# Supplementary materials for

## 1 Co-polarization patterns

The full-wave simulated and measured co-polarization patterns of the metasurfaces are given in Figs. S1–S3. The peak value of the simulated cross-polarized pattern is 7.96 dB larger than that of the co-polarized pattern for the cosecant beams, 1.31 dB larger than that of the co-polarized pattern for the flat-top beam, and 5.20 dB larger than that of the co-polarized pattern for the double beam. Nevertheless, this does not affect the verification of the effectiveness of the SDR algorithm, which is the key of this work.

## 2 Gain of the metasurfaces

In the design, the metasurfaces are illuminated by a quasi-plane, and thus the absolute gain of the metasurface arrays cannot be obtained directly. Instead, we compare the scattered patterns of the metasurfaces with those of an equal-size metal plate. Figs. S4a, S5a, and S6a show the simulated radar cross section (RCS), whose unit is dBsm. Figs. S4b, S5b, and S6b show the experimental results, in which the received field strength is measured and plotted in dB. The peak values of the scattering patterns are summarized in Table S1.

Table S1  Summary of the peak values of the scattered patterns

| Sample | Cosecant beam | | Flat-top beam | | Double beam | |
|---|---|---|---|---|---|---|
| | Simulation | Measurement | Simulation | Measurement | Simulation | Measurement |
| Reference metal | 19.8 | −39.5 | 12.6 | −45.8 | 12.6 | −45.9 |
| Metasurface | 5.3 | −51.8 | 0.3 | −56.5 | 3.0 | −52.6 |

The simulation results are in dBsm, while measurement results are in dB
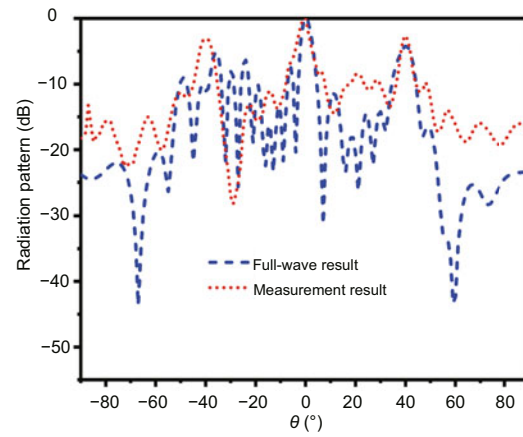
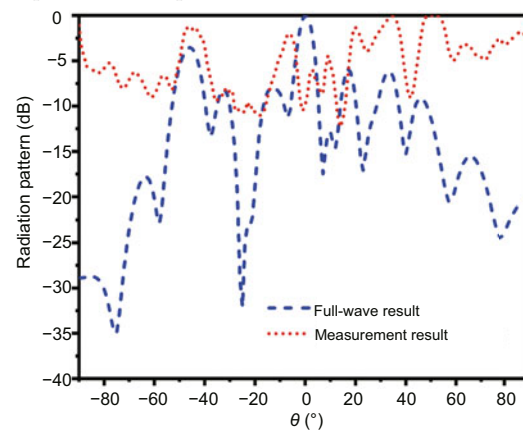**Fig. S1  Co-polarization pattern of the cosecant-beam metasurface**



**Fig. S2  Co-polarization pattern of the flat-top-beam metasurface**
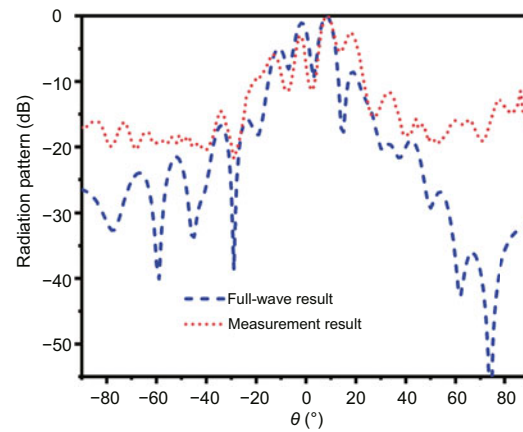


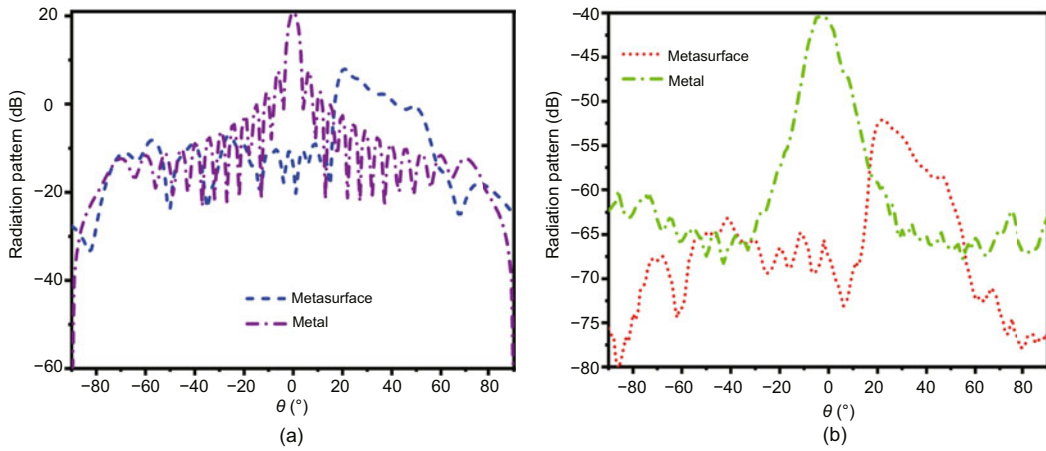**Fig. S3  Co-polarization pattern of the double-beam metasurface**

**Fig. S4** Scattered patterns of the cosecant-beam metasurface and an equal-size metal plate: (a) full-wave simulation; (b) experimental measurement
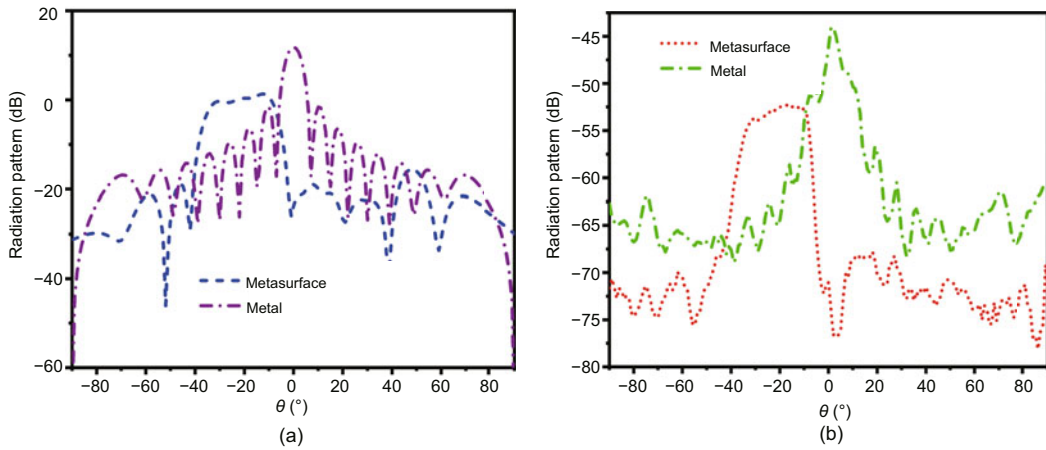


**Fig. S5** Scattered patterns of the flat-top-beam metasurface and an equal-size metal plate: (a) full-wave simulation; (b) experimental measurement
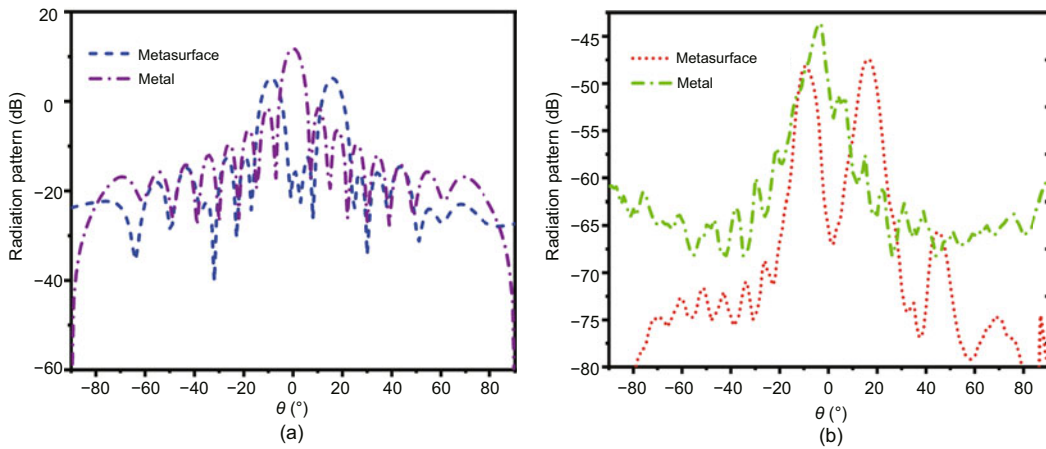


**Fig. S6** Scattered patterns of the double-beam metasurface and an equal-size metal plate: (a) full-wave simulation; (b) experimental measurement