Compact Dual-/Tri-band SIW Filtering Antennas Using Cavity-Backed Slots

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***Abstract*—Compact dual-/tri-band SIW filtering antennas using cavity-backed slots are proposed. By etching a pair of open-loop slots (OLSs) and a slot on the SIW cavity, the slot can be treated as a radiator as well as a resonator. As a result, a dual-band filtering performance with four radiation nulls (RNs) is obtained, achieving high selectivity and good out-of-band suppression. The formation mechanism of RNs is analyzed. To further prove this design method, two pairs of OLSs and a horizontal straight slot are simultaneously etched on the SIW cavity, achieving the tri-band filtering response with 6 RNs in the stopband. Two prototypes are fabricated and tested for demonstration, showing the excellent dual-band filtering response with center frequencies of 4.56 and 5.7 GHz, and the superior tri-band filtering response with center frequencies of 4.1, 4.82 and 5.62 GHz. Moreover, both designs exhibit the compact size of 0.4 ×0.5 λ^2_0 due to compact structures.**

Keywords*—*Compact, dual-band, tri-band, SIW filtering antenna, cavity-backed slot

I. Introduction

In recent years, modern communication systems are moving towards miniaturization, integration and multiple functions. Thus, the RF front-end components with compact structures and multiple functions are highly demanded.

Due to the advantages of reducing the number of antenna elements, decreasing the cost, increasing the channel capacity, transceiving with frequency diversity, avoiding the additional cascaded filters and reducing the insertion loss, multi-band filtering antennas have become the good candidate for modern communication systems. Recently, some multi-band filtering antennas have been reported successively [1]-[5]. In [1]-[3], the dual-band filtering antennas in the form of microstrip were presented, aching good filtering performance in both operating passbands. In [4]-[5], the tri-band microstrip filtering antennas with multiple radiation nulls (RNs) were implemented. However, the extra filtering circuits with large size and complex structures were used by these multiple filtering antennas, which inevitably increases the overall antenna volume and extra losses.

SIW filtering antennas own the merits of high quality factor, high power-handing capability and low insertion loss [6], which have been massively investigated by scholars. However, most of these designs work in a single passband. Only several SIW filtering antennas operating in dual-band were successfully implemented [7]-[9]. In [7] and [8], the dual-band SIW filtering antennas using multiple cascaded SIW cavities were designed, resulting in good selectivity and out-of-band suppression. But, because of cascaded SIW cavities, the size is large, the processing difficulty is accordingly increased. Although the dual-band filtering response was achieved using the half mode SIW cavity [9], it still occupied a large size. In addition, to the best of our knowledge, the tri-band filtering antenna utilizing SIW technology has not been reported.

Here, compact dual-band and tri-band SIW filtering antennas using cavity-backed slots are proposed. Through etching a pair of open-loop slots (OLSs) and a horizontal slot on the SIW cavity, all slots act as radiators as well as resonators. Four RNs can be introduced in the stopband, resulting in the great dual-band filtering performance with sharp roll-off and high stopband suppression. By further etching two pair of OLSs and a slot, the tri-band filtenna with 6 radiation nulls can be achieved, further proving our proposed method of designing SIW multi-band filtering antennas. Both designs are fabricated and tested, reasonable agreement between simulation and measurement values can be observed.

II. Dual-band SIW filtering antenna

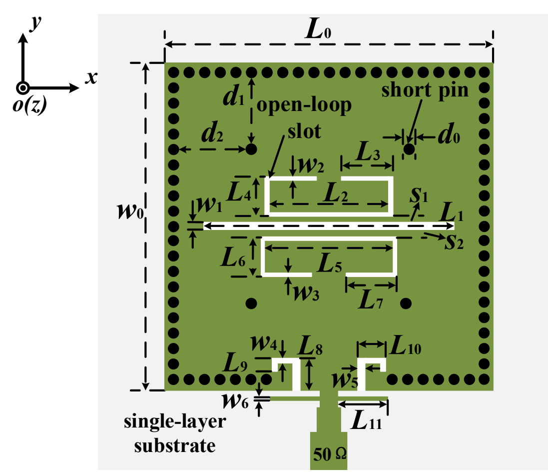

Fig. 1. Structure of dual-band SIW filtering antenna.

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A. Antenna Configuration

Fig. 1 is the structure of the proposed dual-band SIW filtenna, which is printed on the single-layer substrate Rogers 4350 with the loss tangent of 0.004, the dielectric constant of 3.48 and the thickness of 1.524 mm. It can be seen, the proposed design is simple, which only is composed of a SIW cavity, two OLSs with the width of W_2/W_3, a horizontal straight slot with the length of L_1, four short pins, and a couple of impedance matching branches loaded on the feedline. In details, the two OLSs are etched back-to-back on the top layer of the SIW cavity, and the horizontal straight slot is embedded in them. The four short pins are symmetrically positioned in the SIW cavity. There is a GCPW transition structure between the SIW cavity and the microstrip transmission line. The overall structure of the antenna is symmetrical on the left and right.

B. Formation Mechanism of Radiation Nulls

The simulated return loss and gain of the proposed dual-band SIW filtering antenna are presented in Fig. 2. Obviously, four deep RNs can be observed in the stopband. In order to study the generation mechanism of the 4 RNs, the surface current distributions on the top layer of the SIW cavities at corresponding nulls are given in Fig. 3. In Fig. 3(a), the current near the OLS_1 is out-of-phase to the current at the feedline. Thus, RN_1 can be generated by source-load coupling [10]. From Fig. 3(b)-(d), the currents at RN_2-RN_4 are reserved inside and outside the slots, as shown by the black arrows. As a results, these out-of-phase currents are cancelled to created RN_2-RN_4.

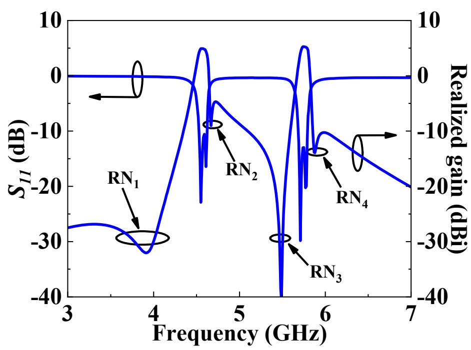
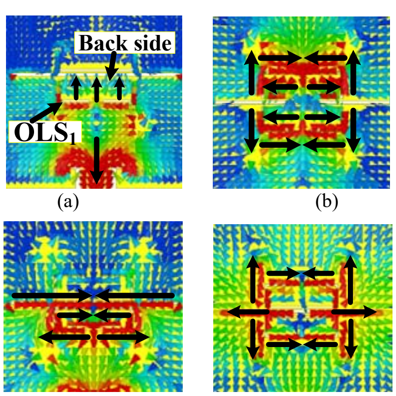


Fig. 2. Simulation of the proposed dual-band SIW filtering antenna.



(a) (b)

(c) (d)

Fig. 3. (a) RN_1, (b) RN_2, (c) RN_3 and (d) RN_4.

C. Simulated and Meaured mesults

The simulated and tested results are plotted in Fig. 4. Two operating passbands of 4.56 GHz and 5.7 GHz are obtained. Four deep RNs are located at 3.8, 4.65, 5.46 and 5.85 GHz, separately, realizing good dual-band filtering performance with good selectivity and deep out-of-band suppression. The radiation pattern are illustrated in Fig. 5, which the good directional radiation properties are obtained. In addition, the small size of 0.40 $\lambda_0 \times 0.53\ \lambda_0$ is acquired.

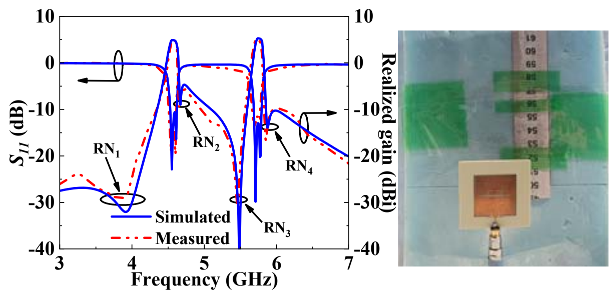
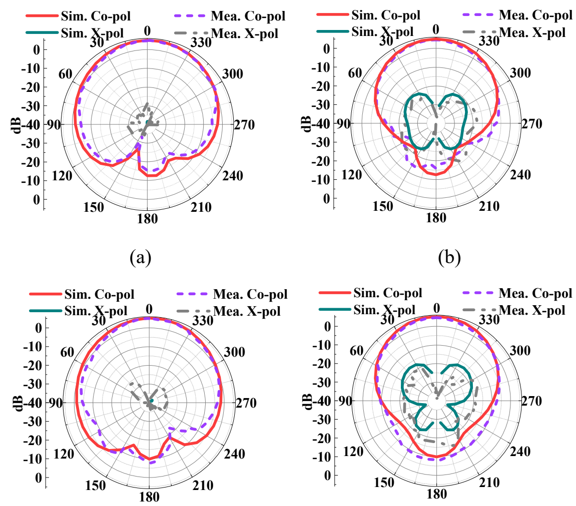


Fig. 4. Simulated and mearures results of the proposed dual-band SIW filtering antenna.



(a) (b)

(a) (b)

Fig. 5. (a) E-/(b) H-plane of 4.56, and (c) E-/(d) H-plane of 5.7 GHz.

III. TRIPLE BAND SIW FILTERING ANTENNA

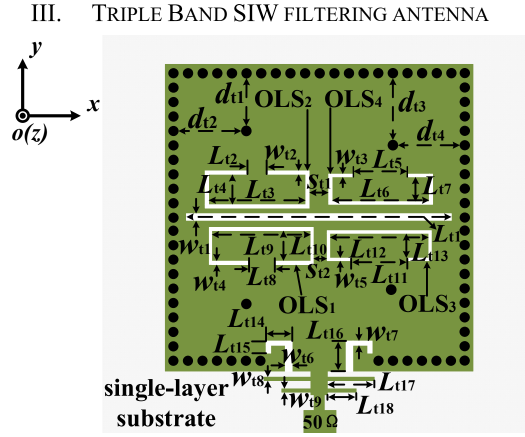


Fig. 6. Configuration of the proposed triple band SIW filtenna.

A. Proposed structure

To further prove our design concept. The triple band SIW filtenna is established, which its configuration is displayed in Fig. 6. The (OLS_1 and OLS_2) and (OLS_3 and OLS_4) are on the left and right side of the SIW cavity, respectively. In addition, one more couple of stubs with the parameter of L_{t18} is located on the microstrip feedline.

B. Simulated and Measured Results

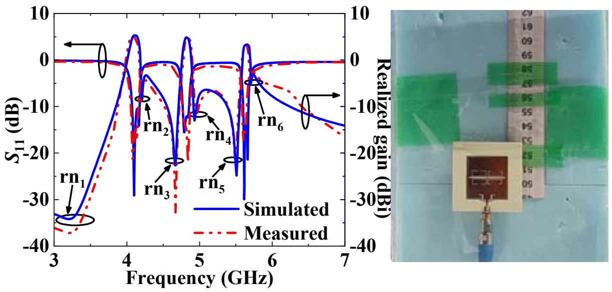


Fig. 7. Simulated and tested results of triple band SIW filtering antenna.

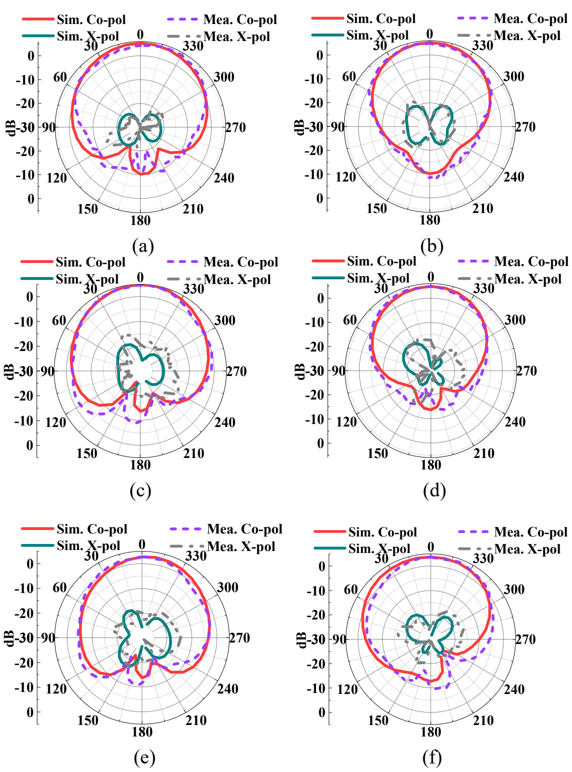


Fig. 8. (a) E-/(b) H-plane of 4.1 GHz. (c) E-/(d) H-plane of 4.82 GHz. (e) E-/(f) H-plane of 5.62 GHz.

The simulated and measured results of the proposed tri-band SIW filtering antenna are presented in Fig. 7. With the same operating mechanism as the dual-band SIW filtenna, the good tri-band filtenna cneterd at 4.1, 4.82 and 5.62 GHz with 6 RNs are obtained. Moreover, a small size of 0.40 $\lambda_0 \times 0.58\ \lambda_0$ is realized. Besides, the simulated and measured radiation patterns are show in Fig.8.

IV. CONCLUSION

In this paper, compact dual-band and tri-band SIW filtering antennas using cavity-backed slots are proposed. By respectively loading one and two pairs of OLSs with embedded straight slot on the SIW cavity, the excellent dual-/tri-band filtering performance can be achieved, introducing four and six RNs in the stopband, separately, and showing high selectivity and deep stop suppression. Both designs feature compact and simple structures, and exhibit the compact size of $0.4 \times 0.5\ \lambda^2_0$

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