LETTER

IEICE Electronics Express, Vol.15, No.5, 1–6

Compact microstrip balanced-to-balanced diplexer using stub-loaded dual-mode resonators

Chao Zhang[a)], **Li Zhu, and Yuehua Li**

School of Electronic and Optical Engineering, Nanjing University of Science and Technology, Road 200, Xiaolingwei, Nanjing 210094, China

a) *enndychang@163.com*

Abstract: A new microstrip balanced-to-balanced diplexer based on stub-loaded dual-mode resonators is presented in this letter. The proposed balanced diplexer primarily consists of two balanced bandpass filter channels, and both channels can be independently designed, thus bringing great flexibility in the diplexer design. Besides, due to the direct connection of two dual-mode balanced filters, no additional matching networks are demanded at the common input port, leading to a significant size reduction. A bandpass coupled line structure is introducing as output feeding line which generates transmission zero on lower side of passband. For demonstration, a prototype balanced diplexer operating at 2.20 and 2.63 GHz is implemented and measured with 3-dB fractional bandwidths of 7.3% and 6.8%. Both simulated and experimental results are provided in satisfactory agreement.

Keywords: stub-loaded dual-mode resonator, bandpass coupled line, balanced-to-balanced diplexer

Classification: Microwave and millimeter-wave devices, circuits, and modules

References

[1] D. Packiaraj, *et al.*: "Cavity diplexer using tapped line interdigital filters," Asia-Pacific Microwave Conference Proc. **1** (2005) 3 (DOI: 10.1109/APMC.2005.1606274).

[2] F. Teberio, *et al.*: "Compact broadband waveguide diplexer for satellite applications," IEEE MTT-S International Microwave Symposium (IMS) (2016) 1 (DOI: 10.1109/MWSYM.2016.7540231).

[3] S. Sirci, *et al.*: "Substrate integrated waveguide diplexer based on circular triplet combline filters," IEEE Microw. Wireless Compon. Lett. **25** (2015) 430 (DOI: 10.1109/LMWC.2015.2427516).

[4] B. Strassner and K. Chang: "Wide-band low-loss high-isolation microstrip periodic-stub diplexer for multiple-frequency applications," IEEE Trans. Microw. Theory Techn. **49** (2001) 1818 (DOI: 10.1109/22.954789).

[5] S. Srisathit, *et al.*: "High isolation and compact size microstrip hairpin diplexer," IEEE Microw. Wireless Compon. Lett. **15** (2005) 101 (DOI: 10.1109/LMWC.2004.842839).

[6] M.-L. Chuang and M.-T. Wu: "Microstrip diplexer design using common T-

DOI: 10.1587/elex.15.20170999
Received September 28, 2017
Accepted February 5, 2018
Publicized February 19, 2018
Copyedited March 10, 2018

IEICE Electronics Express, Vol.15, No.5, 1–6

shaped resonator," IEEE Microw. Wireless Compon. Lett. **21** (2011) 583 (DOI: 10.1109/LMWC.2011.2168949).
[7] J. Shi and Q. Xue: "Novel balanced dual-band bandpass filter using coupled stepped-impedance resonators," IEEE Microw. Wireless Compon. Lett. **20** (2010) 19 (DOI: 10.1109/LMWC.2009.2035954).
[8] B. Xia, *et al.*: "A new balanced-to-balanced power divider/combiner," IEEE Trans. Microw. Theory Techn. **60** (2012) 2791 (DOI: 10.1109/TMTT.2012.2203926).
[9] Y. G. Zhou, *et al.*: "Compact balanced-to-balanced microstrip diplexer with high isolation and Common-Mode suppression," IEEE Microw. Wireless Compon. Lett. **24** (2014) 143 (DOI: 10.1109/LMWC.2013.2291856).
[10] A. Arbelaez-Nieto, *et al.*: "A novel via-free microstrip balanced-to-balanced diplexer for narrow-band applications," Microw. Opt. Technol. Lett. **57** (2015) 567 (DOI: 10.1002/mop.28902).
[11] W. Jiang, *et al.*: "Microstrip balanced quad-channel diplexer using dual-open/short-stub loaded resonator," IEEE MTT-S International Microwave Symposium (IMS) (2016) 1 (DOI: 10.1109/MWSYM.2016.7540232).
[12] J. P. Wang, *et al.*: "Study of a new planar-type balun topology for application in the design of balun bandpass filters," IEEE Trans. Microw. Theory Techn. **64** (2016) 2824 (DOI: 10.1109/TMTT.2016.2594257).

1 Introduction

The diplexer is a three-port network that splits incoming signals from a common input port into two channels with different operating frequencies. It is a significant RF component for communication systems. As we know, the diplexer can be realized in various techniques such as cavity, waveguide, microstrip and substrate-integrated waveguide (SIW) [1, 2, 3, 4]. Among them, the microstrip diplexer is the preferred one due to its low cost and compact layout. Most microstrip diplexers in published literatures are constructed in single-ended structures [5, 6]. Although balanced circuits [7, 8] like balanced filter and power divider are widely used in modern systems owing to their higher immunity and good common-mode (CM) rejection performance, but balanced microstrip diplexer is discussed only in limited literatures in recent years. Zhou *et al.* propose a balanced diplexer with uniform impedance resonators and short-ended microstrip parallel-coupling feedlines [9]. Although it can operate without extra junction matching network, but the performance in upper passband is not as good as that in lower passband. By applying 16 close loops, a via-free and compact diplexer is proposed in [10]. However, both the return losses and insertion losses were poor. In addition, with dual-open/short-stub loaded resonators, Jiang *et al.* design a quad-channel balanced diplexer [11], but it is only suit for narrow-band application. Therefore, it is significant to further improve the performance of the balanced diplexers.

In this letter, a new microstrip balanced-to-balanced diplexer has been proposed. The proposed balanced diplexer is made up of two balanced bandpass filter paths. Each balanced bandpass filter path can be designed independently based on two identical stub-loaded dual-mode resonators. It should be mentioned that no extra matching networks are required at the common balanced input port in our proposal. Transmission zeros (TZs) are generated by the output feeding line which

DOI: 10.1587/elex.15.20170999
Received September 28, 2017
Accepted February 5, 2018
Publicized February 19, 2018
Copyedited March 10, 2018

has bandpass coupled line structure. For demonstration, a prototype balanced-to-balanced diplexer operating at 2.20 and 2.63 GHz is designed, fabricated and measured with 3-dB fractional bandwidths of 7.3% and 6.8%. The performance of practical diplexer agrees with simulation well.

2 Design of balanced-to-balanced diplexer

Fig. 1 depicts the configuration of proposed balanced diplexer. Basically, the diplexer is composed of two balanced filter channels with a common input feed line, and each balanced filter channel is implemented based on a pair of stub-loaded dual-mode resonators which derived from E-shape resonators. As shown in Fig. 1, the employed each pair of resonators (A and A′ or B and B′) is rotationally symmetrical with regard to the centre of the common input feed line and has to operate simultaneously at the same frequency. In addition, the bandpass coupled line structure in [12] is adopted as the output feeding line to generate TZs at low frequency region.

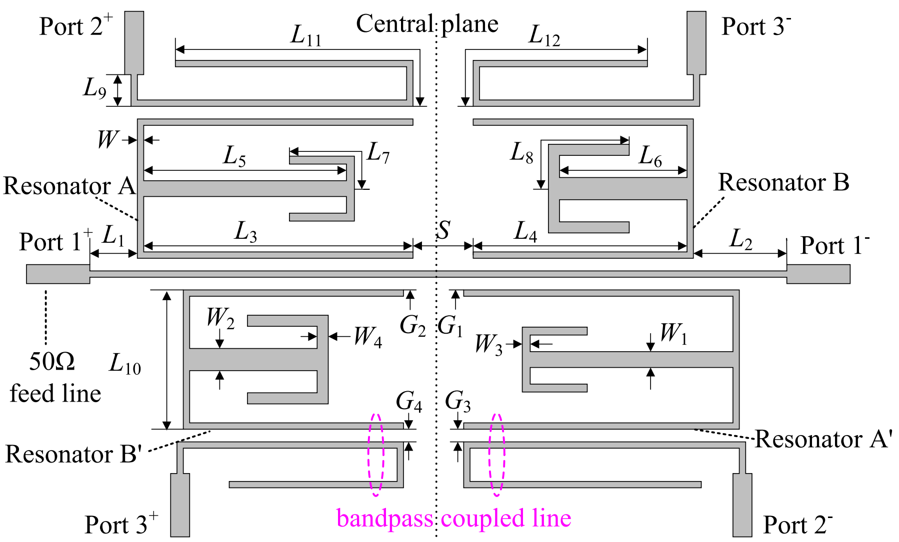

Fig. 1. The configuration of proposed balanced diplexer

Fig. 2 depicts schematic view of the involved stub-loaded dual-mode resonator with its bisections. The resonator can be expounded with even-/odd-mode theory, then two fundamental resonant frequencies can be obtained as

$$f_{even} = \frac{c}{2(L_1 + L_2)\sqrt{\varepsilon_e}}, \quad f_{odd} = \frac{c}{4L_1\sqrt{\varepsilon_e}} \tag{1}$$

where c is the speed of light in free space, ε_e is the effective dielectric constant of microstrip line. Note that $Y_2 = 2Y_1$ is assumed for simplification. Obviously, the stub length L_2 can be adjusted to achieve proper even-mode resonant frequencies while the odd-mode ones maintains. In this context, we can utilize the property to achieve a proper bandwidth of the balanced diplexer.

The equivalent circuits of the proposed balanced diplexer under differential-mode (DM)/CM are illustrated in Fig. 3. Under DM excitation, the central line can be viewed as an electric wall, so a virtual-short-to-ground is present along the

DOI: 10.1587/elex.15.20170999
Received September 28, 2017
Accepted February 5, 2018
Publicized February 19, 2018
Copyedited March 10, 2018

IEICE Electronics Express, Vol.15, No.5, 1–6

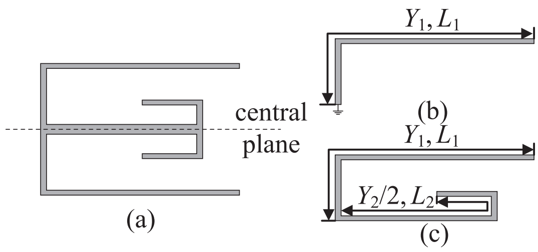

Fig. 2. The schematic of involved stub-loaded dual-mode resonator (a) Integral layout (b) Odd-mode bisection (c) Even-mode bisection

symmetric line. The corresponding equivalent circuit can be obtained as shown in Fig. 3(a). As we can observe, the bandpass-type coupled-line is formed at both input/output ports under DM excitation, thus two dual-mode bandpass filtering responses can be performed between the input and two output ports.

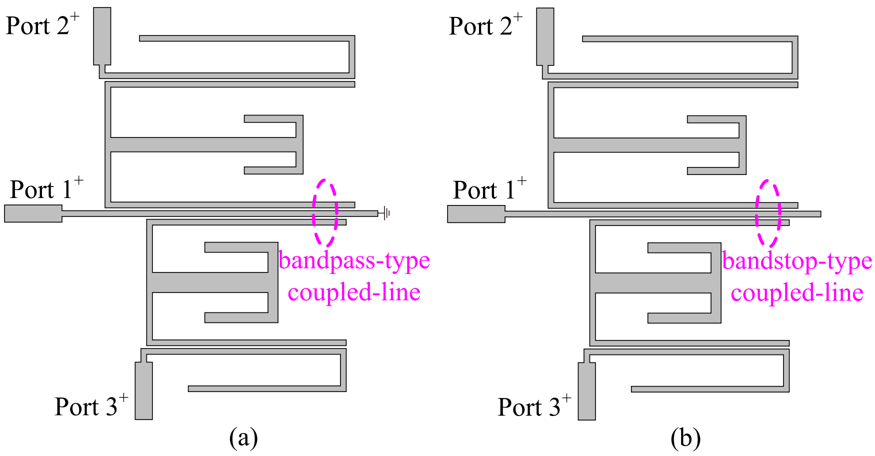

Fig. 3. Equivalent circuit of proposed diplexer (a) differential-mode (b) common-mode

Fig. 4 gives the related coupling scheme of the proposed diplexer under DM excitation. Port $1^+/1^-$ is the input balanced port, then Port $2^+/2^-$ and Port $3^+/3^-$ are output balanced ports. Nodes (1, 2 and 1′, 2′) represent the resonant modes of stub-loaded resonators in two filter channels. It should be noted that the bandwidth of these dual working passbands can be adjusted individually by fine tuning the lengths (L_1, L_2 and S) and the gaps ($G_1/G_3, G_2/G_4$).

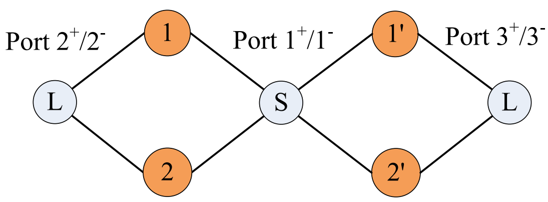

Fig. 4. Coupling of proposed balanced diplexer under differential-mode excitation

DOI: 10.1587/elex.15.20170999
Received September 28, 2017
Accepted February 5, 2018
Publicized February 19, 2018
Copyedited March 10, 2018

IEICE Electronics Express, Vol.15, No.5, 1–6

Alternatively, an open-circuited-to-ground boundary condition is present along the symmetric line under CM operation. Under this circumstance, the signals at the input port can't be transmitted to two output ports due to the bandstop-type coupled-line as illustrated in Fig. 3(b).

3 Implementation and measurement

In order to validate our concept, a prototype of proposed balanced diplexer is designed and fabricated on a 0.508 mm thick Rogers RO4003C substrate with permittivity of 3.55, loss tangent of 0.0027. Final dimensions labeled in Fig. 1 are summarized as follows (Units: mm): $L_1 = 3$, $L_2 = 5.9$, $L_3 = 17$, $L_4 = 13.5$, $L_5 = 12.9$, $L_6 = 8.05$, $L_7 = 5.65$, $L_8 = 6.5$, $L_9 = 0.95$, $L_{10} = 8.8$, $L_{11} = 17.2$, $L_{12} = 13.2$, $W = 0.4$, $W_1 = 1$, $W_2 = 1.4$, $W_3 = 0.5$, $W_4 = 0.7$, $S = 3.8$, $G_1 = 0.2$, $G_2 = 0.2$, $G_3 = 0.2$, $G_4 = 0.2$. The photograph of fabricated diplexer is shown in Fig. 5. The dimension of practical diplexer is about $0.61\ \lambda_g \times 0.34\ \lambda_g$, where λ_g is the guided wavelength at 2.20 GHz.

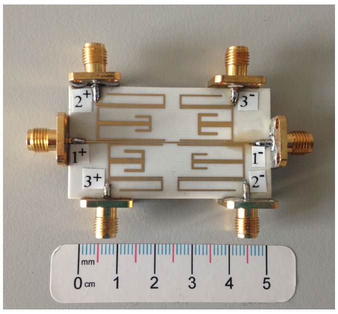

Fig. 5. The photograph of the practical balanced-to-balanced diplexer

The simulation is conducted by the commercial software, ANSYS HFSS, and the measurement is executed on the Agilent N5244A vector network analyzer. The performances of simulation and measurement are in good agreement and they are both illustrated in Fig. 6.

For the DM operation, as shown in Fig. 6(a), the measured DM fractional bandwidth are of 7.3% and 6.8%, respectively, with two central frequencies of 2.20 and 2.63 GHz. The measured minimum in-band insertion losses are about 1.06 and 1.09 dB, while both return losses are better than 17 dB. The TZs at 1.35 GHz and 1.75 GHz are generated by the bandpass coupled line of output ports, which help a lot to improve the frequency selectivity. What is more, the TZs at the high side of each passband are generated due to the quarter-wavelength resonance of the stub loaded in the dual-mode resonator. For CM response, the suppressions in both channels are better than 23 dB, which shown in Fig. 6(b). Fig. 6(c) depicts the isolation between two filter channels under DM/CM operation, which are both better than 38 dB.

DOI: 10.1587/elex.15.20170999
Received September 28, 2017
Accepted February 5, 2018
Publicized February 19, 2018
Copyedited March 10, 2018

ELectronics EXpress

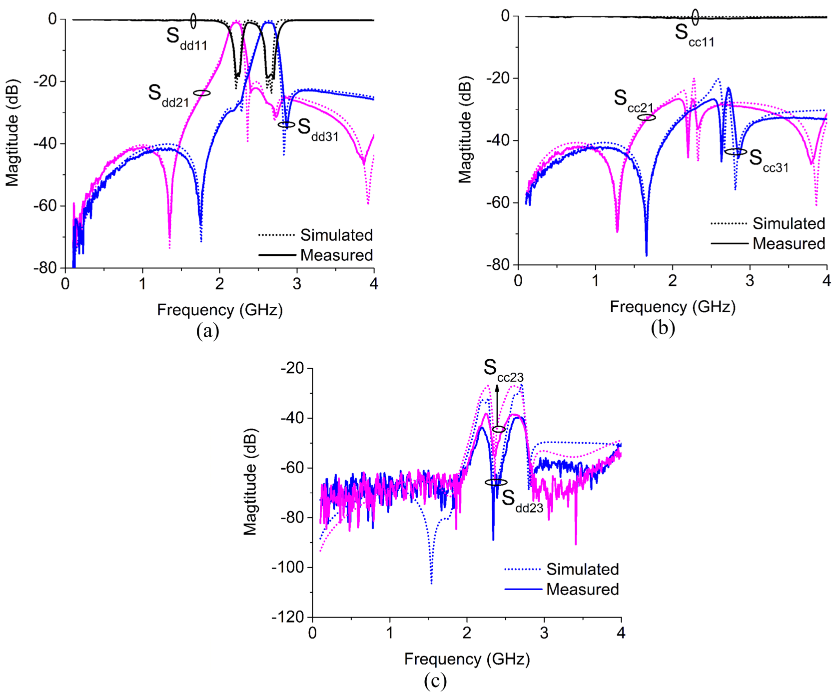

Fig. 6. Performance of diplexer (simulated and measured)
(a) Differential-mode responses
(b) Common-mode suppression
(c) Isolation

4 Conclusion

In this letter, a new balanced-to-balanced microstrip diplexer is proposed and designed. The proposed balanced diplexer primarily consists of two balanced bandpass filter paths, and each balanced filter path can be designed independently based on two identical stub-loaded dual-mode resonators. The measured results show good DM performance of the proposed balanced diplexer, with high CM suppression and good isolation. Owing to these properties, it is our belief that the proposed balanced diplexer can obtain widespread application in many balanced circuit systems.

DOI: 10.1587/elex.15.20170999
Received September 28, 2017
Accepted February 5, 2018
Publicized February 19, 2018
Copyedited March 10, 2018