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Miniaturized diplexer with wide-stopband based on half-mode substrate integrated waveguide

Key words: Diplexer; Substrate integrated waveguide (SIW); Miniaturization; Half-mode; Wide-stopband; Intrinsic modes; Suppression technique

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Motivation

1. Due to the significant impact on wireless communication systems, the trend in diplexer design focuses on wide-stopband performance, high isolation, low insertion loss, and miniaturization.
2. In a conventional design, T-junctions are used in diplexers to separate two passbands. Many studies aim to minimize the circuit size by eliminating T-junctions. Nevertheless, both multi-layer technology and folded SIW increase the design complexity and manufacturing costs.
3. Building on the topology that combines DMR and SMRs, various techniques have been implemented to achieve wide-stopband SIW diplexers without T-junctions. However, in these studies, since the TE_{202} mode in the SMRs is not completely suppressed, the boundary of the stopband is limited to around $2f_1$.

Main idea

1. Using half-mode substrate integrated rectangular cavities (HMSIRC)s as DMR and SMRs overcomes the limitations of SMRs on the miniaturization and wide-stopband performance.
2. The TE_{202} mode is effectively eliminated from SMRs as the specific even modes in HMSIRC are not excited due to magnetic walls in the symmetry plane. The TE_{102} mode is suppressed. Therefore, the diplexer can obtain a wider stopband only through second-order resonance.
3. The usage of HMSIRC)s, coupled with a reduced number of resonators, further minimizes the circuit size.

Method

1. To eliminate T-junctions, the diplexer combines a dual-mode resonator (DMR) with single-mode resonators (SMRs). The employment of HMSIW technology breaks through the limitations of SMRs on miniaturization.

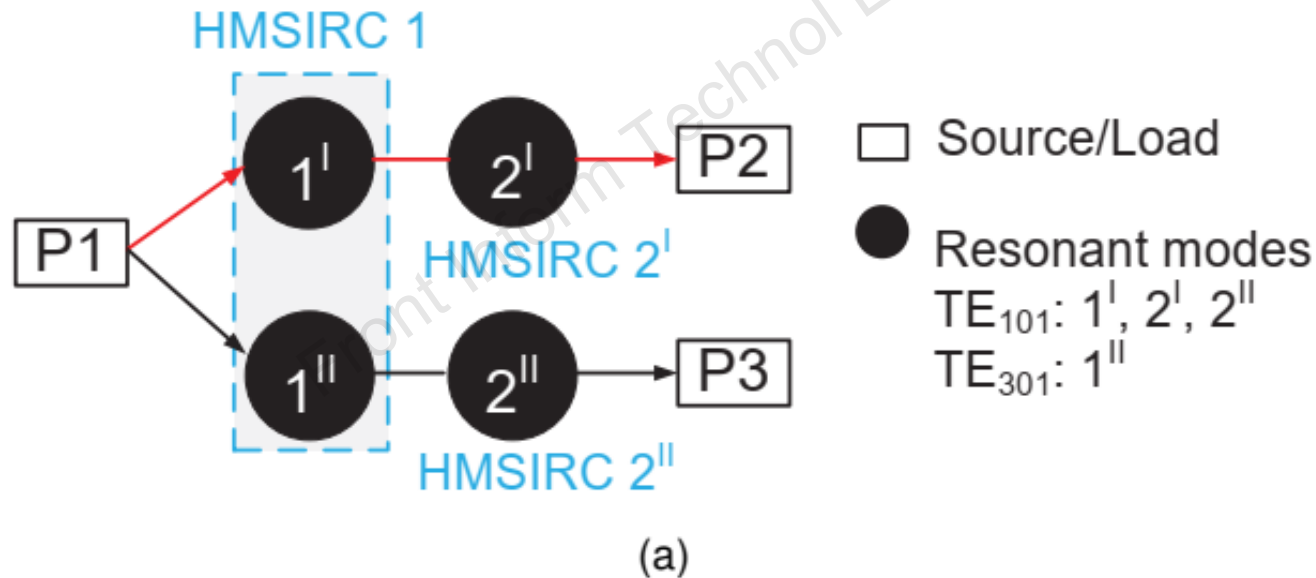


Fig. 2 Proposed SIW diplexer based on HMSIRCs: (a) coupling topology

Method

2. To achieve wide-stopband, the third mode in DMR and the second mode in SMRs should be suppressed. The second mode in SMRs is the TE_{102} mode. Due to the inhibition of the TE_{102} mode in SMRs, the first unsuppressed mode in SMRs is the TE_{301} mode, which specifies the stopband boundary of the diplexer. Consequently, the stopband of the proposed diplexer can be extended to $2.236f_1$ at most.

Table 1 Cases of higher-order mode characteristics of half-mode substrate-integrated rectangular cavity (HMSIRC) with different W/L values

	Case 1 [1, 1.633]	Case 2 [1.633, 2.828]	Case 3 [2.828, $+\infty$)
1 st mode	TE_{101}	TE_{101}	TE_{101}
2 nd mode	TE_{102}	TE_{301}	TE_{301}
3 rd mode	TE_{301}	TE_{102}	TE_{501}
f_2^r/f_1^r	[1.581, 1.784]	[1.374, 1.784]	(1, 1.374]
f_3^r/f_1^r	[1.784, 2.236]	[1.172, 1.837]	(1, 1.914]

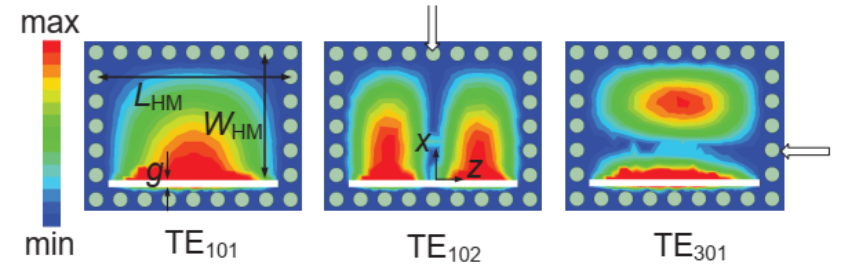


Fig. 1 Electric field magnitude distributions of TE_{101} , TE_{102} , and TE_{301} modes in a half-mode substrate-integrated rectangular cavity (HMSIRC). W_{HM} and L_{HM} denote the width and length of the HMSIRC, g is the width of the gap on the metal layer

Major results

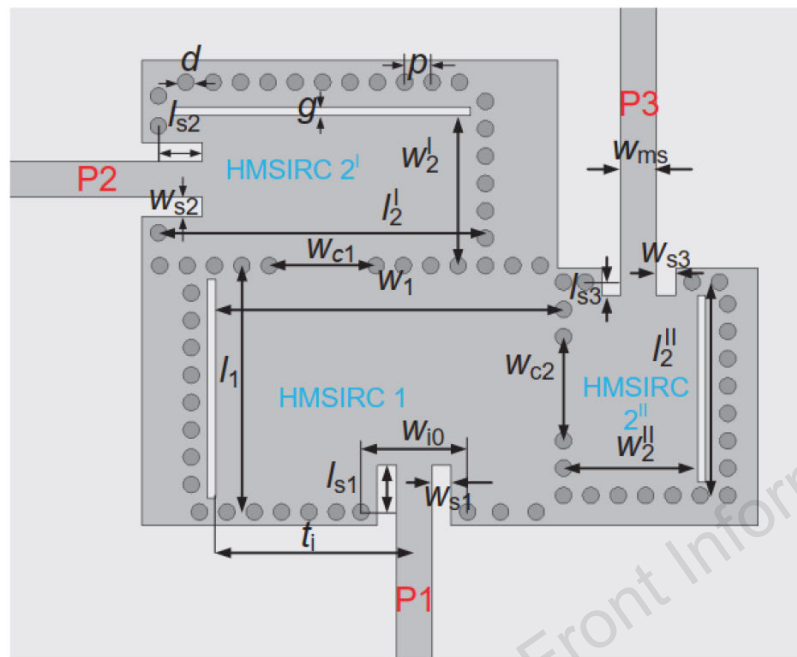


Fig. 2 (b) Geometric configuration

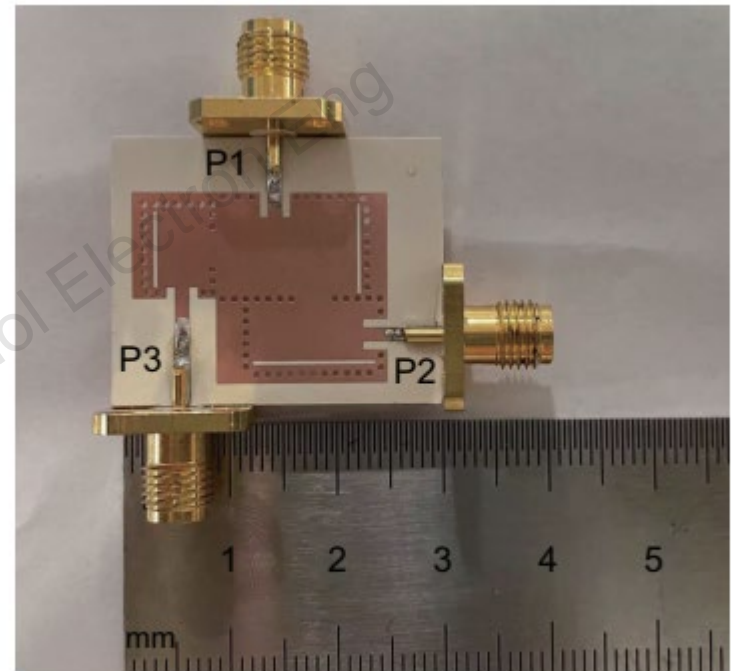


Fig. 5 Photograph of the fabricated prototype

Major results

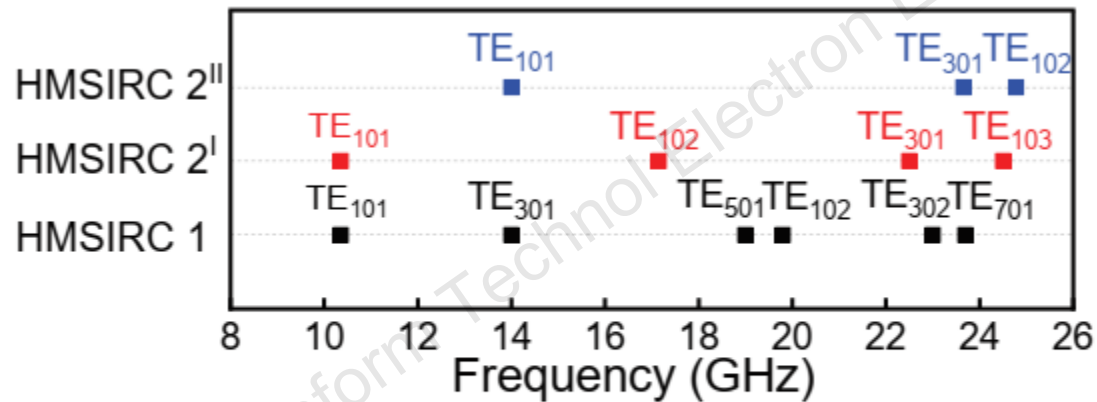


Fig. 7 Frequency spectrum of the initial resonances for the HMSIRCs in the proposed diplexer

Major results

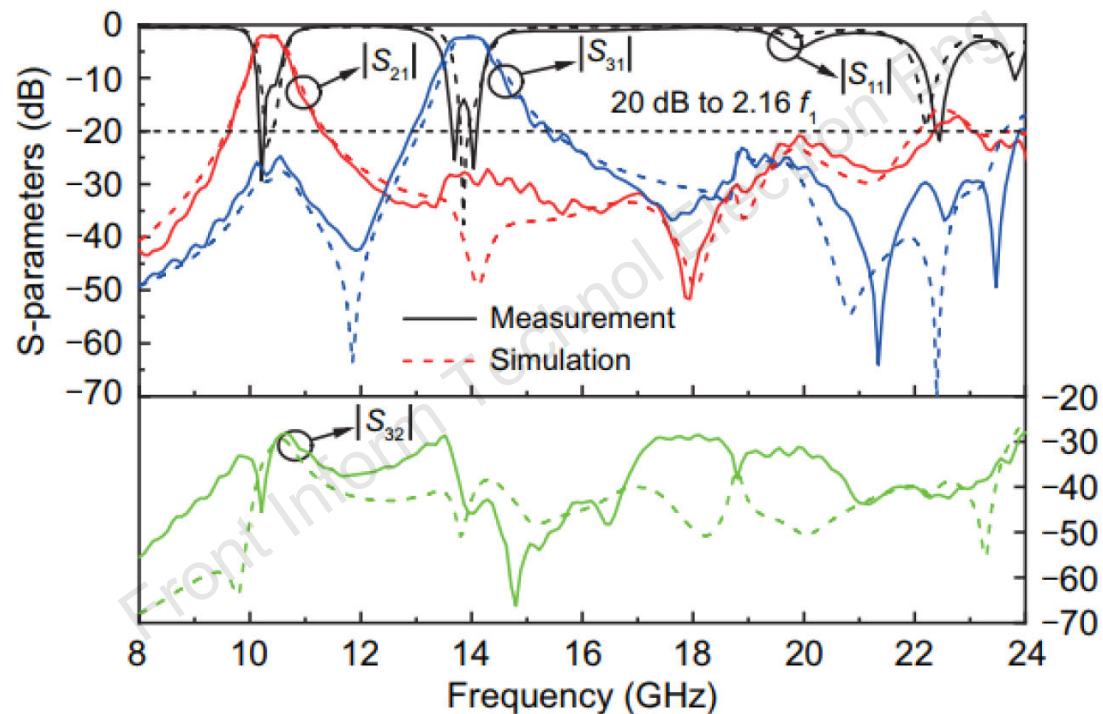


Fig. 4 Comparison between the simulation and measurement results of the proposed diplexer

Major results

Table 3 Comparison with other reported SIW diplexers

Reference	Order	f_1/f_2 (GHz)	-3 dB bandwidth/ FBW (%)	Isolation (dB)	Rejection/ Stopband	IL (dB)	Size (λ_g^2)
Zhou et al. (2018a)	3/3	12/14	4.9/5.65	27	20 dB/ $1.45f_1$	1.34/1.41	2.77
Iqbal et al. (2019)	2/2	10.5/13.5	3.71/1.7	42	20 dB/ $2f_1$	0.8/1.35	2.78
Zhou and Wu (2021)	3/3	3.5/5	4/3.2	45.8	20 dB/ $1.7f_1$	2.77/2.55	1.62
	4/4	3.5/5.5	3.43/2.55	27.6	20 dB/ $2.05f_1$	3.41/3.4	1.136
Xie et al. (2020)	2/2	10/12.25	4/3.2	20	24 dB/ $1.79f_1$	2.05/1.65	2.34
	2/2	8/12	3.43/2.55	20	20 dB/ $2.05f_1$	1.84/2.88	1.54
Ma et al. (2023)	3/3	12/14	2.04/2.44	22	20 dB/ $1.32f_1$	2.51/2.19	3.47
	3/3	12/14	3.73/3.99	47	20 dB/ $2.02f_1$	1.39/1.37	3.62
Liu et al. (2023)	4/4	34.95/36.44	1.73/1.39	28.9	20 dB/ $2.37f_1$	4.24/5.1	12.6
This work	2/2	10.34/13.9	5.7/5.83	28.1	20 dB/ $2.16f_1$	2.03/2.33	1.363

Conclusions

1. A planar SIW diplexer is proposed based on HMSIW technology, featuring a wide-stopband and a small circuit size.
2. The dimensions of the diplexer are $22.5 \text{ mm} \times 17 \text{ mm}$ ($1.343\lambda_g \times 1.015\lambda_g$). The measured stopband extends to $2.16f_1$ with a rejection of more than 20 dB.
3. A second-order prototype based on TE₁₀₁/TE₃₀₁ DMR is designed and fabricated, covering a wide range of frequency ratios.



Ziyu ZHOU received her B.S. degree in Integrated Circuit Design and Integrated Systems from Xidian University, Xi'an, China, in 2020. Since 2022, she has been a Ph.D. candidate in Integrated Circuit Science and Engineering at Xidian University. Her current research interests include advancing filters and high-performance RF front-ends based on substrate integrated waveguides.



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