

THE DESIGN TECHNIQUE FOR COAXIAL RESONATOR CAVITY DUPLEXER

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Abstract—A general design technique for the coaxial resonator cavity duplexer is proposed in this paper, based on the design method of the general Chebyshev band-pass filter. We can obtain the coupling matrixes of cross-coupled resonator duplexer by optimization technique, and complete the design of duplexer fast. The proposed duplexer is designed and fabricated with the 1.92–1.98 GHz downlink and 2.11–2.17 GHz uplink frequencies. Across the bandwidth, the measured insertion losses at the both bands are less than 1 dB, while the input and output return losses are well below 20 dB. More than 50 dB isolation performance is obtained from the duplexer. The measured results approximately meet all the conditions of the design targets.

1. INTRODUCTION

As the frequency spectrum becomes more crowded, communication systems require transmit and receive using one antenna in many frequency spectrum ranges. Duplexer becomes critical component in the functioning of a wireless transceiver, because it allows simultaneous transmission and reception of signals from a single antenna.

With a single antenna, duplexer is normally used in RF transceiver to isolate a transmitter and a receiver electrically. To achieve high-dynamic range transceiver, a high-isolation and low insertion loss duplexer design is needed [1–5]. Duplexer can be realized in various media, for example microstrip or waveguide [2–7]. Though planar microstrip is preferable due to its easy integratability and compatibility with standard manufacturing process, but low unloaded-Q in a planar microstrip resonator causes high insertion loss and poor isolation performance. Numerous techniques have been introduced

to improve the isolation performance but most of the techniques are yet improbable to apply in practice. For example, the stepped-impedance coupled-line resonator based hairpin filter [8] and the double-loop resonator [9] though considerably increase the isolation performance but the complexity in their design and implement issues are of mainly practical concerns. Therefore, this paper describes the coaxial resonator cavity duplexer based on the design method of the general Chebyshev band-pass filter, high unloaded-Q in a coaxial resonator cavity causes low insertion loss. In Section 2, the utilization of the design of the general Chebyshev band-pass filter enables the two finite transmission zeros of such resonators close to and on the opposite side in the other pass-band respectively, resulting in high isolation between both channels. To validate the performance, the proposed scheme is designed for the UMTS communication systems at the center frequencies of 1.95 GHz for downlink and 2.14 GHz for uplink channels, while each operates at 60 MHz bandwidth. The design results are presented in Section 3 and finally are concluded in Section 4.

2. COAXIAL RESONATOR CAVITY BAND-PASS FILTER

Coaxial resonator cavity filters achieve magnetic coupling or capacitive coupling by opening iris or placing probe between two cavities. The values of the magnetic or capacitive coupling are controlled by the dimensions of the iris or probe. The position and number of transmission zeros is determined by cross coupling between coaxial resonators. Considering the unloaded-Q factor of the coaxial resonators and the power capability, the volume of coaxial resonator are achieved by changing the size of its inner and outer conductors. In a word, the coaxial resonator cavity filter with the characteristic of equal-ripple general Chebyshev function has many advantages, such as smaller volume, narrower band-pass, better slope and higher power capability. So it has become study focus because of its expanded perspective.

The design specifications are as follows

RX channel

Center frequency	1.95 GHz
Bandwidth	60 MHz
Return loss	20 dB
Transmission zeroes	2.05 GHz and 2.14 GHz

TX channel

Center frequency	2.14 GHz
Bandwidth	60 MHz
Return loss	20 dB
Transmission zeroes	2.085 and 1.95 GHz
Isolation between RX and TX	50 dB.

2.1. General Chebyshev Filtering Function

Compared to the familiar pure Chebyshev function, the advantages of general Chebyshev function as follows.

- (1) The positions of all N of the prescribed transmission zeros are arbitrary. Those zeros locate ω axis become the finite transmission zeros of the corresponding function, others will affect the characteristic of group delay.
- (2) The general Chebyshev function keeps the characteristic of equal-ripple.
- (3) Because the transmission zeros are arbitrary, the general Chebyshev filtering function has asymmetric or symmetric characteristics.

From [13], we can obtain the following expressions.

$$S_{11}(\omega) = \frac{F_N(\omega)}{E_N(\omega)} \quad S_{21}(\omega) = \frac{P_N(\omega)}{\varepsilon E_N(\omega)} \quad (1)$$

$$S_{21}^2(\omega) = \frac{1}{1 + \varepsilon^2 C_N^2(\omega)} \quad (2)$$

$$C_N(\omega) = \frac{1}{2} \left[\frac{\prod_{n=1}^N (c_n + d_n) + \prod_{n=1}^N (c_n - d_n)}{\prod_{n=1}^N \left(1 - \frac{\omega}{\omega_n}\right)} \right] \quad (3)$$

$$\begin{aligned} \varepsilon &= \frac{1}{\sqrt{10^{RL/10} - 1}} \cdot \left. \frac{P_N(\omega)}{F_N(\omega)} \right|_{\omega=1} & c_n &= \omega - \frac{1}{\omega_n} \\ d_n &= \omega' \left(1 - \frac{1}{\omega_n^2}\right)^{1/2} & \omega' &= (\omega^2 - 1)^{1/2} \end{aligned} \quad (4)$$

The reductions of the expressions are presented in [13]. $C_N(\omega)$ is known as the filtering function of degree N and has the general Chebyshev characteristic [12].

2.2. Coupling-Matrix

Generally speaking, filters with finite transmission zeroes are designed by cross-coupling resonators. As illustrated in Fig. 1, coupling matrix will be obtained by synthesizing the elements values. Because there is a very close relationship between topology of the structure and coupling matrix, it is very important to make sure the topology of the structure. The network topology with finite transmission zeroes can be realized fast by using three resonators cross-coupled network [10, 11].

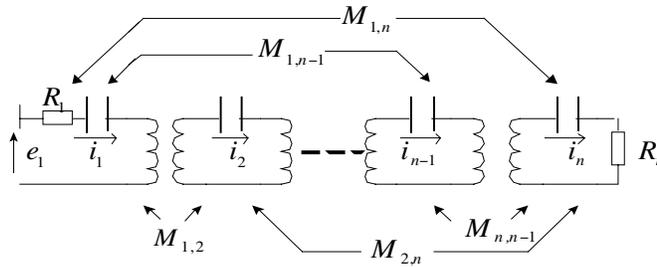


Figure 1. N resonators cross-coupled network.

Then using CT form as illustrated in Fig. 2.

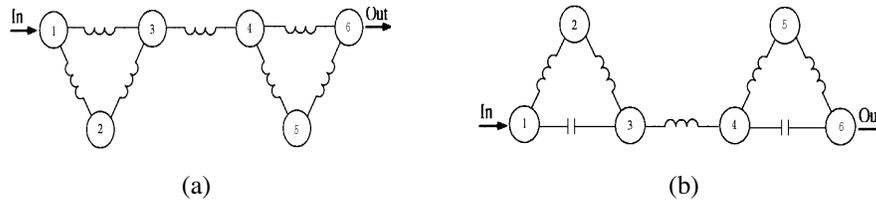


Figure 2. Network topology of filters with finite transmission zeroes. (a) Center frequency is 1.95 GHz. (b) Center frequency is 2.14 GHz.

The synthesis process of the corresponding coupling-matrices of Fig. 2 will be shown in the following. Consider the design specifications of filters, normalized coupling-matrices M_{01} and M_{02} are obtained according to the method introduced in [12–14].

$$R_1 = R_2 = 1.0041$$

$$M_{01} = \begin{bmatrix} 0.0099 & -0.2527 & -0.5372 & -0.5684 & -0.1794 & 0.0000 \\ -0.2527 & 0.8914 & 0.2722 & -0.0075 & 0.0045 & -0.2638 \\ -0.5372 & 0.2722 & -0.4392 & 0.0000 & 0.0000 & -0.5372 \\ -0.5684 & -0.0075 & 0.0000 & 0.2350 & -0.2207 & 0.5684 \\ -0.1794 & 0.0045 & 0.0000 & -0.2207 & -0.9483 & 0.1794 \\ 0.0000 & -0.2638 & -0.5372 & 0.5684 & 0.1794 & 0.0099 \end{bmatrix}$$

$$R_1 = R_2 = 1.0032$$

$$M_{02} = \begin{bmatrix} -0.0153 & -0.2764 & -0.5260 & -0.5743 & -0.1577 & 0.0000 \\ -0.2764 & -0.8906 & -0.2935 & -0.0038 & 0.0038 & 0.2823 \\ -0.5260 & -0.2935 & 0.4969 & 0.0000 & 0.0000 & 0.5260 \\ -0.5743 & -0.0038 & 0.0000 & -0.1830 & 0.2011 & -0.5743 \\ -0.1577 & 0.0038 & 0.0000 & 0.2011 & 0.9638 & -0.1577 \\ 0.0000 & 0.2823 & 0.5260 & -0.5743 & -0.1577 & -0.0153 \end{bmatrix}$$

R_1 is the internal resistance of the voltage source, R_2 is the load resistor at the output.

Then, the Matlab programs are compiled to optimize coupling-matrixes according to the optimization technique introduced in [15]. M_{01} and M_{02} are initial coupling-matrixes, but we set no coupling entries to zero. And the inverse normalized coupling-matrixes optimized are M_1 and M_2 . (The inverse normalization is to multiply FBW to coupling-matrixes optimized.)

$$M_1 = \begin{bmatrix} 0.0003 & 0.0255 & 0.0050 & 0 & 0 & 0 \\ 0.0255 & -0.0068 & 0.0183 & 0 & 0 & 0 \\ 0.0050 & 0.0183 & 0.0013 & 0.0180 & 0 & 0 \\ 0 & 0 & 0.0180 & 0.0010 & 0.0187 & 0.0026 \\ 0 & 0 & 0 & 0.0187 & -0.0034 & 0.0258 \\ 0 & 0 & 0 & 0.0026 & 0.0258 & 0.0003 \end{bmatrix}$$

$$M_2 = \begin{bmatrix} -0.0004 & 0.0220 & -0.0085 & 0 & 0 & 0 \\ 0.0220 & 0.0116 & 0.0155 & 0 & 0 & 0 \\ -0.0085 & 0.0155 & -0.0019 & 0.0163 & 0 & 0 \\ 0 & 0 & 0.0163 & -0.0012 & 0.0170 & -0.0022 \\ 0 & 0 & 0 & 0.0170 & 0.0026 & 0.0235 \\ 0 & 0 & 0 & -0.0022 & 0.0235 & -0.0004 \end{bmatrix}$$

The FBWs of two filters are 0.0280 and 0.0308.

The insertion and return loss of the synthesized filters are shown in Fig. 3.

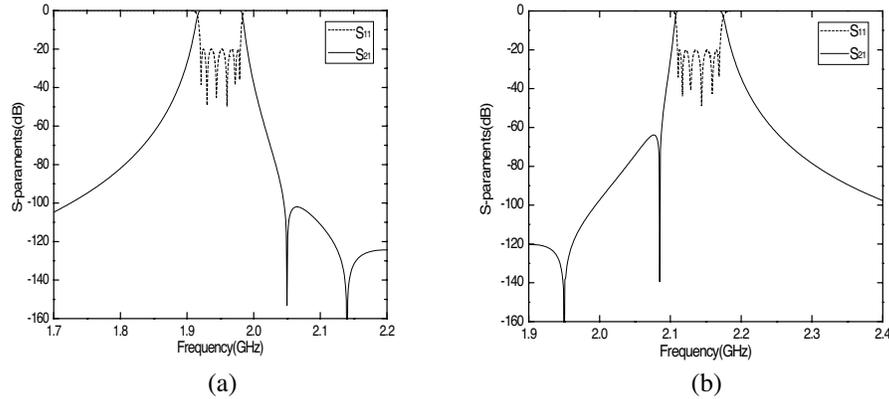


Figure 3. Inverse normalized frequency insertion and return loss of filters. (a) Center frequency is 1.95 GHz (b) Center frequency is 2.14 GHz.

2.3. Model Simulation

Generally speaking, there are two methods to design duplexer. One is to design the band-pass filters first, connect the T-Junction next and optimize filters; the other is to design the band-pass filters first, connect the T-Junction and tune the T-Junction next.

In this paper, the second method is adopted. We designed two coaxial resonator cavity band-pass filters which center frequencies are 1.95 GHz and 2.14 GHz respectively, and connected the two filters with T-Junction to be a duplexer. The high-isolation duplexer is gained by using the EDA software to optimize the T-Junction.

First, we set up a single resonator cavity in Ansoft, and change the

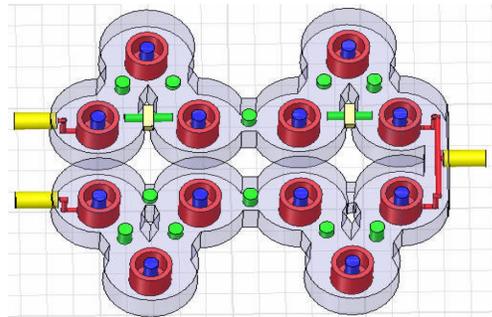


Figure 4. Simulation model of duplexer in Ansoft.

dimensions of inner and outer conductors to make resonant frequencies at center frequencies. Second, the sizes of irises or probes are changed in simulation to realize the coupling coefficients. At last, the simulation model is obtained in Ansoft, shown in Fig. 4.

The tune bolts of resonance and coupling are taken into account in these simulations. So the complex structure of simulation model and numbers of parameters are unavoidable, but the physical realization of duplexer is feasible [16, 17].

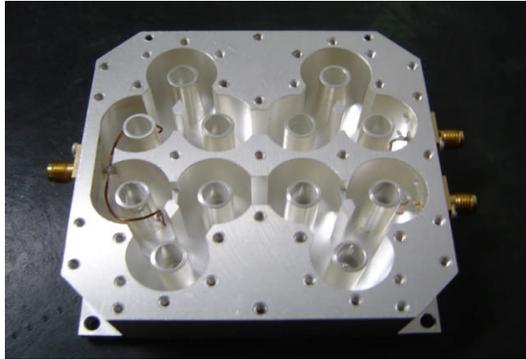


Figure 5. Photo of duplexer.

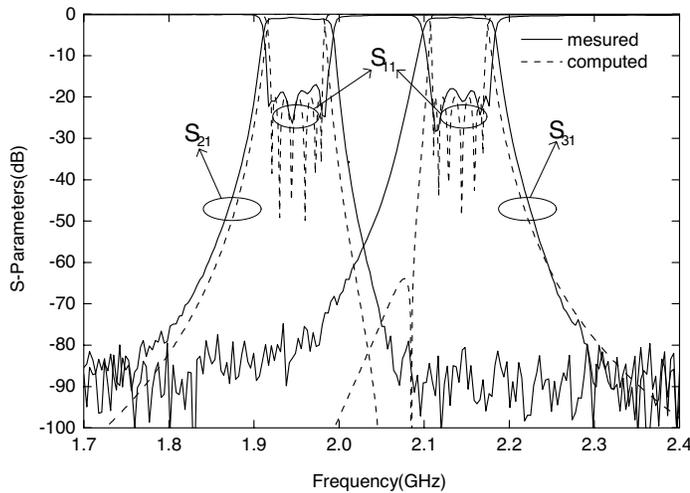


Figure 6. Measured and computed traces.

3. MEASURED DATA

Figure 6 shows the measured return loss and insertion loss of the duplexer in Fig. 5. The measured return loss of the duplexer is about 20 dB, which in-band insertion loss is smaller than 1 dB, and the isolation between two pass-bands is 50 dB. The measured data agrees well with the conditions of the design targets. In Fig. 6, because of the effect of noise we can not see the four transmission zeros designed, but it does not affect the performance of the cavity duplexer.

4. CONCLUSION

On the base of the design of the general Chebyshev band-pass filter with finite transmission zeros, the coaxial resonator cavity duplexer in Fig. 5 is designed and realized in this paper. The measured results in Fig. 6 approximately meet all the conditions of the design targets, so this method is provided correct and feasible.

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