A Broadband SIW-Based Filtering Antenna for 5G mmWave Base Station Application

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***Abstract*—A broadband mmWave base station filtering antenna based on substrate-integrated-waveguide (SIW) structure is presented in this paper. The base station antenna consists of a pair of patches, two groups of L-shaped probes, and an SIW feeding structure. A wide band is obtained by etching the defected ground structure (DGS) and barbell slot on the SIW and loading the differential-fed L-shaped probe. Meanwhile, the filtering response is obtained by etching H-shaped slots on each radiating patch and adjusting the structure of SIW and probe. Simulation results show that the proposed antenna achieves an impedance bandwidth of 23.72-29.90 GHz and the realized gain is better than 6.3 dBi. The out-of-band suppression is greater than 12 dB.**

***Index Terms*—Filtering antenna, millimeter-wave, broadband, base station antenna**

I. Introduction

With the increasing demand for speed and capacity in mobile communications, mmWwave antennas play an important role in communication systems with high data rates and wide operating bandwidth. In 5G mmWave applications, antennas with filtering functions can suppress out-of-band noise to improve signal-to-noise ratio. Therefore, millimeter-wave antennas with large bandwidth and filtering functions are getting more and more attention.

For the traditional filtering antenna, antennas and filters work separately, requiring matching circuits or devices to connect [1], which increases system loss and additional physical size. The filtering antenna can be realized by adding specific structures to the feed structure. Examples include loading short-circuit branches [2], open-circuit stepped-impedance resonators (OCSIRs) [3], and designing absorptive filtering feed network [4] to introduce a filtering response on the feed, which reduces size and insertion loss. Specific parasitic components such as parasitic patch [5], slot [6] or Metasurface [7] were employed in antenna structures to achieve filtering response without using complex feeding structures.

Owing to the advantages of low transmission loss, low cost, and ease of integration, substrate-integrated-waveguide (SIW) is considered an excellent choice in millimeter-wave antenna design. In this article, a broadband filtering antenna is proposed. A wideband filtering antenna is obtained by adding L-shaped probes and defected ground structure (DGS) based on SIW. The proposed antenna can well cover 5G mmWave frequency bands (n257/n258/n261 bands: 24.25-29.5 GHz) and has out-of-band suppression characteristic, which can be well used in 5G mmWave base station applications.

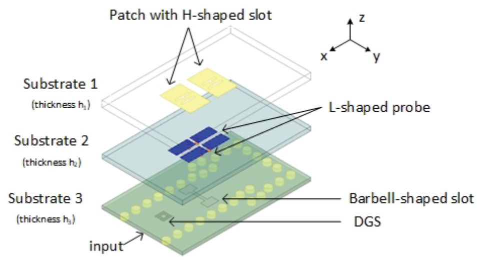
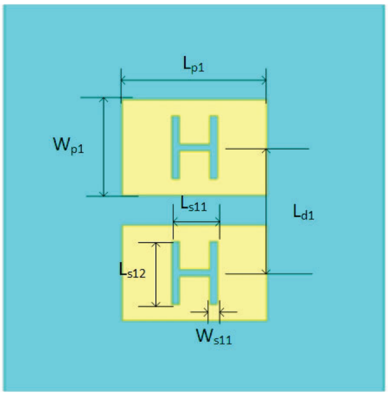


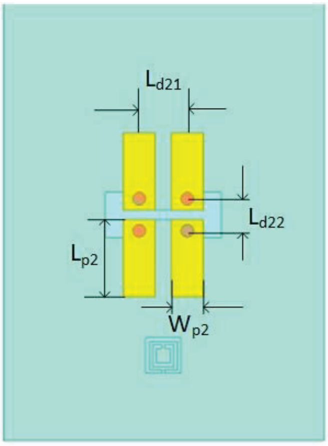
Fig. 1. 3D view of the proposed filtering antenna.

II. Antenna Design

As shown in Fig. 1, the proposed filtering antenna is a multilayer structure. The upper and middle substrates (substrate 1 and substrate 2) use Rogers RT/duroid 5880 with dielectric constant of 2.2 and loss tangent of 0.0009, where the thickness of substrate 1 (h_1) is equal to 0.787 mm and the thickness of substrate 2 (h_2) is equal to 0.6 mm. The bottom substrate (substrate 3) uses Rogers RO4003 with a dielectric constant of 3.55 and electrical loss tangent 0.0027 (the thickness of substrate 3: h_3 = 0.4 mm). In Fig. 2(a), the upper surface of substance 1 is printed with a pair of symmetrical radiation patches in which H-shaped slots are etched. In substrate 2, two groups of L-shaped probes are loaded on the two outer sides of the coupling slot, shown as Fig. 2(b). Thus the radiation patch antenna is fed by two groups of differential L-probes to obtain a wide band. As shown in Fig. 2(c), substrate 3 is an SIW feeding structure, and its upper surface is etched with a barbell slot and open-loop DGS. The slot can feed two pairs of probes differentially, and the barbell slot can adjust the impedance matching. DGS can expand bandwidth. SIW is designed as a structure with three different widths, which can well adjust the inherent radiation null generated by SIW. Table I shows the final optimized parameters.



(a)



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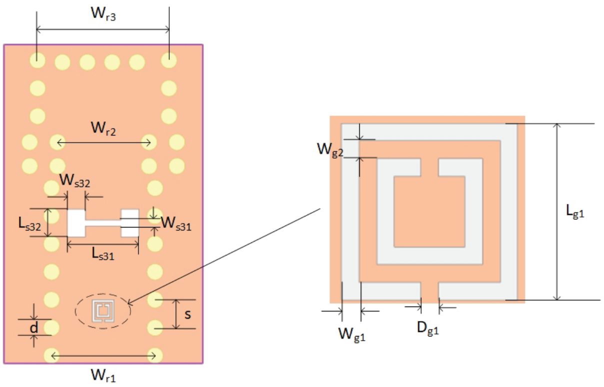
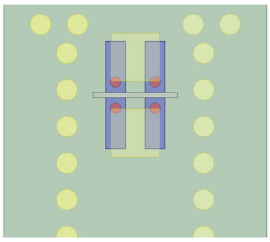


(c)

Fig. 2. Configuration of the proposed antenna. (a) Substrate 1. (b) Substrate 2. (c) Substrate 3.

TABLE I
GEOMETRIC PARAMETERS (UNIT:MM)

Parameter	L_{p1}	W_{p1}	L_{d1}	L_{s11}	W_{s11}	L_{s12}
Value	3.8	2.5	1.65	0.95	0.2	1.65
Parameter	L_{p2}	W_{p2}	L_{d21}	L_{d22}	d	s
Value	2.4	1.1	1.5	1	0.8	1.4
Parameter	W_{r1}	W_{r2}	W_{r3}	L_{s31}	W_{s31}	L_{s32}
Value	5.2	4.6	6.6	3.6	0.3	1.4
Parameter	W_{s32}	L_{g1}	W_{g1}	W_{g2}	D_{g1}	
Value	0.3	1.1	0.11	0.11	0.11	



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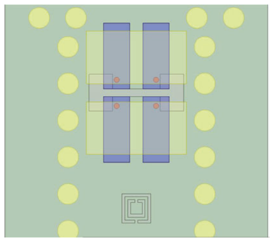

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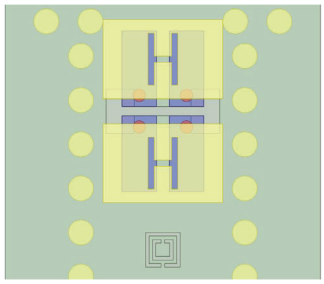

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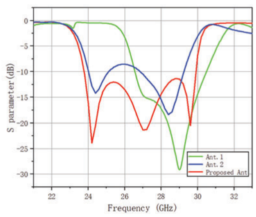
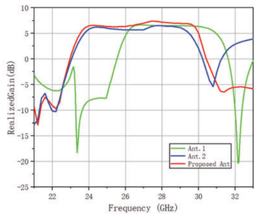
Fig. 3. Configuration of the proposed antenna. (a) Ant. 1. (b) Ant. 2. (c) Proposed antenna.



(a)

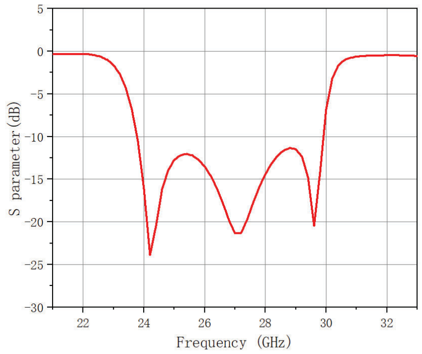


(b)

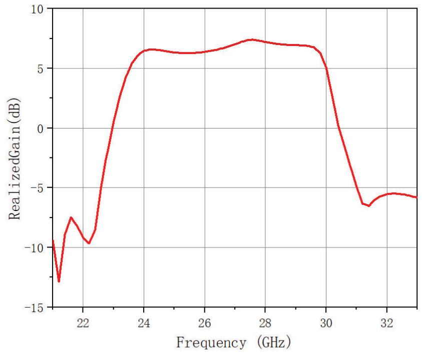
Fig. 4. Comprision of Ant. 1, Ant. 2 and Proposed antenna. (a) S-parameters. (b) Realized gain.

Through the changes from the original antenna (Ant. 1) to the transition antenna (Ant. 2) to the finally proposed filtering antenna (Proposed antenna), the working mechanism is analyzed, as shown in Fig. 3, and then the performance of these three antennas is compared and discussed. Ant. 1 consists of an SIW, two pairs of L-shaped probes, and a pair of patches. On the basis of Ant. 1, the rectangular slot is modified into a barbell slot and the defected ground structure is added on the top surface of SIW to obtain Ant. 2. The proposed filtering antenna is obtained by etching H-shaped slots on each radiating patch of Ant 2.

As shown in Fig. 4, Ant. 1 has an impedance bandwidth of 26.3-30.7 GHz with two radiation nulls in the lower resistance band and one radiation null in the upper resistance band. After adding the barbell slot and the defected ground structure, Ant. 2 has a wider impedance bandwidth, and at the same time, the two radiation nulls of the lower lower resistance are close

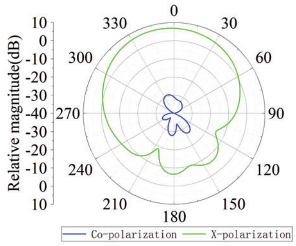


(a)

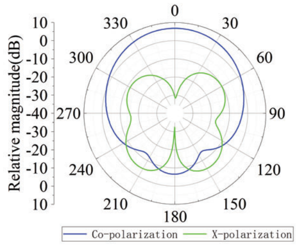


(b)

Fig. 5. Performance of proposed filtering antenna (a) S-parameters. (b) Realized gain.



(a)



(b)

Fig. 6. Radiation patterns of proposed filtering antenna at 27 GHz. (a) E-plane, (b) H-plane.

together to optimize the suppression of the lower resistance bandwidth. After the patch is etched into the H-shaped slot, the proposed antenna has a wider stopband in the upper stopband. After optimizing the parameters, a wider impedance bandwidth is obtained.

III. Simulation Result And Discussion

In Fig. 5(a), the simulation S-parameter of the proposed filtering antenna is displayed. The simulated operating frequency band is 23.72-29.90 GHz. The peak realized gain of the proposed filtering antenna is displayed in Fig. 5(b). The proposed antenna can achieve a realized gain of more than 6.3 dBi, and the average realized gain is 7 dBi. The out-of-band suppression is better than 12 dB, which proves that the proposed filtering antenna has a good filtering effect. Radiation patterns of the proposed filtering antenna at 27 GHz are shown in Fig. 6.

IV. Conclusion

In this paper, a broadband filtering antenna is proposed, covering a bandwidth of 23.05% from 23.72 to 29.90 GHz ($|S11| <$ -10 dB). The proposed antenna achieves a peak realized gain of 6.9 ± 0.6 dBi and the out-of-band suppression is greater than 12 dB. The proposed antenna achieves large bandwidth, covering multiple frequency bands of millimeter-wave (n257/n258/n259 band: 24.25-29.5 GHz), and has good filtering characteristic, which can be a competitive candidate for 5G mmWave base station applications.

Acknowledgment

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