Physica C: Superconductivity and its applications 525–526 (2016) 48–51

Contents lists available at ScienceDirect

Physica C: Superconductivity and its applications

journal homepage: www.elsevier.com/locate/physc

A low loss superconducting filter with four states based on symmetrical interdigital-loaded structure

Tianqi Gao, Bin Wei*, Bisong Cao, Dan Wang, Xubo Guo

State Key Laboratory of Low-Dimensional Quantum Physics, Department of Physics, Tsinghua University, Beijing 100084, China

ARTICLE INFO

Article history:
Received 1 December 2015
Revised 25 February 2016
Accepted 18 March 2016
Available online 6 April 2016

Keywords:
Superconducting
Reconfigurable filter
Symmetrical structure
Low loss

ABSTRACT

This paper presents a new symmetrical interdigital-loaded microstrip structure. The symmetrical structure can be applied to design a filter that can work at different frequencies. The filter has similar in-band response at each working frequency with low insertion loss. Based on the proposed structures, a low-loss six-pole high temperature superconducting (HTS) filter with four different working states is designed and fabricated. The center frequency of the filter can be tuned discretely from 1.382 GHz to 1.193 GHz. All four states have similar in-band characters, whereas the insertion losses are less than 0.3 dB. The measured results are consistent with the simulations.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

High-temperature superconducting (HTS) microstrip filters with low insertion loss and sharp skirt rejection have been applied in mobile communication systems to enhance the receiving performance. Many types of filters, such as ultra-narrow passband filter [1], wide-stopband passband filter [2], multi-band filter [3,4] and so on, have been reported, realized with HTS thin films.

Among them, reconfigurable filters play an important part in wireless communication systems as well as reconfigurable systems. The reconfigurable filters have low losses with relatively compact structures. They are required to work at different frequencies at different time, and to cooperate with the whole reconfigurable system. Thus, it is of importance to keep the filter with similar in-band responses, or rather similar S_{11} and S_{21} curves, at all the working frequencies. Basically, it seems as if the S_{11} curve of the filter is just moved to the other working frequencies with slight change. However, the in-band responses of reconfigurable filters usually change worse and worse, when the working frequency is far away from the fundamental frequency. Reported reconfigurable filters always have low pole numbers, limited tuning range and unsatisfactory return losses [5–11]. So far, it is still difficult to design high-order low-loss reconfigurable filters with similar in-band responses of different states.

This paper presents a kind of symmetrical interdigital-loaded microstrip structure. This structure can be applied to design filters which can work at different frequencies with similar in-band characters. The structure consists of a symmetrical tuning part, which includes a series of interdigital capacitors, and a main part that determines the working frequency range of the filter. Based on the proposed structure, a six-pole HTS filter is designed and fabricated. The filter's layout is shown in Fig. 1. The filter has four different working frequencies, just like a reconfigurable one. The center frequencies can be tuned discretely from 1.382 GHz to 1.193 GHz, with the relative unchanged bandwidth of approximately 1.8%. Similar in-band response, including S_{11} and S_{21} curves are achieved in such a high-order filter with different states. Besides, the return loss in the entire tuning range is higher than 14 dB, whereas the insertion loss is less than 0.3 dB. The measured results agree well with the simulations.

2. Analysis and design of the Filter

2.1. Model of the symmetrically reconfigurable method

Filters are commonly designed based on the coupling matrix method, which includes the coupling matrix of coupling coefficients $M_{i,i+1}$ and external Q_e . The coupling matrix can accurately describe the filter's in-band and out-band responses, or S_{11} and S_{21} curves. $M_{i,i+1}$ and the external Q_e are all functions of the fractional bandwidth (FBW) of a filter according to the said method [12]. The center frequency f_0 varies in a range in a reconfigurable filter, whereas the absolute bandwidth always changes. Maintaining the S_{11} curve unchangeable indicates that $M_{i,i+1}$ and Q_e should also remain unchangeable during the state tuning. In other words

* Corresponding author. Tel.: +86 10 62772764; fax: +86 10 62792473.
E-mail address: weibin@mail.tsinghua.edu.cn (B. Wei).

http://dx.doi.org/10.1016/j.physc.2016.03.008
0921-4534/© 2016 Elsevier B.V. All rights reserved.

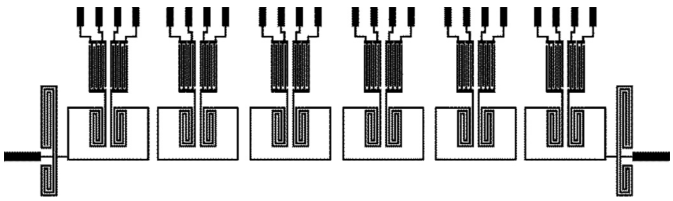

Fig. 1. Layout of the filter.

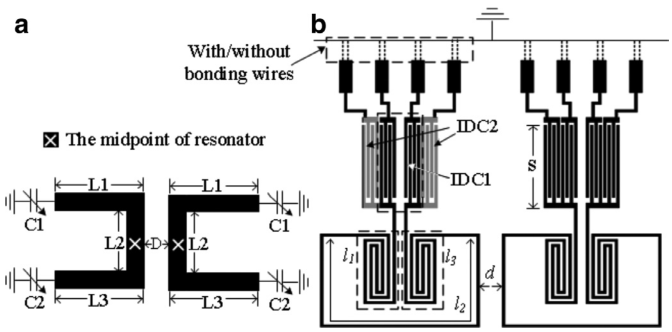

Fig. 2. (a) Simplified equivalent circuit model of the symmetrical tuning method. (b) Layout of the proposed symmetrical resonator.

$M_{i,i+1}$ and Q_e should be independent of f_0 as follows:

$$\frac{\partial Q_e}{\partial f_0} = 0 \tag{1}$$

$$\frac{\partial M_{i,j+1}}{\partial f_0} = 0 \tag{2}$$

Besides, the FBW of the filter is also a constant. In particular:

$$\frac{\partial \text{FBW}}{\partial f_0} = 0, \quad \text{or} \quad \frac{\partial \text{BW}}{\partial f_0} = \text{constant} \tag{3}$$

Thus, if a reconfigurable filter with similar in-band responses works at different frequencies, its FBW does not change.

Increasing quantity of resonators results in a more susceptible in-band response of the filter. The incalculable changes happened at the complex S_{11} and S_{21} curves make it difficult to design high-order low-loss reconfigurable filters. Thus, a fixed internal coupling and external Q_e must be achieved.

A symmetrical interdigital-loaded microstrip structure is proposed to achieve the fixed internal coupling. Technically, loading a variable capacitor between the ground and one end of the resonator is often applied to tune the center frequency. In the proposed symmetrical method, two equal variable capacitors are loaded at both ends of each resonator. The simplified equivalent circuit is shown in Fig. 2(a). C_2 is equal to C_1 and L_3 is equal to L_1 at any time in this case. The resonator's center frequency changes by adjusting C_1 and C_2 simultaneously. However, the current distribution near the resonator's midpoint does not move because the C_2 and C_1 are absolutely the same. Furthermore, the resonator is completely symmetrical by the midpoint because L_3 is equal to L_1. Since the current distribution in the middle part (L_2) only slightly changes upon tuning, magnetic coupling, instead of electrical coupling, should be applied between resonators. The coupling coefficient between adjoining resonators only slightly changes among different states in this symmetrical design, as shown in Fig. 4.

The working frequency range of the filter rests with $L_1 + L_2 + L_3$ in Fig. 2(a). L_2 and D determine the range of the coupling coefficient, which depends on the filter FBW. $C_1 + C_2$, which is equal to $2 \times C_1$, determine the width of the tuning range. These parameters can be adjusted independently, and thus, in theory, the model of the symmetrical resonator is suitable for different types of filters with different working frequency.

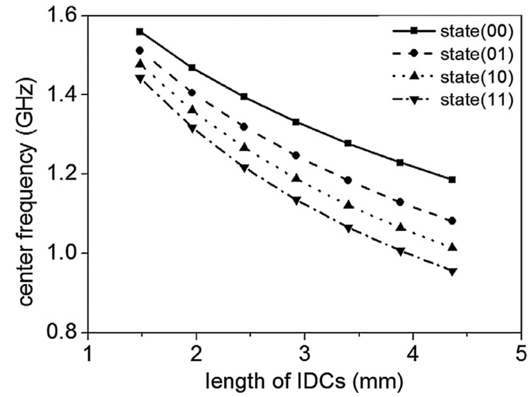

Fig. 3. Center frequencies of all states change with the length of IDCs.

2.2. Design of the symmetrical resonator

Ying [13] proposed a HTS reconfigurable resonator loaded with a HTS IDC array at the end of a microstrip to minimize the loss in the HTS reconfigurable filter. The resonator achieves a series of states with different center frequencies. Instead of the common variable capacitors, IDC arrays are applied to decrease the insertion loss.

A symmetrical interdigital-loaded resonator is proposed in this work, as shown in Fig. 2(b). The resonator consists of the main part, tuning part, and bonding part. The main part includes l_1, l_2, and l_3, which are almost equivalent to $L_1 + L_2 + L_3$ in Fig. 2(a) and determine the resonator's center frequency. For compactness, l_1 and l_3 are designed to be spiral-in-spiral-out microstrip lines. l_2 provides the magnetic coupling between adjoining resonators. The tuning part consists of parallel IDCs (i.e., IDC_1 and IDC_2) at both ends of the resonator. The equivalent capacitance $C_{IDC1+IDC2}$ is equivalent to C_1 or C_2 in Fig. 2(a), which is determined by the finger number and the IDC length. The bonding part is made up of a series of bonding blocks, which can be connected to the ground by bonding wires. By connecting none IDCs, or single IDC_1, or single IDC_2, or both IDCs, to the ground, separately, four different working states are realized, named as states (00), (01), (10), and (11), respectively. The state of filter when IDC_1 is connected to the ground is named (01). And the one when IDC_2 is connected to the ground is named (10). The state (11) is realized when both IDC_1 and IDC_2 are connected to the ground. By changing the distance between IDC1 and IDC2, the frequencies of all four states can be tuned with different degrees. Hence the (11) state can be slightly tuned as well.

The whole tuning range is adjustable by changing the length s of the IDC, as shown in Fig. 2(b). When s increases, the center frequency of each state decreases in a similar trend, and the range of the four states increases accordingly, as shown in Fig. 3. When s is changed from 1.5 mm to 4.4 mm, the tuning range increases from 7% to 19%.

A simulated result on the comparison of the coupling coefficient among different states is shown in Fig. 4. This figure demonstrates that the coupling coefficient between two adjoining resonators only slightly changes among different states. Thus, Eq. (2) is approximately satisfied.

2.3. Design of the filter

An L-band six-pole HTS filter is designed using the symmetrical interdigital-loaded resonator. Its layout is shown in Fig. 1. The

Download English Version:

https://daneshyari.com/en/article/1817332

Download Persian Version:

https://daneshyari.com/article/1817332

Daneshyari.com