Bionic Antenna with Low RCS for Microstrip Application

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Abstract

In order to solve the conflict between radar cross section (RCS) reduction and performance of microstrip antenna, bionics principle is applied to antenna, and a bionic butterfly microstrip antenna is presented in this letter. This structure is cutting the fuscous area of butterfly wings in the sunshine away based on bow-tie patch. Simulation and measured results and analysis demonstrate that this bionic antenna can not only guarantee the antenna radiation performance, but also reduce the RCS of the antenna significantly at frequency range from 4 GHz to 8GHz, the largest reduction is up to 23dBsm.

Keywords : Bionics Microstrip Antenna Radar cross section (RCS) Bow-tie patch

1. Introduction

Radar cross section (RCS) is measurement for the scattering power from the special direction as the planar waving irradiation. In the modern war, the system of antennas is inevitable parts in military affairs and important contributors for the overall RCS of military platform. How and what reduce the RCS is signality for war's victory and defeat under the complex electromagnetic surroundings. Microstrip patch antennas (MPA) are very popular in aerospace systems because of their intrinsic advantages, such as light weight, low profile, easily fabricate, and easily conform to aircraft. Recently, according to particular structure of MPA, lots of schemes are proposed to reduce the RCS by scholars [1-4], but these schemes reduce RCS at the cost of antenna radiation performance. The variety of antenna gain and bandwidth are the primary criterion which weigh the schemes of reducing RCS. Reduction of the RCS of an antenna without compromising its radiation characteristics has been an important task for scholars.

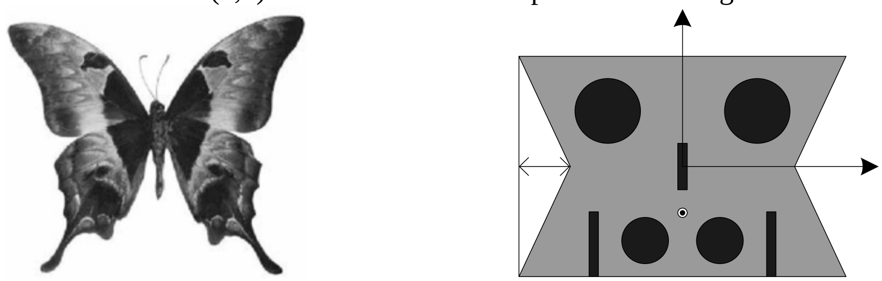
The most problem of reducing the RCS is taking into account antenna radiation characteristic and scattering characteristic, it requires antennas only radiate and receive radar wave from ours, meanwhile not reflect and scatter radar wave from enemy, this conflict is difficult to solve. The technology of stealth is not singularity technology, but that all kinds of technologies are combined. Because the routine measures of stealth don't apply simply to antenna, new ideas are needed to explore. Biology organism is optimization structure which adapting to subsistence、competition、propagation in the evolution of nature. Experiments have proved that a seagull has 200 times larger RCS than a cowbird, while they are of a similar size. The dimension of a bee is smaller than a sparrow, but the RCS of a bee is 16 times larger than that of a sparrow [5]. Biological methods and systems found in nature can be applied to the study and design of engineering systems and modern technology, from which the concept of bionics is derived. In [6], the insect tentacle structure is proposed to design a low-RCS ultra wideband antenna. In [7], the sunflower structure is proposed to design a low-RCS ultra wideband antenna. However, the application of bionics in design of low-RCS microstrip antenna has never been seen.

Biology produces or changes their bodies color by using their wizardly organism structure in order to protect them. The butterfly has flowery color. The research on butterfly's squama finds that these squamas have vision stealth obviously by absorbing, reflecting, scattering and diffusing the different frequency light-wave. Thereinto, the fuscous areas of butterfly wings can absorbing the energy of sunshine to supplement itself and it is not easily discovered in the vision. Hereby, a bionic butterfly microstrip antenna is presented. This structure is cutting the fuscous area of butterfly wings in the sunshine away based on bow-tie patch to reduce electromagnetic wave reflection and scattering in these area. This bionic antenna can not only guarantee the antenna radiation performance, but also reduce the RCS of the antenna significantly.

2. Antenna Design

Design the rectangular microstrip antenna operating at 3.23GHz as reference antenna. It is printed on a 2-mm-thick substrate with the relative dielectric constant of 2.65. The patch dimension of reference antennas is $35 \times 26.4mm^2$. Choose the center of patch as center of coordinate. A coaxial probe location is (0,5). Then, the gain and bandwidth of reference antennas are 7.34dBi and 3% respectively.

As shown in Fig.1, the black area is needed to cut away by cutting slots. The patch dimension of bionic antennas is $35 \times 23.8mm^2$, $WS = 5.5mm$ .The center location of big circular slots with 3.5mm radius are (8,6)、(-8,6)respectively. The center location of small circular slots with 2.5-mm-radius are (4,-8)、(-4,-8)respectively. The center location of long rectangular slots with 7-mm-length and 1-mm-width are (-9.5,-8.4)、(9.5,-8.4)respectively. The center location of short rectangular slot with 5-mm-length and 1-mm-width are (0,0). Meanwhile the other parameter settings are never changed.

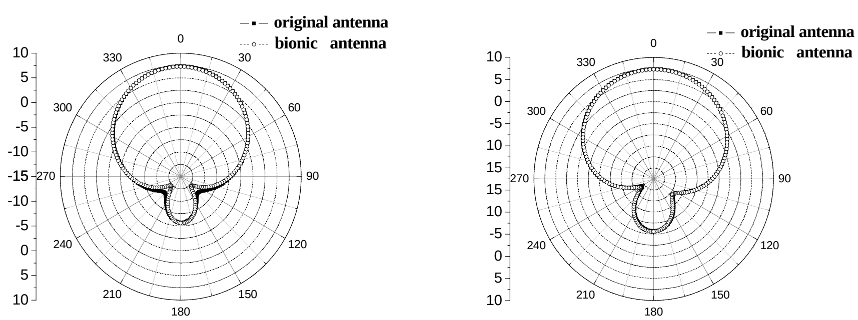


(a) (b)

Fig.1. (a) Butterfly shape (b) Bionic antennas

3. Results and Discussions

Simulation can indicate that the operation frequency of bionic antennas is 3.23GHz and the gain of bionic antennas is 7.25dBi with only reduction of 0.09dBi. Fig 2 depicts the radiation patterns of the original antennas and the bionic antennas are almost indistinguishable. As shown in Fig 3, the bionic antennas bandwidth is 2.18% with decrease of 0.82%. Fig 4 depicts the measured S11 of the two antennas using the vector network analyzer AgilentN5230A. It can be observed that the two antennas both operate at 3.23GHz and the bandwidth of the original antennas and the bionic antennas are 2.8% and 2%, respectively. So, the measured and simulated results obtain a good agreement. As shown in Fig 5, the current distributions of operating dominant mode TM10 are not destroyed. Thus, the bionic structure design has no obvious effects on the antenna radiation performance.



E plane H plane

Fig.2. Radiation patterns of the original patch antenna and the bionic antenna at 3.23GHz

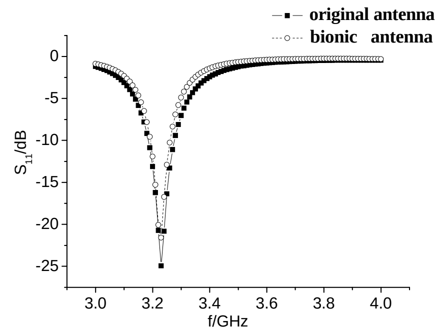


Fig.3. Simulated s11 comparison of the original patch antenna and the bionic antenna

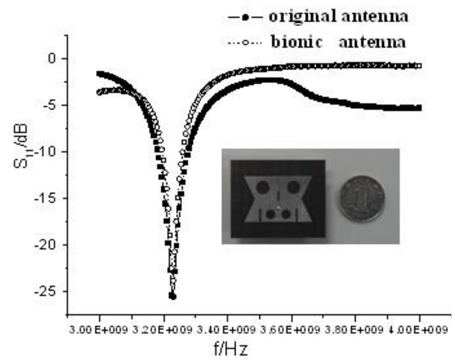


Fig.4. Measured s11 comparison of the original patch antenna and the bionic antenna

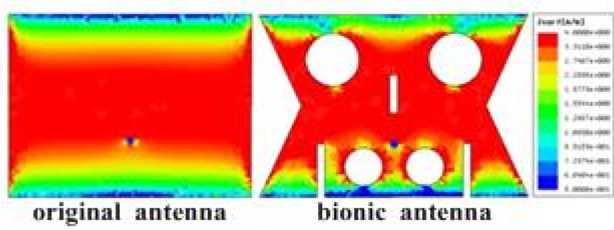


Fig.5. Current distributions of the original patch antenna and the bionic antenna at 3.23GHz

Fig.6 shows the RCS comparison of the two antennas at the incident angle $(60°, 0°)$. It can be seen that all of the RCS peaks of original antenna are restrained. When the θ polarized plane wave illuminates the original antenna, TM21 mode is generated at 7.2GHz. According to Newman's method [8], these RCS peaks are caused by some combination of the impedance and pattern factor resonance of some modes. The TM21 mode can be clearly observed through the simulated current distributions shown in Fig.7. The bionic structure cut off the surface current to some extent. The maximum current amplitudes are restrained, and the RCS value at 7.2GHz is further reduced by 23 dBsm.

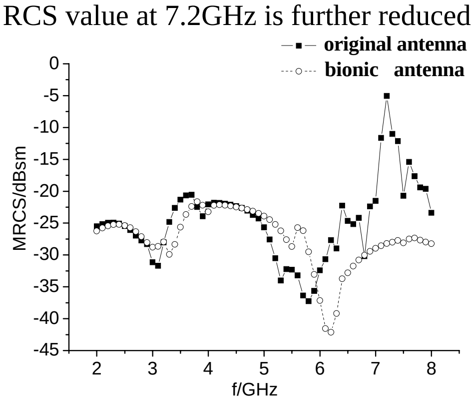


Fig.6. RCS comparison of the original patch antenna and the bionic antenna. $(\theta = 60°, \varphi = 0°)$

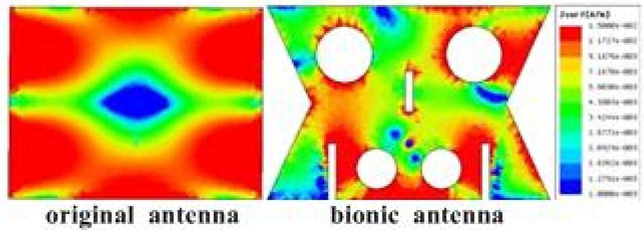


Fig.7. Current distributions of the original patch antenna and the bionic antenna $(\theta = 60°, \varphi = 0°)$ $f = 7.2GHz$

Fig.8 shows the RCS comparison of the two antennas at the incident angle $(60°, 45°)$. The RCS is reduced almost in the whole frequency range of 4.5-8GHz. For the three obvious RCS peak at 6.4GHz, 7.2GHz and 7.5GHz, the RCS reductions reach 15dBsm, 18dBsm and 17dBsm, respectively. Meanwhile, the RCS of operating bandwidth also is also reduced. These reductions of RCS peaks also can be explained by the current distributions. The bionic structure destroys the resonance TM12 mode、TM21mode、TM03mode. As shown in Fig.9, the surface current in the antenna decreases obviously at TM12 mode and TM03mode.

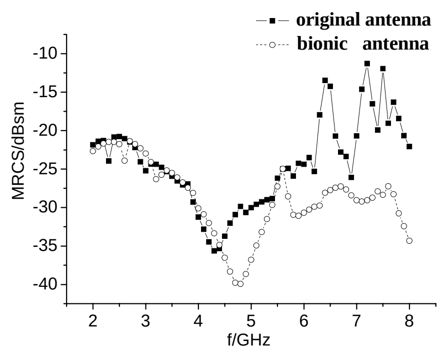
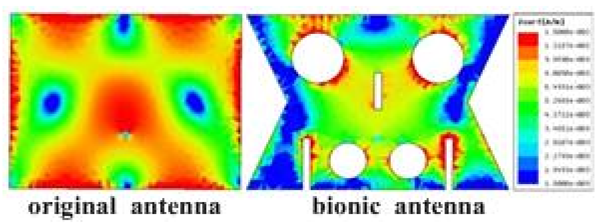
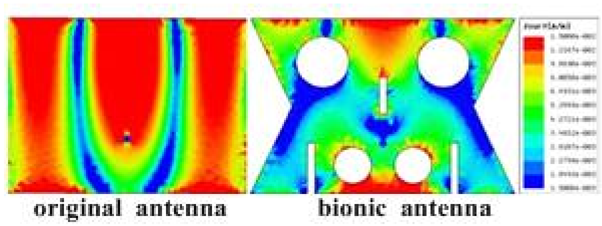


Fig.8. RCS comparison of the original patch antenna and the bionic antenna. $(\theta = 60°, \varphi = 45°)$



(a) $f = 6.4GHz$



(b) $f = 7.5GHz$

Fig.9. Current distributions of the original patch antenna and the bionic antenna $(\theta = 60°, \varphi = 45°)$

Fig.10 shows the RCS comparison of the two antennas at the incident angle $(60°, 90°)$. The RCS is reduced almost in the whole frequency range of 6-8GHz. For the two obvious RCS peak at 6.5GHz and 7.8GHz, the RCS reductions reach 13dBsm and 15dBsm, respectively. These reductions of RCS peaks also can be explained by the current distributions. the bionic structure destroy the resonance TM12 mode and TM13mode As shown in Fig.11, the surface current in the antenna decreases obviously at TM13 mode.

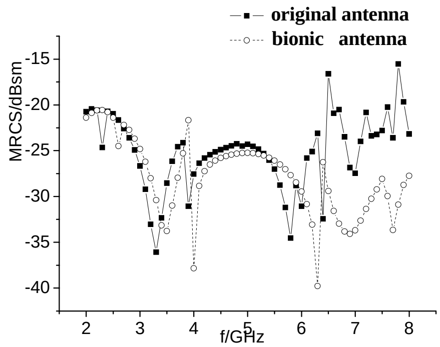


Fig.10. RCS comparison of the original patch antenna and the bionic antenna. $(\theta = 60°, \varphi = 90°)$

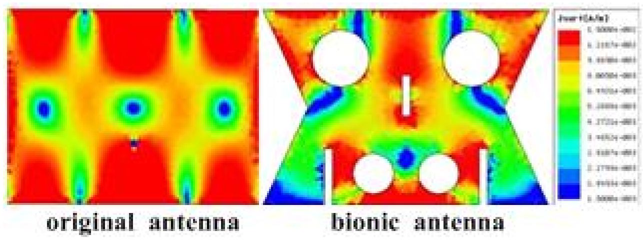


Fig.7. Current distributions of the original patch antenna and the bionic antenna $(\theta = 60°, \varphi = 90°)$ $f = 7.8GHz$

4. Conclusion

Bionics principle is applied to microstrip antenna radar cross section reduction in this letter. Simulation and measured results and analysis demonstrate that this bionic antenna reduce the RCS of the antenna significantly, the largest reduction is up to 23dBsm. At the same time, the radiation performance of bionic antenna has almost no change. The gain and bandwidth of bionic antenna only reduce by 0.09dBi and 0.8%, respectively. It solves the conflict between radar cross section (RCS) reduction and performance of microstrip antenna greatly.

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Acknowledgments

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