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Three-dimensional-printed low-sidelobe dual-band dual-polarized antenna array for Ku-band satellite communications

Key words: 3D printing; Dual band; Dual polarization; Ku band; Low sidelobe; GWG antenna; Satellite communications

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Motivation

1. Satellite communications (SATCOMs) have the advantages of wide coverage, long communication distance, and little impact of natural disasters. In view of its long communication distance and complex communication path, its antenna has a strong demand for high gain performance.

2. The traditional hollow waveguide antenna is a commonly used high-gain antenna, but it has the defects of high side lobes and complex processing. If these shortcomings can be overcome, the performance of the antenna can be improved and the processing complexity can be reduced.

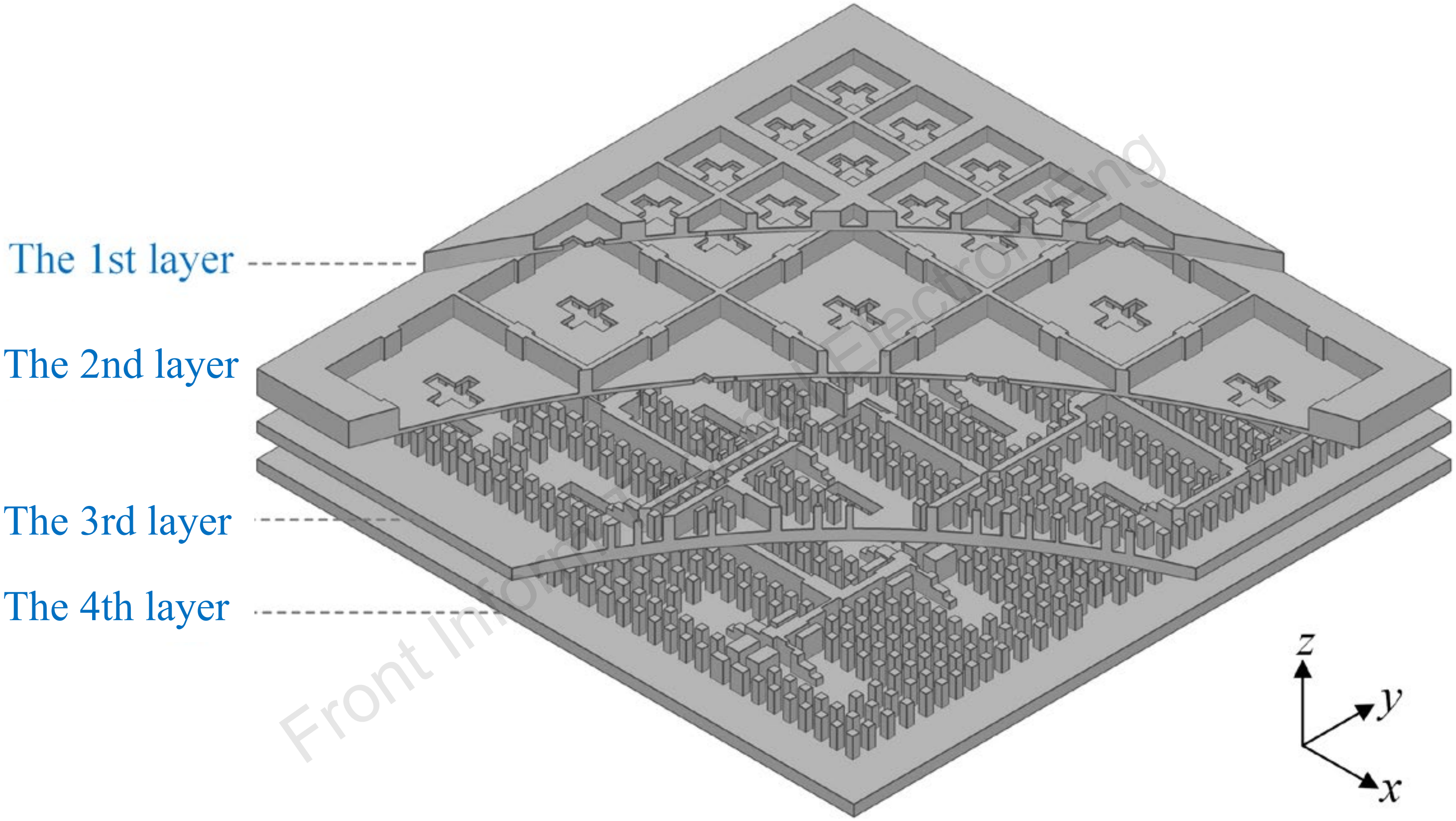
Main idea

1. We design a 2×2 slot antenna unit using a metal cavity. To enhance the gain, the design is optimized through mode analysis.

2. To realize the two-dimensional (2D) tapered amplitude distribution, an unequal T-junction power divider with a large power division ratio is proposed.

3. Based on the structural characteristics of GWG, the antenna is processed by metal 3D printing techniques. The antenna is split into four layers for independent printing and finally obtained as a whole through screw assembly.

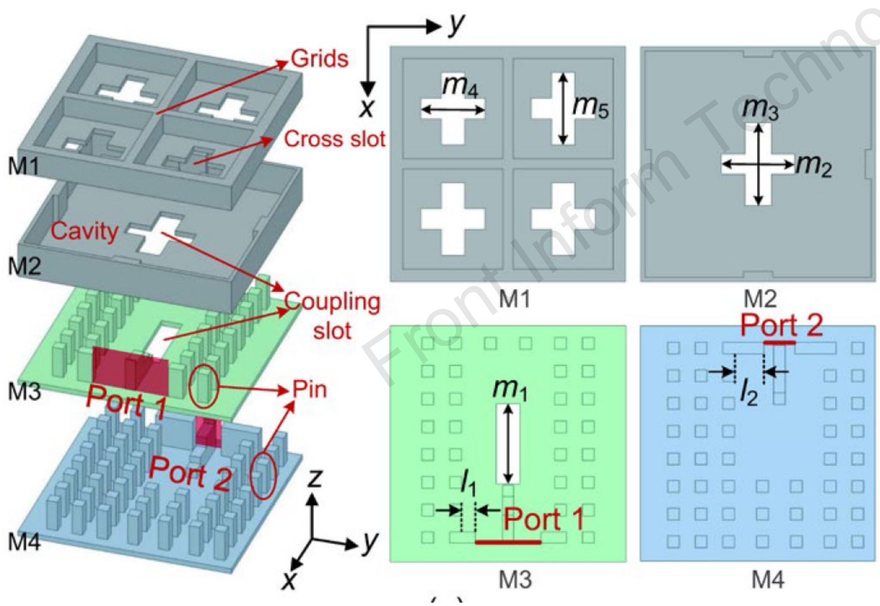
Array structure



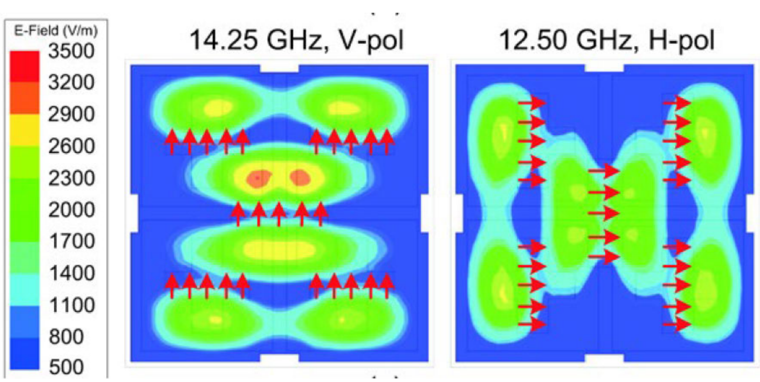
The antenna array consists of four stacked metal layers. The first layer is cross radiation slots. The second layer is back cavities. The third and fourth layers are feeding networks of vertically polarized (V-pol) and horizontally polarized (H-pol) waves.

Method

1. M1 and M2 together serve as the radiator of the subarray, which contains a 2×2 cross-slot and a cavity. The stacked GWGs and cross-slots are used to achieve orthogonal feeding. It can also be seen that the cavity generates quasi-TE_{420} mode under port 1 excitation and quasi-TE_{240} mode under port 2 excitation.



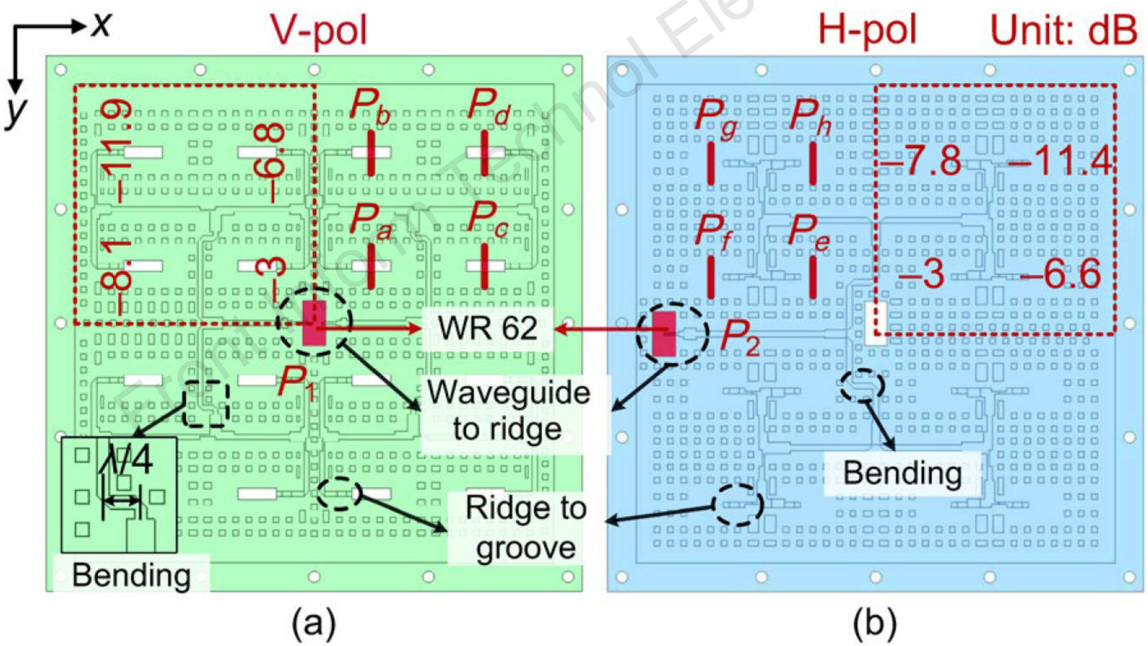
Three-dimensional view and top view of the subarray



Electric field of the cavity

Method

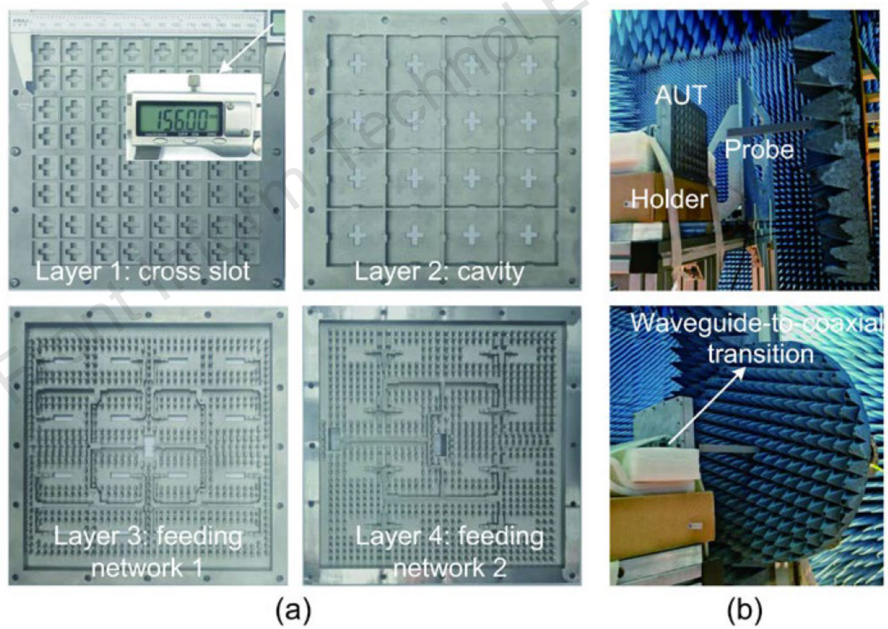
2. The power divider is designed by RGW, and two three-step transitions from ridge to groove are designed. To achieve a Taylor distributed feeding network, a new type of unequal T-junction power divider is applied.



Geometries of feeding network 1 (a) and feeding network 2 (b)

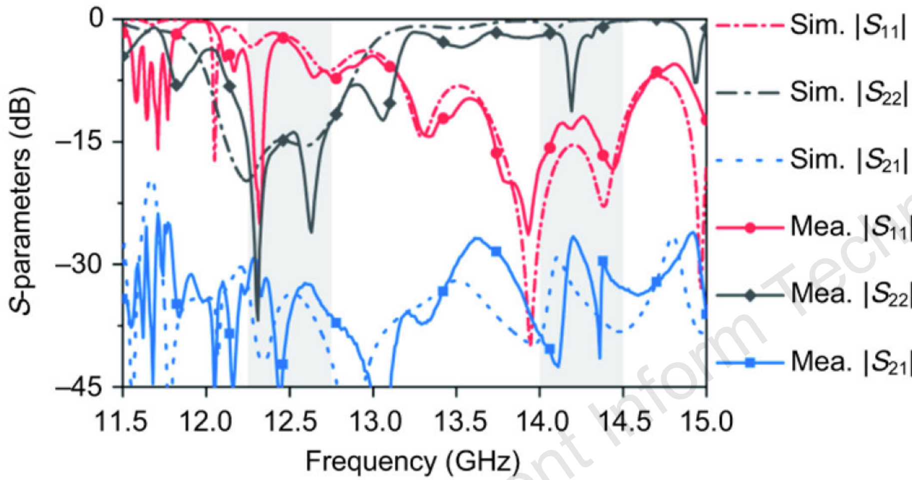
Method

3. Metal 3D printing technology, direct metal laser sintering (DMLS), is used to fabricate the antenna in layers. The antenna is divided into four layers and printed separately. Metal walls are added around the feeding networks to serve as supporting structures and meet the gap height between layers, and round holes are used to assemble the antenna with screws.

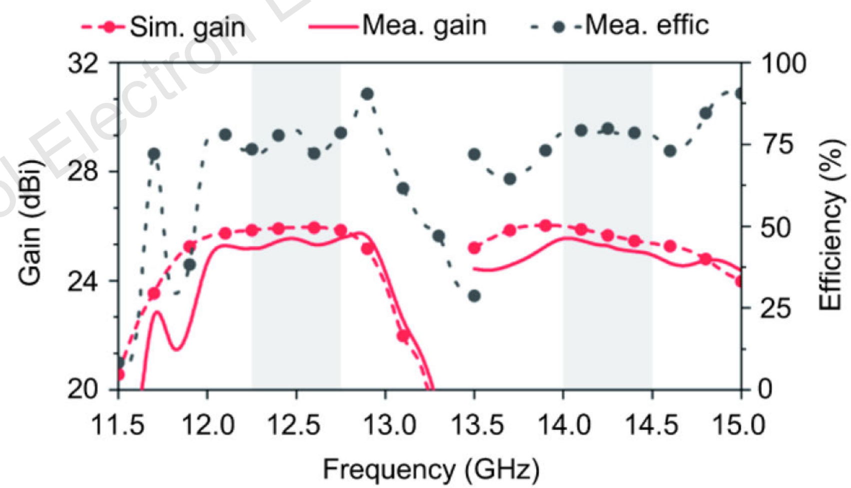


Different layers of the fabricated antenna and measurement setup: (a) top view of different layers of the antenna; (b) measurement setup in the chamber

Major results

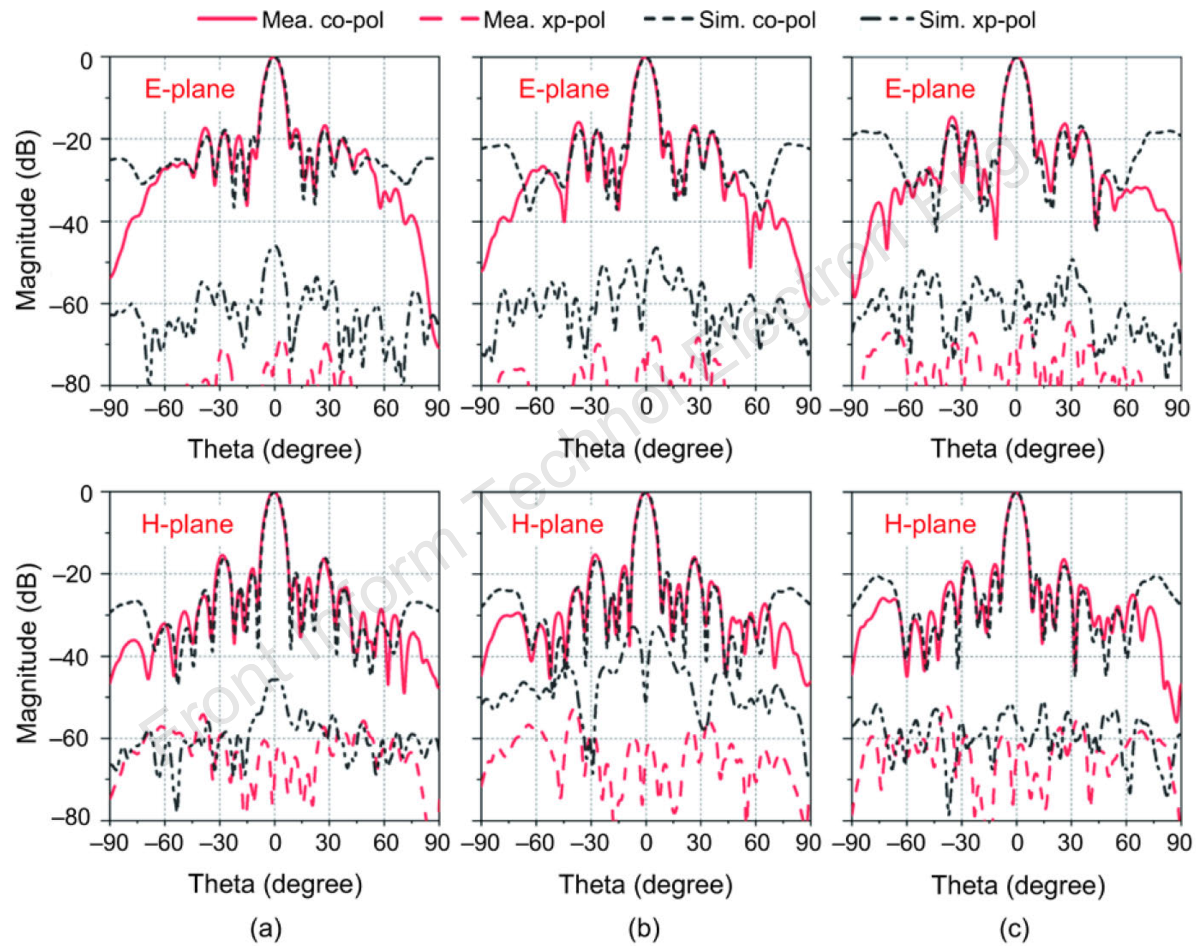


Measured and simulated *S*-parameters of the antenna



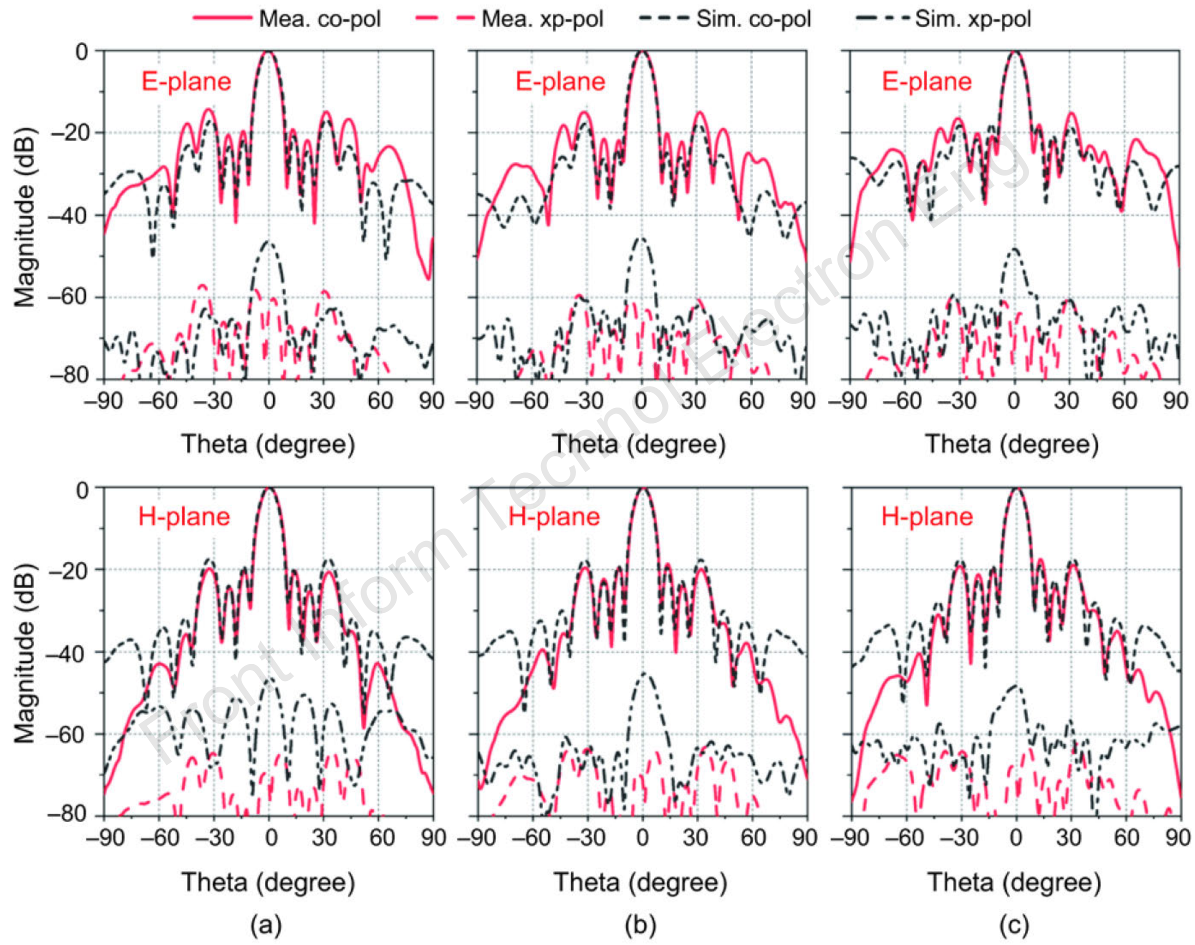
Measured and simulated gain and efficiency

Major results



Measured and simulated normalized far-field radiation patterns of the antenna under V-pol port excitation: (a) 14.00 GHz; (b) 14.25 GHz; (c) 14.50 GHz

Major results



Measured and simulated normalized far-field radiation patterns of the antenna under H-pol port excitation: (a) 12.25 GHz; (b) 12.50 GHz; (c) 12.75 GHz

Conclusions

1. This paper proposes a method for an 8×8 dual-band dual-polarized slot antenna array for Ku-band SATCOM.

2. The radiation element is designed using cavity mode analysis to ensure good gain performance.

3. To eliminate the high SLL caused by excessive slot spacing, the tapered feed distribution is designed, achieving an SLL below −17.4 dB.

4. The antenna array is fabricated by the metal 3D printing process. The measurement results are in good agreement with the simulation results, and the measured efficiency is >72%, which verifies the practicability of the antenna design scheme.