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A parasitic coupling network concept for mutual coupling utilization in wideband multielement antenna arrays

Key words: Active reflection coefficient (ARC); Antenna array; Parasitic coupling network (PCN); Scanning array; Wideband

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Motivation

1. Tightly coupled array has been widely adopted in balanced-excitation antenna arrays, but for unbalanced-excitation antennas, the concept of mutual coupling utilization is scarcely introduced.
2. Since the network analysis is precise and general and has potential, the design of the decoupling network can be stretched to that of a coupling network for mutual coupling utilization, which has rarely been reported.

Main idea

1. The parasitic network is traditionally employed in antenna decoupling, but the parasitic coupling network (PCN) breaks the limitation and is expanded to the mutual coupling utilization.
2. An unbalanced-excitation antenna, i.e., a dual-layer coupled microstrip antenna, is selected as the basic element for the coupling utilization; previously, balanced-excitation antennas have been the most common.
3. The PCN design is simple to follow, and it is easy to judge whether the mutual coupling can be used or not according to the derived mutual coupling utilization condition for the planar large-scale multielement antenna array.
4. The PCN is practical for both one- and two-dimensional wideband antenna arrays, and has potential for use with large-scale arrays.

Method

1. To deduce the mutual coupling utilization condition, an $(M \times N)$ -port network is constructed to represent an antenna array with $M \times N$ elements.

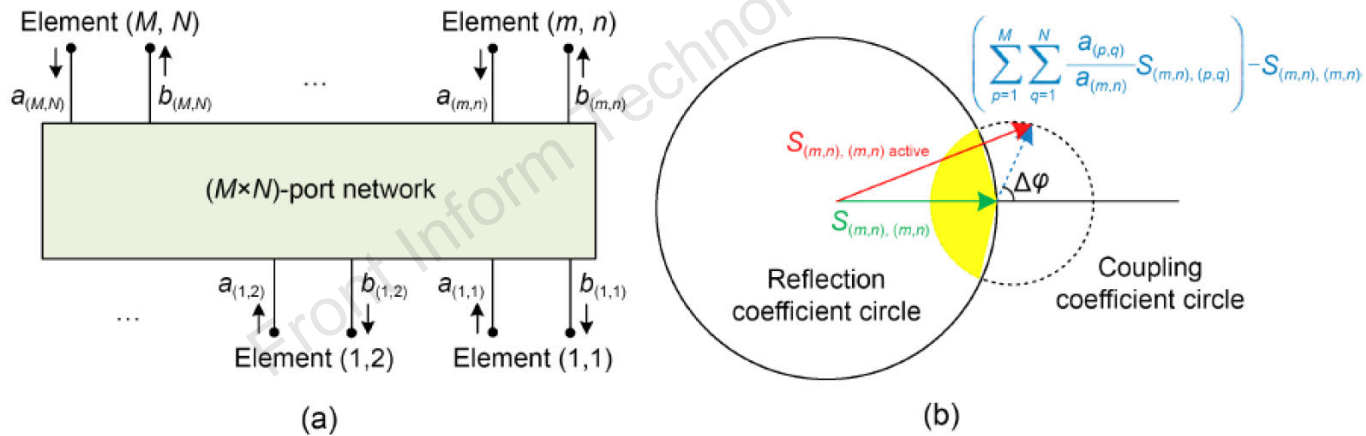


Fig. 1 Analysis of the mutual coupling utilization condition: (a) network model; (b) calculation of the active reflection coefficient (ARC). References to color refer to the online version of this figure

Method (Cont'd)

2. For H-plane antenna array, a shorted stepped microstrip parasitic element is inserted between two patches on the middle substrate, which is linked to the coupling network via a metal probe.

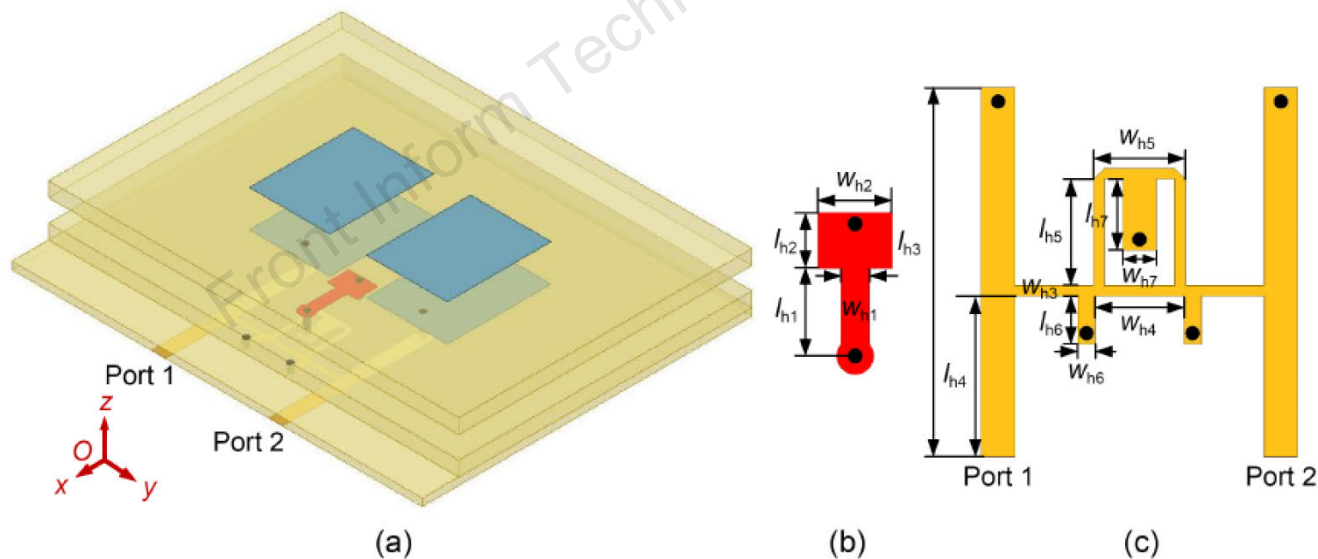


Fig. 6 PCN implementation for the two-element H-plane antenna array: (a) overall view; (b) parasitic element; (c) coupling network

Method (Cont'd)

3. For E-plane antenna array, one meander line is augmented to the parasitic element to ensure the symmetric arrangement of the coupling network .

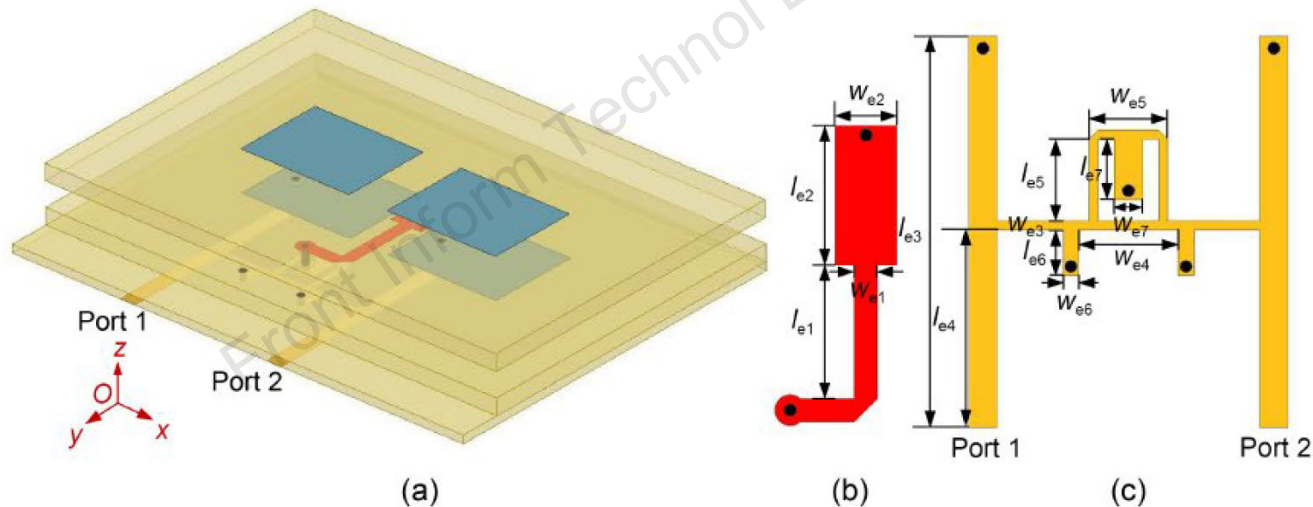


Fig. 13 PCN implementation for the two-element E-plane antenna array: (a) overall view; (b) parasitic element; (c) coupling network

Method (Cont's)

4. For an 8×2 antenna array, PCN is extended to two elements along the H-plane based on a linear eight-element E-plane array.

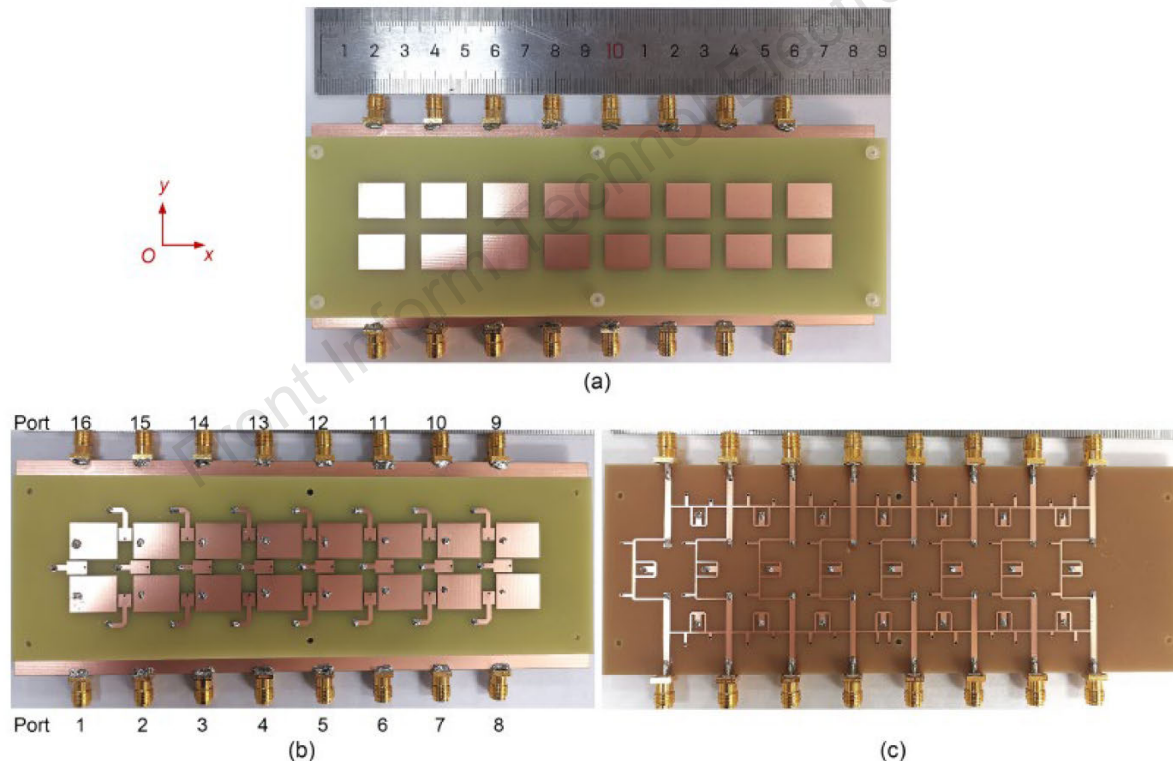


Fig. 16 Prototype of the proposed PCN for the two-dimensional 8×2 antenna array: (a) upper patches; (b) lower patches and parasitic elements; (c) coupling network

Major results

H-plane antenna array

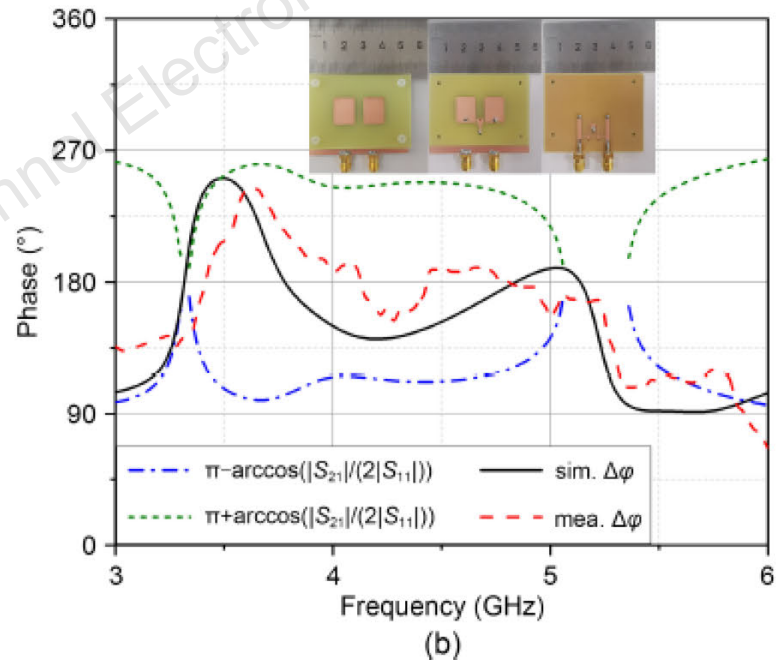
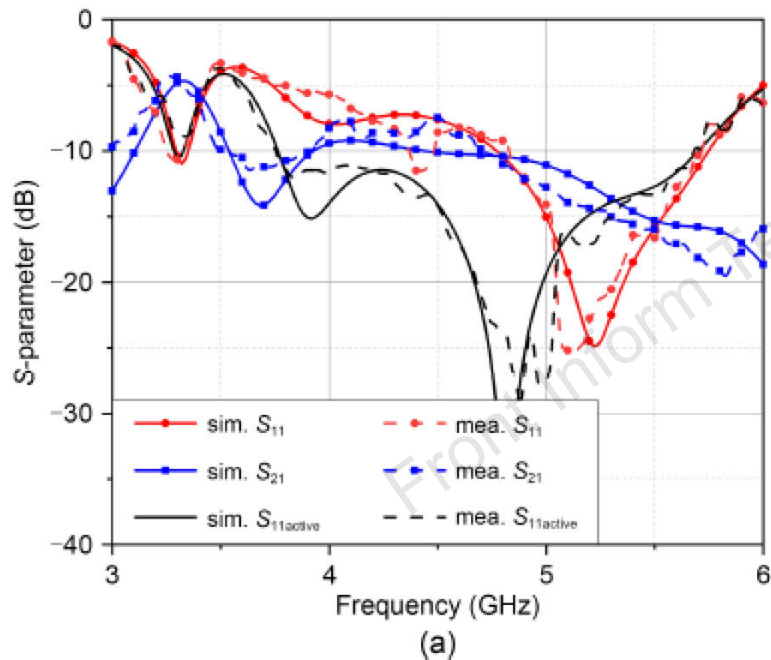


Fig. 8 S -parameters and phase differences of the H-plane antenna array with the PCN: (a) S -parameters; (b) phase differences and the fabricated array

Major results (Cont'd)

E-plane antenna array

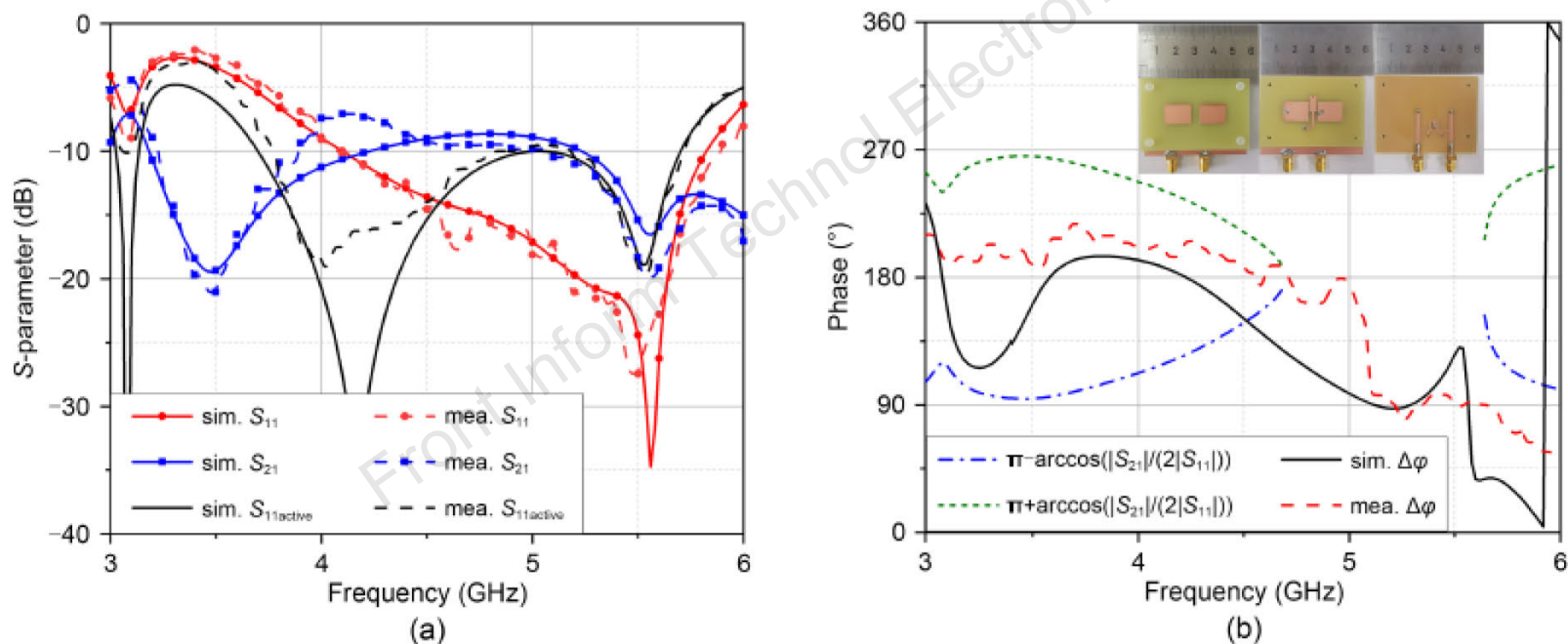


Fig. 15 S -parameters and phase differences of the E-plane antenna array with the PCN: (a) S -parameters; (b) phase differences and the fabricated array

Major results (Cont'd)

8×2 antenna array

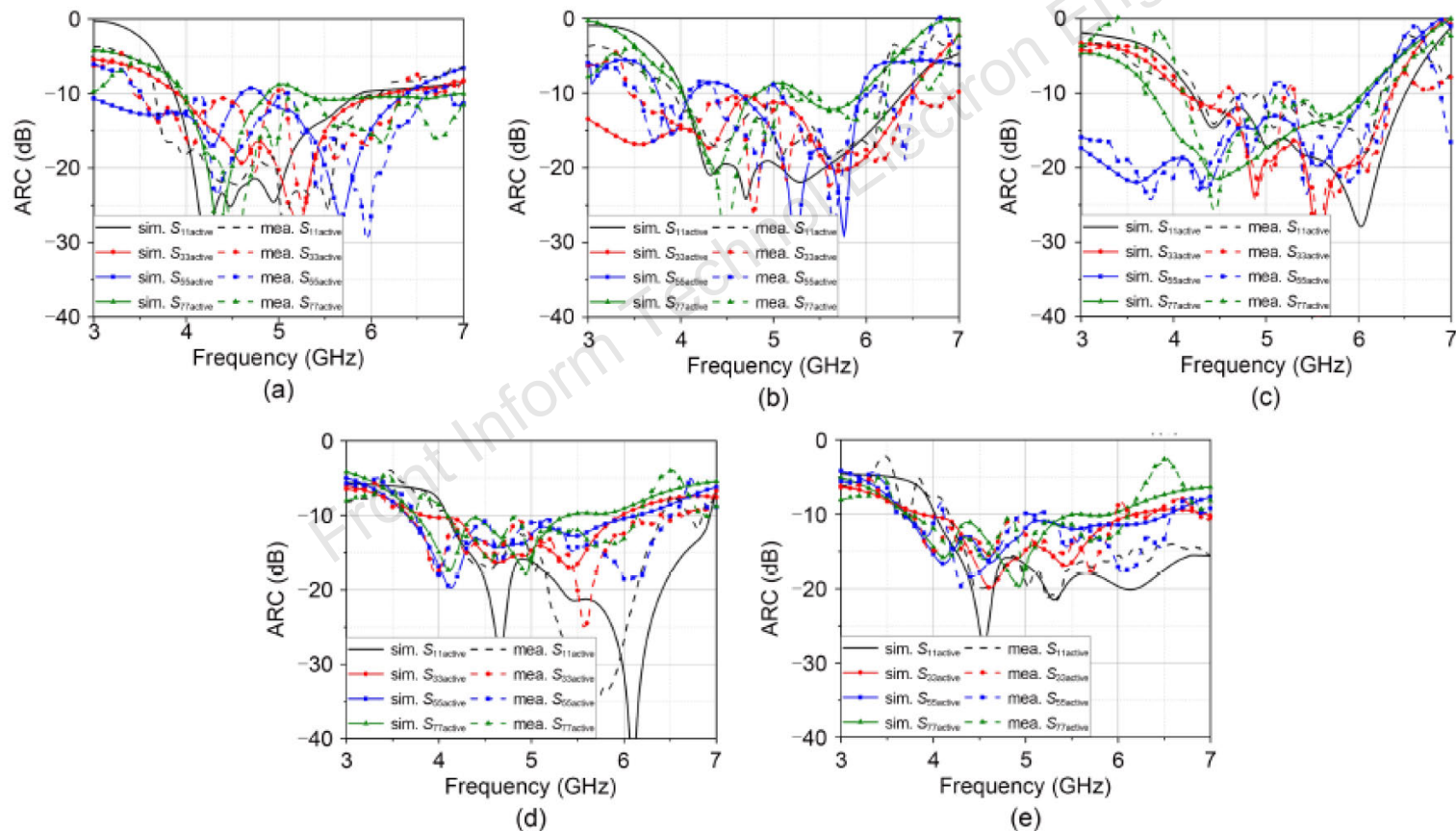


Fig. 19 Scanning ARCs of the 8×2 antenna array with the PCN: 30° (a), 45° (b), and 60° (c) for E-plane scanning; 30° (d) and 45° (e) for H-plane scanning

Major results (Cont'd)

8×2 antenna array

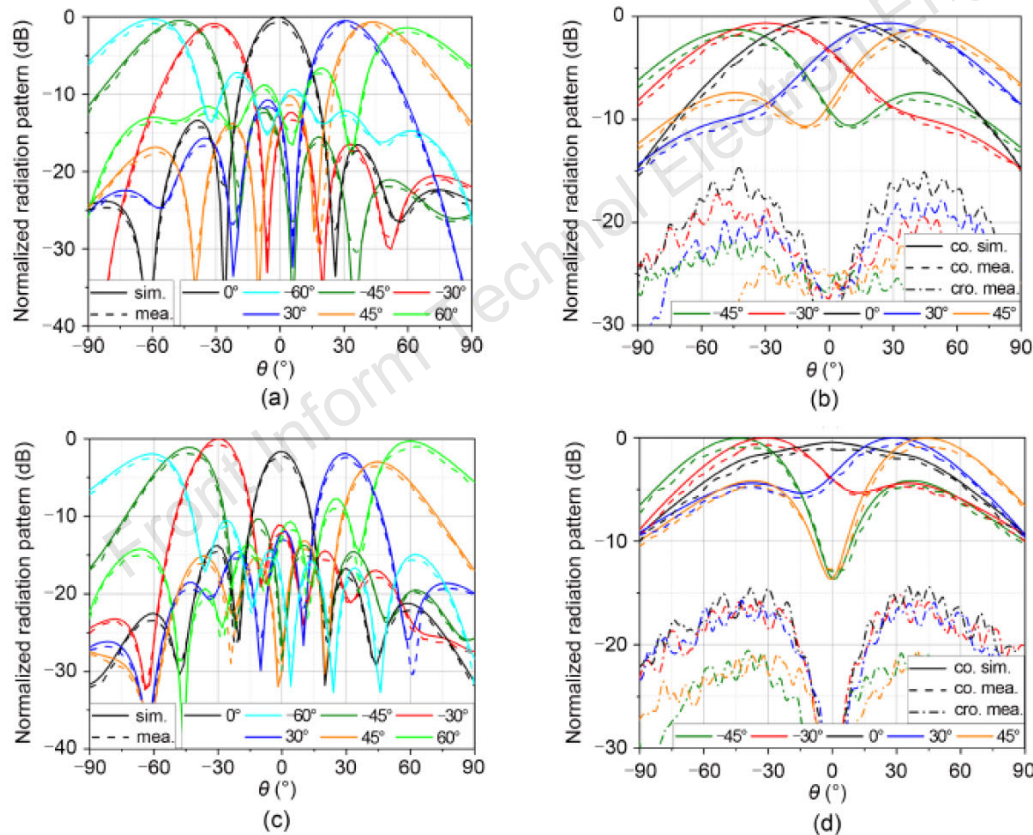
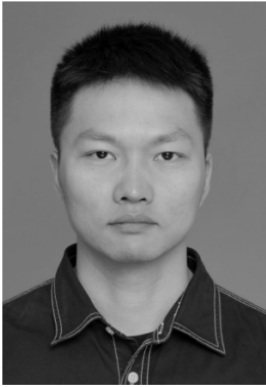


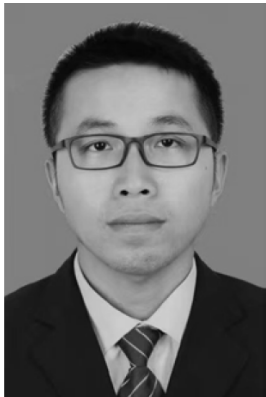
Fig. 21 Normalized scanning radiation patterns of the 8×2 antenna array with the PCN: 4.5 GHz (a) and 5.5 GHz (c) for E-plane radiation patterns; 4.5 GHz (b) and 5.5 GHz (d) for H-plane radiation patterns

Conclusions

1. The mutual coupling utilization condition is deduced according to the network model, as well as the PCN implementation in an $(M \times N)$ -element antenna array.
2. Compared with those without the PCN, the characteristics of two-element H- and E-plane arrays, multielement one-dimensional arrays, and the two-dimensional array, are improved, including approximately 40% overlapped ARC bandwidths, normal radiation patterns, steady gains, and applicable scanning characteristics.
3. The novel PCN illustrates its potential application in wideband unbalanced-excitation large-scale phased antenna arrays.
4. Future research can focus on PCN design for various kinds of antennas. In addition, the optimization algorithm can be employed to hasten PCN design.



Xiaojun ZOU received the PhD degree in electronic science and technology from Air Force Engineering University, Xi'an, China, in 2022. He is currently a lecturer with the College of Information and Communication at National University of Defense Technology. His current research interests include antenna array, coupling manipulation technology, and metasurface.



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