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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)

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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.

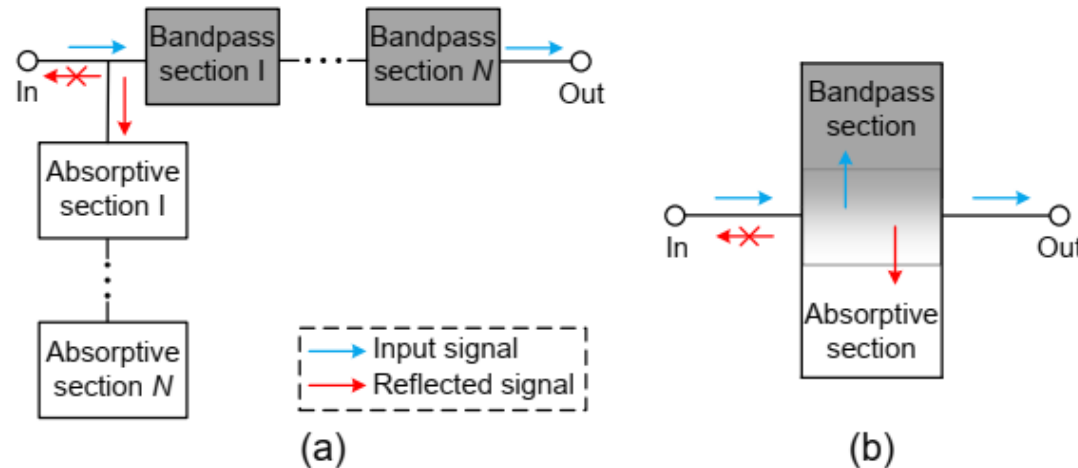


Fig. 1 Conceptual operation mechanism of the input-reflectionless bandpass filter: (a) traditional cascaded system; (b) fusion design method

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

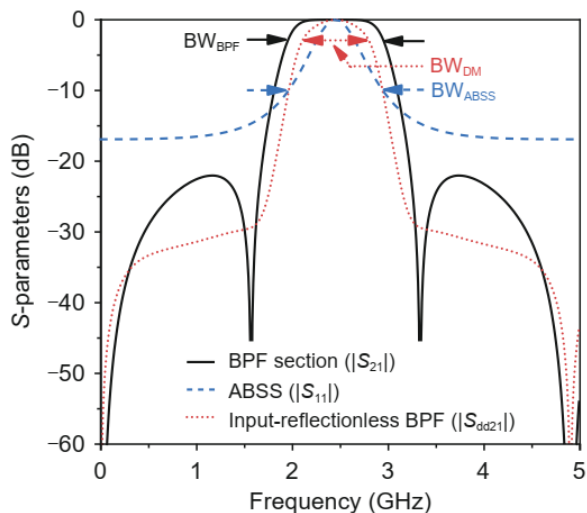


Fig. 10 Comparison between the calculated differential mode frequency response of the proposed input-reflectionless balanced BPF and the frequency responses of its ABSS and BPF section ($Z_a=26 \Omega$, $Z_b=60 \Omega$, $Z_c=120 \Omega$, $Z_d=120 \Omega$, $R_a=50 \Omega$, $R_b=150 \Omega$, $Z_{oe}=151.7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

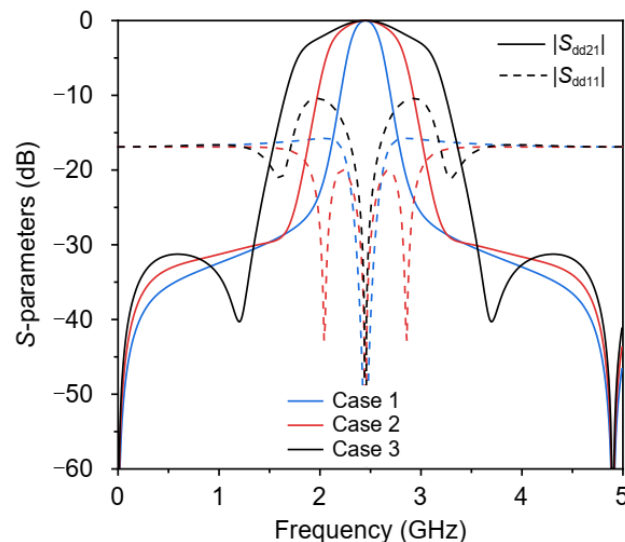


Fig. 11 Calculated differential mode frequency responses of different cases in Table 1 ($\alpha=1$ is fixed) (References to color refer to the online version of this figure)

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.

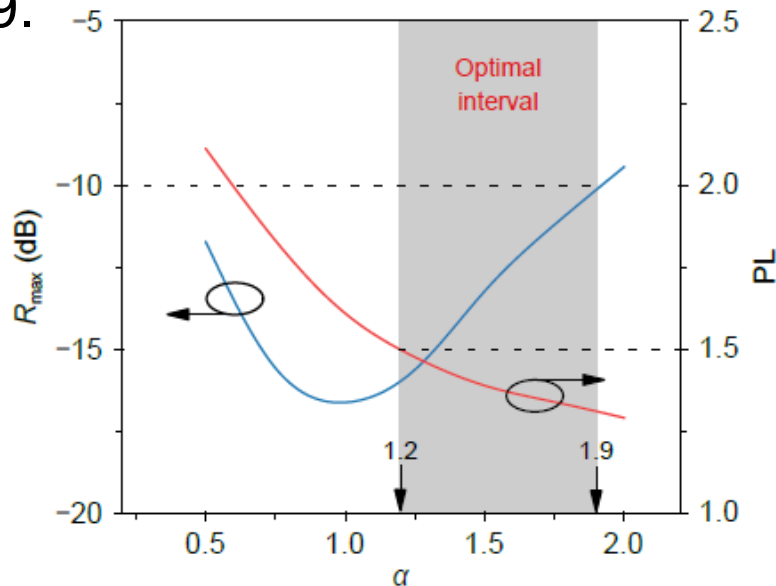


Fig. 13 Performance of the proposed input-reflectionless balanced BPF with varied α in Table 2 (R_{\max} and PL)

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.

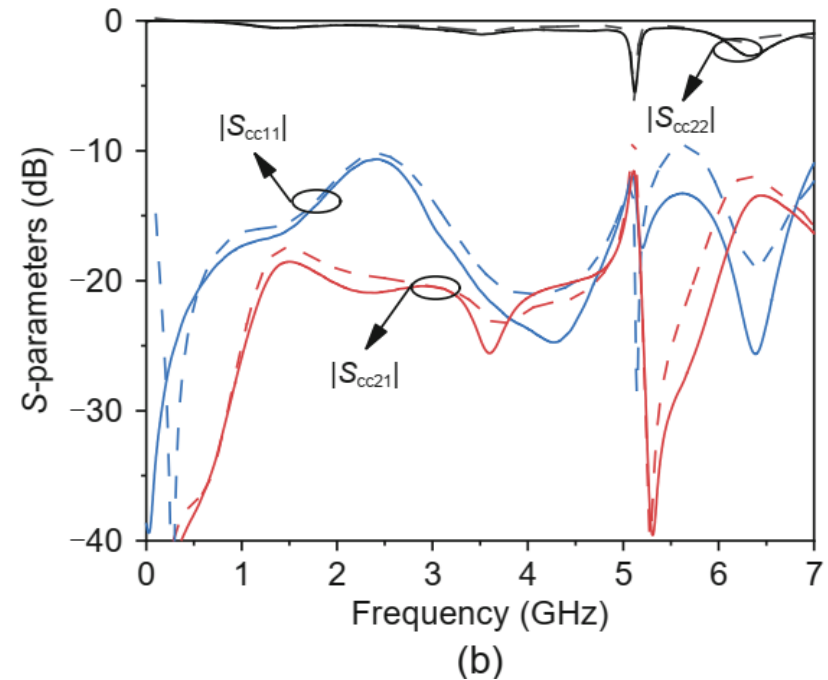
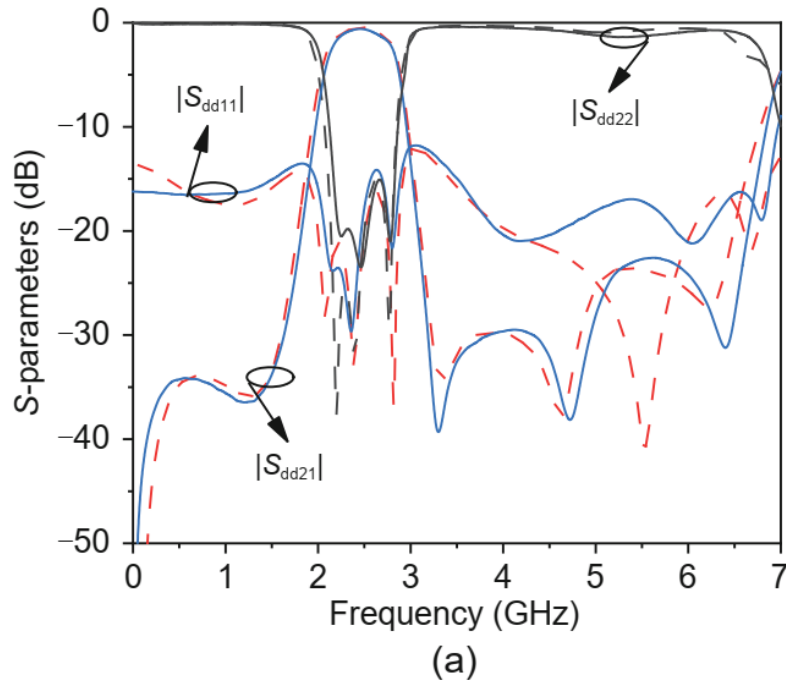


Fig. 17 Simulation (dashed lines) and measurement (solid lines) results of the proposed input-reflectionless balanced BPF: (a) differential mode; (b) common mode (References to color refer to the online version of this figure)

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.



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