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Two Back-to-back Three-port Microstrip Open-loop Diplexers

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Abstract— A four-port diplexer consisting of two back-to-back three-port microstrip-open loop diplexers combined with a 180° phase shifter in one branch is presented. The technique achieves high Tx/Rx isolation with relatively low degree filters. Two back-to-back three-port microstrip-open loop diplexers with tapped-feeds are simulated which enabling miniaturization and cost reduction. Simulated results of Tx/Rx diplexer devices at 1.95/2.14 GHz are presented and 52.05dB Tx/Rx isolation is achieved with only second-order filters.

Keywords—four-port network; lumped-element; microstirp diplexer; high isolation

I. Introduction

Radio frequency (RF) and microwave applications have stimulated the rapid development of new communication systems. The research work is focused on the third generation (3G) mobile communication systems. The diplexer is generally employed in order to share one antenna for both transmitting and receiving. Therefore, how to design a bandpass filter and diplexer at low cost and with high performance is currently of great interest. Microstrip bandpass filters can be easily mounted on a dielectric substrate and can provide a more flexible design of the circuit layout [1]. The square open-loop resonators filters have been known for years. The compact high performance microwave bandpass filters are highly desirable in the wireless communication systems [2]. The design of different filters and diplexers was discussed in [3-4] in which conventional diplexers offer low cost (microstrip structure) but offer poor signal isolation (worse than 20dB) and high signal losses. For bandpass filter based diplexer designs, the conventional technique gives poor isolation performance; consequently, a technique to achieve high signal isolation is required. High signal isolation was proposed by using four-port network [5] as shown in Fig. 1. To achieve the realized prototype, the alternative technique for size reduction and high isolation signal by using tapped-feed can be presented in here.

In this paper, an alternative design technique of microstrip four-port diplexer for high Tx/Rx isolation with relatively low-order filter topology is introduced. The design technique is based on two back-to-back second-degree microstrip-open loop diplexers with tapped-feeders, which are combined to form a four-port diplexer. The design frequencies of the four-port diplexer are 1.95 GHz and 2.14 GHz for Tx and Rx module, respectively.

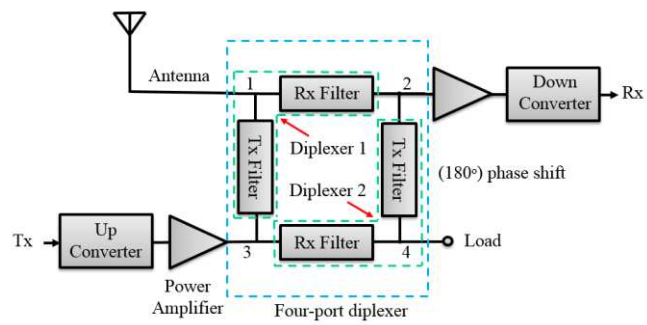

Fig. 1. Schematic diagram of four-port diplexer using two back-to-back three-port diplexers with amplitude and 180° phase cancellation technique between Rx and Tx channel

II. Filter Design

The microstrip open-loop filters are designed at the centre frequency of 1.95 GHz and 2.14 GHz for Tx and Rx module, respectively, with 20-dB bandwidth of 50 MHz (FBW=2.6% at 1.95 GHz, 2.3% at 2.14 GHz). The loaded normalized lowpass prototype filter element values (g_i) can be calculated as in [2]. The calculated values of the Chebychev bandpass filter with 0.044 dB ripple are given as g_0=1, g_1=0.6682, g_2=0.5462 and g_3=1.2222.

The external values can be calculated by

$$Q_e = \frac{g_0 g_1}{FBW} \tag{1}$$

The external coupling at 1.95 GHz and 2.14 GHz are 25.7 and 29.05, respectively.

The coupling coefficient $K_{i,i+1}$ is given by

$$K_{i,i+1} = \frac{FBW}{\sqrt{g_1 g_2}} \tag{2}$$

The coupling coefficient $K_{i,i+1}$ between two resonators at 1.95 GHz and 2.14 GHz are K_{12}=0.0426, K_{12}=0.0387, respectively.

The proposed microstrip filters are based upon square open-loop resonator with tapped-feed. The filters are designed on a RT/Duroid substrate having a thickness h = 1.27mm with relative dielectric constant εr =10.2. The filters were simulated by AWR microwave office. To implement microtrip resonator filters by using tapped-feed configurations, the external coupling and internal coupling between two resonators are extracted. The relationship between external coupling and tapped-feed position is shown in Fig. 2. Base on (1), the Q_e values at 1.95 GHz and 2.14 GHz are equal to 2.225 mm and 2.005 mm, respectively. The relationship between internal coupling coefficient and space between resonators is pictured in Fig. 3. As defined in (2), the $K_{i,i+1}$ values at 1.95 GHz and 2.14 GHz are equal to 0.18 mm and 0.29 mm, respectively.

Fig. 4 shows a square open-loop resonator with tapped-feed. The filters are designed at the centre frequency of 1.95 GHz and 2.14 GHz for Tx and Rx module, respectively, The dimensions of the microstrip open-loop resonator are listed in table I. The passband insertion loss (IL) is less than 1.526 dB and 1.495 dB for Tx and Rx band, respectively. The return loss (RL) in both channels is better than 20 dB in the passband as shown in Fig. 5 and 6.

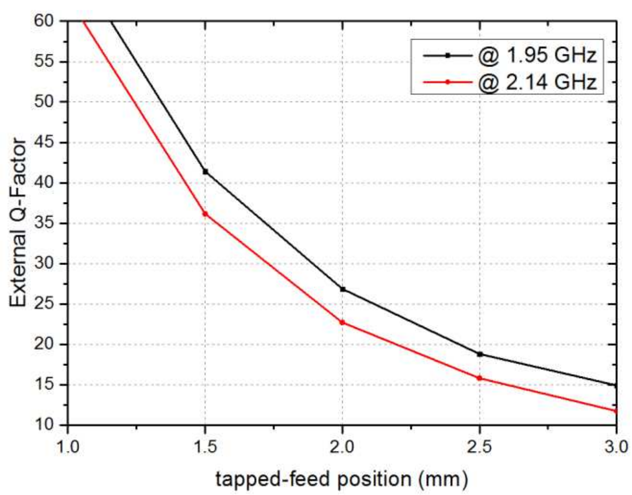

Fig. 2. External quality factor of microstrip open-loop

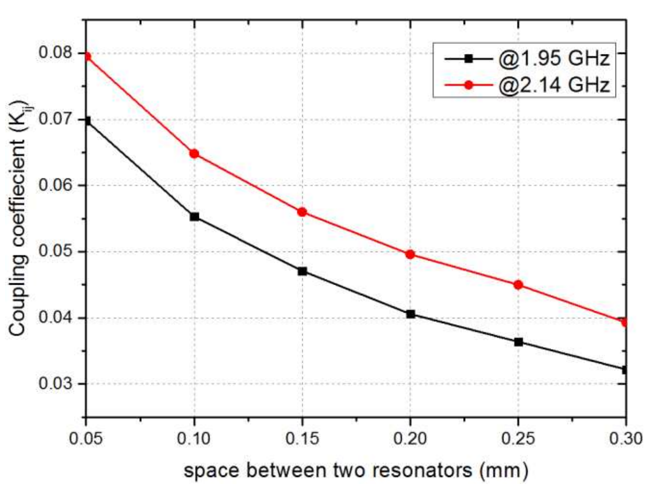

Fig. 3. Coupling coefficient of microstrip open-loop

TABLE I. DIMENSIONS OF MICROSTRIP OPEN-LOOP FILTERS

Dimensions	**T_X=1.95 GHz**	**R_X=2.14 GHz**
Microstrip width (w)	1mm	1mm
Space between two resonators (s)	0.18 mm	0.29 mm
Tapped-line feed (x)	2.2 mm	1.8 mm
Resonator length (a)	7.4 mm	7.4 mm
Open-loop length (b)	2.48 mm	1.119 mm
Feed length (f)	5 mm	5 mm

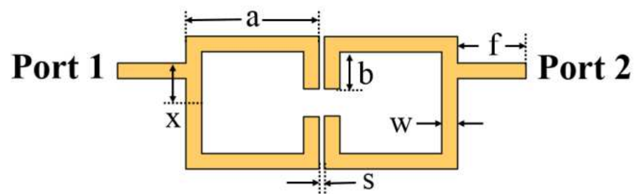

Fig. 4. Schematic diagram of microstrip open-loop resonator with tapped-feed

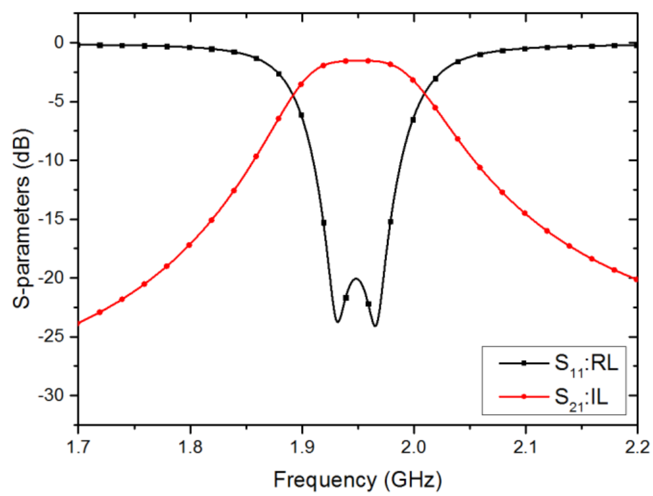

Fig. 5. Simulated results of RL and IL of at 1.95 GHz

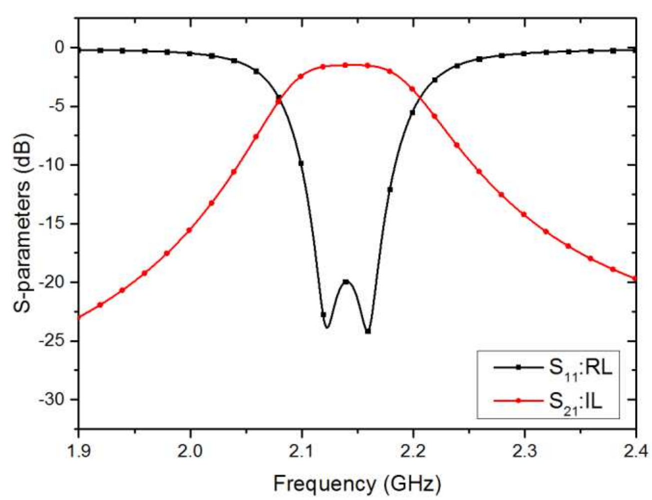

Fig. 6. Simulated results of RL and IL at 2.14 GHz

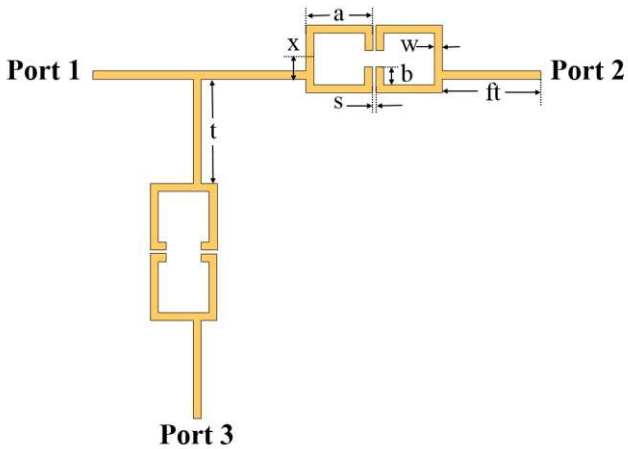

Fig. 7. The microstrip three-port diplexer design

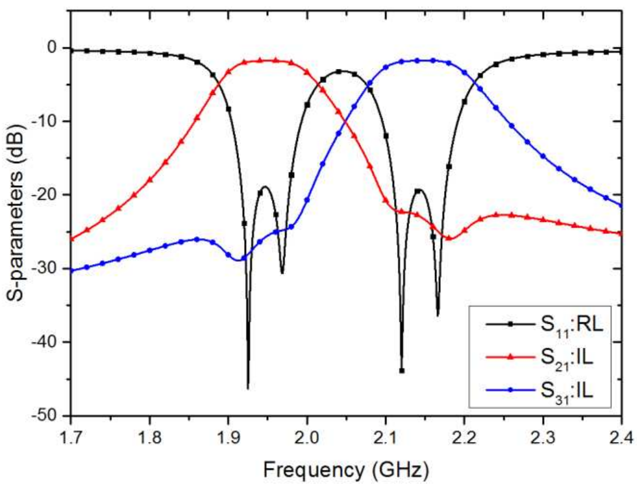

Fig. 8. Simulated results of RL and IL of three-port diplexer

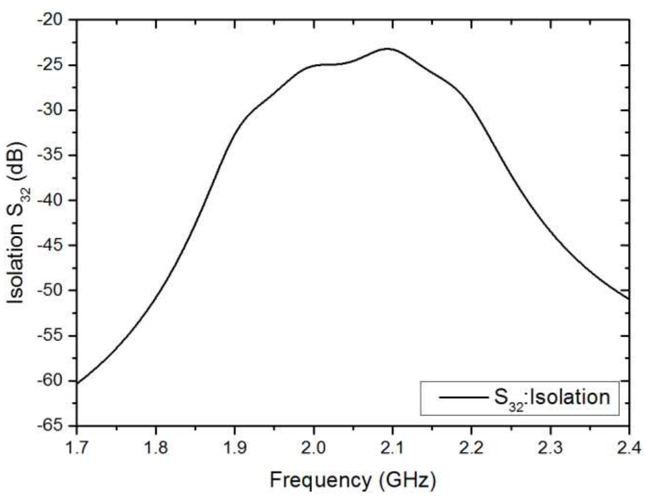

Fig. 9. Simulated results of isolation (S_{32}) of three-port diplexer

III. THREE-PORT DIPLEXER

The diplexer design is based on the design of the two bandpass filters independently: one of them meeting the desired frequency band in the Tx band at 1.95 GHz and the other desired frequency band in the Rx band at 2.14 GHz. Then, the T-junction is connected the two independent bandpass filters together. The geometry of proposed diplexer is shown in Fig.7. The dimensions of the microstrip open-loop diplexer are listed in table II.

TABLE II. DIMENSIONS OF MICROSTRIP OPEN-LOOP THREE-PORT DIPLEXER

Dimensions	T_X=1.95 GHz	R_X=2.14 GHz
Microstrip width (w)	1mm	1mm
Space between two resonators (s)	0.18 mm	0.29 mm
Tapped-line feed (x)	2.225 mm	2.005 mm
Resonator length (a)	7.4 mm	7.4 mm
Open-loop length (b)	2.48 mm	1.119 mm
Feed length (ft)	14 mm	14 mm
Tap length (t)	14.8 mm	

The passband IL in Rx band is less than 1.781 dB and Tx band 1.767 dB. The RL in both channels is better than 18.9 dB in the passband as plotted in Fig. 8. The simulated isolation between Rx and Tx band is better than 23.2 dB in transmit and receive band as shown in Fig.9.

IV. FOUR-PORT DIPLEXER

Four-port diplexer for high Tx/Rx isolation with relatively low-order filter topology is presented in Fig. 10. The design technique is based on two back-to-back second-degree microstrip-open loop diplexers with tapped feeders, which are combined to form a four-port diplexer. The delayed-line is use to tune the phase between port 2 and 4 to achieve 180° phase shift. The dimensions of the microstrip open-loop diplexer are listed in table III.

TABLE III. DIMENSIONS OF MICROSTRIP OPEN-LOOP FOUR-PORT DIPLEXER

Dimensions	R_X=1.95 GHz	T_X=2.14 GHz
Microstrip width (w)	1mm	1mm
Space between two resonators (s)	0.18 mm	0.29 mm
Tapped-line feed (x)	2.225 mm	2.005 mm
Resonator length (a)	7.4 mm	7.4 mm
Open-loop length (b)	2.48 mm	1.119 mm
Feed length (ft)	14 mm	14 mm
Tap length (t)	14.8 mm	
Microstrip line m)	3 mm	
Microstrip line (k)	13.75	
Microstrip line (n)	6.8 mm	

The simulated results show that the passband insertion loss (IL) in Tx band is less than 2.01 dB while, in Rx band, it is less than 1.82 dB as plotted in Fig. 11. The comparison of signal isolation, S_{32}, of four-port diplexer and three-port diplexer isolation between Rx and Tx band is shown in Fig. 12 The simulated signal isolation of the conventional three-port

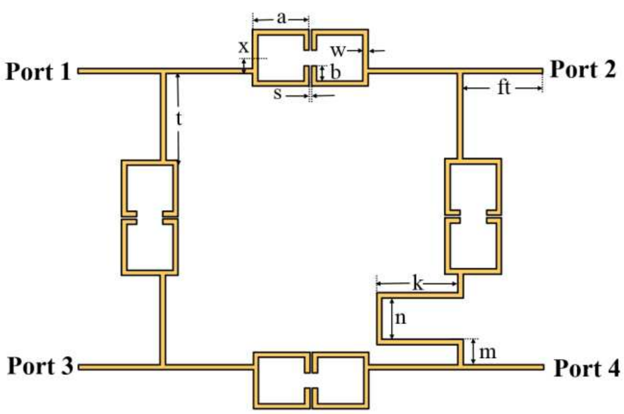

Fig. 10. The microstrip four-port diplexer design

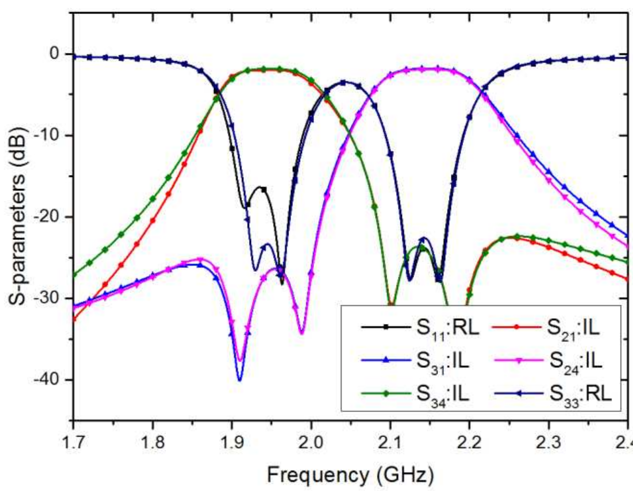

Fig. 11. Simulated results of RL and IL of four-port diplexer

diplexer is 23.2 dB and it is 52.05 dB for the four-port diplexer. It can be seen that the four-port microstrip diplexer still has signal isolation (S_{32}) better than the existing state-of-the art diplexers [6-7].

The phase responses of S_{21} and S_{34} have the same phase but, for S_{31} and S_{24}, phase difference between these parameters are 180° or out of phase. Fig. 13 depicts the phase responses of S_{31} and S_{24}. To achieve an optimum Tx/Rx isolation, the phase of S_{31} and S_{24} are designed to be 80.52° and -99.4°, respectively, resulting in a phase difference of 179.92°.

V. CONCLUSIONS

High Tx/Rx isolation using a four-port diplexer is proved by using microstrip open-loop resonator with tapped-feeders. The technique achieves high isolation with two back-to-back low degree diplexers. The four-port diplexer is designed at the centre frequency of Tx at 1.95 GHz, Rx at 2.14 GHz with BW=50MHz. The microstrip four-port diplexer can enhance the isolation (S_{32}) more than 28.85 dB from the conventional diplexer. Finally, this RF interference rejection technique can be used in wireless communication systems where small size, low losses and low complexity are required.

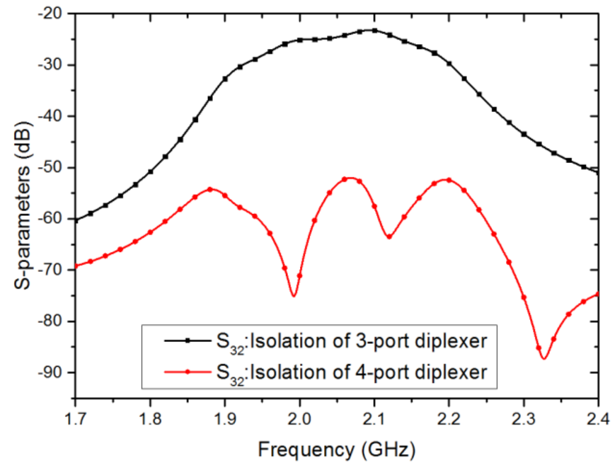

Fig. 12. Comparison of simulated results of isolation (S_{32}) between three-port diplexer and four-port diplexer

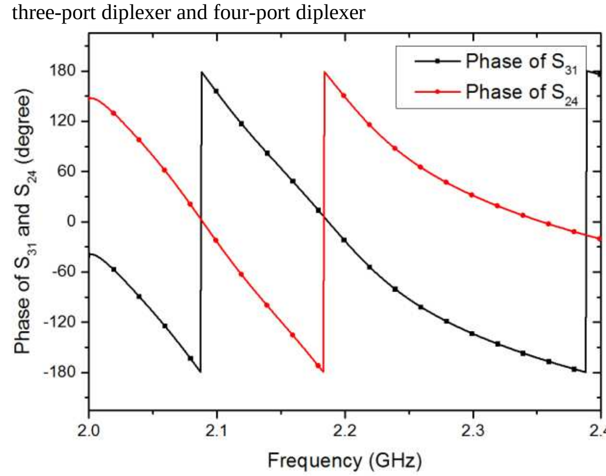

Fig. 13. Simulated phases of S_{31} and S_{24} with 179.92° phase difference at 2.14 GHz

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