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An array of two periodic leaky-wave antennas with sum and difference beam scanning for application in target detection and tracking

Key words: Antenna; Leaky-wave antenna (LWA); Substrate-integrated waveguide (SIW); Sum and difference beam; Target detection and tracking

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Motivation

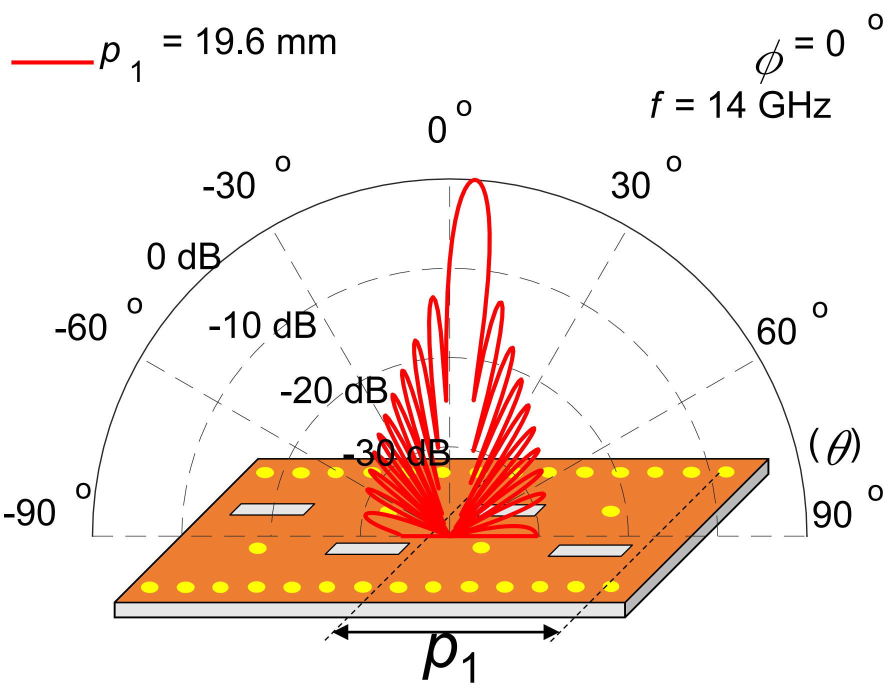
- In a single beam scanning radar, the target detection accuracy is limited by the beam width and it is inconvenient to achieve target tracking. Sum and difference beam scanning is preferred for high-accuracy radar.
- For target detection and tracking applications, a mechanical scanning antenna is bulky and a phased array usually requires complex feed networks. A simpler alternative is to use leaky-wave antenna (LWA), which has beam scanning with frequency.
- LWA with sum and difference beam scanning capability offers a potential and low-cost solution for achieving high-accuracy target detection and tracking. Therefore, it possesses significant application value in radar systems.

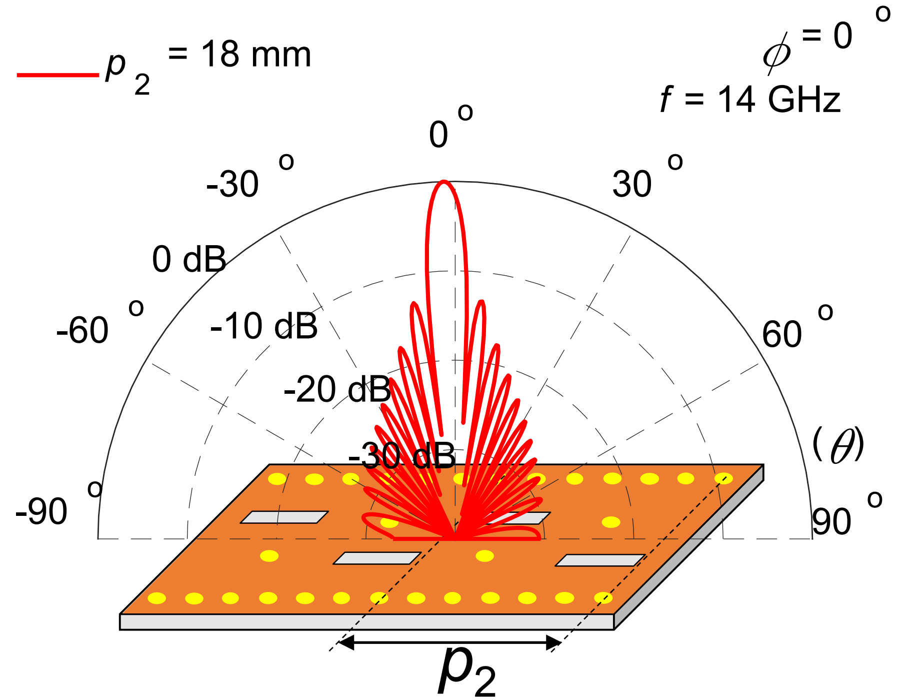
Main idea

- Two periodic LWAs of different periods generate two main beams of slightly different radiation angles, which can be merged to a sum beam or a difference beam, depending on the in-phase or out-phase of the excitations.

Method

- A periodic LWA can generate a beam through the radiation of its $n=-1$ space harmonic
- Two LWAs with slightly different periods can generate two beams with slightly different angles

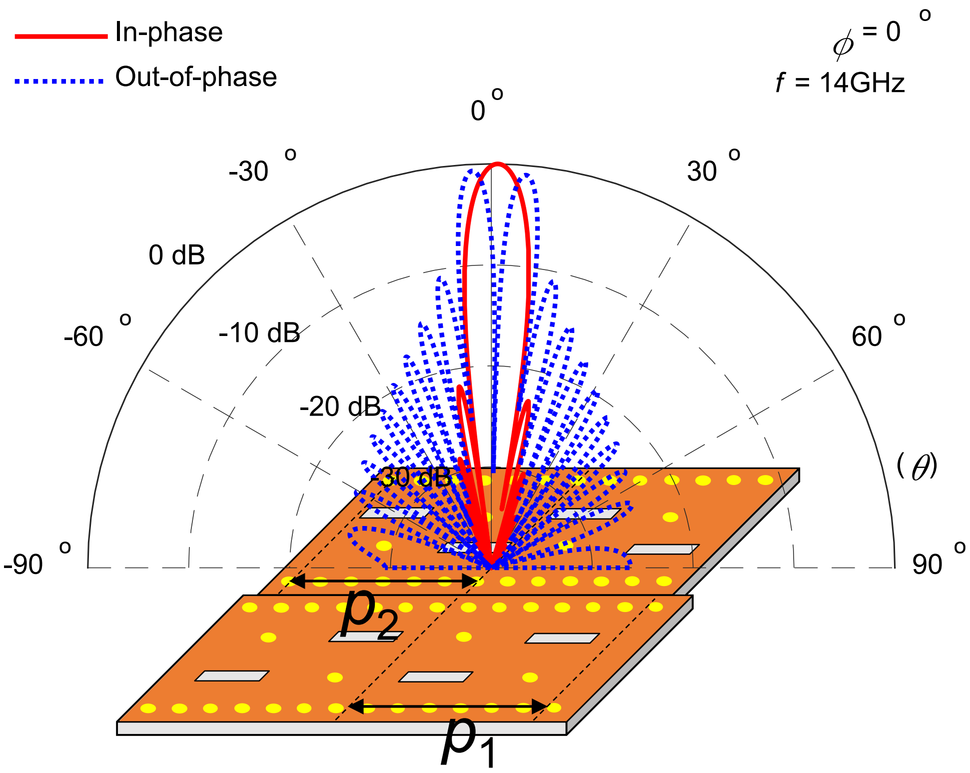




Method (Cont'd)

- According to the principle of complex far-field superposition, the two complex far-field patterns are merged to obtain the sum and difference beam.

$$F_{\Sigma/\Delta}(\theta) = \int_0^L (M_{s1} + M_{s2}) e^{jk_0 x \sin\theta} dx$$
$$= A_1 \cdot \left(\frac{1 - e^{jk_0 L \sin\theta} e^{-\alpha_1 L} e^{-j\beta_{-1,1} L}}{\alpha_1 + j\beta_{-1,1} - jk_0 \sin\theta} + \rho \cdot \frac{1 - e^{jk_0 L \sin\theta} e^{-\alpha_2 L} e^{-j\beta_{-1,2} L}}{\alpha_2 + j\beta_{-1,2} - jk_0 \sin\theta} \right)$$



Feeding structrue

- Design a wideband 180° hybrid whose operating band is consistent with the array of two periodic LWAs

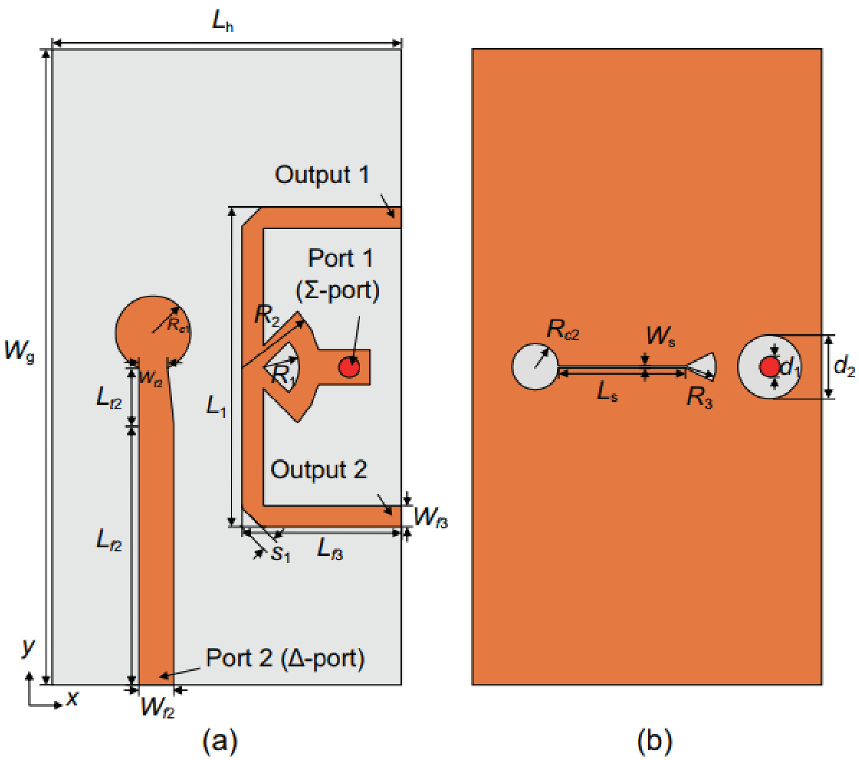


Fig. 2 Geometry of the wideband 180° hybrid: (a) top view; (b) bottom view

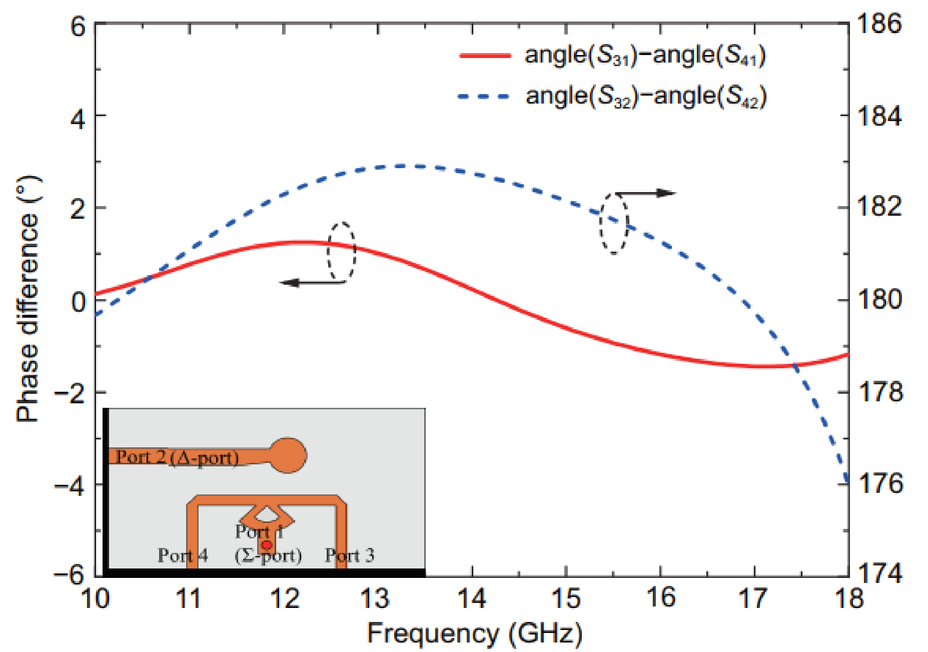


Fig. 7 Phase difference between the two output ports (ports 3 and 4) of the wideband 180° hybrid

Measurement

The proposed antenna

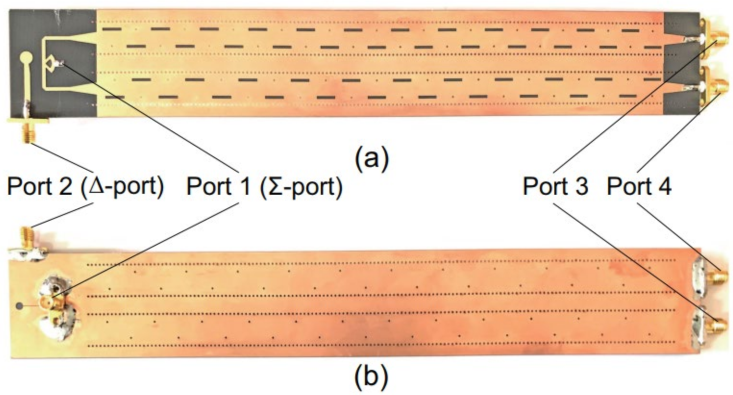


Fig. 10 Array of two periodic LWAs with different periods integrated with the 180° hybrid: (a) top view; (b) bottom view (LWA: leaky-wave antenna)

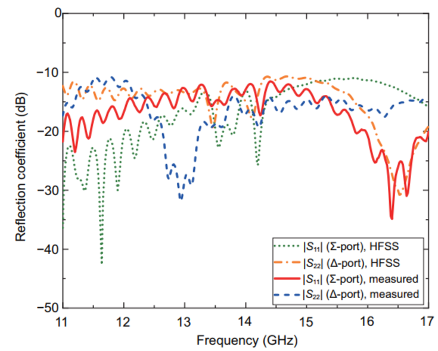


Fig. 11 Simulated and measured reflection coefficients of the Σ-port and Δ-port for the proposed antenna

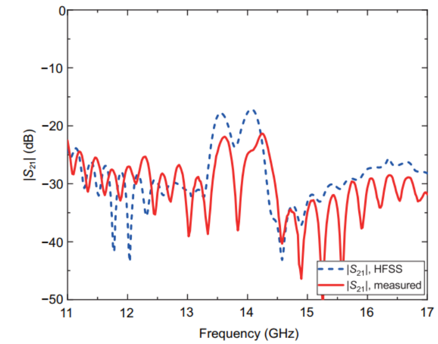


Fig. 12 Simulated and measured isolation between the Σ-port and Δ-port for the proposed antenna

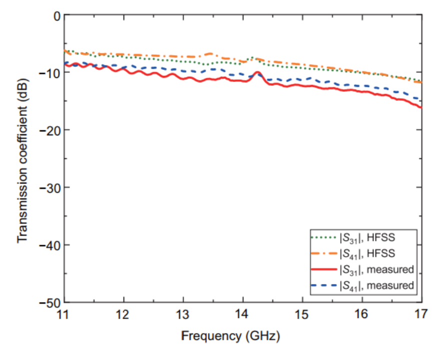


Fig. 13 Simulated and measured transmission coefficients between the Σ-port and the two output ports for the proposed antenna

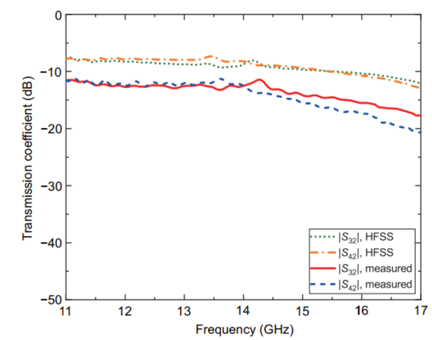
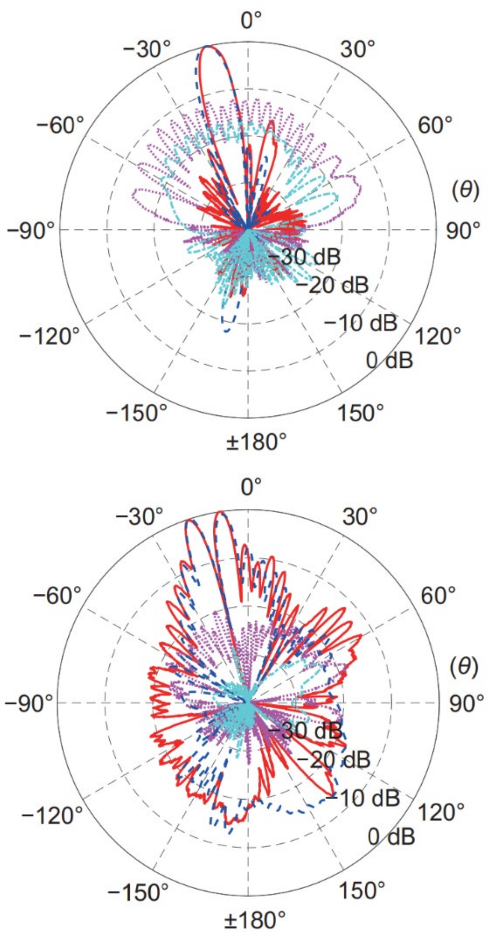


Fig. 14 Simulated and measured transmission coefficients between the Δ-port and the two output ports for the proposed antenna

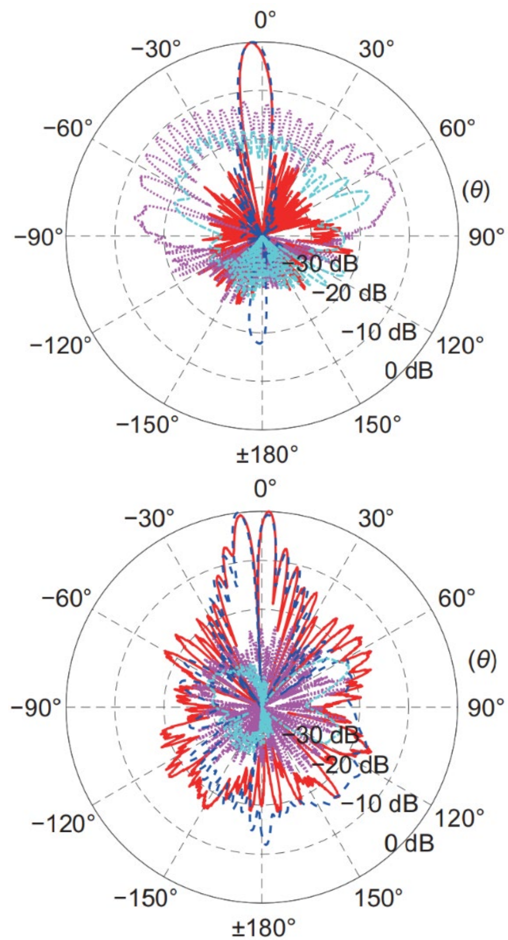
S parameters for the proposed antenna

Measurement (Cont'd)

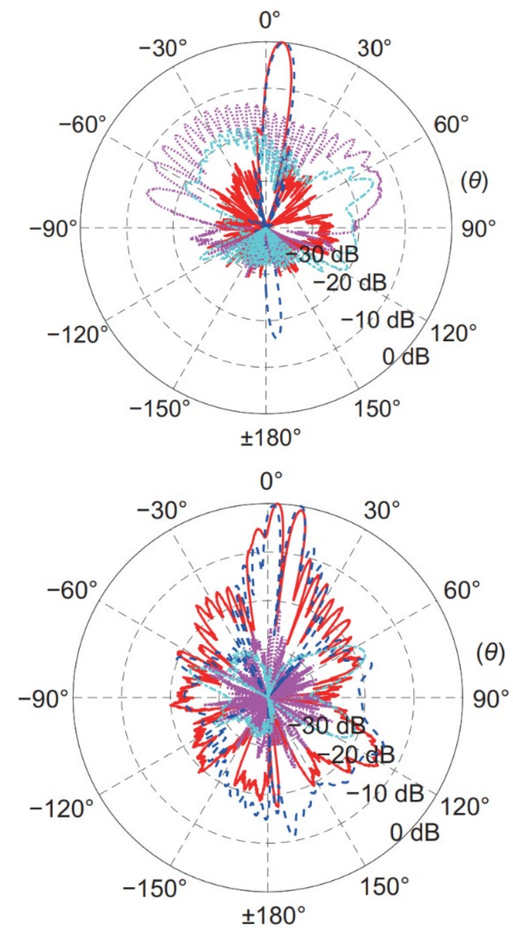
Sum beam and difference beam



f=12.5 GHz



f=13.5 GHz



f=14.5 GHz

Measurement (Cont'd)

Gain for sum beam

Null depth for difference beam

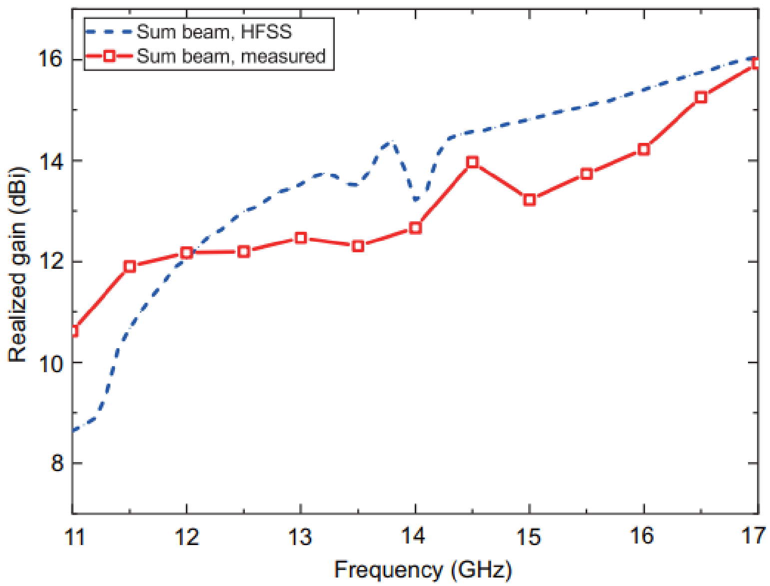


Fig. 17 Simulated and measured realized gains of the sum beam for the proposed antenna

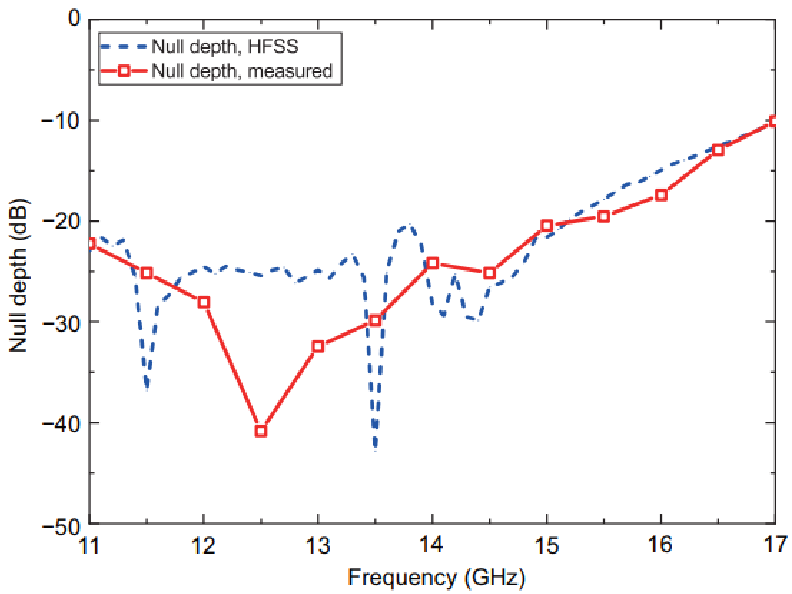


Fig. 19 Simulated and measured null depths for the proposed antenna

Measurement (Cont'd)

Scanning angles

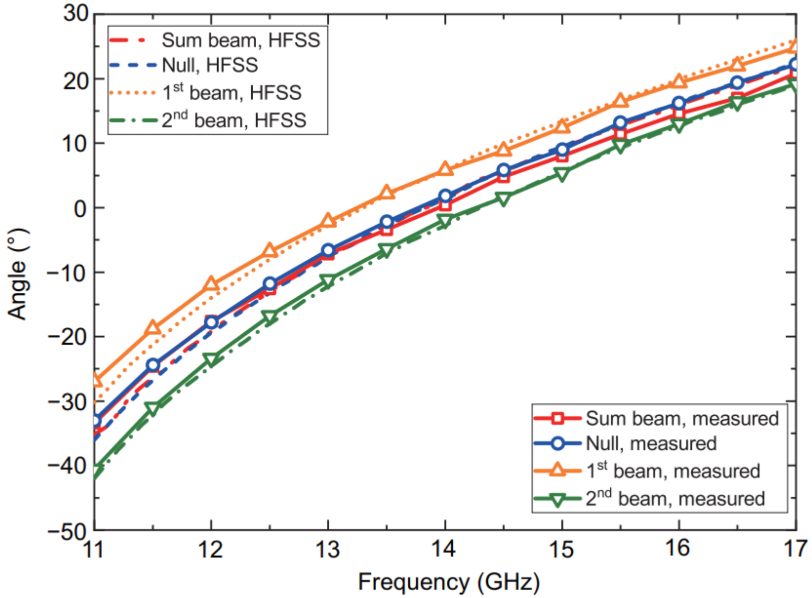


Fig. 20 Angles of the sum beam, null, first beam, and second beam from the simulated and measured radiation patterns

Efficiency

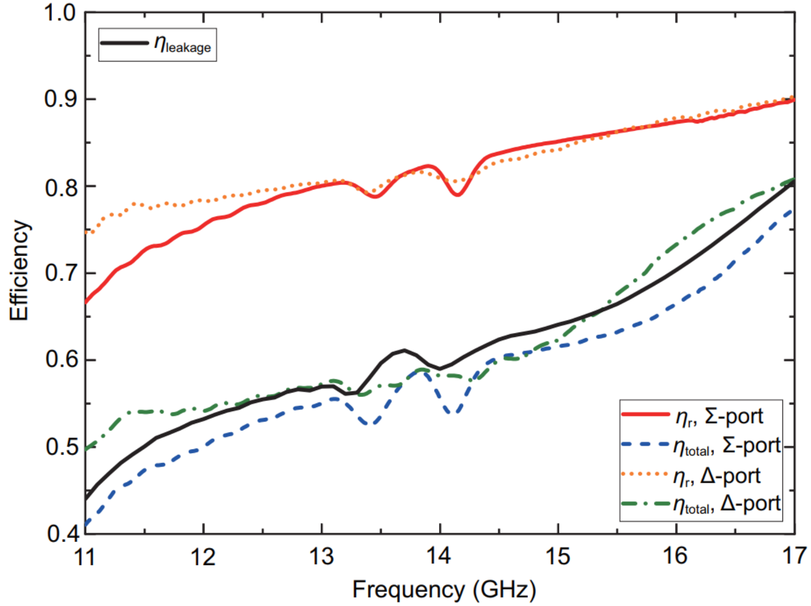


Fig. 21 Leakage efficiency ($\eta_{leakage}$), radiation efficiency (η_r), and total efficiency (η_{total}) for the proposed antenna

Conclusions

- An array of LWAs integrated with 180° hybrid, which has functionality of sum and difference beam scanning, is proposed and can be applied in high-accuracy radar for searching and tracking.
- The sum beam scans from −33.4° to 20.8° in the operating band from 11 to 17 GHz. The angle of null is consistent with the radiation direction of the sum beam.
- The sum beam can reach up to 15.9 dBi and the lowest null depth is −40.8 dB in the operating band.

Mianfeng HUANG received the B.S. degree in electronic engineering from Sun Yat-sen University, Guangzhou, China, in 2020, where he is currently pursuing the M.Eng. degree. His current research interests include leaky-wave antennas and periodic structures.

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