Broadband L-Shaped Probe Fed Suspended Metasurface Antenna

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***Abstract*—A suspended metasurface antenna with an L-shaped probe is proposed for broadband operation. A metasurface printed onto the bottom surface of a thin substrate is separated from a ground plane by an air gap with a thickness of $0.1\lambda_0$ (λ_0 is the free-space wavelength at the center operating frequency). With a compact metasurface area of $0.34\lambda_0 \times 0.43\lambda_0$, the proposed suspended metasurface antenna can achieve an impedance bandwidth of 38.4% with a stable radiation pattern and a peak gain of 9.6 dBi.**

Keywords*— *L-probe; broadband antenna; compact antenna; metasurface

I. Introduction

The operating bandwidth of a microstrip path antenna has been significantly increased to about 30% with the utilization of an L-shaped probe feed [1], [2]. The L-shaped probe has been placed underneath a metasurface to simultaneously excite the transverse magnetic (TM) leaky wave and transverse electric (TE) surface wave resonances and therefore achieve wideband performance as well. An operating bandwidth of 34.5% and a peak gain of 10.3 dBi has been demonstrated with a metasurface area of $0.72\lambda_0 \times 0.57\lambda_0$ (λ_0 is the free-space wavelength at the center operating frequency) [3]. To widen the operating bandwidth with enhanced gain, a dipole fed suspended metasurface antenna has been proposed by merging a dipole mode and a TE surface wave resonance mode. An operating bandwidth of 33.6% and a peak gain of 11.5 dBi have been obtained with an enlarged metasurface area of $1.25\lambda_0 \times 0.58\lambda_0$ [4].

A compact broadband antenna is usually preferred for the fixed/phased array antenna design or for some special platforms with size constraint. Therefore, the application of the aforementioned broadband antennas may be undesired due to the relatively large antenna aperture. In this paper, an L-shaped probe fed suspended metasurface antenna is proposed for larger bandwidth while with a compact radiating aperture.

II. Antenna Design And Measurement

The configuration and dimensions of the proposed L-shaped probe fed suspended metasurface antenna are shown in Fig. 1. A metasurface is printed on the bottom surface of a 0.813 mm thick Rogers RO4003C substrate ($\varepsilon_r = 3.55$, $\tan\delta = 0.0027$), and is separated from a ground plane by an air gap with a height of h. The metasurface consists of 2 × 2 rectangular patches with a periodicity and gap width of (p_x, g_x) and (p_y, g_y) along the x- and y-direction, respectively. An L-shaped probe is formed with a vertical probe and a horizontal strip printed on the top surface of the RO4003C substrate. The horizontal rectangular strip has a width of W_f and a length L_f. The inner conductor of a 50-Ω SMA launcher serves as the vertical cylindrical probe with a diameter D_p and a distance of d_f away from the center of the metasurface.

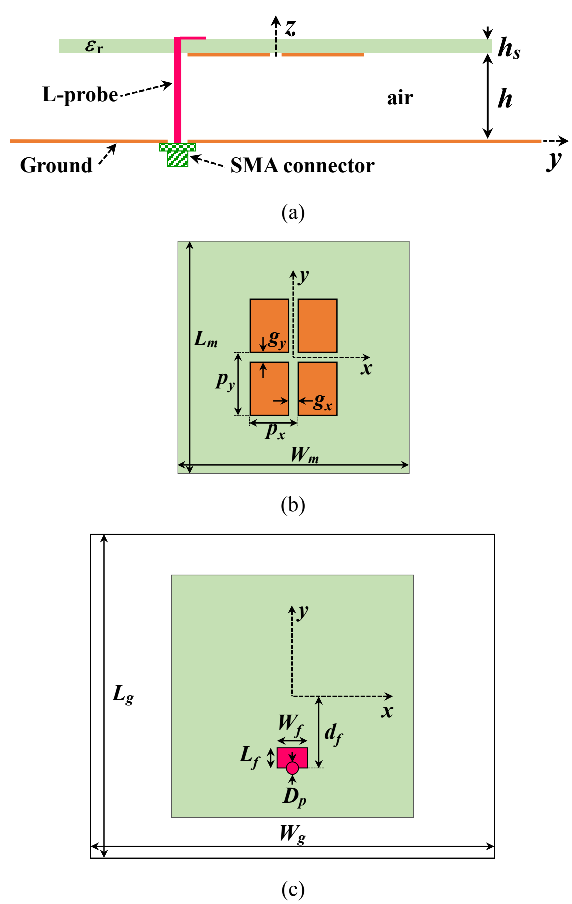

Fig. 1. Configuration of the L-probe fed suspended metasurface antenna. (a) Side view of the antenna. (b) Top view of the metasurface. (c) Top view of the L-probe. ($h_s = 0.813$, $h = 6.6$, $p_x = 11.15$, $p_x = 14.15$, $g_x = 0.3$, $g_y = 0.3$, $D_p = 1.27$, $L_f = 2.2$, $W_f = 3$, $d_f = 16.2$, $L_m = W_m = 60$, $L_g = 80$, $W_g = 100$. unit: mm)

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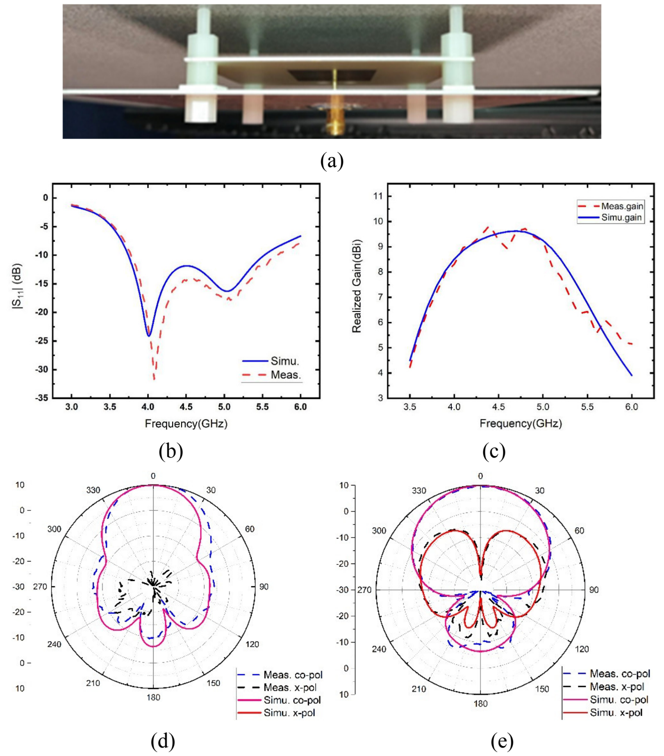

Fig. 2. (a) Photograph of the metasurface antenna prototype; (b) measured and simulated $|S_{11}|$; (c) realized gain; (d) measured and simulated radiation patterns in the *E*-plane at 4.5 GHz; and (e) measured and simulated radiation patterns *H*-plane at 4.5 GHz.

TABLE I

PERFORMANCE COMPARISON OF THE L-PROBE FED ANTENNAS

Antenna	Center freq. (f_0)	Radiator aperture	Operating band ($\lvert S_{11}\rvert <$ 10 dB)	Peak gain
L-probe fed patch [1]	4.6 GHz	40mm × 23.8mm or $0.61\lambda_0 \times 0.36\lambda_0$ or $0.22\lambda_0^2$	3.8–5.4 GHz, 34.7%	9.6 dBi
Proposed work	4.64 GHz	22mm × 28mm or $\mathbf{0.34\lambda_0 \times 0.43\lambda_0}$ or $0.146\lambda_0^2$	3.75–5.53 GHz, **38.4%**	9.6 dBi

λ_0 is the free-space wavelength referring to the center operating frequency.

Fig. 2(a) shows the photograph of the L-probe fed suspended metasurface antenna prototype. The measured and simulated results are compared in Figs. 2(b)–(e). The proposed antenna has a simulated impedance bandwidth of 38.4% from 3.75 GHz to 5.53 GHz with a peak gain of 9.6 dBi. The measured impedance bandwidth is 40% from 3.8 GHz to 5.7 GHz with a peak gain of 9.8 dBi. A stable broadside radiation pattern is obtained across the broad bandwidth. The measured radiation patterns at 4.5 GHz agree well with the simulations in both the *E*-plane and *H*-plane.

The simulated input impedance of the antenna is shown in Fig. 3(a). The TM_{01} mode of the suspended metasurface is found at the resonant frequency of 4.32 GHz. The corresponding electric field distribution is shown in Fig. 3(b). The

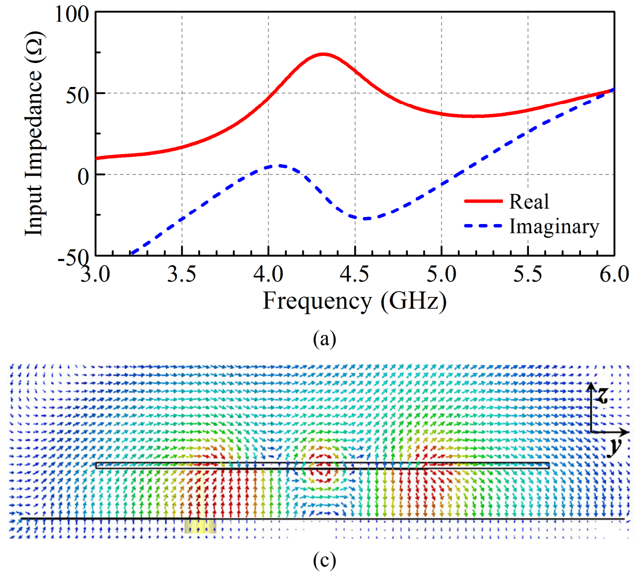

Fig. 3. (a) Simulated input impedance of the antenna against frequency and (b) simulated electric field distribution in the *yz*-plane at 4.32 GHz.

electromagnetic waves are radiated from both the two open ends and the center gap area, resulting in a lower quality factor of the TM_{01} mode for an enhanced bandwidth as compared with the conventional patch antenna.

In comparison with the L-probe fed conventional patch antenna, as summarized in Table I, the proposed L-robe fed suspended metasurface antenna achieves a wider bandwidth of 38.4% with a reduced aperture area of $0.34\lambda_0 \times 0.43\lambda_0$. The reduced aperture will feature the advantage to suppress the mutual coupling between the antenna elements in the array antennas and multiple-input multiple-output (MIMO) antenna systems.

III. CONCLUSION

A broadband compact suspended metasurface antenna fed by an L-shaped probe has been proposed. An operating bandwidth of 38.4% has been achieved with an aperture area of $0.34\lambda_0 \times 0.43\lambda_0$. Owing to its enhanced bandwidth and reduced aperture, the proposed antenna shows promising potential in the applications of various wireless systems.

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