage of this tap input/output coupling over the gap coupling [10] is the relationship between the external Q-factor and the coupling location. For the gap coupling, the external Q-factor decreases with the increase of coupling location. Note that the coupling location is referred to the radial distance from the edge of the disk as shown in Fig. 3. To achieve strong coupling using the gap coupled, the coupling location is relatively large whereas for the tap coupling, the coupling distance is relatively small. Therefore, the tap coupling can achieve strong input/output coupling without distorting too much of the circular disk structure. It must be pointed out that this input/output coupling is only applicable on the TM_{010} mode of the circular disk resonator due to the radial surface current distribution.

4 Conclusion

We have shown a new HTS five pole bandpass filter using the high power TM_{010} mode of a circular patch resonators on a sapphire substrate. We have described the filter design, fabrication and experiment. We have also discussed a new way of implementing the input/output coupling for TM_{010} mode circular disk resonator. This new input/output coupling can achieve the required input/output coupling for narrowband filter with minimum distortion of the circular disk structure. This filter is also shown a promising results for satellite communication system applications at 12 GHz with huge reduction in size and maintaining the high unloaded Q-factor of the resonators.

References

[1] D. Zhang, G.-C. Liang, C. F. Shih, Z. H. Lu, and M. E. Johansson, "A 19-Pole Cellular Bandpass Filter Using 75-mm-Diameter High Temperature Superconducting Thin Films," *IEEE Microw. Guilded Wave Lett.*, vol. 5, pp. 405-407, 1995.

[2] G. L. Matthaei and G. L. Hey-Shipton, "Novel Staggered Resonator Array Superconducting 2.3-GHz Bandpass Filter," *IEEE Trans. Microwave Theory and Tech.*, vol. MTT-41, No. 12, pp. 2345-2352, 1993.

[3] J. S. Hong, M. J. Lancaster, D. Jedamzik, and R. B. Greed, "8-Pole Superconducting Quasi-Elliptic Function Filter for Mobile Communications Application," *IEEE MTT-S Intl. Microwave Symp. Digest*, vol. 1, pp. 367-370, 1998.

[4] S. H. Talisa, M. A. Janocko, C. K. Jones, B. R. McAvoy, J. Talvacchio, and G. R. Wagner, "Microwave Superconducting Filters," *IEEE Trans. Mag.*, vol. 27, pp. 2544-2547, 1991.

[5] J. G. Bednorz and K. A. Muller, "Possible high Tc Superconductivity in the Ba-La-Cu-O System," *Z. fur Phys.*, vol. 64, p. 189, 1986.

[6] H. Chaloupka, M. Jeck, B. Gurzinski, and S. Kolesov, "Superconducting Planar Disk Resonators and Filters with high power handling capability," *Electron. Lett.*, vol. 32, pp. 1735-1737, 1996.

[7] S. Kolesov, H. Chaloupka, A. Baumfalk, F.-J. Goertz, and M. Klauda, "High Temperature Superconducting Disk Resonator Filters with High Power Handling Capability," *ISEC*, vol. 6, pp. 272-274, 1997.

[8] A. Baumfalk, H. Chaloupka, M. Klauda, S. Kolesov, and C. Neumann, "HTS Power Filters for Output Multiplexers in Satellite Communications," *Appl. Supercond. Conf.*, 1998.

[9] None, *EM User's Manual*. : Sonnet Software, Inc., 1993.

[10] T. Hayashi, T. Mikazuki, N. Suzuki, and Y. Nagai, "Coupling Structure for Superconducting Disk Filters," *Electron. Lett.*, vol. 30, pp. 1424-1425, 1994.