Wideband low-profile CPW-fed slot-loop antenna using an artificial magnetic conductor

Xin Li, Yong-Chang Jiao and Li Zhang✉

A wideband low-profile slot-loop antenna is proposed based on an artificial magnetic conductor (AMC) reflector which is applied to a slot-loop antenna to obtain directional radiation patterns. Compared with an antenna using a metal reflector, the AMC reflector can reduce the profile of the antenna and enhance operating bandwidth. The AMC consists of 4 × 6 patches with ring slots and slits. A coplanar waveguide is introduced to the proposed slot-loop antenna so that the antenna can directly attach to the AMC surface. Thus, a low profile of $0.05\lambda_L$ is realised (λ_L is the wavelength at the lowest operating frequency). Simulation and experimental results indicate that the proposed antenna obtained a 37.9% impedance bandwidth, a 36.7% 3-dB gain bandwidth, and a 6.85 dBi peak gain.

Introduction: With the rapid development of wireless systems, many antennas are required to be conformal to the carrier. Therefore, the design of low profile directional antennas becomes a new issue in recent years. Directional radiation patterns could be obtained by using reflectors in antenna designs. Compared with the metal reflector, an artificial magnetic conductor (AMC) surface exhibits adjustable reflection phases in the operating band [1]. Thus, the antennas could be placed near AMC reflectors to obtain a lower profile.

Recently, many types of research indicate that the antenna loaded with AMC cannot only obtain characteristics of directional radiation patterns and low profile but also broaden the operation bandwidth [2–7]. In this Letter, a wideband low-profile coplanar waveguide (CPW)-fed slot-loop antenna over AMC ground is proposed. Compared with the gap coupling fed structure, the AMC reflector could be directly attached to the antenna with the use of CPW feeding structure. Thus, the profile of the antenna could be further reduced. The dimensions of the proposed antenna are 42 × 28 × 3 mm^3 ($0.67\lambda_L \times 0.45\lambda_L \times 0.05\lambda_L$). The proposed antenna is simulated by ANSYS HFSS v15.0, and a prototype is manufactured and tested. Simulation and experimental results indicate the proposed antenna obtained a 37.9% impedance bandwidth, a 36.7% gain bandwidth, and a 6.85 dBi peak gain. Compared with the state-of-art literature, the proposed antenna has lower profile and wider bandwidth.

AMC surface: The proposed artificial magnetic conductor unit consists of four cross-shaped slots and a ring slot is shown in Fig. 1*a*. The AMC is printed on an FR4 substrate. The thickness of the substrate is 2 mm with relative dielectric constant $\varepsilon_r = 4.4$.

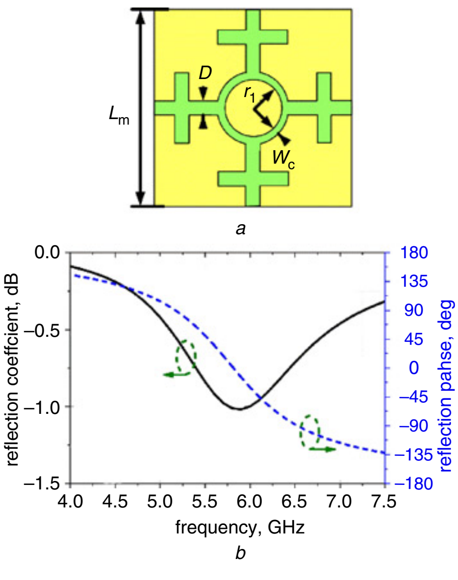

Fig. 1 *Geometry of AMC unit cell, and the reflection coefficient and phase characteristics of the AMC structure*

a AMC unit cell: $L_m = 7$ mm, $r_1 = 1$ mm, $w_c = 0.3$ mm, $D = 0.5$ mm
b Reflection coefficient and phase of the AMC

In general, an AMC operation bandwidth is defined in the frequency between ±90°. The reflection coefficient and phase characteristics are shown in Fig. 1*b* indicate that the proposed structure has an operating band of 5.03–6.73 GHz.

Wideband slot-loop antenna with AMC surface: The configuration of slot-loop antenna is shown in Fig. 2*a*. The antenna printed on an FR4 substrate. The thickness of the substrate is 1 mm with relative dielectric constant $\varepsilon_r = 4.4$. The antenna consists of several slots and strips, with the dimensions 23.8 mm × 11.9 mm.

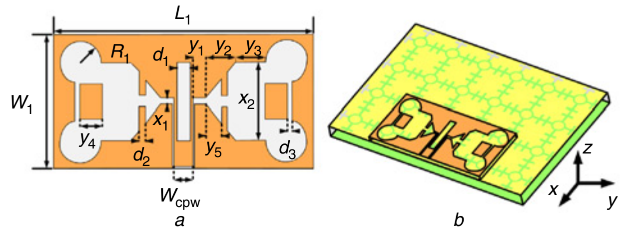

Fig. 2 *Geometry of the proposed wideband low-profile slot-loop antenna*

a Slot-loop antenna: $L_1 = 23.76$ mm, $W_1 = 11.88$ mm, $x_1 = 0.54$ mm, $x_2 = 7.02$ mm, $y_1 = 1.2$ mm, $y_2 = 2.7$ mm, $y_3 = 2.7$ mm, $y_4 = 1.94$ mm, $y_5 = 1.45$ mm, $d_1 = 1.2$ mm, $d_2 = 0.5$ mm, $d_3 = 0.5$ mm, $R_1 = 1.95$ mm, $W_{cpw} = 1.7$ mm
b Slot-loop antenna with AMC surface

The AMC surface is periodically formed by the AMC unit (four unit cells in the *x*-direction and six unit cells in the *y*-direction), which is directly attached to the antenna with the use of a 50-Ω CPW feed line. As a result, the profile of the proposed antenna is $0.05\lambda_L$. The specific structure of the antenna with AMC surface is exhibited in Fig. 2*b*.

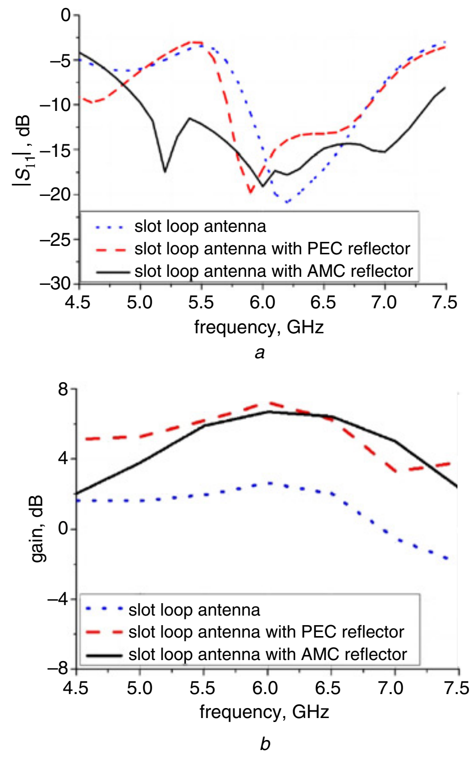

Fig. 3 *Simulation results of different antennas*

a $|S_{11}|$
b Gain

To illustrate the advantages of the AMC reflector, the influences of the metal and AMC reflectors on the slot-loop antenna are studied. It should be noted that the size of the metal reflector is also 42 mm × 28 mm and the profile of the slot-loop antenna using metal ground is 13.5 mm ($0.19\lambda_L$). As shown in Fig. 3*a*, the original antenna without reflector operates at 5.87–6.86 GHz with a relative bandwidth of 15.6%. The antenna with metal reflector has a relative bandwidth of 18.4%, which has no obvious improvement. However, by introducing the AMC structure, the bandwidth of the slot-loop antenna is enhanced to 37.9%. Moreover, according to Fig. 3*b*, there are 4.49 and 4.09 dBi increases in maximum gains when metal or AMC reflector is used, respectively.

Results and discussions: A prototype antenna is fabricated as shown in Fig. 4. Simulated and measured results depicted in Fig. 5 show that the −10 dB impedance bandwidths are 37.9% (5.01–7.35 GHz) and 39.1% (4.85–7.21 GHz), respectively. The measured 3-dB gain bandwidth of the proposed antenna is 37.5% (5.0–7.31 GHz), while the simulated one is 36.7% (5.02–7.28 GHz). The simulation results are generally matched with the experimental results. The tolerances of the manufacturing process and the measured environment mainly affect the different results.

Fig. 4 *Manufactured prototype of the slot-loop antenna*

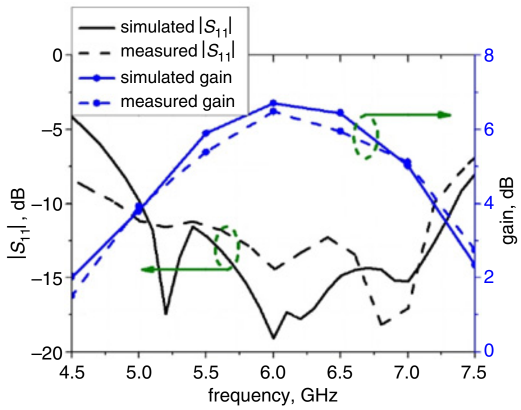

Fig. 5 *Simulated and measured results*

Fig. 6 shows the normalised far-field patterns of proposed slot-loop antenna in the *xoz* and *yoz* planes at 6 GHz. It indicates that the proposed design has directional radiation patterns.

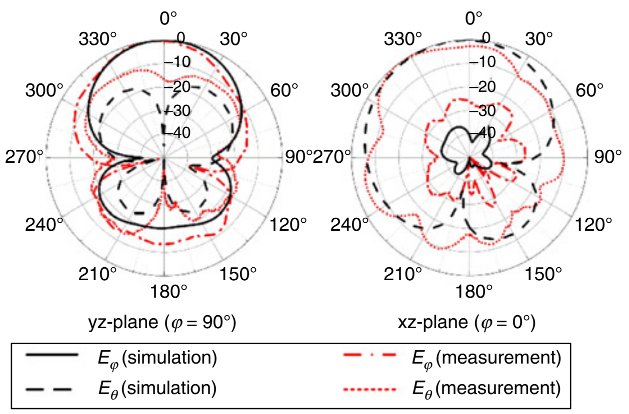

Fig. 6 *Normalised far-field patterns of the proposed antenna in the xoz and yoz planes at 6 GHz*

For a fair comparison, all sizes are expressed as the wavelength at the lowest operating frequency listed in Table 1. According to the table, the proposed antenna has a wider operating bandwidth and a lower profile than antennas in [2–5].

Table 1: Comparison of the proposed and previous antennas

Design cases	Profile (λ_L)	Bandwidth
[2]	0.087	10.38% (5.525–6.13 GHz)
[3]	0.059	5.34% (2.37–2.50 GHz)
[4]	0.078	31.41% (4.67–6.41 GHz)
[5]	0.145	16.7% (1.64–1.94 GHz)
Proposed antenna	0.05	37.9% (5.01–7.35 GHz)

Conclusion: In this Letter, a wideband low-profile slot-loop antenna with an AMC reflector is proposed. By using the AMC reflector, the proposed antenna obtains directional radiation patterns with a wide operating bandwidth. Compared with the antenna using a metal reflector, the profile of the proposed antenna is reduced to $0.05\lambda_L$. The results indicate that the antenna has a wide impedance of 37.9% (5.01–7.35 GHz) and a gain bandwidth of 36.7% (5.02–7.28 GHz). The performances are compared to the state-of-art literature to demonstrate that the proposed design has a low profile and wide operating bandwidth.

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One or more of the Figures in this Letter are available in colour online.

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