A novel low-scattering and wideband monopole antenna based on artificial magnetic conductor

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Abstract. A novel low-scattering monopole antenna based on the phase cancellation between perfect electric conductor (PEC) and artificial magnetic conductor (AMC) is designed, the bandwidth of RCS reduction is 9.3 GHz~11.3 GHz, and the maximum RCS reduction value reaches 26.2 dB at 10.1 GHz. Besides, a wideband range of 10 dB return loss is achieved for the proposed design, compared with the original reference antenna, of 3.3 GHz~12.2 GHz (114.84%) and the radiation pattern is also kept in good condition. Finally, a prototype of the proposed new low-scattering monopole antenna was manufactured and measured, the experimental results coincide well with simulated counterpart.

1. Introduction

Nowadays, the metamaterials has been widely penetrated into aerospace, wireless communication [1], military equipment [2-4] and other related fields. The anti-radar stealthy technology based on metamaterials [5-8] has been applied to military equipment to decrease the radar cross section (RCS), which is characterized the scattering echo of target with the incidence of normal electromagnetic wave. The antenna in the stealthy platform, as a combination of scattering and radiation source, make a great contribution to the overall RCS, and therefore the first step to realize electromagnetic stealth of the whole platform is to reduce the RCS in antenna.

Several methods have been proposed in literatures to reduce RCS as well as keep the radiation performance of antenna [9,10], such as adopting radar absorbing material [11] changing the shape of the radiation patch [12], and destructive cancellation between different cells. The metallic perfect electric conductor (PEC) reflect the incident waves with a 180° phase change while AMC cells present a 0° phase change to the reflected wave within its working frequency, as in [13], the destructive interference between PEC and AMC is first applied to achieve RCS reduction, the 10 dB RCS reduction is obtained within the work frequency of AMC (15 GHz~16 GHz). Keeping the radiation performance of proposed antenna is a crucial issue, in [14], the octagonal ring arrangement composite surface is placed around waveguide slot antenna as the ground, the bandwidth of 10 dB RCS reduction...
is 5.24 GHz~5.92 GHz, besides, the gain is improved by 5 dB to obtain an improvement on radiation performance.

To make further efforts on broadening the impedance bandwidth of monopole antenna [15] and improving its scattering performance [16], a design approach aimed at reducing the RCS and increasing the bandwidth is proposed in this paper, details of the proposed ultra-wideband monopole antenna with lower RCS are describe and experimental results of the radiation performance are presented and analyzed.

2. Design of Proposed AMC Cell
Full numerical analysis of the AMC cells has been carried out by means of the software HFSS using a unit cell with Floquet port and appropriate periodic boundary conditions, the prototype of proposed AMC cell is shown as Fig.1. A 2 mm Polytef substrate with dielectric constant $\varepsilon_r=2.65$ and tangent of 0.003 is employed, on the top layer, a periodic element with unit length $D=5$ mm is designed, the effect of side length $L1$ of the periodic patch on the reflection phase condition is simulated and shown in Fig.2. According to the model of RLC equivalent circuit [17], an equation relationship among the resonant frequency $f$, equivalent inductance $L$ and the equivalent capacitance $C$ is given as (1):

$$f = \frac{1}{2\pi \sqrt{LC}}$$

With the side length of patch is increased, the gap between the metallization edge is reduced, and the equivalent capacitance $C$ is enhanced, and then the resonant frequency is decreased, from the Fig.2, it is observed that the resonant frequency is decreased with the increase of the side length $L1$, the simulation results indicate that the resonant frequencies $f$ at 9.6 GHz, 8.8 GHz, 7.7 GHz with bandwidths, defined for the distance between reflection phase $\pm 90^\circ$, of about 7.9 GHz~11.7 GHz, 7.4 GHz~10.5 GHz, 6.6 GHz~9.0 GHz, respectively.

![Figure 1. Prototype of the proposed AMC unit cell](image1.png)

![Figure 2. Effect of L1 on reflection phase](image2.png)
3. Design and Analysis of Proposed Antenna

The schematic configuration of the proposed low-RCS wideband planar monopole antenna with AMC reflector is shown in Fig.3 (b), and the reference antenna without loading AMC reflector is depicted in Fig.3 (a). The square radiation patch has a side length of $L_p=8$ mm and is printed on a Polytef dielectric substrate of length $W=50$ mm, thickness $h=2$ mm and relative permittivity $\varepsilon_r=2.65$, which is fed by the coplanar waveguide of length $L=18.1$ mm, $L_c=20.8$ mm, $g=0.5$ mm respectively. The AMC block composed by $3\times 10$ unit cells whose side length $L_1=4.6$ mm is loaded upon the substrate, with the corresponding ground on the bottom.

![Schematic of Antenna Configuration](image)

**Figure 3.** Proposed antenna: (a) reference; (b) after loading the AMC block

The preservation of the reference antenna radiation properties is a vital target for the proposed antenna design. The return loss curve after loading the AMC cells is shown as Fig.4, the original reference antenna shows multi frequency characteristic for 10 dB return loss bandwidths on 3.9 GHz~5.8 GHz, 7.3 GHz~9.7 GHz and 11.2 GHz~12.1 GHz, respectively, corresponding to an impedance bandwidth of 40.43%, 26.67% and 7.69% with respect to the resonant frequencies. However, the bandwidth of proposed monopole antenna loaded with the AMC reflector cover 3.3 GHz~12.2 GHz (114.84%), that is due to the surface current distribution of reference antenna is changed after loading the AMC block, following with the improved impedance matching. Besides, the radiation patterns at resonant frequencies is depicted in Fig.5, loading the AMC reflecting screen hardly has any significant impact at the lower resonant frequency, the gain is enhanced in certain directions at the third resonant frequency, we could conclude that the novel low-RCS monopole antenna work well.
The main idea of this paper is aimed at the design of a surface that reflects the incident plane wave in phase and counter-phase simultaneously, and achieve a null in specular direction, the power of incident wave will be reflected over other directions. The simulated results of monostatic RCS is depicted in Fig.6, the RCS is reduced over the 9.3 GHz~11.3 GHz compared with the reference antenna, meet the pervious theory, and obtained the maximum RCS reduction value 26.2 dB at 10.1 GHz.
4. Fabrication and Measurement

Once the structure of the proposed antenna is confirmed, a prototype was fabricated, as depicted in Fig.7. The return loss against frequency for the proposed monopole antenna was measured by using the Agilent N5224A vector network analyzer and is presented in Fig.8, the 10 dB return loss bandwidth is extended to 3.4 GHz~12.4 GHz (113.92%), coincidence with the simulated counterpart, and thus the proposed low-RCS antenna has an ultra-broad bandwidth.

![Prototype of proposed low-RCS wideband monopole antenna](image1)

Figure 7. Prototype of proposed low-RCS wideband monopole antenna

![Experimental results of return loss](image2)

Figure 8. Experimental results of return loss

The monostatic behavior of the proposed structure has been evaluated by means of the standard horn antenna reflection coefficient characterization in an anechoic chamber. And from the obtained results in Fig.9, it can be seen that RCS reduction is reached within 8.9 GHz~11.2 GHz, match with the simulated results.
5. Conclusion

The principle of destructive interference between PEC and AMC for RCS reduction in monopole antenna has been validated both theoretically and experimentally, reasonable agreement between the simulation and measurement is achieved. In addition, the radiation performance is also improved by loading the AMC reflector on the monopole antenna, the measured bandwidth of new antenna cover 3.4 GHz–12.4 GHz (113.92%), and the radiation pattern is preserved compared with the original antenna, and thus obtain a low-RCS and wideband monopole antenna. In addition, the bandwidth of 10 dB RCS reduction is still insufficient, for further work, it is aimed at extending the bandwidth of 10 dB RCS reduction by improving the proposed structure.

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