Compact Quad-Channel High Temperature Superconducting Diplexer Based on Stub-Loaded Square Ring Resonators

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Abstract— A compact quad-channel high temperature superconducting (HTS) diplexer based on stub-loaded square ring resonator (S-LSRR) is proposed. Two stubs are symmetrically loaded to a square ring resonator, and four resonant modes are excited for dual-channel applications. A square patch is added to the resonator to control its resonant modes to a certain degree. Then the designed channel filters are combined to a common port via a interdigital finger. Base on the proposed resonator, a quad-channel diplexer with central frequencies of 2.4GHz, 3.2GHz, 3.9GHz and 5.6GHz is designed. The diplexer was fabricated on 2-in-diameter 0.5mm-thick MgO wafer with double sided YBCO films. The designed diplexer occupies a compact size of $0.25\lambda_g \times 0.45\lambda_g$, where λ_g is guided wave length at the center frequency of first passband.

Index Terms—high temperature superconducting diplexer, stub-loaded square ring resonators, interdigital finger, quad-channel diplexer, central frequencies.

➢ DESIGN OF QUAD-CHANNEL DIPLEXER

A. Stub-Loaded Square Ring Resonators

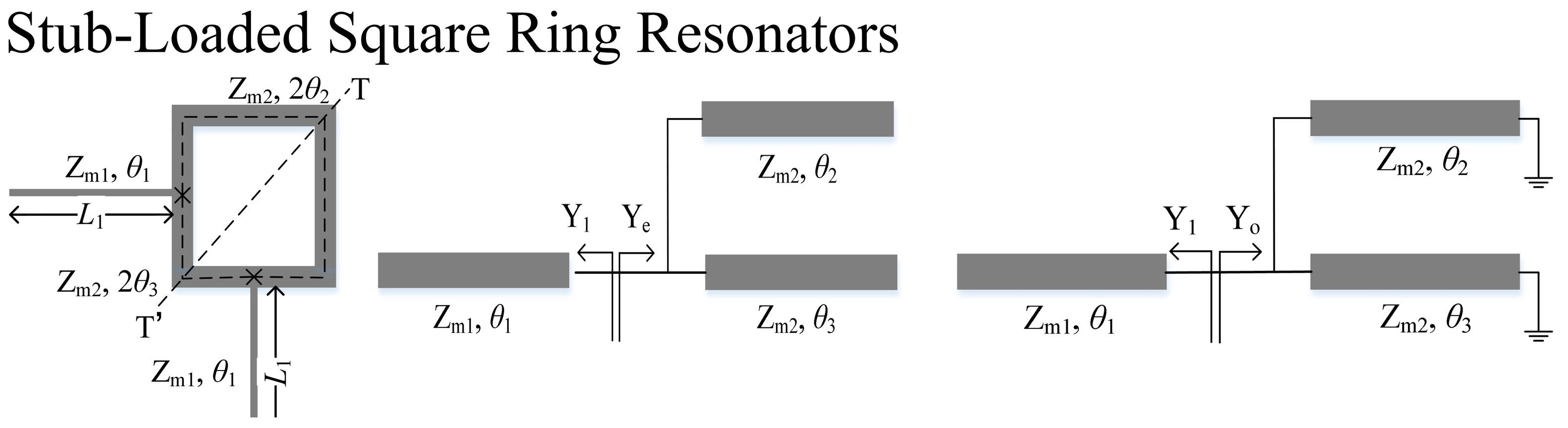

Fig. 1 (a) Schematic of stub-loaded square ring resonators. (b)Equivalent even-mode circuit of the resonator. (c)Equivalent odd-mode circuit of the resonator.

Fig. 1(a) shows the schematic of a stub-loaded square ring resonator. Even-odd mode analysis theory is applied to analyze the structure. When the resonator is excited by even modes and odd modes, their resonant condition can be expressed as

$$\mathrm{Im}(Y_1+Y_e)=0 \quad (1)$$

$$\mathrm{Im}(Y_1+Y_o)=0 \quad (2)$$

$$Y_1 = jY_{m1}\tan\theta_1 \quad (3)$$

$$Y_e = jY_{m2}\tan\theta_2 + jY_{m2}\tan\theta_3 \quad (4)$$

$$Y_o = -jY_{m2}\cot\theta_2 - jY_{m2}\cot\theta_3 \quad (5)$$

$$(\tan\theta_2+\tan\theta_3)/\tan\theta_1 = -R_z \quad (6)$$

$$R_z = Y_{m1}/Y_{m2} = Z_{m2}/Z_{m1} \quad (7)$$

$$(\cot\theta_2+\cot\theta_3)/\tan\theta_1 = R_z \quad (8)$$

A transmission coefficient of the resonator is shown in Fig. 2. There are four resonant peaks (f_1, f_2, f_3, f_4) and two transmission zeros (TZ_1, TZ_2) in frequency range that are taken into consideration. Fig. 3 illustrates the four resonant modes f_1, f_2, f_3, f_4, TZ_1 and TZ_2 frequency responses of stub-loaded square ring resonator with different lengths of loaded stub L_1 under all the other sizes fixed.

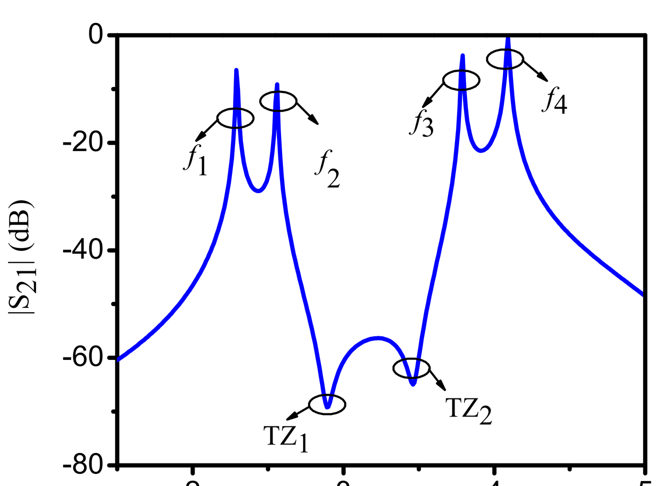

Fig. 2. Frequency response of S_{21} magnitude under weak coupling.

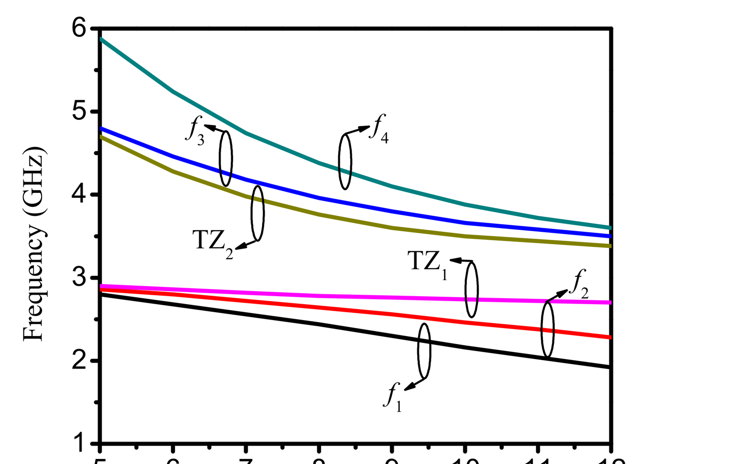

Fig. 3. Frequency of four modes versus the changed length L_1 of loaded stub.

B. Modified Stub-Loaded Square Ring Resonators

In order to control the frequency of the four modes as flexible, a square patch is added on the corner along with axis of symmetry (TT') in the resonator, as indicated in Fig. 4. The patch added in the modified stub-loaded square ring resonator can be utilized to control the modes f_2, f_3, while f_1, f_4 remain unchanged. Through this method, the four resonant modes f_1, f_2, f_3, f_4 of the resonator can be designed intuitively and well set in the diplexer.

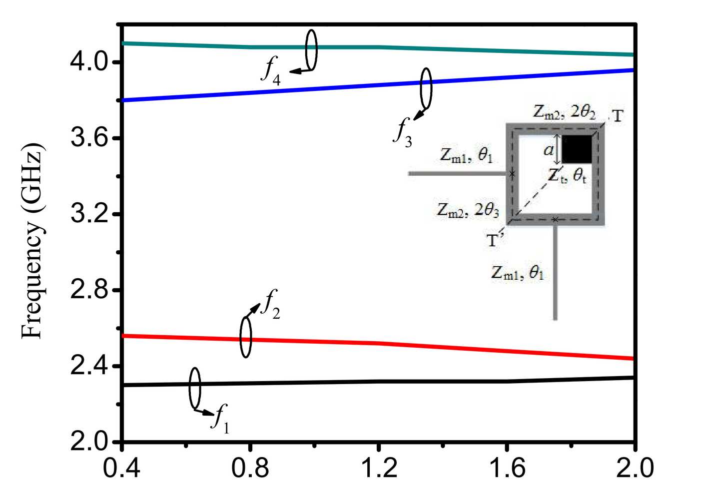

Fig. 4. Frequency of four modes versus the length a of square patch in modified stub-loaded square ring resonator.

C. Diplexer

Fig. 5 demonstrates the layout of proposed HTS diplexer. The diplexer consists of two quad-mode stub-loaded square ring resonator. Fig. 6 illustrates the topological structure diagram of the HTS diplexer in this paper. Black dots represent the four modes f_1, f_2, f_3, f_4 in stub-loaded square ring resonator. The dimension parameters in Fig. 5 are as follows: a=4.42, b=1.86, W_1=0.5, W_2=0.2, W_3=0.04, d_1=0.5, d_2=0.2, L_1=5.6, L_2=5.41, L_3=14.19, L_4=12.24, L_5=3.99, L_6=16.25, g=0.06, l_1=1.96, l_2=2.06, l_3=2.38, l_4=2.66, l_5=1.36, l_6=1.92, l_7=1.84, and l_8=2.56. (Unit: mm)

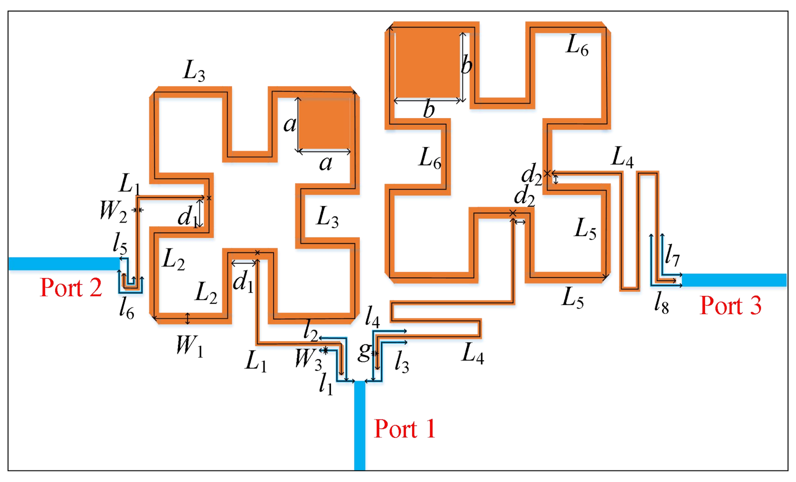

Fig. 5. Layout of the designed HTS diplexer.

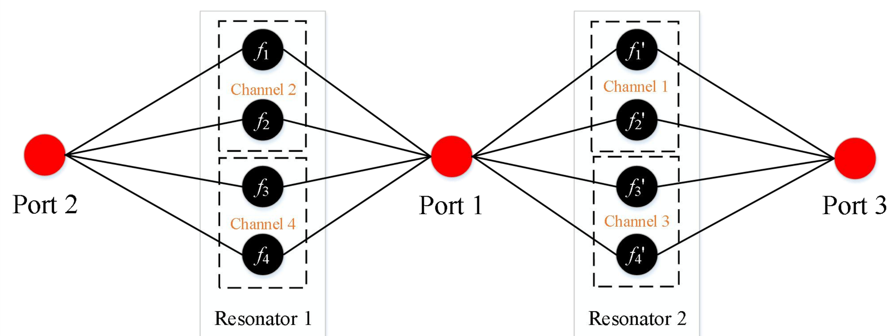

Fig. 6. Coupling diagram of the designed HTS diplexer.

➢ FABRICATION AND EXPERIMENTAL PERFORMANCE

Measurements of the HTS diplexer were carried out by using Agilent E5072A network analyzer at 75 K. Simulated and measured results of the HTS diplexer are compared in Fig. 7. A comparison of isolation between em simulation and measurement is shown in Fig. 8 and the photograph of the fabricated HTS diplexer is also illustrated in Fig. 9.

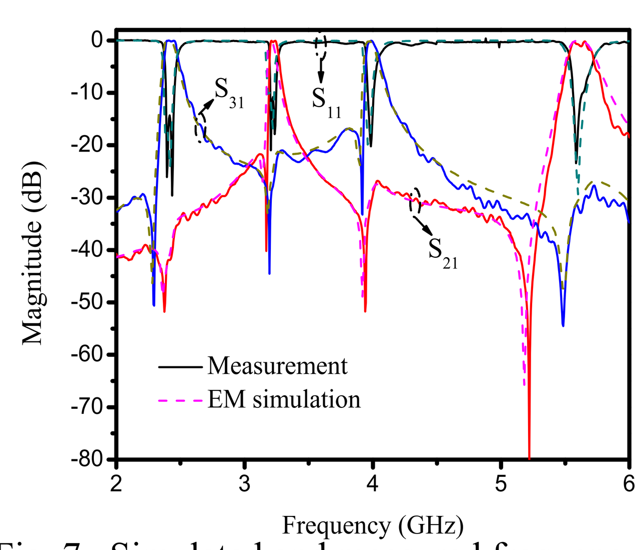

Fig. 7. Simulated and measured frequency response of the HTS diplexer.

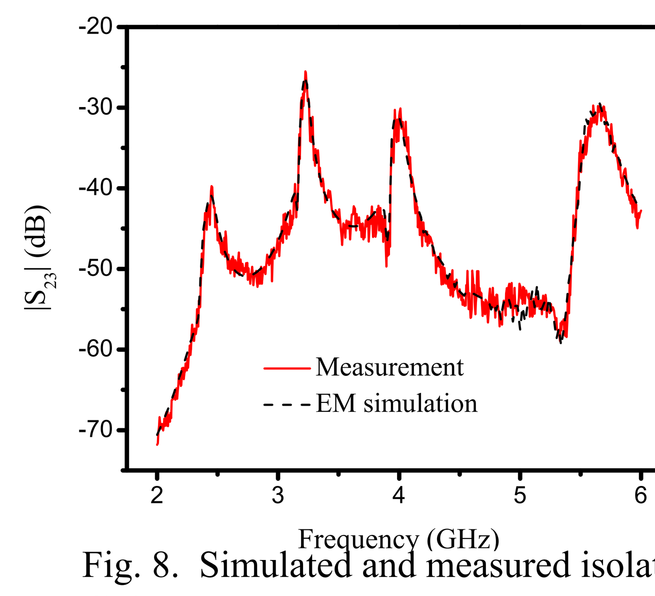

Fig. 8. Simulated and measured isolations of the HTS diplexer.

The four channels bandwidth are 2.36-2.47 GHz, 3.17-3.25 GHz, 3.93-4.03 GHz, 5.52-5.73 GHz, respectively. The insertion loss is 0.15 dB (@channel 1), 0.48 dB (@channel 2), 0.17dB (@channel 3), 0.12dB (@channel 4). Return loss of each four channels is greater than 18 dB, and isolation between Port 2 and Port 3 is greater than 26 dB.

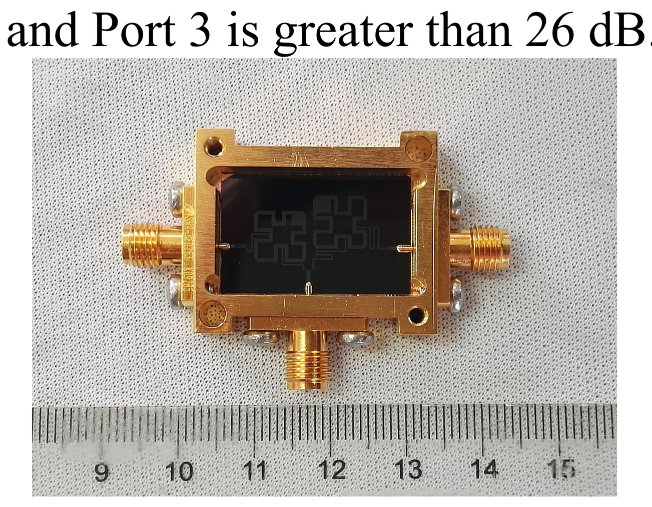

Fig. 9. Configuration of the manufactured quad-channel diplexer.

Ref. No	Channels	FiltersNumber	Isolation (dB)	IL (dB)	ProcessTechnology	Circuit Size ($\lambda_g \times \lambda_g$)
[6]	2	3	>26	1.83/1.52	PCB	0.82×0.86
[7]	2	6	>22	0.3/0.3	HTS	0.14×0.13
[9]	4	4	>30	0.8/1/0.7/1.5	PCB	0.19×0.4
[10]	4	4	>30	2.49/2.5/2.9/2.4	PCB	0.19×0.48
[11]	4	4	>30	2.62/2.9/2.6/2.7	PCB	—
[13]	4	24	>55	0.4/0.33/0.35/0.45	HTS	0.71×1.56
This work	4	2	>26	0.15/0.48/0.17/0.12	HTS	0.25×0.45

TABLE I Comparison of Proposed Diplexer With Other Referenced

Table I compares the proposed diplexer with those reported ones.

Conclusion

In this paper, a compact HTS diplexer with quad-channel locates at 2.4 GHz, 3.2 GHz, 3.9 GHz and 5.6GHz, based on S-LSRR is proposed. The resonant principle is well studied. Then the designed channel filters are combined to the common port via a interdigital finger. The size of the entire diplexer is 18 mm×25mm, which amounts to $0.25\lambda_g \times 0.45\lambda_g$. The fabricated diplexer express well performance and match well with the simulations.