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APERTURE COUPLED MICROSTRIP ANTENNA WITH LOW RCS

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Abstract—Research of antenna Radar Cross Section (RCS) is very important for low observable platform. Aperture coupled microstrip antenna is fit for the low RCS antenna design because the feed network produce less effect on scattering of microstrip patch. A novel aperture coupled microstrip antenna is proposed, which utilizes the chip-resistor load, ground slot and miniaturization, to realize RCS reduction. Aperture coupled antenna with rectangular patch is chosen as the reference antenna. Two antennas are simulated and measured. The measured results show that the designed antenna realizes only 0.5 dB gain loss while RCS are reduced in almost all the frequency band.

1. INTRODUCTION

Antenna is a special scatter and its scattering is related with the feed load. When the feed port is math loaded, the scattering is structural mode scattering. If not, part of the received energy is reradiated which contributes antenna mode scattering [1, 2]. The backscattering radar cross section of microstrip patch antennas, including the effect of the feed termination impedance, has been studied [3–8]. Most of the antenna forms are with coaxial feed or microstrip feed. As we know, the feed network of antenna is also one of the contributions to the total RCS of antenna, which is with very complicated scattering process. Plane waves pass through the feedline. If the port is not matched, part of the waves will be reflected back and then reradiate just like the antenna radiation pattern. Part of the waves will be reflected back to the port and then reflected to the antenna. This process will continue ceaselessly. So the scattering analysis of feed network is one of the difficult topics of antenna RCS research. To reduce the complicity, aperture coupled antenna [9–11] is found to be a good candidate for low RCS antenna [5]. The feed network of aperture coupled antenna is on the other side of the dielectric material which reduce its contribution to the antenna RCS. Also, the ground plane can be used to reduce antenna RCS by cutting slots.

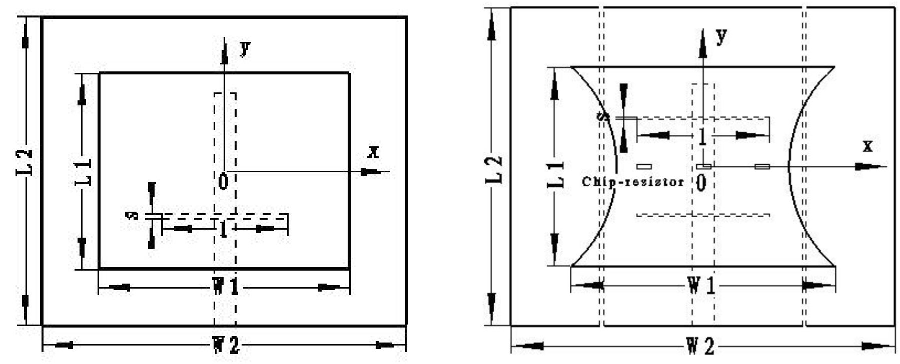
In this paper, a novel aperture coupled antenna with chip-resistor load, ground slot and miniaturization [12] is illustrated. Chip-resistor is distributed along the center of the patch which can be used to control the RCS mode of antenna while maintain the radiation mode. Ground slot is cut to change the surface current of the antenna. The shape of the patch is also designed as the miniaturization shape. Three technologies are combined together to design the final antenna. For comparison, aperture coupled antenna with rectangular patch is chosen as standard reference antenna which is at the same resonance frequency with the designed antenna. The designed antenna is called loaded antenna in the figures for convenience. The radiation and scattering performance of two antennas are designed and analyzed. Prototypes are fabricated and measured under the same test condition. Analysis and measured results show that designed antenna maintains the radiation performance of standard antenna while RCS is greatly reduced in the whole frequency band.

2. ANTENNA PERFORMANCE

The standard reference antenna and designed loaded antenna are as shown in Fig. 1. The standard reference antenna is with the rectangular patch and one coupled slot. The designed antenna is with curvilinear shape which is used to reduce antenna effective area to reduce RCS. Three chip-resistors are distributed along the center of patch. On the ground, four slots are cut indicated as dashed line. On the bottom of the dielectric is the microstrip feed line. Detailed dimensions of two antennas are listed in Table 1. The center coordinates of the horizontal coupled slots in the designed antenna are $(0, 7)$ and $(0, -7)$. Vertical slots are with the center coordinates $(12.25, 0)$ and $(-12.25, 0)$, with the width 0.5 mm. For comparison, two antennas are designed with

Table 1. Detailed dimensions of two antennas.

Parameter (in mm)	W1	L1	W2	L2	s	l
Standard antenna	32	25	46.4	39.4	0.6	16
Designed antenna	32	22.3	46.4	36.7	0.3	16



(a) (b)

Figure 1. Antenna structures and detailed dimensions of two antennas. (a) Standard reference antenna (b) Designed loaded antenna.

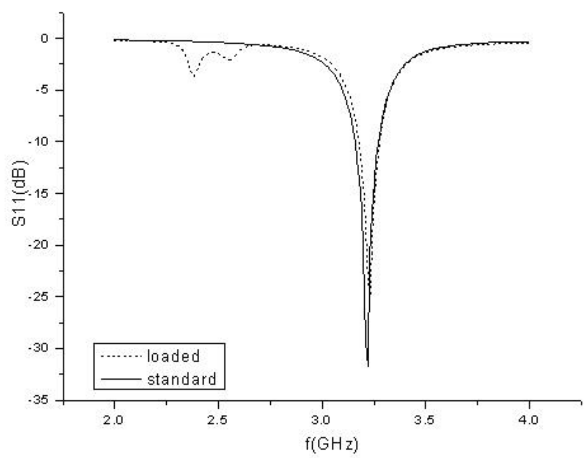
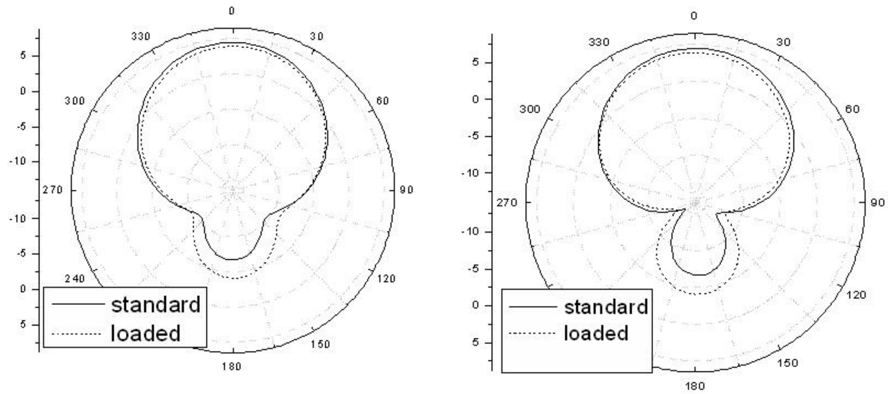


Figure 2. Simulated S_{11} of two antennas.

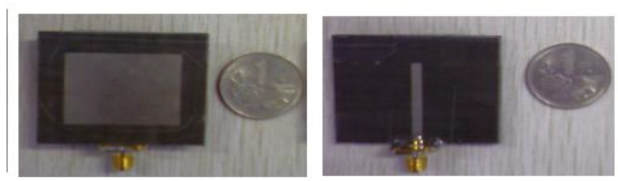
the same dielectric material. The dielectric constant is with $\varepsilon_r = 2.65$. Heights of two dielectrics are $h_1 = 1\,\text{mm}$ and $h_2 = 2\,\text{mm}$.

Commercial software HFSS based on the finite element method (FEM) is used to simulate and optimize the antennas. Chip-resistor is optimized to find the 50 ohm reduces the antenna bandwidth least. The position is chosen along the center of the patch to produce lease effect on the radiation mode and is fit for the control of other RCS modes. To reduce the in band RCS, multiple slots are cut on the ground

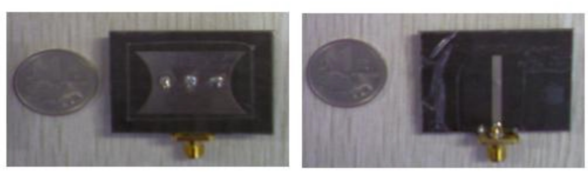


(a) (b)

Figure 3. Radiation patterns of two antennas. (a) Phi = 0° (b) Phi = 90°.



(a)



(b)

Figure 4. Pictures of two antennas. (a) Top and bottom of the standard reference antenna (b) Top and bottom of the designed loaded antenna.

to control the current of patch for better RCS reduction [5]. After optimization process, designed loaded antenna and standard reference antenna are both resonant at frequency 3.22 GHz. Simulated S_{11} is as shown in Fig. 2. Fig. 3 shows the radiation patterns of two antennas at center frequency. According to the design, two antenna prototypes are fabricated as shown in Fig. 4, which shows the top and bottom

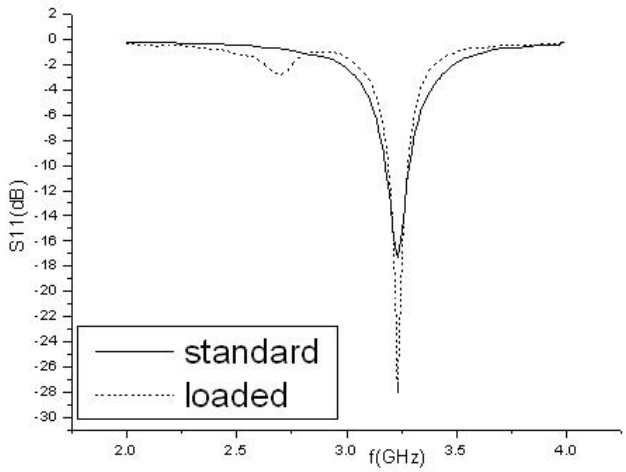


Figure 5. Measured S_{11} of two antennas.

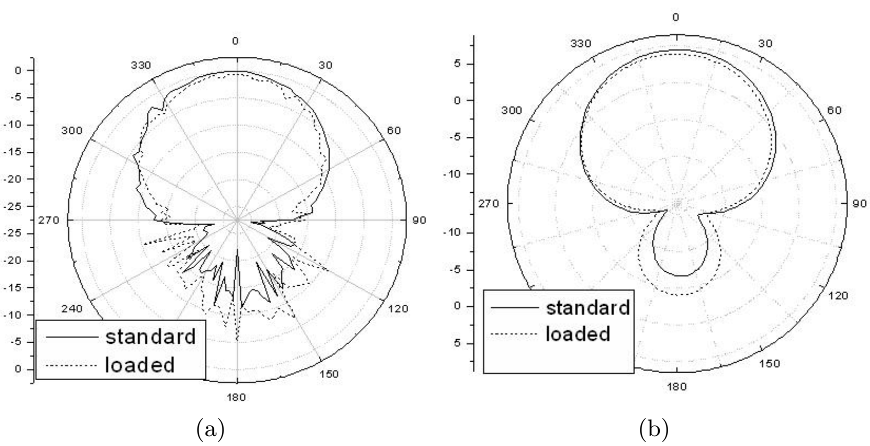


Figure 6. Measured radiation patterns of two antennas. (a) Phi = 0° (b) Phi = 90°.

surfaces of two antennas.

Two antennas are fed with SMA connector and measured with vector network analyzer. Fig. 5 shows the measured S_{11}. It can be seen that two antennas realize the same resonant frequency and good match. Under the same far field test system, the radiation patterns of two antennas are measured as shown in Fig. 6. Two antennas have similar radiation performance. The gain difference is just 0.5 dB, which is very worthwhile for the RCS reduction.

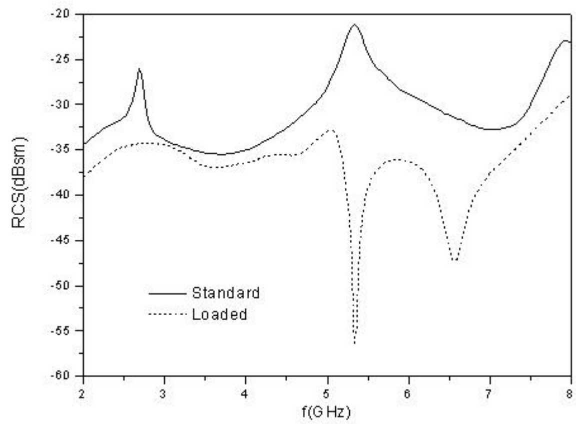


Figure 7. RCS of two antennas under plane wave incident from $\theta = 60°$, $\varphi = 0°$.

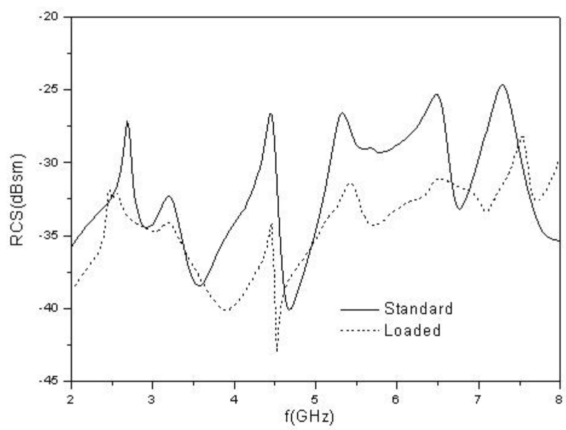


Figure 8. RCS of two antennas under plane wave incident from $\theta = 60°$, $\varphi = 45°$.

Fig. 7 shows the RCS of two antennas with the θ polarized plane wave incident from $\theta = 60°$, $\varphi = 0°$. In the whole frequency band from 2 GHz to 8 GHz, RCS of designed loaded antenna is much smaller than the standard reference antenna. The RCS of designed antenna is almost all below -35 dB. Fig. 8 shows the RCS of two antennas with the θ polarized plane wave incident from $\theta = 60°$, $\varphi = 45°$. Under this direction, more modes of antenna are excited. It can be seen that most of the modes are reduced to some extent.

3. CONCLUSION

The radiation and scattering performance of a novel aperture coupled antenna which combines chip-resistor, ground slot and miniaturization is illustrated. The designed antenna realize rather good RCS reduction while maintains good radiation performance. RCS in the whole frequency band is reduced with gain loss just 0.5 dB, which can be used to design low RCS antenna on the low observable platform.

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