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Stacked arrangement of substrate integrated waveguide cavity-backed semicircle patches for wideband circular polarization with filtering effect

Key words: Circularly polarized; Filtering response; Patch antenna; Substrate integrated waveguide

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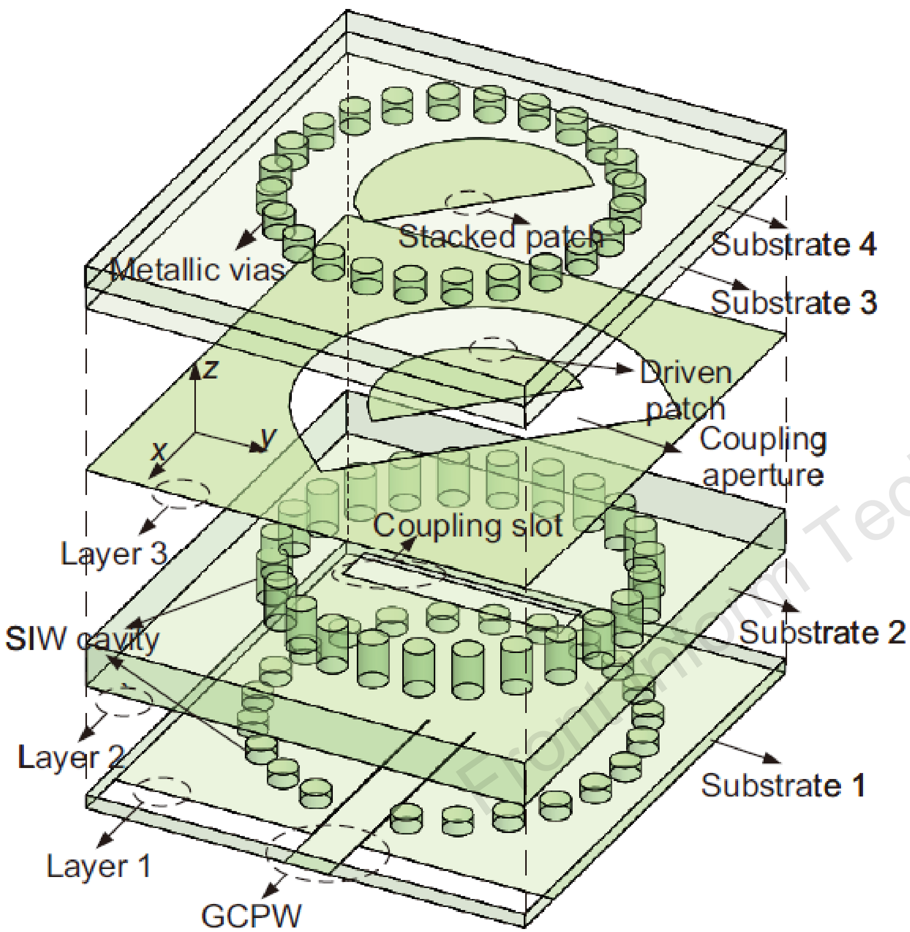
Motivation

- As the development of satellite wireless communications leads to congestion in traditional frequency bands, there will be a preference for higher frequency bands, such as X- and Ku-band, to meet the growing demand for capacity.
- Substrate integrated waveguide (SIW) exhibits excellent performance in terms of high *Q* value and low loss, and the more important feature is that it is suitable to work with planar structures as the last-order resonant element of the whole antenna.
- Filtennas achieve compact integration of band pass filters and antennas, while avoiding the transition loss associated with interconnections.

Configuration of the proposed antenna

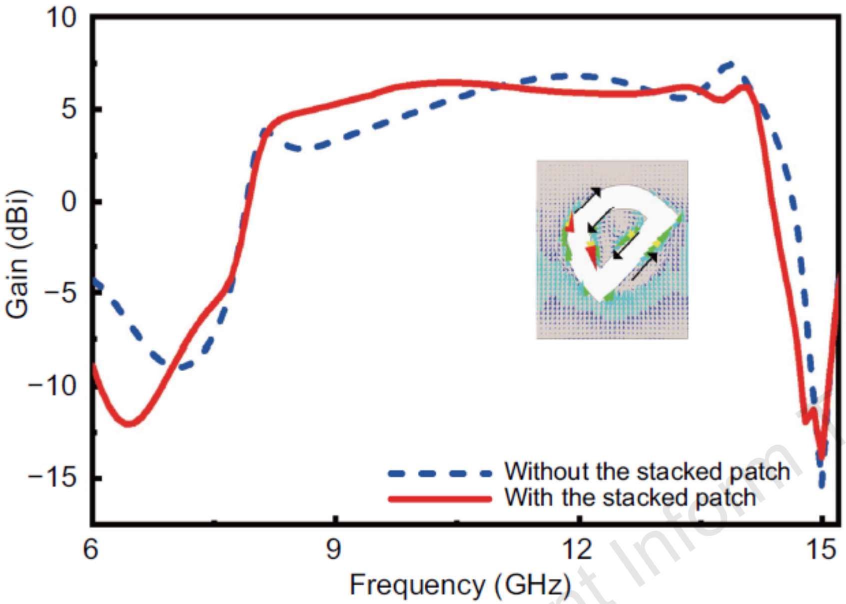


Configuration of the proposed antenna

- Configuration
  - Four-layer dielectric substrates of Rogers 5880, consisting of three cavity layers and an isolation layer.
  - A 50 Ω grounded coplanar waveguide (GCPW) is adopted as feeding element.
  - The driven patch is embedded in the aperture supported by the SIW cavity to produce a bandpass filtering effect.
  - The chamfered semicircle patch on the top layer serves as the stacked patch, while collaborating with the slot to deliver circularly polarized (CP) radiation.

Filtering and stacking characteristics

- Operating mechanism

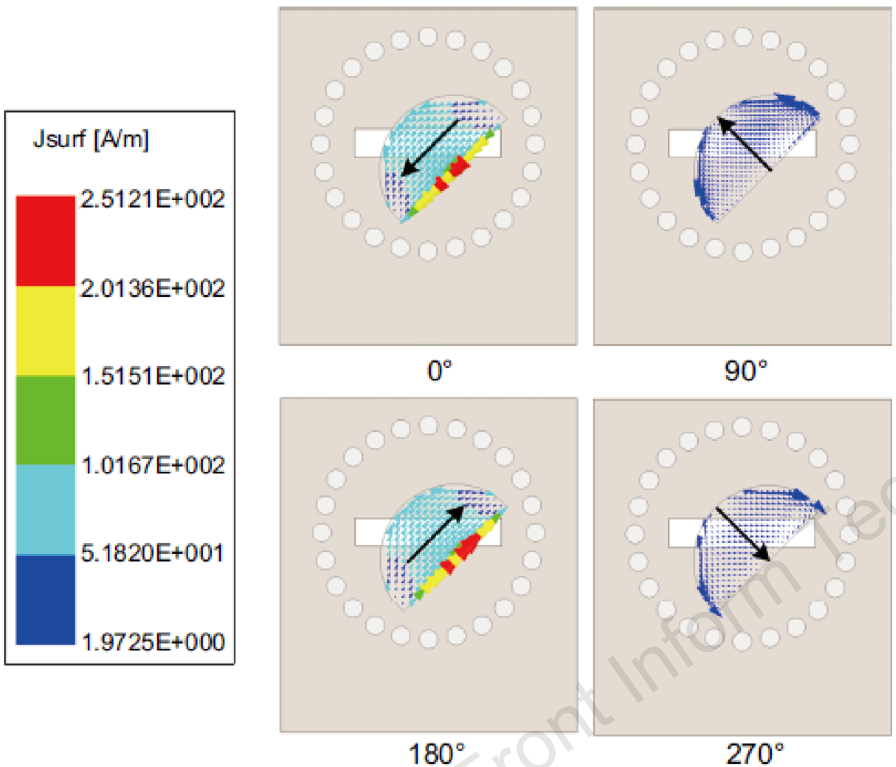


Gain curves & current distribution

- One radiation null created toward the boresight can be attributed to the centrosymmetric TM_{110} mode of the driven patch.
- The other radiation null created at higher frequency is the result of mixed coupling between the SIW cavity-backed aperture and the embedded patch.

- It is observed that the antenna with the stacked patch exhibits more stability in gain and more acute roll-off rates.

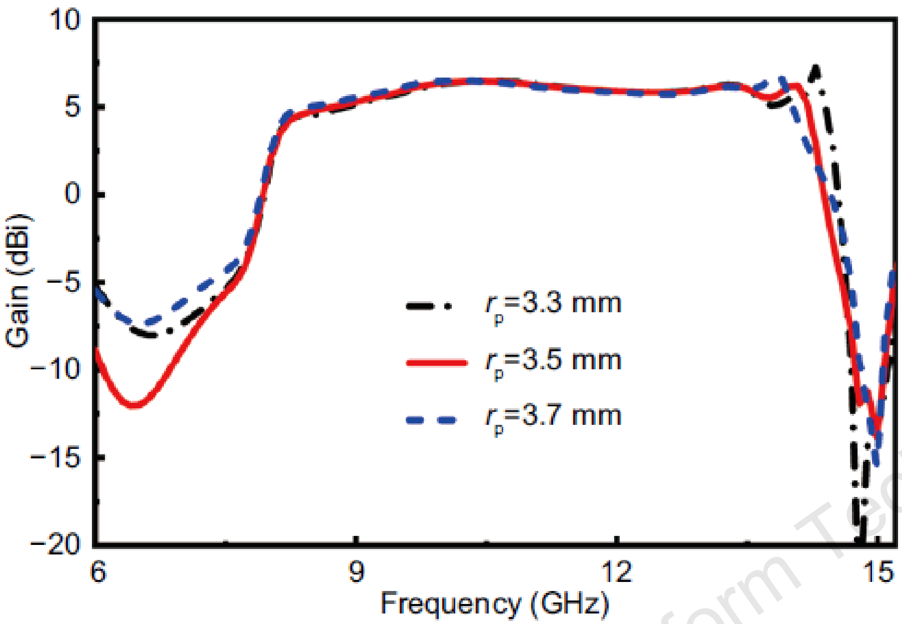
Circular polarization (CP) analysis

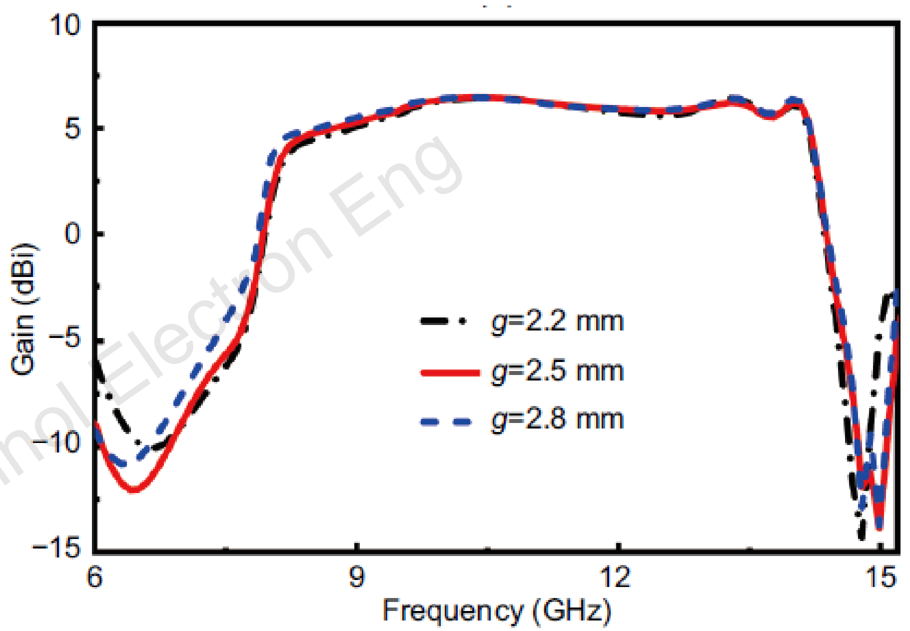


Current distributions on a rotated corner-truncated patch at 13.4 GHz with different phases

- The realization of CP requires two orthogonal components that satisfy specific preconditions.
  - A phase difference of 90° corresponding to the distance limit between the slot and the patch should be $\lambda/5$.
  - The equal magnitude corresponding to the rotation angle should maintain 45°.
- Two corners are symmetrically chamfered to extend the operating bandwidth and sharpen the passband edges.

Influence of driven patch



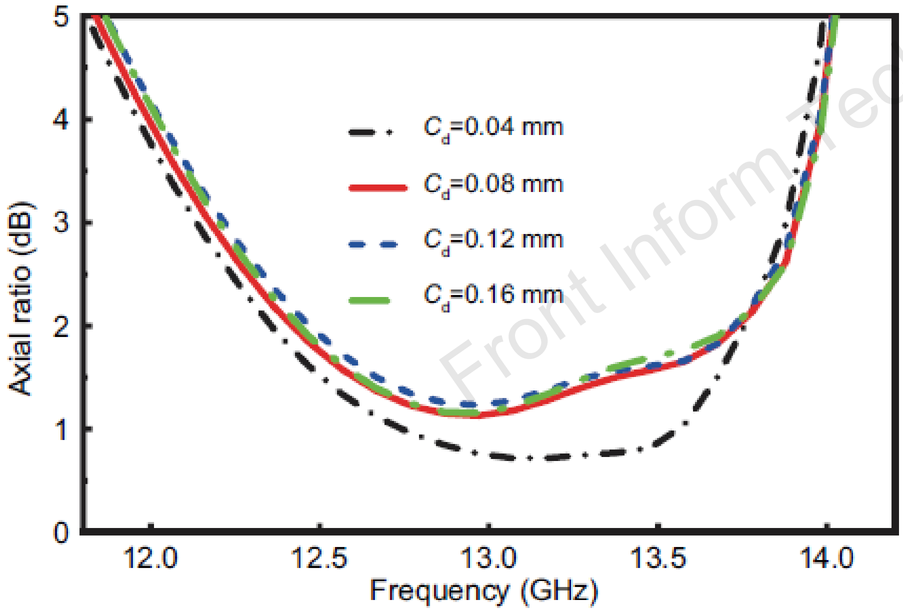


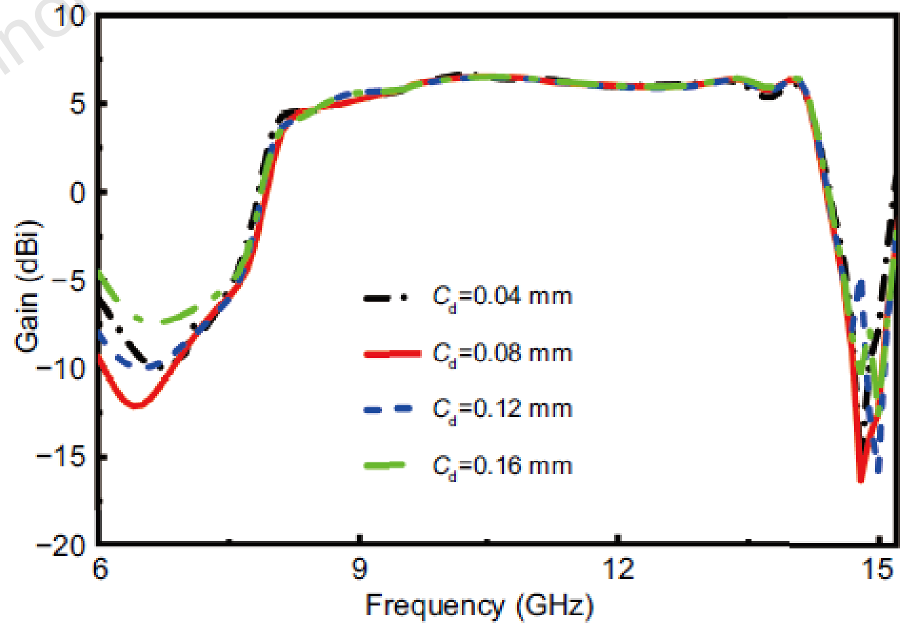
- The radius r_p of the patch affects null 1 by determining the microstrip resonant mode and further impacts null 2 by changing the mixed coupling relationship.

- The distance *g* between the embedded patch and the top surface of the SIW cavity affects mainly the frequency of null 2.

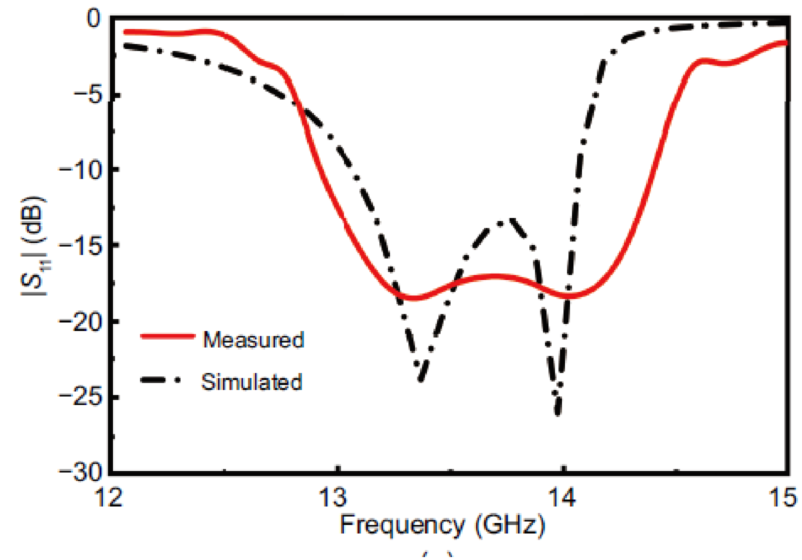
Influence of stacked patch

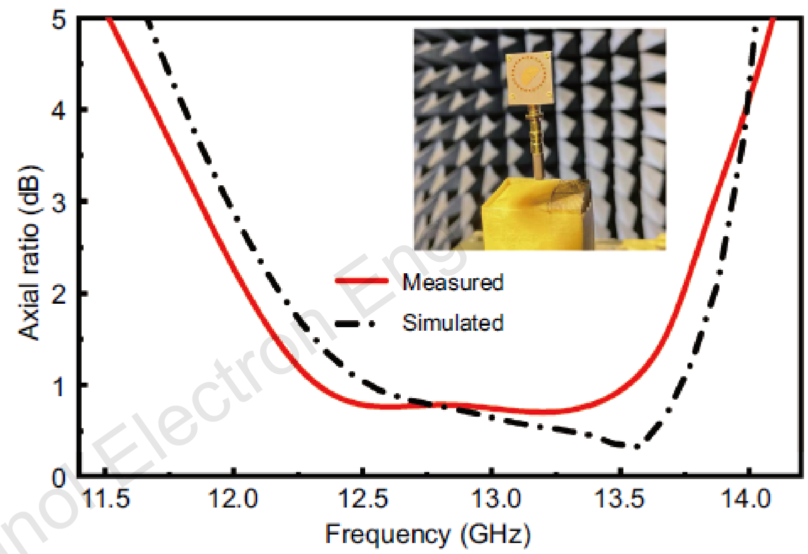
- From lengthy discussion of the chamfered side (C_d), it can be inferred that the stacked patch with two symmetrically truncated corners could be available for tuning axial ratio (AR) and beneficial to the filtering effect.

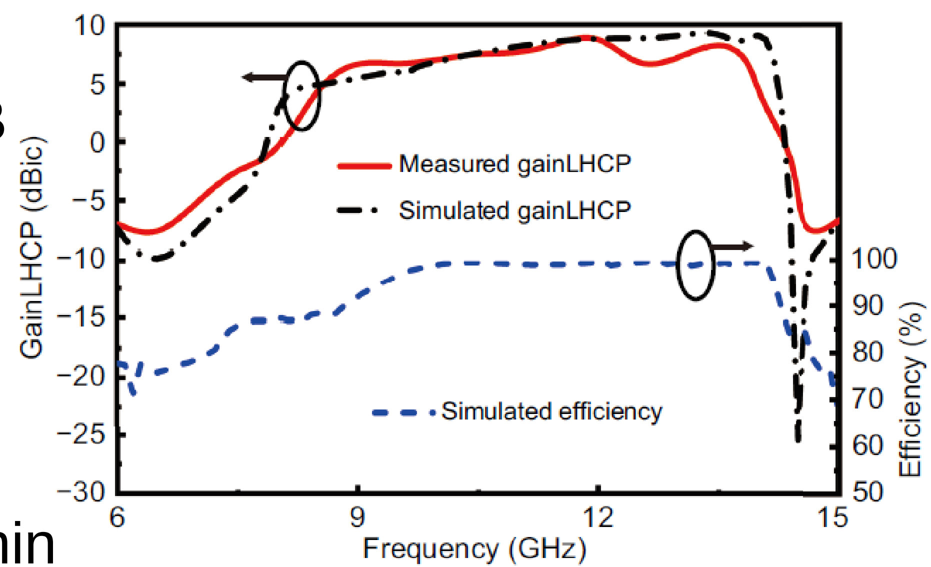




Experimental results







- The measured −10-dB impedance bandwidth is 10.83% and the 3-dB AR bandwidth is 15.54%.
- The measured peak gainLHCP reaches 8.9 dBic and the average in-band gainLHCP is >7 dBic.
- The overall efficiency is >80% within the entire operating frequency band.

CP filtering antennas comparison

Table 2 Comparison with other reported CP filtennas

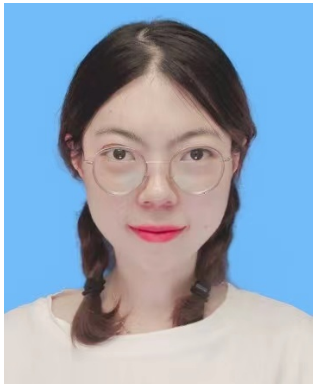
Reference	−10-dB $\lvert S_{11}\rvert$ (%)	3-dB AR (%)	Peak gain (dBic)	3-dB gain (%)	Profile (*λ_0)	Extra filtering circuit
Wu et al. (2018)	10.30	8.80	5.80	9.00	0.0280	Yes
Tang et al. (2020)	8.10	4.50	8.60	N.A.	0.0300	Yes
Jiang and Werner (2015)	12.50	12.50	5.20	N.A.	0.0700	Yes
Wang et al. (2020)	3.80	3.80	6.10	N.A.	0.0820	Yes
Li TJ and Gong (2018)	7.60	1.30	6.77	9.90	0.0292	No
Ji et al. (2021)	7.20	3.90	8.00	N.A.	0.0360	No
This work	10.83	15.54	8.90	50.87	0.1600	No

AR: axial ratio; CP: circularly polarized; N.A.: not applicable

- By comparison, this design achieves the most stable and the widest 3-dB gain bandwidth and good bandpass filtering response without any extra circuit.
- In addition, a wider AR bandwidth has also been implemented to improve practicality for more convenient applications.

Conclusions

- A novel stacked CP antenna with filtering effect based on SIW technology is presented and fabricated for demonstration.
- Experimental results suggest that this design produces a wide AR bandwidth and stable gain with two radiation nulls by means of multiple coupling between SIW cavities, embedded driven patch, corner-truncated stacked patch, and radiating slot.
- Without additional filter circuits and utilization of dominant resonant modes, a wide range of applications in X- and Ku-band satellite wireless communication will be facilitated.



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