A 19-Pole Cellular Bandpass Filter Using 75-mm-Diameter High-Temperature Superconducting Thin Films

Dawei Zhang, G.-C. Liang, C. F. Shih, Z. H. Lu, and M. E. Johansson

***Abstract*—A 19-pole bandpass filter designed for the 900-MHz cellular communication band with 25-MHz bandwidth is reported using a compact forward-coupled approach in microstrip configuration. The filter was fabricated using 75-mm-diameter, double-side-coated $YBa_2Cu_3O_7$ (YBCO) high-temperature superconducting (HTS) thin films grown by a single-source MOCVD technique on a $LaAlO_3$ substrate. Measurement of the filter at 77 K showed a dissipation loss of 0.5 dB, corresponding to an average unloaded Q-factor of 10 000 in 75-mm-diameter microstrip resonators. A minimum return loss of 15 dB was obtained from measurements at 77 K.**

I. Introduction

THE CELLULAR communications industry represents a rapidly expanding commercial marketplace. With the development of technology and high customer expectations, carriers are faced with demands to increase capacity and improve the call quality. To that end, the performance of the RF front end of the base-station is very critical. In conventional preselect filters in cellular communication, cavity filters have to be used to achieve the required unloaded Q values. These cavity filters are large, especially when a large number of poles have to be used in the filter to achieve the required rejection skirts. Superconducting planar filters represent a promising technological breakthrough and opportunity for possible applications in such cellular communication systems. Unloaded Q-factors on the order of 40 000 have been demonstrated in the planar superconducting microstrip configuration at 77 K [1]. With such high resonator Q values, very-narrowband filters (0.27% fractional bandwidth) have been realized in the planar microstrip form [2]. For the same reason, filters with a large number of poles can be achieved in a compact, planar circuit configuration. In this letter, we report the design and fabrication of a 19-pole bandpass filter at 900 MHz. The compact, forward-coupled microstrip filter was fabricated using 75-mm-diameter, double-sided YBCO HTS thin films on a $LaAlO_3$ substrate. The measured response of this 19-pole filter showed a dissipation loss of 0.5 dB with minimum return loss of 15 dB across the passband of the filter.

II. Filter Design

In low-frequency applications, such as the current cellular communications near 900 MHz, it is difficult to fit a conventional microstrip quarter-wavelength, parallel-coupled filter within the limited size of currently available superconducting wafers. For example, the length of a 900 MHz half-wavelength microstrip resonator on a 0.5-mm-thick $LaAlO_3$ (LAO) substrate ($\varepsilon = 24.1$) is over 43 mm. It is impossible to fit a 19-pole filter with such resonators on a single 75-mm-diameter $LaAlO_3$ substrate using this quarter-wavelength parallel-coupled approach. In this work, a forward-coupled microstrip filter structure was used. This filter structure is the most compact distributed-element filter structure in the microstrip configuration. It consists of a parallel array of fully aligned half-wavelength resonators. Coupling is controlled by the separation of the adjacent resonators. The design approach of such forward-coupled, narrow-band filters is based on the coupling due to the even and odd-mode phase velocity difference of fully aligned half-wavelength microstrip lines [1], [3]. The resonator elements are coupled over their full half-wavelength extent, instead of the conventional quarter-wavelength coupling. Consequently, the backward coupling is at a null. If there were no forward-coupling (which would be the case in a stripline configuration [4]), there would be no transmission at all. The filter response is dominantly a result of the forward coupling between the resonant sections, which is a predictable function of the difference in the phase velocities of the even and odd modes of the coupled lines. The filter center frequency was designed at 900 MHz, with a bandwidth of 25 MHz. Fig. 1 shows the mask layout of the 19-pole filter on a

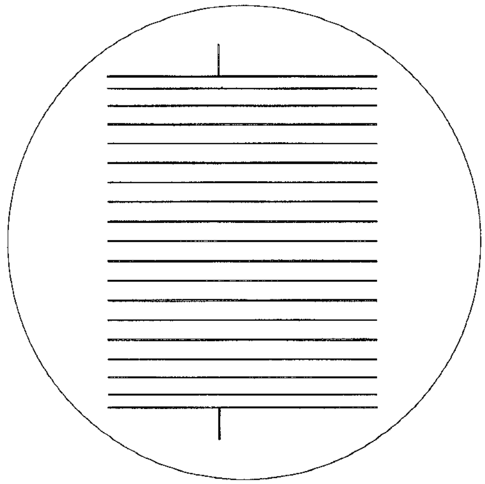

Fig. 1. Mask layout of the 19-pole, 900-MHz cellular bandpass filter on a 75-mm-diameter wafer.

Manuscript received June 2, 1995.
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IEEE Log Number 9414649.

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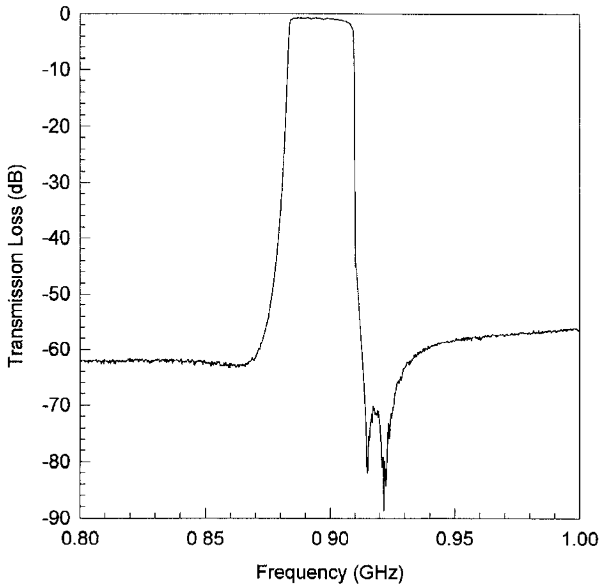

Fig. 2. Measured transmission response of the 19-pole, 900-MHz cellular bandpass filter at 77 K. The minimum dissipation loss in the passband is 0.5 dB.

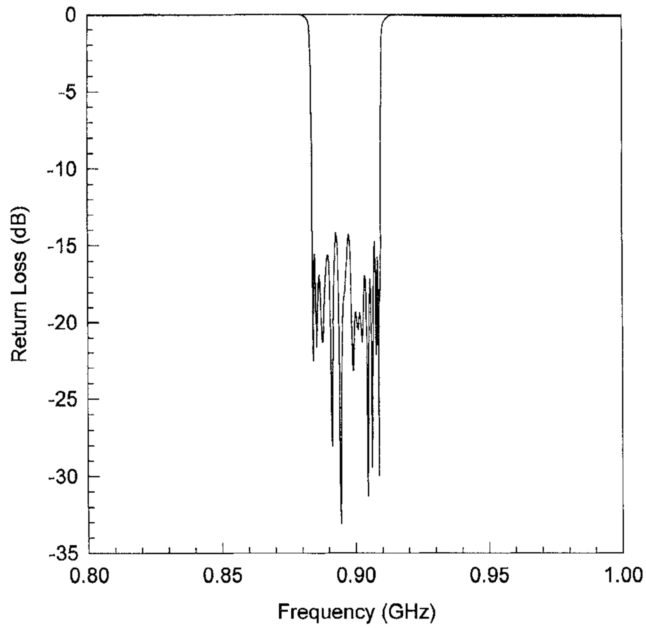

Fig. 3. Measured return loss response of the 19-pole, 900-MHz cellular bandpass filter at 77 K This filter exhibits a 15 dB minimum return loss.

75-mm-diameter $LaAlO_3$ wafer. Detailed comparison between simulation and measurement of this class of filters were shown in [3]. This forward-coupled approach has also been used to achieve HTS filters for high power applications where low-impedance (10-Ω) resonator lines were used to reduce the current density [5], [6].

III. Filter Fabrication

The filter was fabricated using 75-mm-diameter YBCO thin films on a 0.5-mm-thick $LaAlO_3$ substrate. Thin films of YBCO were sequentially grown on both sides of 75-mm-diameter $LaAlO_3$ substrates by a single-source MOCVD technique [7]. The YBCO films on both sides of the $LaAlO_3$ substrates had thickness greater than 4000 Å, T_c's of 87–88.5 K, and microwave surface resistance as low as 23 mΩ at 94 GHz and 77 K. It was found that the substrate temperature during deposition, brought to the desired value by radiant heating, played a critical role in the production of very low surface resistance YBCO films. The filter patterning was accomplished by ion milling. The back side YBCO film was coated with a silver/gold layer using an ion beam deposition technique at room temperature. This normal metal layer provided an electrical contact between the ground plane and the filter package.

IV. Filter Measurement Results

Fig. 2 shows the measured transmission response of the 19-pole filter at 77 K. This filter exhibits very sharp skirts because of the large number of poles used. Three extra transmission zeroes were located on the upper band-edge of the filter passband, which made the upper band-edge rejection extremely sharp. These transmission zeroes were accomplished by cross-coupling of non-adjacent resonator lines. The 45-dB out-of-band rejection point is 0.8 MHz from the upper band-edge. Within the passband, the minimum dissipation loss of the 19-pole filter is 0.5 dB, indicating an average unloaded resonator Q value of about 10 000 across the entire 75-mm-diameter wafer. The ultimate rejection of about 60 dB at the rejection band is primarily the feedthrough level of the filter package.

The transmission response of the filter is somewhat rounded at the upper band-edge. This higher loss is partly because of the extra-sharp skirt at the upper band-edge, due to the extra transmission zeroes imposed by the cross-coupling of the nonadjacent resonator lines.

Fig. 3 shows the measured return loss of the 19-pole filter at 77 K, illustrating that a minimum return loss of 15 dB has been achieved. In this figure, 14 resonator poles can be clearly seen from the return loss response, which indicates an excellent impedance match in the filter.

V. Conclusion

In summary, we have demonstrated a 19-pole bandpass filter with 25 MHz bandwidth at 900 MHz on a single 75-mm-diameter superconducting wafer with double-side-coated YBCO thin films. The measured responses of the filter showed a 0.5-dB dissipation loss, and a minimum return loss of 15 dB in the filter passband. The excellent performance of the 19-pole filter demonstrates the first 19-pole planar cellular filter achieved on a single superconducting wafer, as well as representing the device quality of the large area YBCO films grown by the single-source MOCVD.

Acknowledgment

The authors would like to thank T. Luong and Q. Thai for filter testing, R. C. Yu for computer data acquisition, and A. Dela Cruz, L. Lui-Wong, and A. Barfknecht for filter processing.

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