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A Simulation Study of the Microwave Diplexer on the Superconductivity Thin Film

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Abstract

We use the general coupled matrix method to design the planar microwave diplexer on the superconductivity $YBa_2Cu_3O_7$ (YBCO) thin film with the MgO substrate, which has an attenuation pole near cutoff frequency with each one filter. Both two high performance bandpass filters can be synthesized by using multiple λ/2-resonators and can be combined the two filters to form a diplexer. The attenuation poles will improve the selectivity of the diplexer and can be obtained by modifying the traditional Chebyshev frequency response. A practical design technique using coupling matrix synthesis algorithm with Chebyshev filtering function, including theoretical and simulated results will be demonstrated.。

Key words: Microwave filter, Diplexer, YBCO

在超導薄膜上設計微波雙工器的數值計算研究

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摘要

本文中使用柴比雪夫多項式，配合耦合矩陣法成功的設計平面式雙工器，並選擇以氧化鎂為基版的釔鋇銅氧高溫超導薄膜為設計材料。將兩組由四個二分之一波長共振器組成，具有多個零點高效能帶通濾波器，相結合設計而成雙工器。利用柴比雪夫多項式具傳輸零點的特性，可以提高雙工器對頻率的選擇能力。另外利用釔鋇銅氧高溫超導薄膜零電阻的優點，在低溫下操作更可以降低微波的損耗，提高雙工器效能。詳細的設計原理與計算的結果，將於文中討論。

關鍵字:微波濾波器，雙工器，釔鋇銅氧

1. Introduction

The discovery of high T_c superconductor (HTSC) gave rise to a new branch of microwave electronics device at liquid nitrogen temperature. Microwave derives utilize both the superconducting properties (low surface resistance) of the HTSC material and dielectric properties (high dielectric constant) of the

MgO substrate. These properties can reduce device's size and decrease the microwave losses. The devices are studied at low microwave powers where the nonlinear effects in the HTSC materials can be ignored.

In communication systems, they demand for filters with high-performance narrow-band bandpass filters having low insertion loss and high selectivity together with linear phase or flat group delay in the passband. Modified Chebyshev-type filters with transmission zeros can be realized by using cross-coupling between resonators [1-3], and the design technique based on coupling matrix becomes useful in determining the coupling coefficients. The Chebyshev filtering function response would satisfy the requirement for the sharp cut-offs at the edge of pass band, together with in-band equiripple-amplitude. In this paper, we present the results of a simulating study of the microwave diplexer on 0.1mm×1cm×1cm YBCO High-T_c superconductor thin film with 0.2mm MgO substrate.

2. Design procedures

In this article, the design method for the half-wavelength microstrip transmission line filter, which is based on the modified Chebyshev polynomial filtering function and coupling matrix methods. The transfer function of the filter is defined by[4]:

$$\left|S_{21}(\omega)\right|^2 = \frac{1}{1+\varepsilon^2 C_N{}^2(\omega)} \qquad (1)$$

Where φ is the normalized frequency variable; is a normalizing constant related to the equiripple level and the in-band return loss; C_N is known as the filtering function of degree N with Chebyshev form:

$$C_N(\omega) = \cosh\left[\sum_{n=1}^{N} \cosh^{-1}(x_n)\right] \qquad (2)$$

$$where\ x_n = \frac{\omega - 1/\omega_n}{1-\omega/\omega_n}$$

And ω_n is the position of transmission zero. If the transmission zeros approach infinity, the frequency response will degenerate to the pure traditional Chebyshev filter response. Figure 1. is showed the modified fourth degree Chebyshev-type frequency response with two transmission zeros.

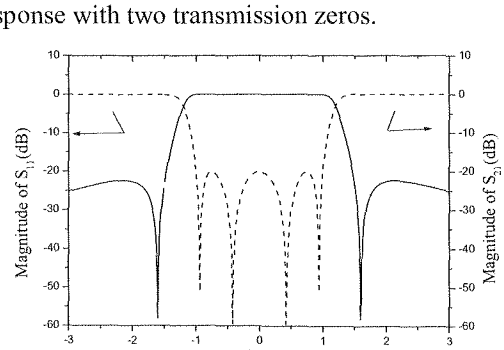

Fig. 1. Four degrees modified Chebyshev-type frequency response with two transmission zeros

The filter structure can be obtained by analyzing the coupling matrix with the frequency response. The element M_{ij} in the coupling matrix represents the coupling coefficient, between the resonator j, and i whereas the input/output coupling effect is discussed by the unload quality factor Q of the first /last resonator. In the network analyzing and synthesis, the most important step is to get the mathematical polynomial from the real world N-pole filter. And it is derived equations from the two-port circuit to N resonators network, as following.

$$\begin{bmatrix} i_1 \\ i_N \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} e_1 \\ e_N \end{bmatrix} \qquad (3)$$

$$\left[jM + j\omega I + R\right] \begin{bmatrix} i_1 \\ i_2 \\ \cdot \\ \cdot \\ i_N \end{bmatrix} = e_1 \begin{bmatrix} 1 \\ 0 \\ \cdot \\ \cdot \\ 0 \end{bmatrix} \text{ or } e_N \begin{bmatrix} 0 \\ 0 \\ \cdot \\ \cdot \\ 1 \end{bmatrix} \qquad (4)$$

Where $y_{12}(=y_{21})$ and $y_{11}(=y_{22})$ are the admittance parameters in the admittance matrix and can be evaluated from scattering matrix (S_{11}, S_{21})[5-9], R is the load impedance matrix, I is the identity matrix and M is the $N\times N$ reciprocal coupling matrix. By comparing eq. (3) and eq. (4), the coupling matrix M which is related to the eigenvalues and eigenvectors of M, that can be determined from the matrix analysis procedure.

3. Results and discussion

The specifications of the filter design which is allowed the IEEE 802.11a standing in this paper are showed that example as follow: Center frequency is 5.1 GHz; frequency bandwidth with return loss 20 dB of passband is 80 MHz. According to the synthesis method mentioned in section 2, the coupling matrix obtained is:

$$M=\begin{pmatrix} 0 & 0.582243 & 0 & 0.094938 \\ 0.582243 & 0 & -0.612024 & 0 \\ 0 & -0.612024 & 0 & 0.582243 \\ 0.094938 & 0 & 0.582243 & 0 \end{pmatrix} \qquad (5)$$

The coupling matrix is used to design and showed the layout in Fig. 2(a), which is designed of four coupled microstripline resonators on 1cm×0.5cm MgO substrate with a relative dielectric constant 10 and thickness 0.2 mm. The filter configuration can represent in a simple diagram shown in Fig. 2(b), which indicates that the magnetic couplings are used in the main line coupling whereas the electric coupling is used in the cross coupling.

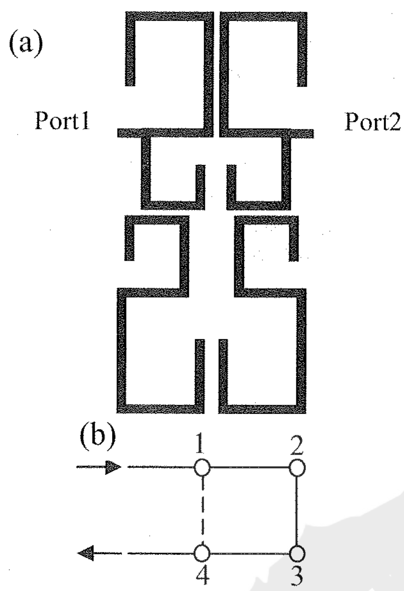

Fig. 2. (a) Layout and (b) model of the single filter designed by coupling matrix.

The filter dimensions are determined based on eq. (5), and the full-wave EM simulation result is shown in Fig. 3. In this case of four-order degree modified Chebyshev function with two of attenuation poles, the evidence shows that a cross-coupling is necessary for the filter with the attenuation poles.

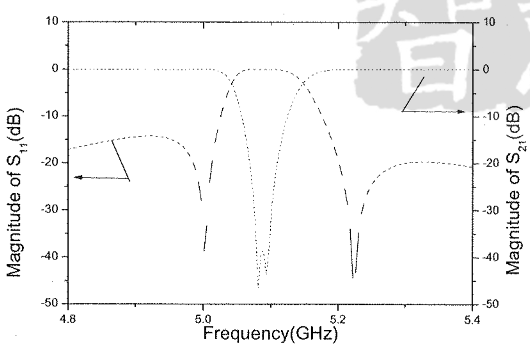

Fig. 3. It was shown the Simulation frequency response of filter with four resonators.

It seems very well from the simulated frequency response and that the design technique is quite useful. The diplexer layout can represent in a simple diagram shown in Fig. 4(a) and the simulation frequency response in diplexer is shown in Fig. 4(b).

In this case, the each filter's design is similar but its center frequency is different. The receive band is 5.059 to 5.137 (GHz) and transmitted band is 5.246 to 5.316 (GHz) at 15dB level.

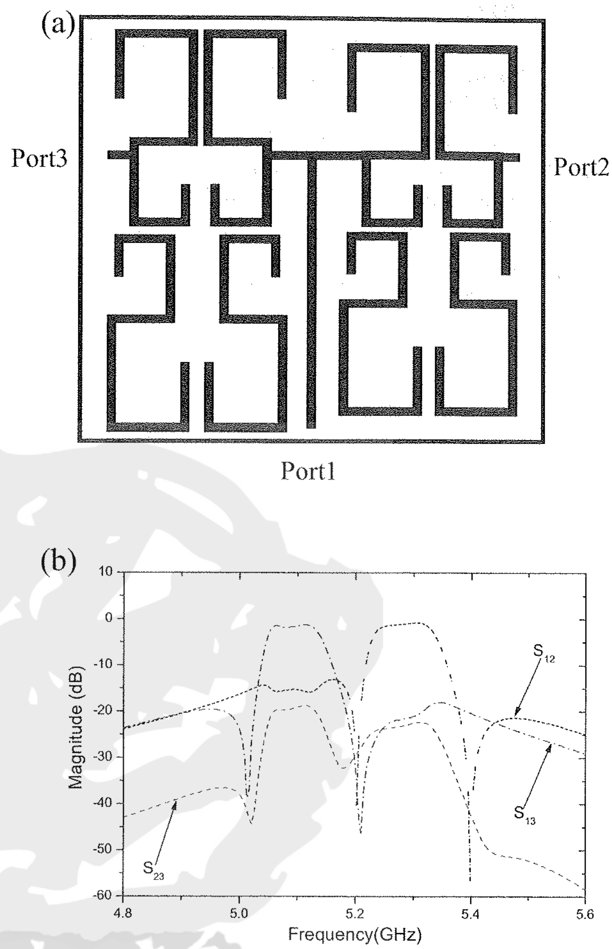

Fig. 4. There are showed (a) the layout and (b) simulation result of frequency response in the diplexer.

4. Conclusion

We successfully synthesize the microstrip type cross-coupled band-pass filters by the Chebyshev filtering functions with 80MHz passband and two attenuation poles. It's easy to use the conception to design the diplexer. This design technique is not only restricted to the application of microstrip line filters or HTSC material. It also can be applied to design using other kinds of transmission line with different number of transmission zeros or the pole of filter. We successfully design the filter and diplexer for YBCO thin film on 1cm×1cm MgO substrate.

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參考文獻

[1] E. Atia and A. E. Williams, *IEEE Transactions on Microwave Theory and Techniques,* **20**, 258 (1972).

[2] J. S. Hong, *IEEE Proc.-Microw. Antennas Propag.*, **147**, 354 (2000).

[3] J. S. Wong, *IEEE Transactions on Microwave Theory and Techniques*, **27,** 44 (1979).

[4] R. J. Cameron, *IEEE Transactions on Microwave Theory and Techniques*, **47**, 433 (1999).

[5] J. S. Hong and M. J. Lancaster, *IEEE Transactions on Microwave Theory and Techniques*, **44**, 2099 (1996).

[6] J.S. Hong and M.J. Lancaster, *Microstrip Filter for RF/Microwave Applications*, John Wiley, New York, (2001).

[7] Hun Nam, H. Lee , Y. Lim, *Proc. IEEE Reg. 10 Int'l. Conf. Electr. Electron Tech.,* , pp. 395-398, (2001).

[8] K.C. Huang, D. Hyland, A. Jenkins, D. Edwards , D.D. Hughes: *IEEE Tran. Applied Superconductivity* **9**, No. 2, (1999).

[9] R.E. Collin, *Foundations for Microwave Engineer,* McGraw-Hill, New York, (1992).