Hai-yang XIA, Jin-can HU, Tao ZHANG, Lian-ming LI, Fu-chun ZHENG, 2020. Integrated 60-GHz miniaturized wideband metasurface antenna in a GIPD process. *Frontiers of Information Technology & Electronic Engineering,* 21(1):174-181. https://doi.org/10.1631/FITEE.1900453

Integrated 60-GHz miniaturized wideband metasurface antenna in a GIPD process

Key words: 60 GHz; Antenna-in-package (AiP); Coplanar-waveguide-fed (CPW-fed) ring resonators; Glass integrated passive device (GIPD); Metasurface antenna; Miniaturized antenna

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Motivation

1. Given the current packaging technologies, as the operating frequency and bandwidth of the 60-GHz band are high, it is still challenging to realize low-cost, compact, and high performance 60-GHz AiP.
2. For mm-Wave applications, up to now, several broadside radiation antennas have been realized using the integrated passive device technology. However, these antennas suffer from poor performance, large size, and complex structure.
3. For mm-Wave applications, the substrate material property is crucial for accurate antenna design and performance. Typically, most material manufacturers provide only material properties at low frequency, which will decrease the mm-Wave antenna simulation accuracy.

Main idea

1. With GIPD manufacturing technology, the proposed antenna was designed on a high dielectric constant glass substrate to achieve antenna miniaturization.
2. Compared with the conventional rectangular patch in the TM_{10} mode, the existence gaps between the patch units reduce the radiation aperture of this proposed antenna.
3. To expand bandwidth, with the feeding CPW-fed bow-tie slot, the metasurface patch supports the TM_{10} and antiphase TM_{20} modes simultaneously.

Method

1. To achieve antenna miniaturization, the proposed antenna is designed on the high dielectric constant glass substrate. Compared with the conventional rectangular patch in the TM_{10} mode, the existence gaps between the patch units reduce the radiation aperture of this proposed antenna.

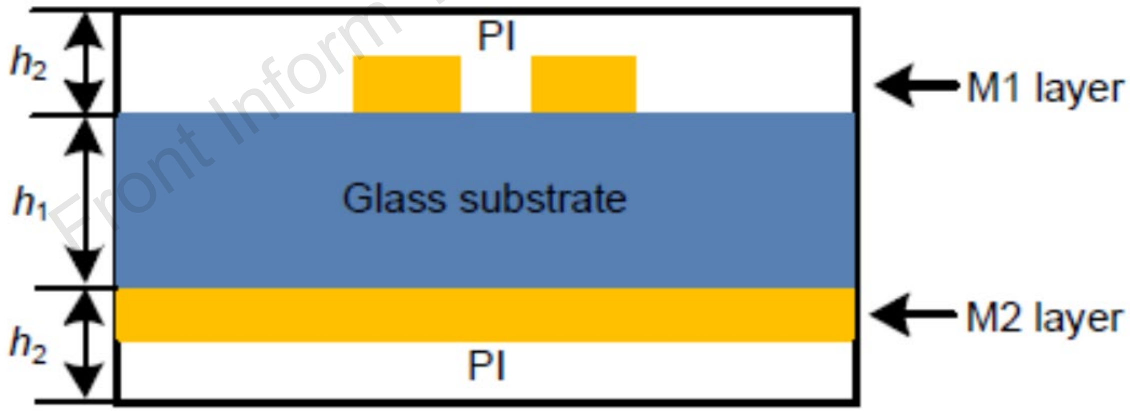
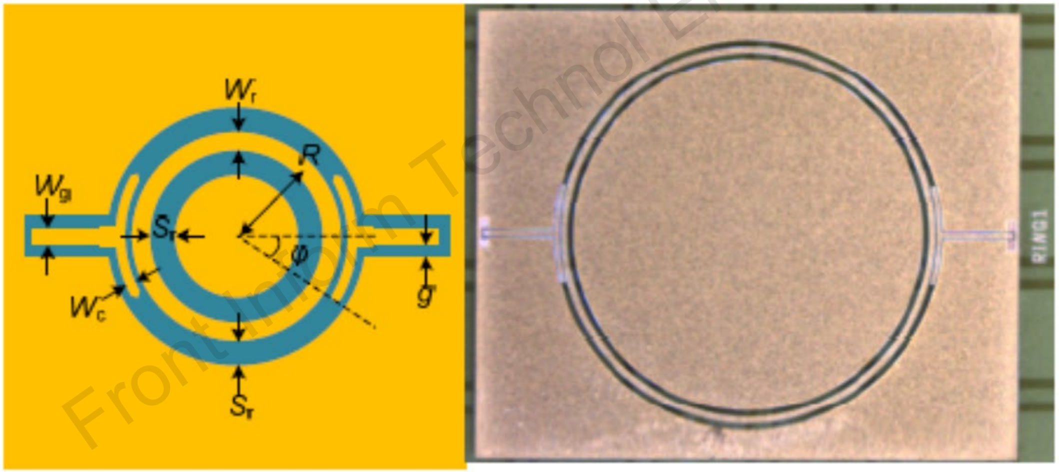


Fig. 1 Simplified cross-sectional view of the antenna layers

Method (Cont’d)

2. To improve the mm-Wave antenna simulation accuracy, a CPW-fed ring resonator method is used to extract the material properties of the glass substrate.



(a) (b)

Fig. 3 Layout of the CPW-fed ring resonator on the glass substrate for ground-signal-ground (GSG) probe testing (a) and photograph of the fabricated CPW-fed ring resonator (b)

Method (Cont'd)

3. With a narrower CPW-fed bow-tie slot and a larger extended angle θ, the bandwidth performance can be improved. To achieve broadband impedance matching, both an open stub and a high impedance line are added, providing capacitance and inductance effects, respectively .

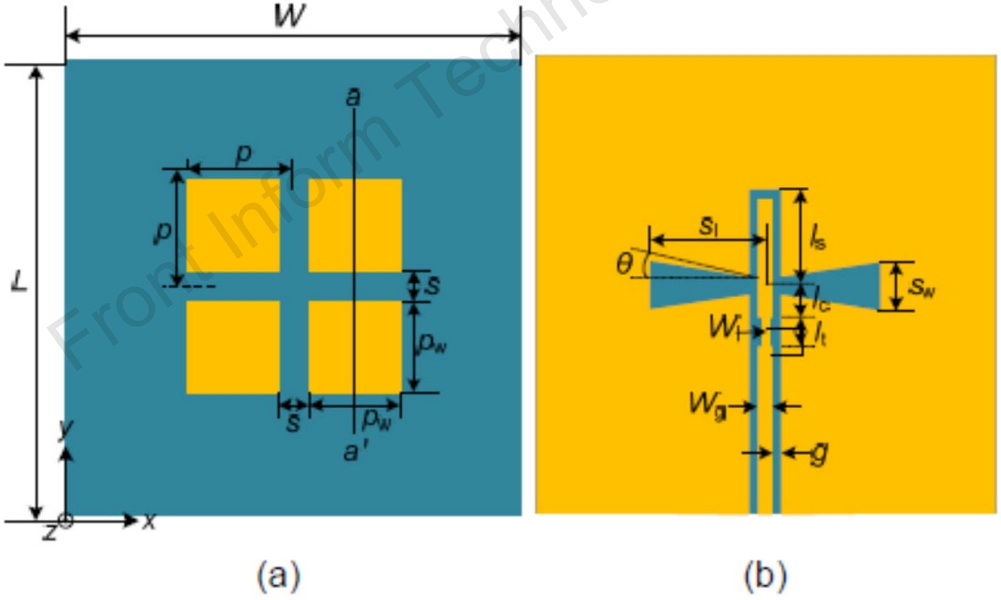


Fig. 6 Geometry of the proposed metasurface antenna: (a) top view; (b) bottom view

Method (Cont’d)

4. Based on the transmission line, the patch unit simulation model is proposed for dispersion relation extraction. The patch supports the TM_{10} and antiphase TM_{20} modes simultaneously, which are close to each other in the RH dispersion branch to improve the impedance bandwidth.

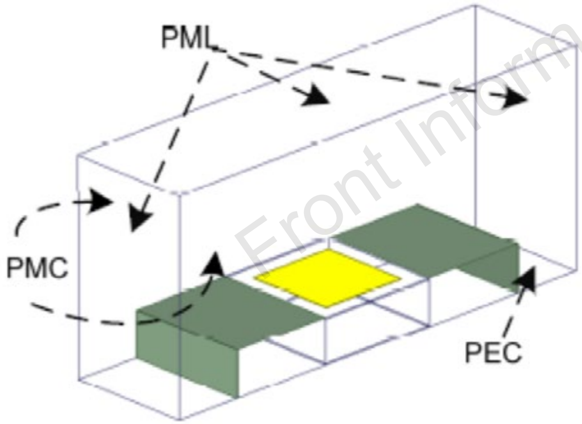


Fig. 7 Patch unit simulation model for the dispersion relation extraction

PMC: perfect magnetic conductor; PML: perfectly matched layer; PEC: perfect electrical conductor

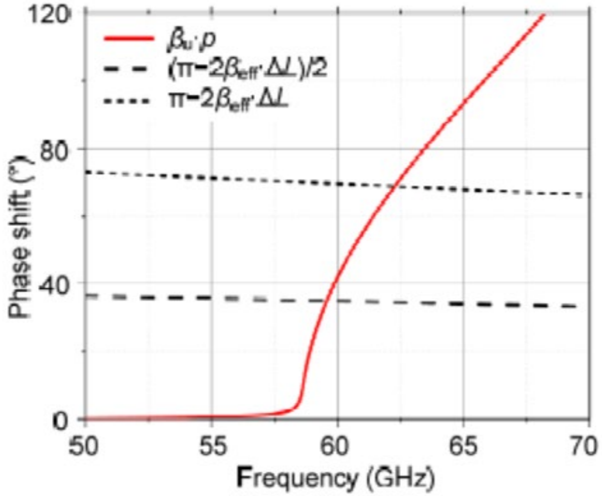


Fig. 10 Dispersion diagram of the patch unit model

Major results

CPW-fed ring resonator

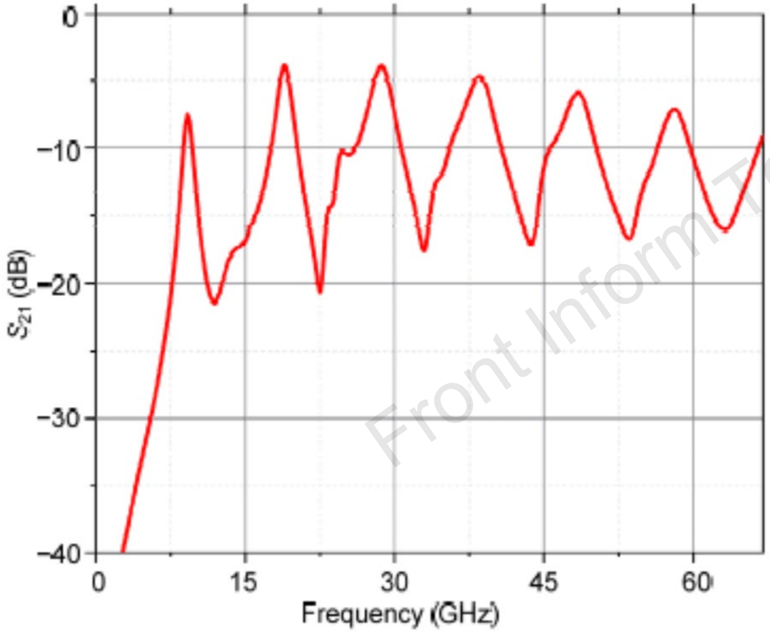


Fig. 4 Measured S_{21} of the CPW-fed ring resonator

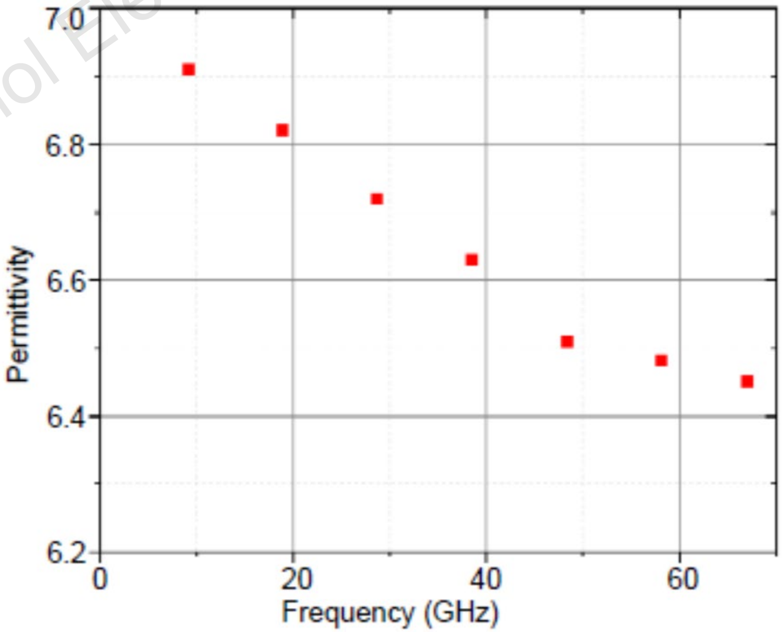


Fig. 5 Dielectric constant of the glass substrate

Major results (Cont'd)

Metasurface antenna

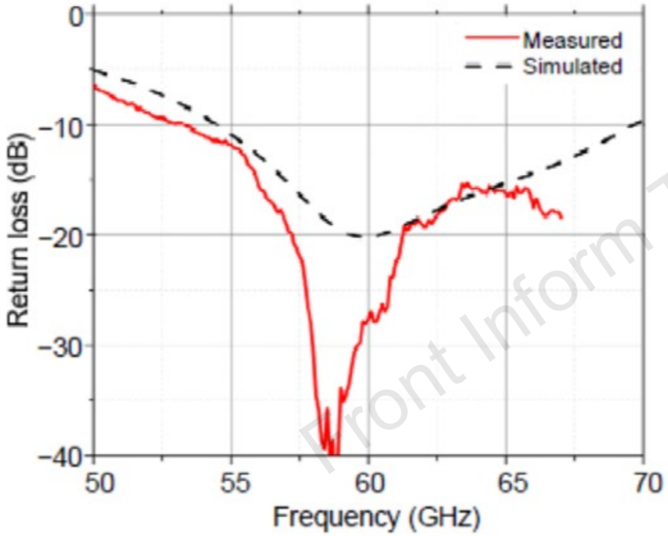


Fig. 12 Simulated and measured reflection coefficients of the proposed antenna

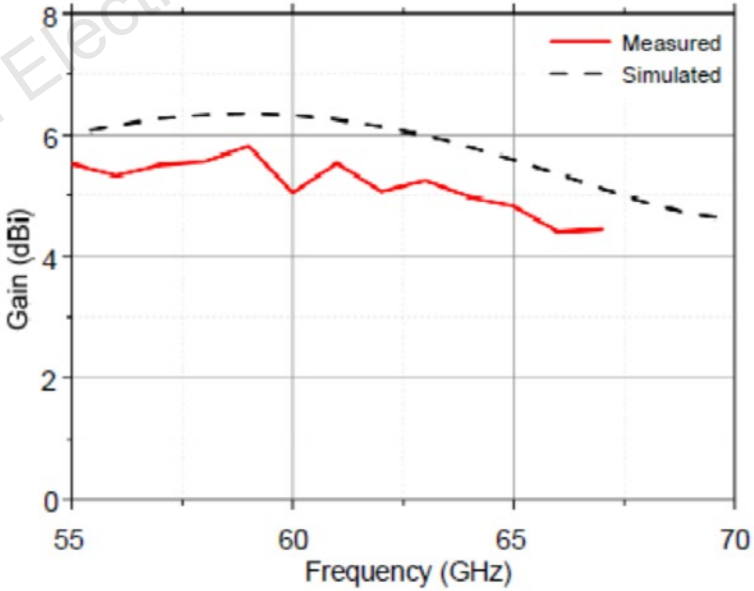


Fig. 14 Simulated and measured gains of the proposed antenna

Major results (Cont’d)

Metasurface antenna

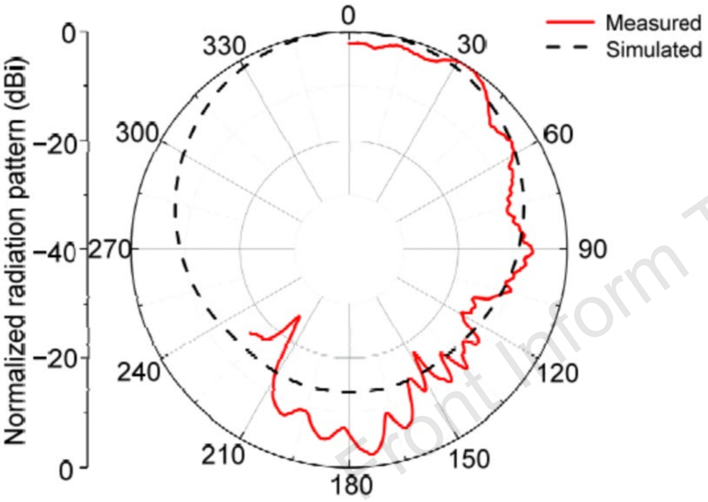


Fig. 15 Simulated and measured normalized radiation patterns of the proposed antenna at 60 GHz in the E-plane

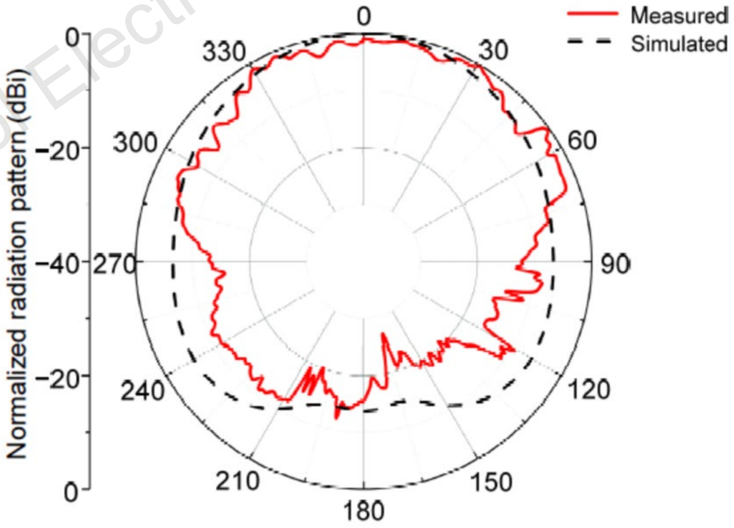


Fig. 16 Simulated and measured normalized radiation patterns of the proposed antenna at 60 GHz in the H-plane

Conclusions

1. With GIPD manufacturing technology, a miniaturized wideband metasurface antenna has been proposed for 60 GHz applications.

2. With a $0.31\lambda_0 \times 0.31\lambda_0$ radiation aperture, the metasurface patch supported the TM_{10} mode and antiphase TM_{20} mode simultaneously.

3. The proposed antenna showed a wide impedance bandwidth from 53.3 to 67 GHz. The measured gain of the antenna was above 4.5 dBi from 57 to 66 GHz.