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Analysis and design of novel wideband and high efficiency millimeter-wave antenna arrays for 60-GHz applications

Key words: 60 GHz; Antenna array; Linearly polarized; Circularly polarized; Millimeter-wave

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Main idea

For an antenna array in the millimeter-wave (mm-Wave) band:

- It is hard to maintain the antenna efficiency of a full substrate-based antenna array with a wide working bandwidth.
- The conventional full metal based antenna arrays with high efficiency, which employ the slot antenna element, are usually limited in the working bandwidth.

To solve the problem:

- Since the low-loss and high-efficiency feeding network in an antenna array contributes much to the overall antenna efficiency, and the substrate-based radiation has little impact on the efficiency, it is possible to ensure both wideband and high antenna efficiency by assembling these two parts together.

Method

- To maintain both the wideband and high efficiency characteristics in a mm-Wave antenna array, a type of mm-Wave antenna array with flexible design at 60 GHz was proposed.
- The antenna array can be divided into two parts: a low insertion loss transmission network and a wideband radiation network.
- A full-metal hollow-waveguide feeding network and a microstrip radiation network are employed to maintain both the working bandwidth and efficiency in the antenna array.
- The two parts of the antenna array are fractional and independent; thus, the linear or circular polarization of the antenna array can be realized by changing only the radiation network without adjusting the feeding network, and two different polarizations are achieved based on only one feeding network.

Method

- Geometry of the linearly polarized antenna

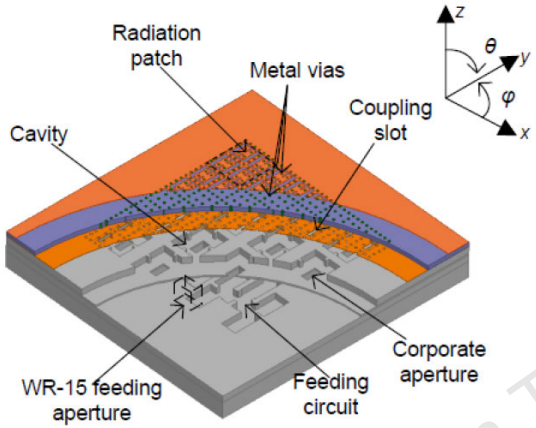

Fig. 1 Linearly polarized antenna array

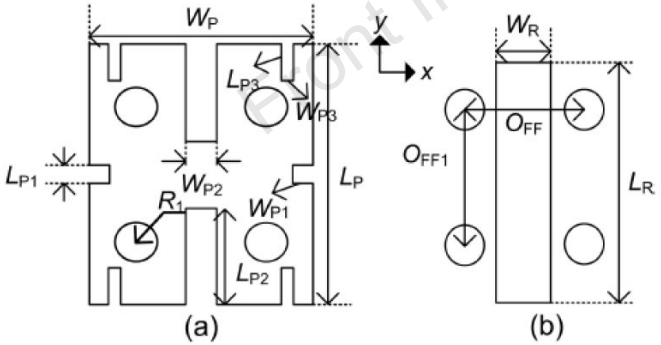

Fig. 3 Detailed geometry of the patch (a) and coupling slots (b)

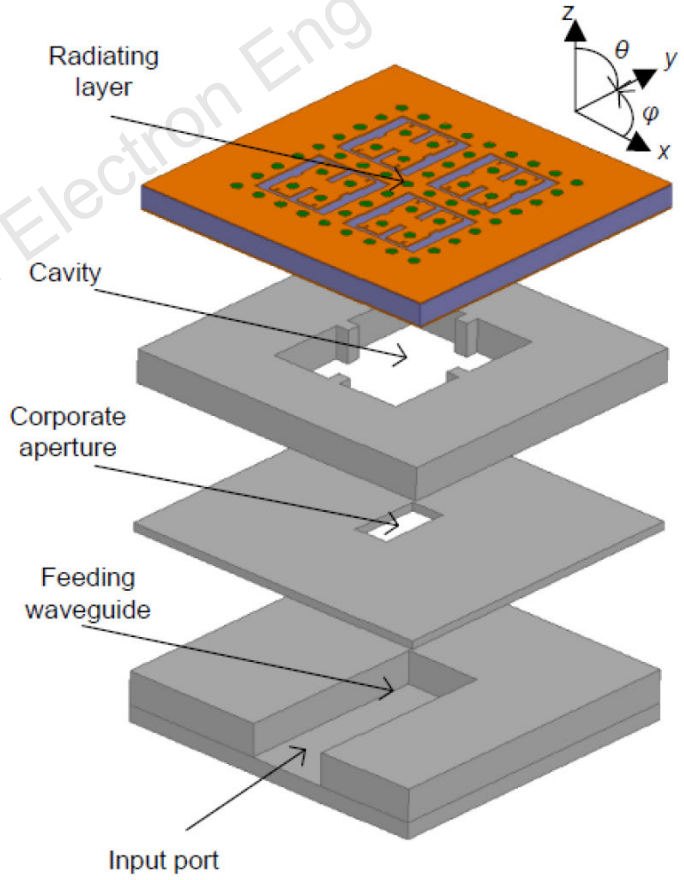

Fig. 17 Configuration of the 2×2 antenna subarray

Method

- Geometry of the circularly polarized antenna

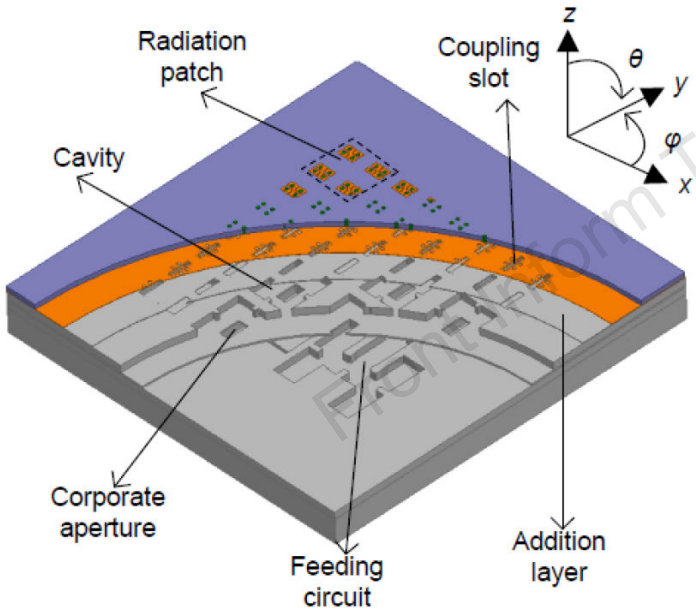

Fig. 27 Configuration of the circularly polarized antenna array

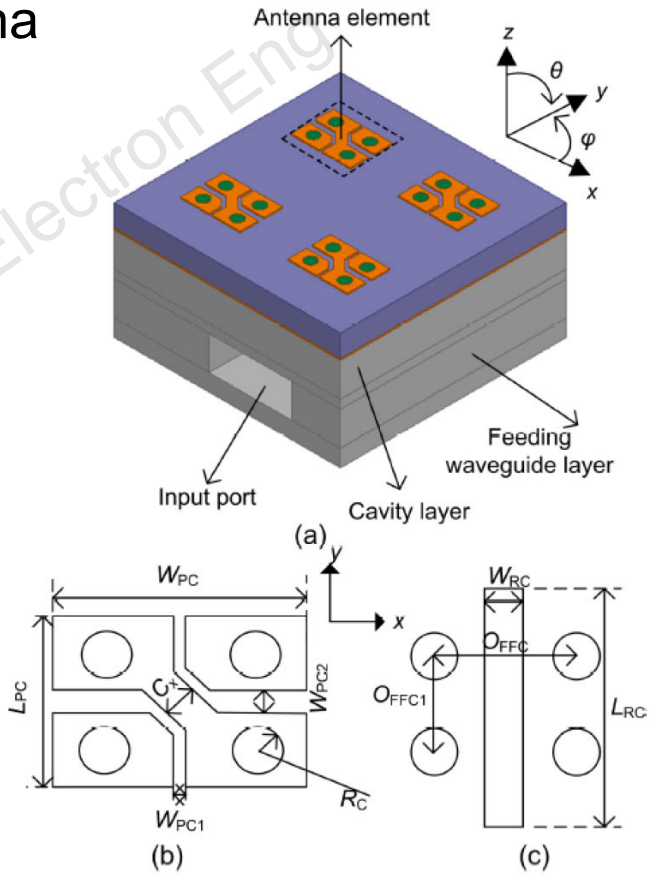

Fig. 28 Configuration of the 2×2 antenna subarray (a), the element patch (b), and its coupling slots (c)

Major results

- Simulation results of the linearly polarized 2×2 antenna subarray

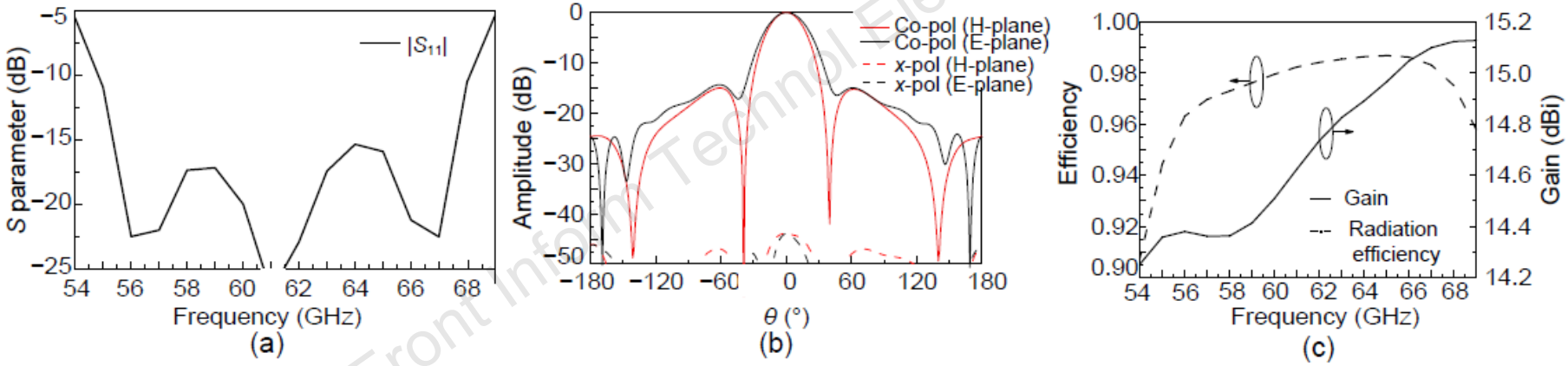

Fig. 19 $|S_{11}|$ **(a), radiation pattern at 60 GHz (b), and gain and radiation efficiency (c) of the 2×2 antenna array (Co-pol: co-polarization;** *x*-**pol:** *x*-**polarization)**

Major results

- Simulation results of the circularly polarized 2×2 antenna subarray

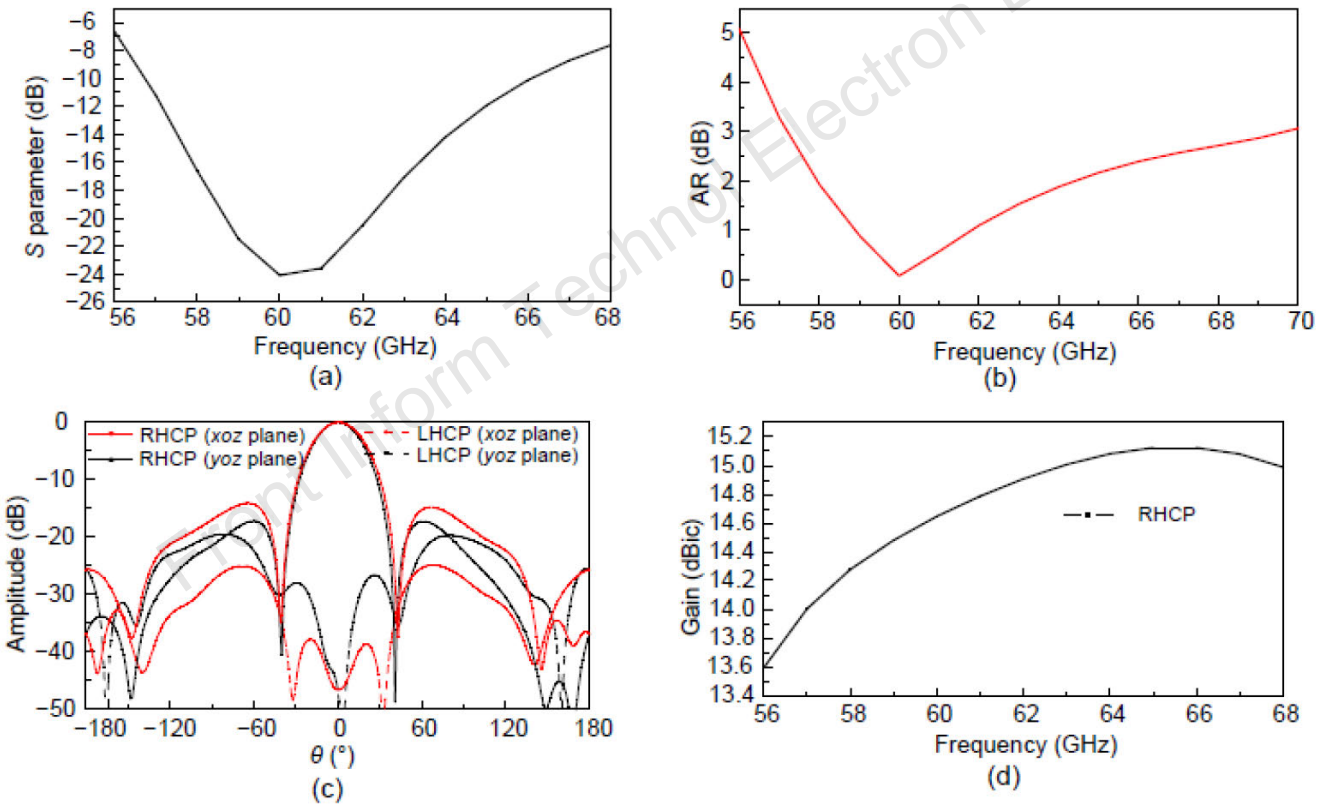

Fig. 29 Simulation results of the antenna subarray: (a) *S* parameter; (b) AR; (c) radiation pattern; (d) gain

Major results

- Simulation results of the circularly polarized 8×8 antenna array

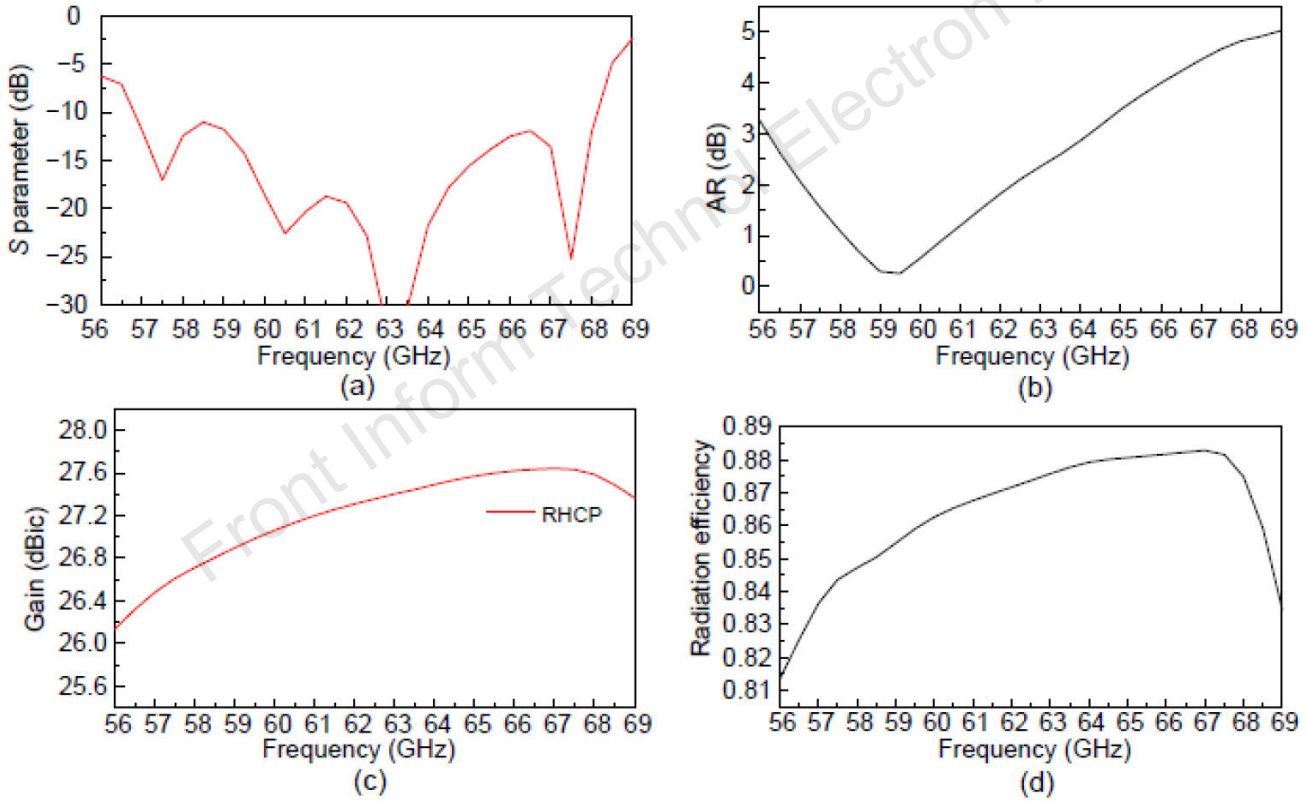

Fig. 30 Simulation results of the 8×8 antenna array: (a) *S* parameter; (b) AR; (c) gain; (d) efficiency

Major results

- Simulation results of the circularly polarized 8×8 antenna array

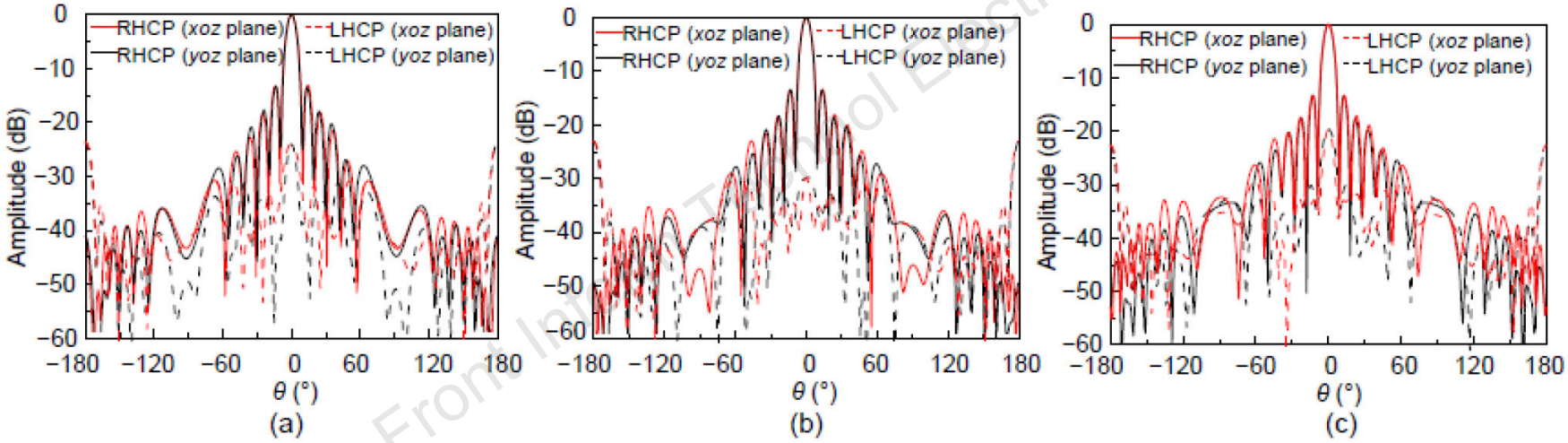

Fig. 31 Simulated radiation patterns of the 8×8 antenna array at 58 GHz (a), 60 GHz (b), and 62 GHz (c) (References to color refer to the online version of this figure)

Major results

- Measurement results of the antenna array

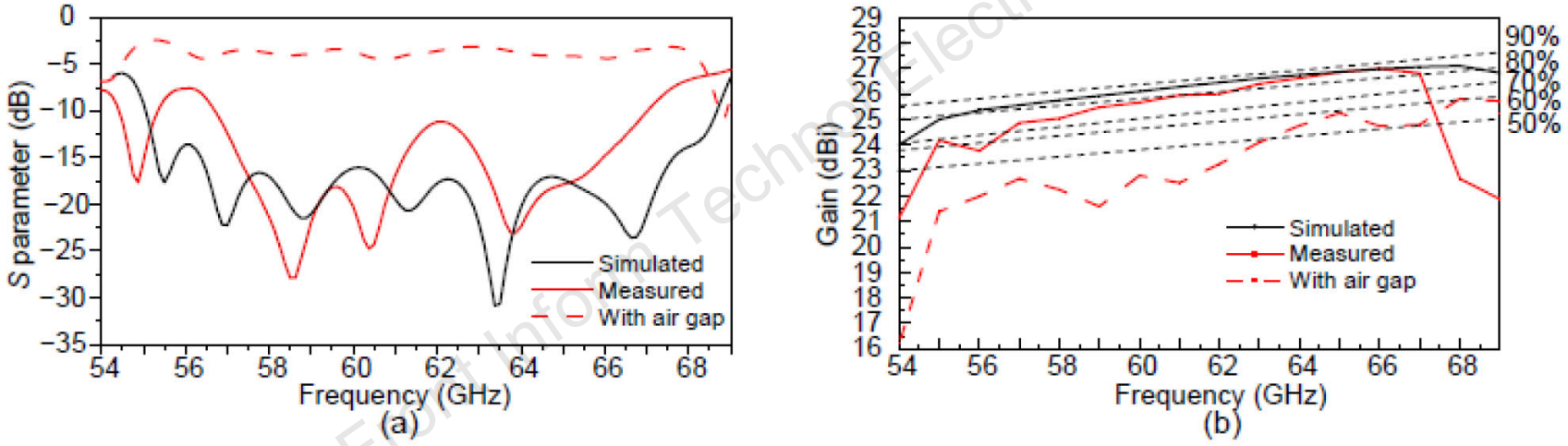

Fig. 33 Simulated and measured $|S_{11}|$ (a) and gain and radiation efficiency (b)

Major results

- Measurement results of the antenna array

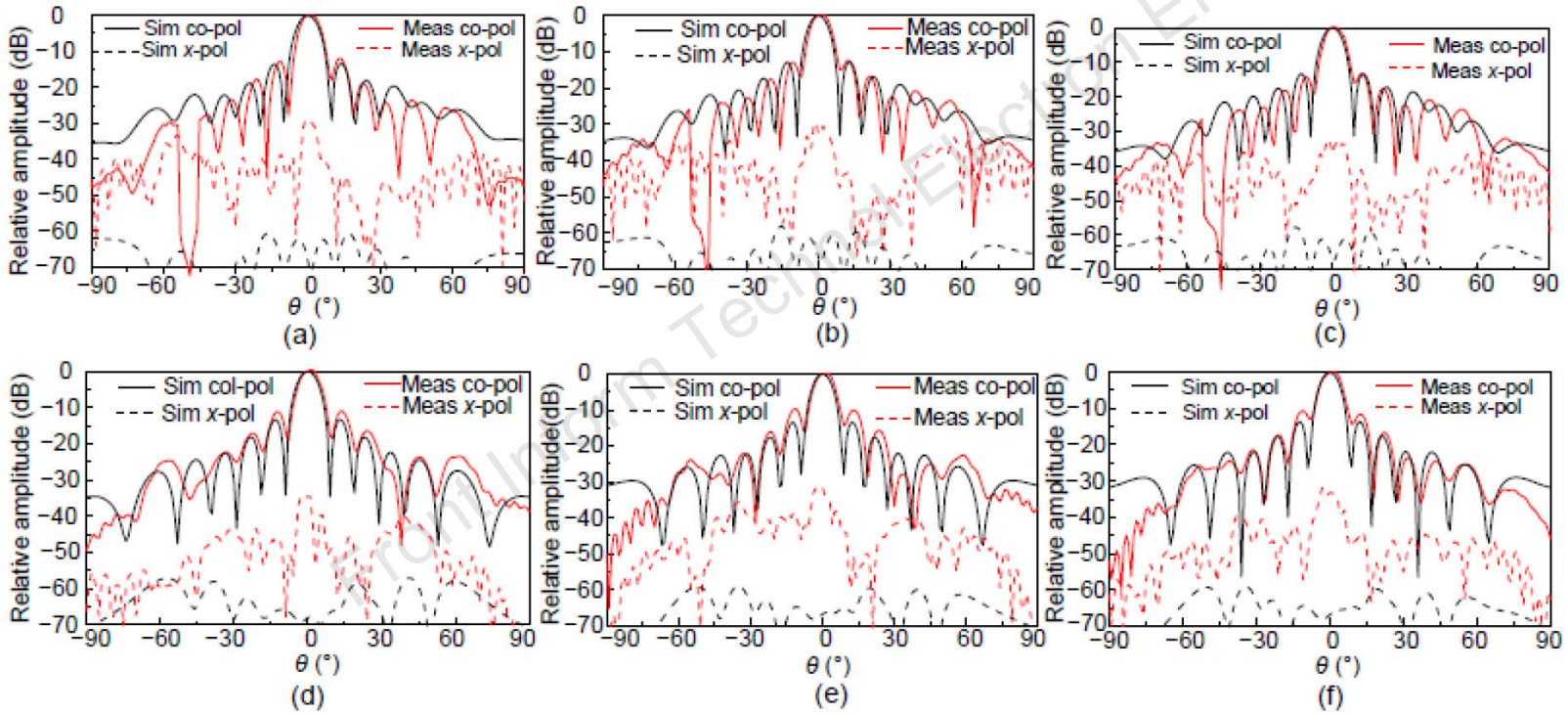

Fig. 34 Simulation and measurement results of the radiation patterns: (a) H-plane at 60 GHz; (b) H-plane at 63 GHz; (c) H-plane at 64 GHz; (d) E-plane at 60 GHz; (e) E-plane at 63 GHz; (f) E-plane at 64 GHz

Sim co-pol: simulated co-polarization; Sim *x*-pol: simulated *x*-polarization; Meas co-pol: measured co-polarization; Meas *x*-pol: measured *x*-polarization

Summary

- A type of mm-Wave antenna array with flexible design at 60 GHz is proposed. The antenna array can be adjusted to be linearly or circularly polarized by simply changing the radiation part, while the feeding part is kept unchanged.
- For the 8×8 linearly polarized antenna array, the simulation results show a bandwidth of 21.6%, a gain of 26.1±1 dBi, and an antenna efficiency of more than 80% in the bandwidth.
- For the 8×8 circularly polarized antenna, the simulation results show that an impedance bandwidth of 18.2% and an AR bandwidth of 13.3% are obtained. Gain and efficiency up to 27.6 dBic and 88% are achieved, respectively.
- A prototype of the linearly polarized antenna array has been fabricated, and the measurement results are in good agreement with the simulation results. A realized gain of more than 23.8 dBi and a measured maximum efficiency of 86% over the band have been obtained.