# Compact Microstrip Diplexer for 4G Wireless Communication

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**Abstract**— A novel compact microstrip diplexer for 4G wireless communication system is proposed. The diplexer is composed of two stub-loaded dual-mode resonators (SLDMRs). The main advantage of stub-loaded dual-mode resonator is that a compact narrowband bandpass filter is easily realized and a transmission zero can be realized in the stopband of each channel, which improves the isolation between two channels. Two SLDMRs are then connected to a common port by the feed lines with two long fingers. Coupling scheme of the diplexer is given and analyzed. The diplexer is in final designed at 2.35 and 2.59 GHz for 4G wireless communication. The circuit is compact and occupies about $0.33\lambda_g \times 0.25\lambda_g$.

## 1. INTRODUCTION

Diplexer is an essential component in the RF front ends of communication system, which is used to transmit and receive signals by a single antenna in communication system. As a newly commercialized mobile communication system, 4G wireless mobile communication is a new emerge technique that can provide high-speed data service for subscribers. Researchers show great interests in developing high performance components for 4G wireless mobile communication systems, such as antennas, filters, and diplexers. A diplexer can be designed by combining two different bandpass filters with a matching network. In [1], a hairpin line diplexer is realized by using stepped-impedance coupled-line resonators. In [2], a diplexer for ultra-wideband systems is proposed using hairpin line wideband bandpass filters. An extra tapped open-stub is added to suppress the spurious responses of the first bandpass filter in the operating range of second filter. In [3] and [4], hybrid resonators and composite right/left-handed (CRLH) quarter-wave type resonators are used to design diplexers. However, the resonators require short-circuit through-holes that results in higher fabrication costs and errors. T-junction is usually used as matching network in a diplexer [3, 5]. Despite of the convenience of design, but the size of the diplexer is large. In [6] a diplexer for UMTS system using dual-mode stripline ring resonators is proposed.

In this paper, a novel diplexer for 4G communication systems is proposed based on two stub-loaded dual-mode resonators (SLDMR) with different sizes. Owing to the quarter-wavelength resonance of the loaded stub, each SLDMR will produce a transmission zero near the passband. Another transmission zero is produced by introducing the coupling between source and load, aiming to improve the isolation of the diplexer. Finally, a diplexer with a compact size operating in the 2.35/2.59 GHz band for 4G communication system is designed. The circuit size is about $0.33\lambda_g \times 0.25\lambda_g$. Simulated results show the isolation between two passband is $-29$ dB and $-38$ dB, respectively.

## 2. ANALYSIS OF THE STUB-LOADED DUAL-MODE RESONATOR

Figure 1 shows schematic of the proposed diplexer. The diplexer consists of two stub-loaded dual-mode resonators and three microstrip feed lines. SLDMR are folded to achieve a compact size. Two DMRs are interconnected by an appropriately designed microstrip junction with characteristic impedance of 50 Ω, thus avoiding the conventional matching circuit of T-junction [2].

The basic configuration of a SLDMR in show in Fig. 2, where $Y_1$, $L_1$, $Y_2$ and $L_2$ denote the characteristic admittances and lengths of the microstrip line and open stub, respectively. Odd- and even-mode theory is used to analysis its resonant characteristics [7].

When the structure is excited by odd-modes, the symmetrical plane can be seen as short-circuited and the resonant frequencies can be expressed as

$$f_{odd} = \frac{(2n-1)c}{2L_1\sqrt{\varepsilon_{eff}}} \tag{1}$$

where $n = 1, 2, 3, \ldots$, $c$ is the speed of light in the free space, and $\varepsilon_{eff}$ is the effective dielectric constant of the microstrip line. Obviously, the odd-mode resonant frequencies are determined only by the open ring resonator.

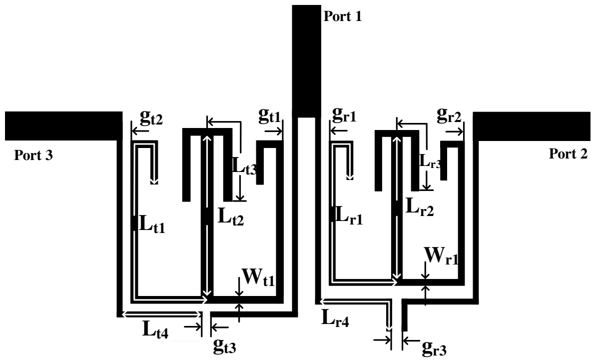


Figure 1: The schematic of the proposed diplexer.

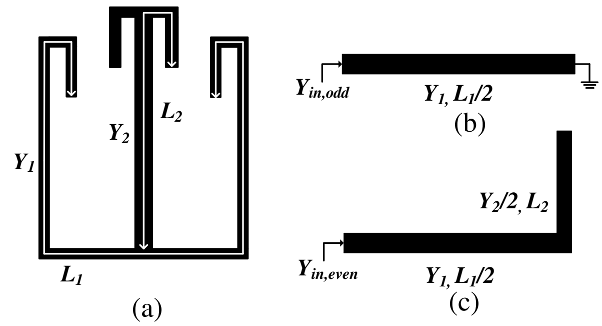


Figure 2: (a) Structure of the stub-loaded DMR, (b) odd-mode equivalent circuit, and (c) even-mode equivalent circuit.

When the structure is excited by even-modes, the symmetrical plane can be seen as open-circuited and the resonant frequencies can are determined by

$$f_{even} = \frac{nc}{(L_1 + 2L_2)\sqrt{\varepsilon_{eff}}} \tag{2}$$

where $n = 1, 2, 3, \ldots$. It is clearly observed that once $L_1$ is determined, the even-mode will vary with the length of the open stub.

Figure 3 shows transmission characteristics of the dual-mode resonators. A transmission zero can be achieved owing to quarter-wavelength resonance of the loaded stub. As to the resonator works at the lower passband, the transmission zero is set in the upper stopband, obtaining to decrease the interference with the upper passband. On the contrary, as to the dual-mode resonator works at upper passband, the transmission is set in the lower stopband, aiming to minimize the interference from the lower passband. Obviously, the position of the transmission zero can be tuned by changing the length of the loaded stub and the bandwidth of the circuit also change with the shift of the transmission zero.

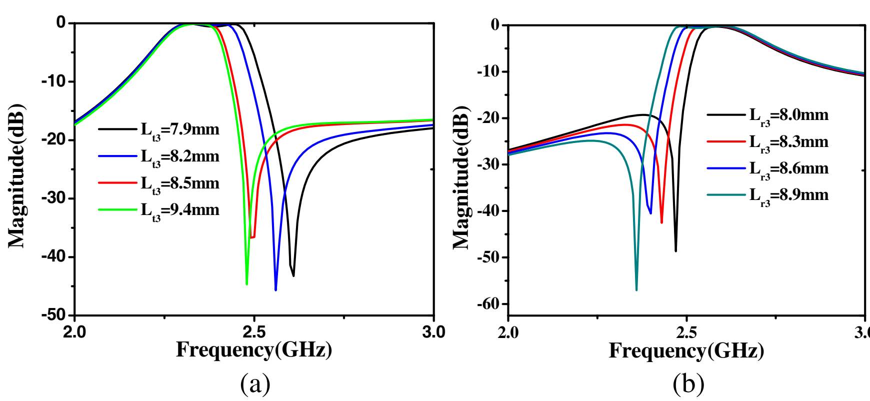


Figure 3: Simulated responses of (a) SLDMR 1 versus $L_{t3}$ when $L_{r3} = 8.9$ mm and (B) SLDMR 2 versus $L_{r3}$ when $L_{t3} = 7.9$ mm.

## 3. ANALYSIS OF THE PROPOSED DIPLEXER

Figure 4 shows the coupling scheme of the proposed diplexer, where the solid lines indicate the main coupling and the dashed lines indicate the cross coupling, black dot and white dot represent resonant modes and soure/load, respectively. Both modes of SLDMR are directly coupled to both source and load. Coupling between source and load is introduced in each channel by increasing the length of the feed lines. By use of source-load coupling, transmission zeroes can be introduced in the stopband, which improves the stopband characteristics while keep the transmission characteristics stable in the passband [8, 9]. The length of the feed lines $L_{t4}$ between port1 and port2, and $L_{r4}$ between port1 and port3 are extended, aiming to introduce direct source-load coupling. Meanwhile, isolation between the two channels of the diplexer is improved. Fig. 5 shows comparisons of transmission characteristics between the diplexer with and without source-load coupling. It is obviously seen that the attenuation of $S_{21}$ improved about 8 dB in the stopband and the attenuation of $S_{31}$ improved about 20 dB in the stopband when the coupling between source and load is introduced.

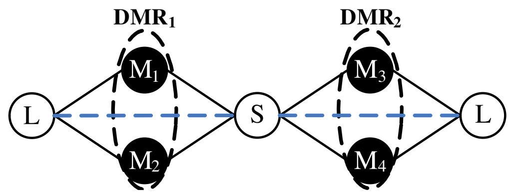


Figure 4: Coupling scheme of the proposed diplexer.

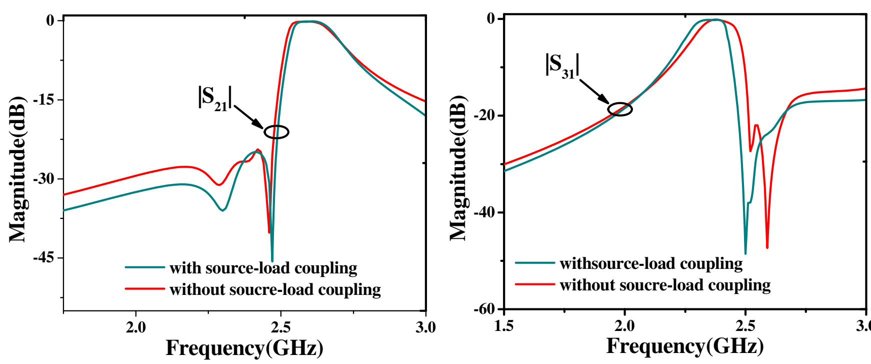


Figure 5: The frequency response of the proposed diplexer compared with the diplexer without source-load coupling.

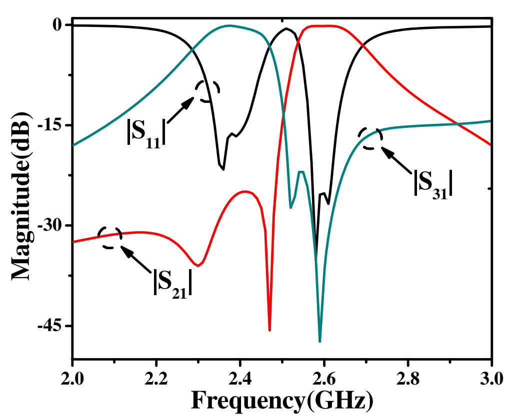


Figure 6: The frequency response of the proposed diplexer.

The simulated results of the proposed diplexer are shown in Fig. 6. A substrate with a dielectric constant of 3.5 and a thickness of 0.8 mm is used in the design. Associated dimensions are: $W_{t1} = W_{r1} = 0.4$ mm, $L_{t1} = 19.5$ mm, $L_{r1} = 21.3$ mm, $L_{t2} = 9.85$ mm, $L_{r2} = 10$ mm, $L_{t3} = 9$ mm, $L_{r3} = 8.2$ mm, $L_{t4} = 5.1$ mm, $L_{r4} = 6.9$ mm, $g_{t1} = g_{t2} = 0.4$ mm, $g_{r1} = g_{r2} = 0.35$ mm, $g_{t3} = 1.7$ mm and $g_{r3} = 1.75$ mm. The diplexer designed for 4G co mmunication system operates in 2.35/2.59 GHz and the simulated 3-dB bandwidths of the two channels are 6.89% and 6.56%, respectively. The simulated isolations between port2 and port3 are below $-30$ dB. The circuit is very compact and it occupies about 23.5 mm $\times$ 13.5 mm.

## 4. CONCLUSIONS

A compact microstrip diplexer using stub-loaded dual-mode resonators is proposed in this paper. The main advantage of the DMR is that a compact bandpass filter with an asymmetric frequency response is easily realized. The bandpass isolation is improved by introducing the source-load coupling. This property is utilized to design a compact high selectivity diplexer, for a system with two extremely close frequency bands. The proposed design offers a simple structure, which allows design flexibility and ease of fabrication.

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