

## A High Performance HTS Filter Subsystem for CDMA

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We designed and fabricated a 16-pole high temperature superconducting (HTS) filter with a 1.2% fractional bandwidth at 830 MHz for CDMA mobile communications. In this paper we describe the design, the test procedure and the obtained results. The filter was fabricated on a 46 mm × 29 mm × 0.43 mm sapphire substrate which was double side coated with YBCO thin films. At a temperature of 70 K, the in-band insertion loss of the filter is less than 0.29 dB, its out-of-band rejection is better than 70 dB and the steepness of the band edges is larger than 40dB/MHz. We also fabricated and tested a HTS subsystem, which consists of the 16-pole HTS filter, a low noise amplifier (LNA) and a Stirling Cooler. Cooled down to 70 K, the HTS subsystem shows a good performance of 0.75 dB noise figure and 1.5 voltage standing wave ratio (VSWR) with 21.5 dB gain.

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### I. INTRODUCTION

The CDMA network is an interference-limited system in which the overall system performance relies on balancing the forward and reverse links. For balanced networks, improvements in the reverse-link sensitivity should be met with similar improvements in the forward direction and improve the capacity and service quality of the network [1]. The high temperature superconducting (HTS) filters have a very low insertion loss, a high selectivity and a large out-of-band attenuation [2–6]. Combined with a cooled, low noise amplifier (LNA), HTS filters could significantly improve sensitivity and selectivity of base stations, which can benefit CDMA networks with increased capacity, coverage efficiency and data rates, and thus match the challenge of the rapid growth in mobile communications market. In this paper, we describe the design and the test of a 16-pole HTS receiver filter for CMDA network. Combining it with a LNA, we assembled a receiver subsystem which showed a good performance.

### II. HTS FILTER DESIGN

Aiming at the front-end subsystem in a CDMA base-station, we designed a 16-pole HTS band-pass filter on the sapphire substrate with 0.43 mm thickness and a comparatively low relative dielectric constant  $\epsilon_r = 9.95$ . The central frequency and fractional bandwidth

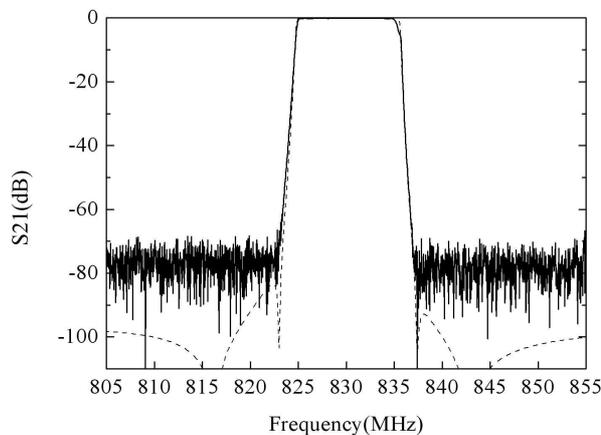


FIG. 1: Responses of the measured and simulated result of the 16-pole HTS filter. (The solid and dashed lines represent the measured and simulated responses, respectively.)

of the HTS filter are 830 MHz and 1.2% respectively.

The CDMA HTS filter consists of a parallel array of half-wavelength resonators. The parameters of this filter include the configuration of the coupled resonators, the spacing between the adjacent resonators and the width and position of the input and output lines. We used computer-aided software Sonnet to simulate the resonance frequency of a single resonator, coupling coefficients between resonators and external quality factor. The details of the parameters determination are shown in [3].

The resonator configuration should be determined first. For the relative dielectric constant is very low, the corresponding half-wavelength of the resonator is actually about 70 mm on the substrate. In order to develop a compact HTS filter, we utilized a resonator configuration of a doubly-folded microstrip line. Simulated by Sonnet, the parameters of the resonator, including lengths, widths and inner spacings were determined. The final resonator we chose is only 1.5 mm width and 21 mm length, which is less than one third of the half-wavelength.

The attractive features of this resonator configuration are not only its small and compact size, but also its advantage that the couplings between non-adjacent resonators are nearly negligible, as a result the all-pole layout of the 16-pole filter can be determined based on Chebyshev prototype considering the couplings between only the neighboring resonators [7]. The width and position of the input and output feed lines were determined according to 50- $\Omega$  characteristic impedance and the external quality factor. After the initial values of the filter parameters were determined, we had to adjust some parameters to get a satisfactory filter response. This adjustment was necessary because of the parasitic coupling between non-adjacent resonators. This coupling is quite weak but not zero. The optimized simulated filter response is shown in Fig. 1. As the figure shows, there are transmission zeros at band edges. These transmission zeros are the result of the galvanic coupling of the

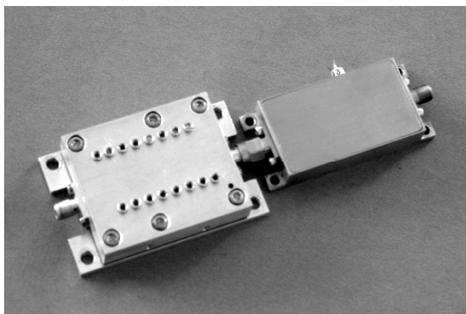


FIG. 2: The assembled HTS filter and LNA.

input and output feed lines to the first and last resonator.

The filter was fabricated using double-sided YBCO film deposited on a  $46 \text{ mm} \times 29 \text{ mm} \times 0.43 \text{ mm}$  sapphire substrate and packaged in a copper shield box (see Fig. 2). Its frequency response was measured by Agilent 8720/ES network analyzer as presented in Fig. 1, the solid line shows the characteristic of the filter measured at 70 K and the dashed line shows the simulated response of the filter. The measured result shows that the pass band is from 825 to 835 MHz, the insertion loss is less than 0.29 dB, the out-of-band rejection is better than 70 dB and the steepness of both band edges is larger than 40dB/MHz, showing excellent consistency with the simulated performance.

### III. HTS SUBSYSTEM PERFORMANCE

We assembled this filter and a LNA with 21.5 dB gain to form a HTS subsystem (see Fig. 2). The filter/LNA combination was mounted onto a cryogenic platform, which is connected to the cold head of a Leybold Stirling Cooler and enclosed in a dewar. It was operated at a temperature of 70 K. The filter/LNA combination benefits greatly from operating at cryogenic temperature in two ways. The HTS filter with its low insertion loss at the input of the LNA will directly improve the noise figure, and the operation of the active component at 70 K will apparently reduce the inherent noise [8].

The packaging process was carried out as reported in our preview work [9, 10], in order to keep good heat exchange between the HTS filter and the Stirling Cooler, and good thermal isolation between inside and outside of the dewar. Then we used Agilent 8720/ES to measure the frequency response of the subsystem. As shown in Fig. 3, the gain in the pass band is about 21.5 dB and with a good flatness in the pass band. The out-of-band rejection is better than 70 dB, and both sides of the band edge show a high selectivity. The voltage standing wave ratio (VSWR) is less than 1.5 from 825MHz to 835MHz as illustrated in Fig. 4.

At 70 K, the noise figure (NF) of the HTS subsystem was also measured using Agilent N8773A noise figure analyzer. As shown in Fig. 5, the noise figure (NF) of the HTS

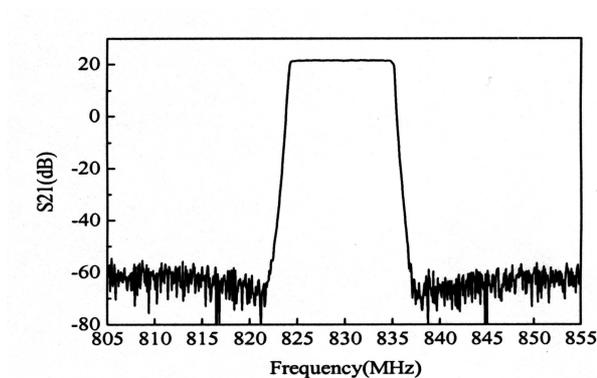


FIG. 3: Measured performance of the HTS subsystem.

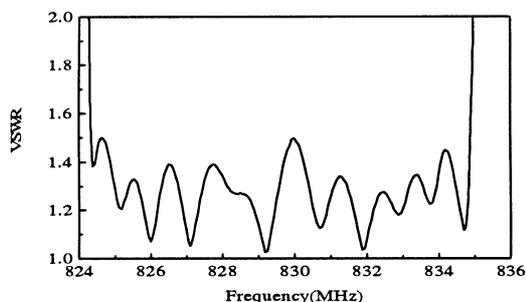


FIG. 4: Measured VSWR of the HTS subsystem.

subsystem is less than 0.75 dB. The result shows that the HTS subsystem has higher sensitivity.

#### IV. CONCLUSION

We developed a 16-pole HTS filter for CDMA mobile communications. The central frequency and the fractional bandwidth of the filter are 830 MHz and 1.2% respectively. The insertion loss in the pass band at 70 K is less than 0.29 dB. The assembled HTS subsystem comprising the HTS filter and the LNA shows a flat low noise figure of 0.75 dB in the pass band and high steepness of the band edges which is larger than 40 dB/MHz. All these results show that the CDMA HTS subsystem we developed has an excellent performance such as the high sensitivity and selectivity.

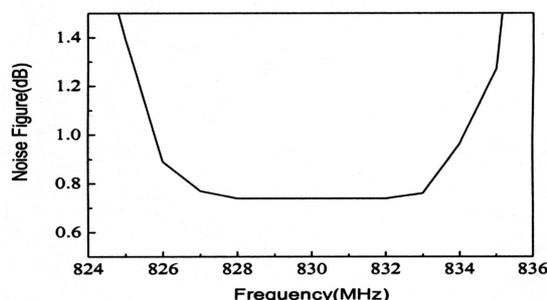


FIG. 5: Measured Noise Figure of the HTS subsystem.

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