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Design of high–order HTS dual–band bandpass filters with receiver subsystem for future mobile communication systems

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ABSTRACT

We have developed two high-order high-temperature superconducting (HTS) dual-band bandpass filters (BPFs) with a receiver subsystem for future mobile communication systems. They feature stub-loaded hair-pin resonators with two types of microstrip lines between them. One has a six-pole design, and the other has an eight-pole design. Both were designed to operate at 2.15 GHz with a 43-MHz (2%) bandwidth for the lower passband and at 3.50 GHz with a 70-MHz (2%) bandwidth for the upper one. They were fabricated using $YBa_2Cu_3O_y$ thin film on a CeO_2-bufferd r-Al_2O_3 substrate. The measured results for both filters agree well with the simulated ones. The HTS dual-band BPF receiver subsystem uses a pulse tube cryocooler and a wideband low noise amplifier (LNA). We measured the frequency response of the six-pole dual-band BPF with and without a wideband LNA with a gain of 10 dB. The measured return losses were close.

1. Introduction

A requirement for achieving high-speed and high-date rate transmission over a wide bandwidth in future mobile communication systems is to use carrier aggregation (CA), which was introduced by the third generation partnership project (3GPP) [1]. This technology aggregates two or more component carriers. There has thus been increasing interest in dual-band bandpass filters (BPFs) [2-8], as they are a promising way to meet this requirement. In particular, a high-pole dual-band BPF with a high-temperature superconductor (HTS) has steep cutoff characteristics and a low insertion loss, making it a promising technology for future mobile communications.

Heng et al. proposed a compact HTS four-pole dual-band BPF using stub-loaded resonator with a controllable coupling and feeding structure [9]. However, it is difficult to fine tune the design parameters, so applying this design to high-order filters is impractical. One approach to overcoming this problem is to use an HTS eight-pole dual-band BPF with a modified stub-loaded resonator [10]. The resonator enables easy tuning of both the frequency and bandwidths, and this approach can easily be extended to high-order filters. However, there have been a few reports on high-pole dual-band BPFs. Moreover, There have been no reports on an HTS dual-band BPF subsystem that uses a compact cryocooler and a low noise amplifier (LNA)

We previously developed novel HTS dual-band BPFs by using stub-loaded hair-pin resonators and a stub-loaded meander line resonator [11-13]. These filters enable independent control of the center frequency and the bandwidths of the lower and upper passbands. Furthermore, they can easily be extended to higher order filters.

In the study reported here, we demonstrated six- and eight-pole HTS dual-band BPFs made using stub-loaded hair-pin resonators, an H-shape micrstrip line (MSL), and additional MSLs. In particular, we developed a method for flexibly adjusting the coupling coefficient for the two passbands. Additionally, we demonstrated an HTS dual-band BPF receiver subsystem that uses a pulse tube cryocooler and a wideband LNA.

2. Design of high pole dual– band pass filters

Sonnet EM software was used to design the filters [14]. Both filters feature designed center frequencies of 2.15 and 3.50 GHz, respectively, for the lower and upper passbands. The designed bandwidths of both passbands of both filters were set to the same fractional bandwidth, 2%. An r-Al_2O_3 substrates with a dielectric constant of 9.9 were used to design the two filters. Both filters were designed with Chebyshev response. The design parameters of the two filters are summarized in Table 1. The coupling coefficients for the two passbands were the same due to the same fractional bandwidths of the two passbands.

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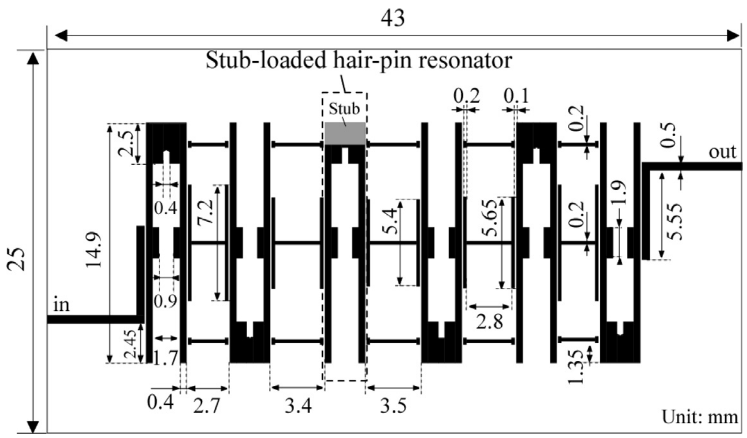
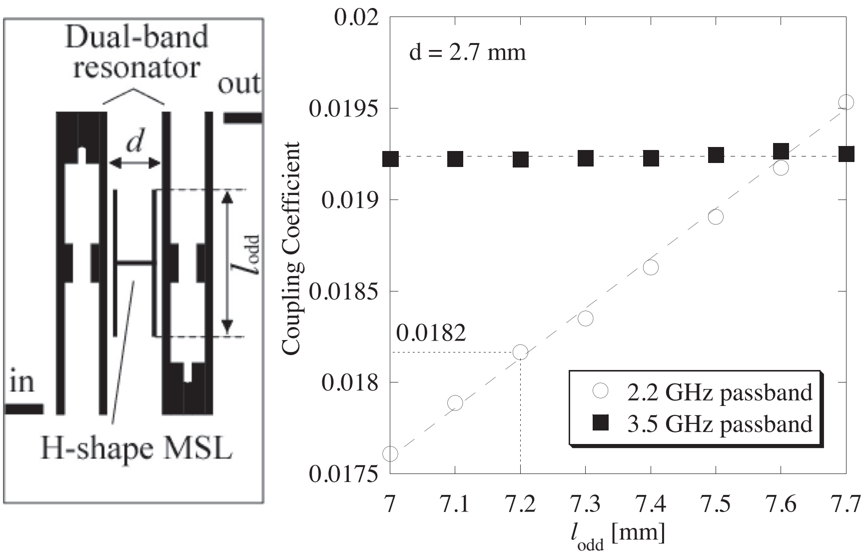


Fig. 1. Layout of six–pole HTS dual– band pass filter.



(a) (b)

Fig. 2. (a) Layout of coupling resonators and H-shape MSL. (b) Relationship between coupling coefficients of a pair of resonators with H-shape MSL and l_{odd}.

Table 1
Design parameters for six–pole and eight–pole dual–band BPFs.

	Center frequency [GHz] 1st/2nd	Band-width [%] 1st/2nd	Coupling coefficients
Six-pole dual-band BPF	2.15/3.5	2/2	$K_{12} = K_{56} = 0.0182$ $K_{23} = K_{45} = 0.0127$ $K_{34} = 0.0120$
Eight-pole dual-band BPF	2.15/3.5	2/2	$K_{12} = K_{78} = 0.0163$ $K_{23} = K_{67} = 0.0118$ $K_{34} = K_{56} = 0.0110$ $K_{45} = 0.0109$

2.1. Six-pole dual–band bandpass filter

Fig. 1 shows the layout of the six-pole HTS dual-band BPF, which uses a stub-loaded hair-pin resonator we previously developed [11,12]. The resonator has two resonance modes: odd (lower passband) and even (upper passband). Their resonant frequencies can be independently tuned [11]. The odd-mode resonant frequency has no impact on the stub, so the filter can generate another coupling pass to independently control the coupling coefficients of the two passbands. This control was achieved by introducing combline coupled stub–loaded hair-pin resonators and two additional MSLs.

The layout of the coupling resonators and H-shape MSL is illustrated in Fig. 2(a). We first adjusted the lower passband coupling coefficient. We control the coupling between the resonators by changing H-shape MSL length l_{odd}. Fig. 2(b) shows the relationship between the coupling coefficients of resonators with H-shape MSL between them and l_{odd}. To obtain the coupling coefficient K_{12} shown in Table 1 for the lower passband, $l_{odd} = 7.2$ mm was identified, as shown in Fig. 2(b). To achieve the same coupling coefficient for the lower and upper passband, we should reduce the upper passband coupling coefficient without changing the lower passband one. We added MSLs to reduce only that of the upper passband without changing the distance between the resonators. We previously reported that placing an H-shape MSL between combline coupled resonators reduces the total coupling