

Yahui ZHU, Jing CAI, Wei QIN, Wenwen YANG, Jianxin CHEN, 2023. Compact input-reflectionless balanced bandpass filter with flexible bandwidth using three-line coupled structure. *Frontiers of Information Technology & Electronic Engineering*, 24(2):314-326. <https://doi.org/10.1631/FITEE.2200261>

Compact input-reflectionless balanced bandpass filter with flexible bandwidth using three-line coupled structure

Key words: Input-reflectionless filter; Balanced bandpass filter (BPF); Differential mode (DM); Common mode (CM); Three-line coupled structure (TLCS)

Corresponding author: Jianxin CHEN

E-mail: jjxchen@hotmail.com

 ORCID: <https://orcid.org/0000-0002-8703-5294>

Motivation

- ❑ Balanced devices have attracted immense attention due to the urgent requirement of immunity to environmental noise, electromagnetic interference, and crosstalk. As an important frequency selection component in radio frequency (RF)/microwave circuits and systems, the balanced implementation of the bandpass filter (BPF) plays a vital role. However, the stability of the operating system is a major challenge to be addressed in balanced BPF designs.
- ❑ It is still a challenge to achieve a balanced BPF that can absorb both differential mode (DM) reflected signals and common mode (CM) noise with large absorption bandwidth (BW) and miniaturized size simultaneously.

Main idea

- ❑ The reflectionless technique is regarded as an effective technique to dissipate the reflected interference energy inside instead of returning it to the source.
- ❑ For the DM, the three-line coupled structure (TLCS) is applied to achieve the bandpass response. Meanwhile, the input coupled-feed line of the TLCS is reused in the input absorption network. This design shows a good fusion of the absorptive and BPF sections, effectively reducing the circuit size, and the BWs of the two sections that can be controlled separately result in a flexibly controllable DM response BW of the proposed input-reflectionless balanced BPF.
- ❑ The relationship between the passband BW of the input-reflectionless balanced BPF and the BWs of the absorptive section (ABSS) and BPF section is discussed. This has not been mentioned in detail before, in either diplexer-based single-end or balanced designs. Meanwhile, detailed analyses of the ratio of the two-part BWs have been given for the first time, which is vital for the passband flatness and reflectionless feature.

Method

- The synthesis codesign method is presented to achieve a balanced BPF that can absorb both DM reflected signals and CM noise with large absorption BW and miniaturized size simultaneously. It has the advantages of compact layout and high performance by taking the ABSS and the BPF section into account simultaneously in a codesign procedure, as shown in Fig. 1b below.

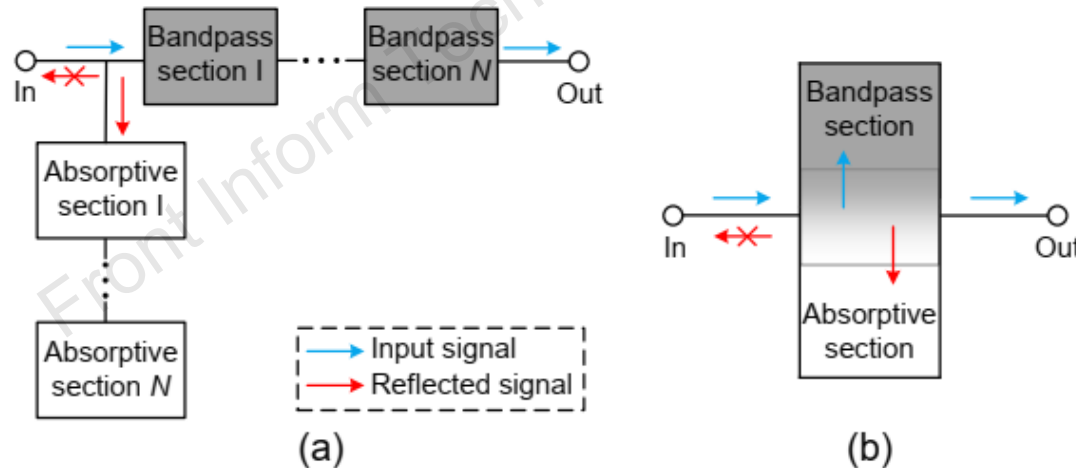


Fig. 1 Conceptual operation mechanism of the input-reflectionless bandpass filter: (a) traditional cascaded system; (b) fusion design method

Major results

□ BW_{DM} (i.e., $|S_{dd21}| > -3$ dB) is flexibly controlled by BW_{BPF} (i.e., $|S_{21}| > -3$ dB) and BW_{ABSS} (i.e., $|S_{11}| > -10$ dB). Regardless of the value of α ($\alpha = BW_{ABSS}/BW_{BPF}$), BW_{DM} is smaller than BW_{BPF} and BW_{ABSS} .

Table 1 Parameters of the input-reflectionless balanced BPFs ($\alpha = 1$)

Case	FBW_{ABSS} (%)	FBW_{BPF} (%)	3-dB FBW_{DM} (%)	Z_a (Ω)	Z_b (Ω)	Z_c (Ω)	Z_d (Ω)	R_a (Ω)	R_b (Ω)	Z_{oe} (Ω)	Z_{oo} (Ω)	k_{cc}
1	21.2	21.2	12.24	20	25	120	120	50	150	139.1	94.9	0.66
2	40.0	40.0	28.57	26	60	120	120	50	150	151.7	80.5	0.58
3	66.1	66.1	44.89	38	78	120	120	50	150	166.6	61.5	0.52

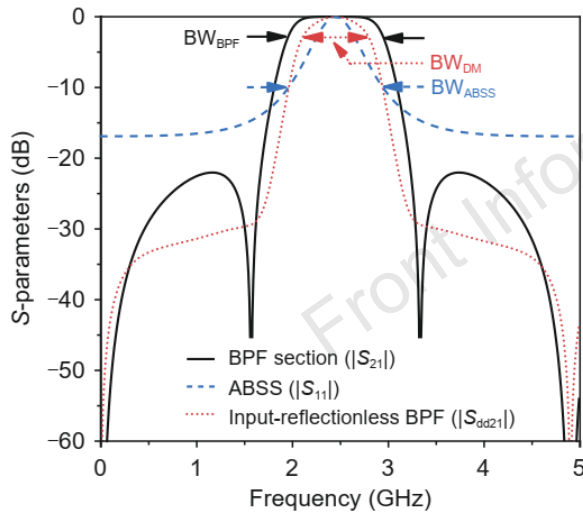


Fig. 10 Comparison between the calculated differential mode frequency response of the proposed input-reflectionless balanced BPF and the frequency responses of its ABSS and BPF section ($Z_a=26 \Omega$, $Z_b=60 \Omega$, $Z_c=120 \Omega$, $Z_d=120 \Omega$, $R_a=50 \Omega$, $R_b=150 \Omega$, $Z_{oe}=151.7 \Omega$, $Z_{oo}=80.5 \Omega$, $k_{cc}=0.58$)

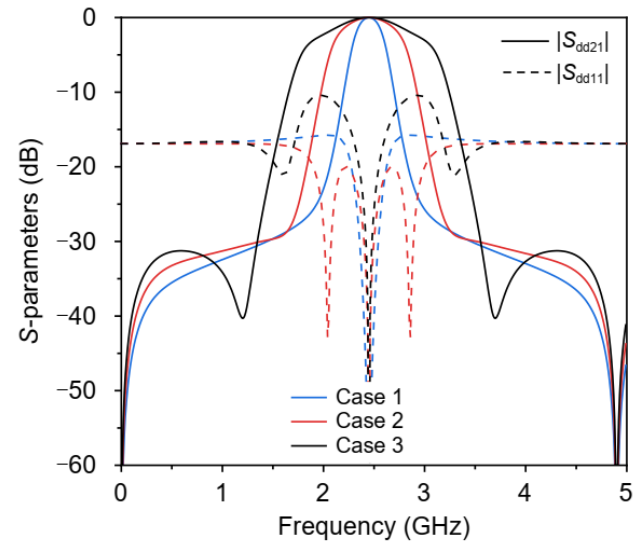


Fig. 11 Calculated differential mode frequency responses of different cases in Table 1 ($\alpha=1$ is fixed) (References to color refer to the online version of this figure)

Major results (Cont'd)

- When α increases from 0.5 to 1, R_{\max} decreases from -11.74 dB to -16.90 dB, while when α increases from 1 to 2, R_{\max} increases from -16.90 dB to -9.45 dB. In addition, PL decreases as α increases, which means that the larger α is, the flatter the passband is. According to Fig. 13 below, to obtain a good compromise between reflectionless performance ($R_{\max} < -10$ dB) and passband performance (PL < 1.5), the optimal interval for α is 1.2–1.9.

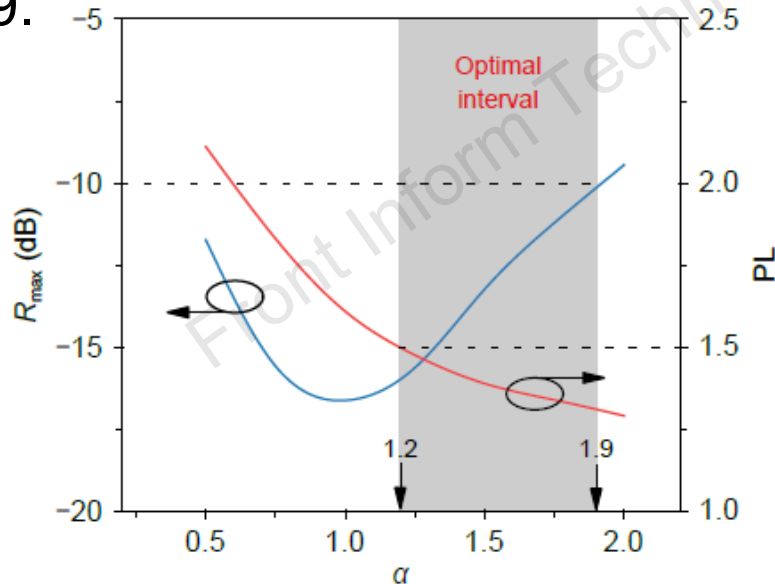


Fig. 13 Performance of the proposed input-reflectionless balanced BPF with varied α in Table 2 (R_{\max} and PL)

R_{\max} : The maximum reflection in the whole band.

PL is defined to quantitatively evaluate the passband flatness (i.e., distortion at the edges of the passband). The larger the PL, the worse the flatness.

$$PL = \frac{3\text{-dB BW}_{DM}}{1\text{-dB BW}_{DM}}$$

3-dB BW_{DM} (i.e., $|S_{dd21}| > -3$ dB)

1-dB BW_{DM} (i.e., $|S_{dd21}| > -1$ dB)

Major results (Cont'd)

- Simulation and measurement results of the proposed input-reflectionless balanced BPF.

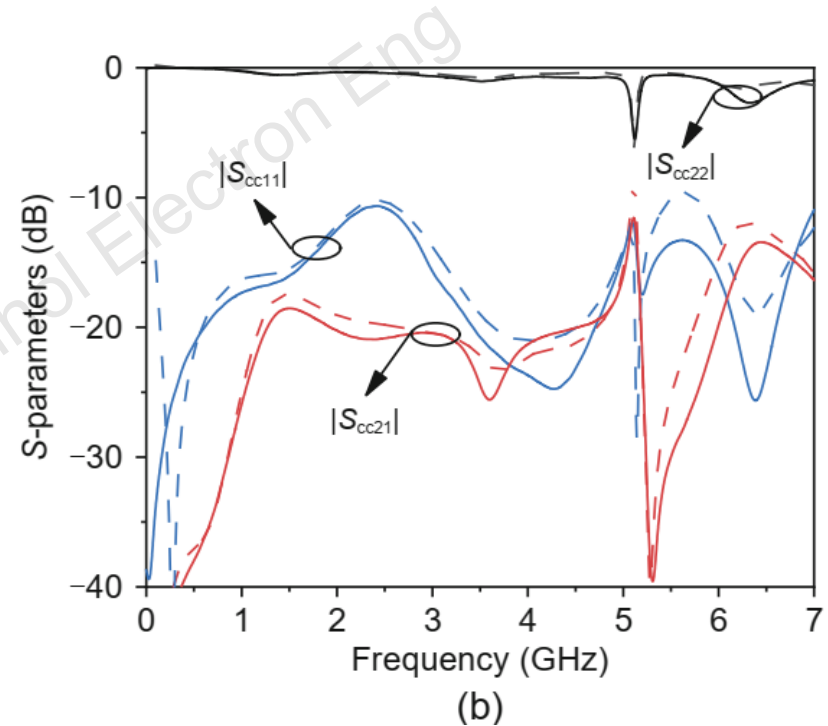
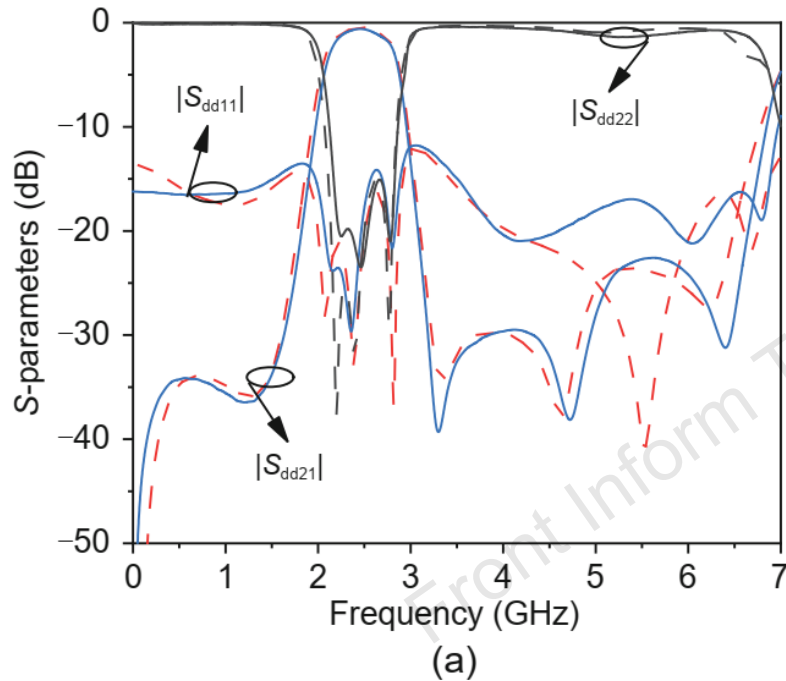


Fig. 17 Simulation (dashed lines) and measurement (solid lines) results of the proposed input-reflectionless balanced BPF: (a) differential mode; (b) common mode (References to color refer to the online version of this figure)

Conclusions

- ❑ The proposed input-reflectionless balanced BPF features an innovative conception of the fusion design, especially reusing the shared transmission lines of the absorptive section and BPF section, resulting in a miniaturized circuit and low insertion loss.
- ❑ The flexible BW of the proposed input-reflectionless balanced BPF can be obtained, so that the specifications of the DM reflectionless filter can be realized in practical applications.
- ❑ The proposed input-reflectionless balanced BPF caters to the development trend of miniaturization and high performance of wireless communication equipment, while eliminating the CM and DM reflected interference signals that are common in the traditional balanced BPF.



Yahui ZHU received her BS degree in electronic information engineering from Nanjing University of Science and Technology Zijin College, Nanjing, China, in 2019. She is currently pursuing the PhD degree in electromagnetic field and microwave technology at Nantong University, Nantong. Her current research interests include microwave devices and antennas.



Jing CAI received his BS and MS degrees in information and communication engineering from Nantong University, Nantong, China, in 2015 and 2018, respectively. He is currently pursuing the PhD degree in electromagnetic field and microwave technology at Nantong University, Nantong. His current research interests include microwave devices and antennas.



Wei QIN received his BS degree in electronic engineering from Southeast University, Nanjing, China in 2007, the MS degree in electromagnetics and microwave technology also from Southeast University in 2010, and the PhD degree in electronic engineering from City University of Hong Kong, Hong Kong, China in 2013.

From July 2013 to November 2013, he was a senior research associate with the State Key Laboratory of Millimeter Waves (HK), City University of Hong Kong. Since 2014, he has been with the School of Information Science and Technology, Nantong University, Nantong, Jiangsu Province, China, where he is currently a Professor. His research interests focus on microwave devices and antennas.



Wenwen YANG received his BS degree in information engineering, MS degree and the PhD degree in electrical engineering from the Southeast University (SEU), Nanjing, China, in 2007, 2010, and 2015, respectively.

Since 2015, He has been with the School of Electronics and Information at Nantong University, Nantong, China, where he is currently an associate professor. From August 2018 to August 2019, he was a visiting researcher with the Polytechnique Montréal, Montréal, Canada. His research interests include RF, microwave and millimeter-wave passive devices, active antenna array, and antennas for wireless communication. He serves as a reviewer for several IEEE and IET journals.



Jianxin CHEN received his BS degree from Huai Yin Teachers College, Jiangsu Province, China, in 2001, the MS degree from the University of Electronic Science and Technology of China (UESTC), Chengdu, China, in 2004, and the PhD degree from the City University of Hong Kong, Kowloon, Hong Kong, China, in 2008.

Since 2009, he has been with Nantong University, Jiangsu Province, China, where he is currently a Professor. He has authored or co-authored more than 100 internationally refereed journal and conference papers. He holds 25 Chinese patents and 3 US patents. His research interests include microwave active/passive circuits and antennas, LTCC-based millimeter-wave circuits and antennas.

Dr. Chen was a recipient of the “New Century Excellent Talents in University” of the Ministry of Education for China in 2011. He was the Supervisor of several conference best paper award winners.