

A Novel Fractal Slot Microstrip Antenna with Low RCS

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Introduction

Stealth technique is very important for modern Electronic War. For low-observable platform, antennas are main contribution to the total radar cross section (RCS), which makes the consideration of antenna scattering more important. Antenna is a special scatterer and its scattering is related with the feed load. When the feed port is match loaded, the scattering is structural mode scattering. If not, part of the received energy is reradiated which contributes antenna mode scattering. The total scattering field is the sum of two components. As microstrip patch antennas are attractive elements due to their inherent advantages, some work [1-4] on the scattering characterization of microstrip patch antennas has been carried out. The RCS reduction of microstrip antenna will reduce the gain. So the design of antenna with good radiation pattern and low RCS is especially important. A fractal slot microstrip patch antenna is designed and fabricated to show good radiation pattern and low RCS, which is helpful to the design of stealth antenna on invisible aircraft.

Antenna Analysis

Moment Method (MM) is used to study the scattering of antenna. As shown in Fig.1, plane wave is incident on the microstrip antenna fed by coaxial cable with load Z_l . The caliber of coaxial cable is represented with equivalent magnetic current loop. RWG basis function and Galerkin method is used in the Moment Method. According to the boundary condition on patch surface, there is.

$$\begin{aligned} & j\omega\mu_0 \int_s G_{xx}^{11}(\bar{r}, \bar{r}') \bar{J}_s(\bar{r}') ds' - \frac{1}{j\omega\epsilon_0} \nabla_s \int_s G_\phi^{11}(\bar{r}, \bar{r}') \nabla'_s \cdot \bar{J}_s(\bar{r}') ds' \\ & + j\omega\mu_0 \int_0^h [\hat{x}G_{xz}^{12}(\bar{r}, \bar{r}') + \hat{y}G_{yz}^{12}(\bar{r}, \bar{r}')] I(z') dz' - \frac{1}{j\omega\epsilon_0} \nabla_s \int_0^h G_\phi^{12}(\bar{r}, \bar{r}') \frac{dI(z')}{dz'} dz' \\ & - \hat{x}E_x^{mag}(\bar{r}, \bar{r}') - \hat{y}E_y^{mag}(\bar{r}, \bar{r}') = \bar{E}_s^i(\bar{r}) \quad \bar{r} \in S \quad (1) \\ & j\omega\mu_0 \int_s [\hat{x}G_{zx}^{21}(z, \bar{r}') + \hat{y}G_{zy}^{21}(z, \bar{r}')] \bar{J}_s(\bar{r}') ds' - \frac{1}{j\omega\epsilon_0} \frac{d}{dz} \int_s G_\phi^{21}(z, \bar{r}') \nabla'_s \cdot \bar{J}_s(\bar{r}') ds' \\ & + j\omega\mu_0 \int_0^h G_{zz}^{22}(z, z') I(z') dz' - \frac{1}{j\omega\epsilon_0} \frac{d}{dz} \int_0^h G_\phi^{22}(z, z') \frac{dI(z')}{dz'} dz' - \hat{z}E_z^{mag} \\ & = E_z^i(z) \quad 0 < z < h \quad (2) \end{aligned}$$

where \vec{r} is the field position vector and \vec{r}' is the source position vector. $\vec{J}_s(\vec{r}')$ is the current on the patch, $I(z')$ is the current on the probe, $E_x^{mag}, E_y^{mag}, E_z^{mag}$ is the electric field of the equivalent magnetic current loop. $\vec{E}_s^i(\vec{r})$ is the total field introduced by incident wave on the original position of patch and $E_z^i(z)$ on original position of the probe when the patch and the probe is removed and dielectric and ground plane remain. MM is used to solve the impedance matrix to get the current distribution, from which RCS is obtained.

Results

Fractal is widely used in electromagnetic field. The concept is used to design the slot of microstrip patch antenna. Strictly speaking, it is a similar fractal with local self similarity and symmetry to assure antenna's regular function.

Firstly a rectangular patch antenna with working frequency 3GHz is designed. The related parameter is $\epsilon_r = 2.62$, antenna thickness is 1.8mm, size of antenna is 29.24mm \times 37mm. The antenna gain is 6.73dBi.

The original patch is meshed 10 \times 10, part of which are removed. After some simulation and optimization process, a fractal slot microstrip patch antenna is obtained as shown in Fig.2. The slot antenna has lower resonant frequency. To improve the frequency and reduce RCS, shorting posts are added. The final antenna with resonant frequency 3GHz has gain 6.04dBi. The gain loss is about 0.69, which is less than 1dB. The measured H plane pattern is shown as in Fig.3. The antenna keeps most of its radiation ability.

Plane wave $\theta=60^\circ$, $\phi=0^\circ$ is incident on the antenna. The RCS of original rectangular patch antenna and the designed slot patch antenna are compared as shown in Fig.4. The RCS reduction at 3GHz is 6.4dB and 24dB at another resonant frequency. There is large RCS reduction during 2.5—7.5GHz.

Conclusion

The analysis of antenna is very important as it is one of the main contributions to the whole RCS of low-observable platform. A new fractal slot microstrip patch antenna is designed and fabricated to show good radiation pattern and low RCS. The work is useful for the design of low RCS antenna on stealth aircraft.

References:

- [1] Hansen, R.C., "Relationships Between Antennas as Scatters and as Radiators", Pro. IEEE, Vol.77 (5), 659-662, 1989.

- [2] Edward H. Newman, David Forrai, "Scattering from a Microstrip Patch", IEEE Transactions on Antennas and Propagation, Vol.AP-35 (3), 245-251, 1987
- [3] David M. Pozar, "Radiation and Scattering from a Microstrip Patch on a Uniaxial Substrate", IEEE Transactions on Antennas and Propagation, Vol.AP-35 (6), 613-621, 1987
- [4] Adrian S. King, Wallace J.Bow, "Scattering from a Finite Array of Microstrip Patches", IEEE Transactions on Antennas and Propagation, Vol.AP-40 (7), 770-774, 1992.

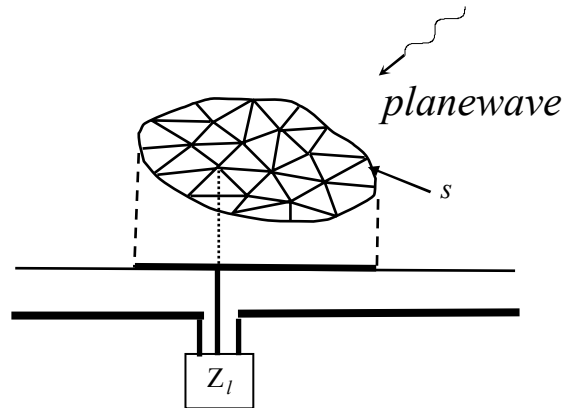


Fig1. Microstrip patch antenna fed by coaxial line with plane wave incident

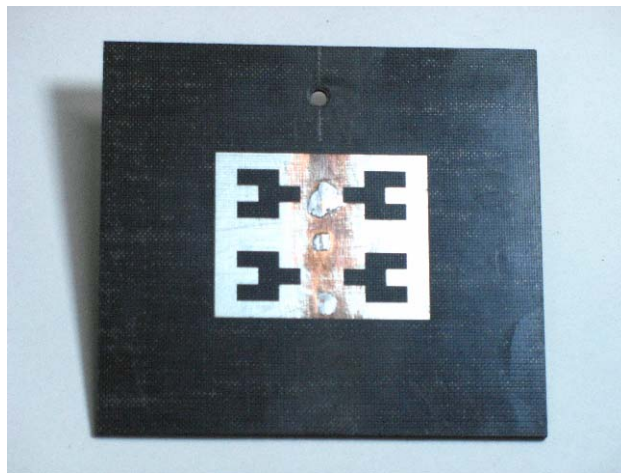


Fig.2 Antenna sample

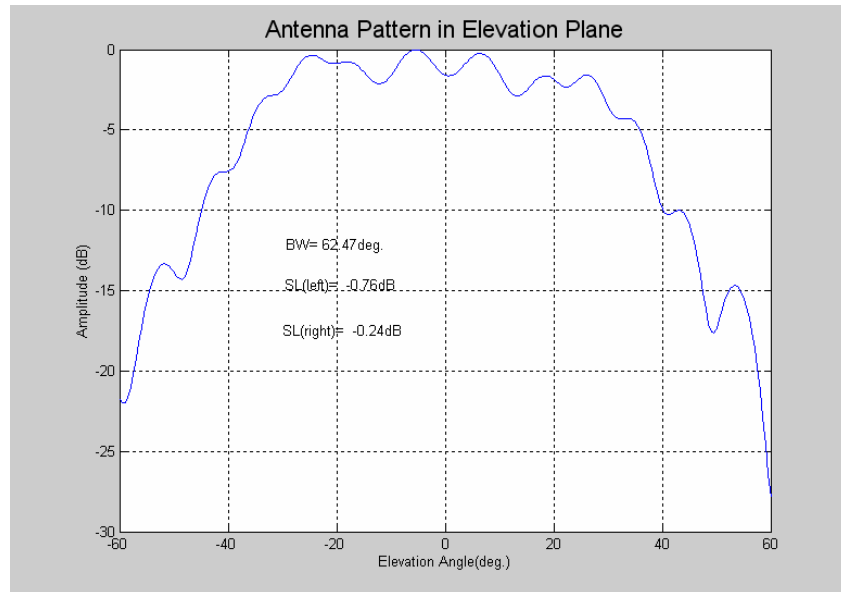


Fig.3 The measured H plane pattern

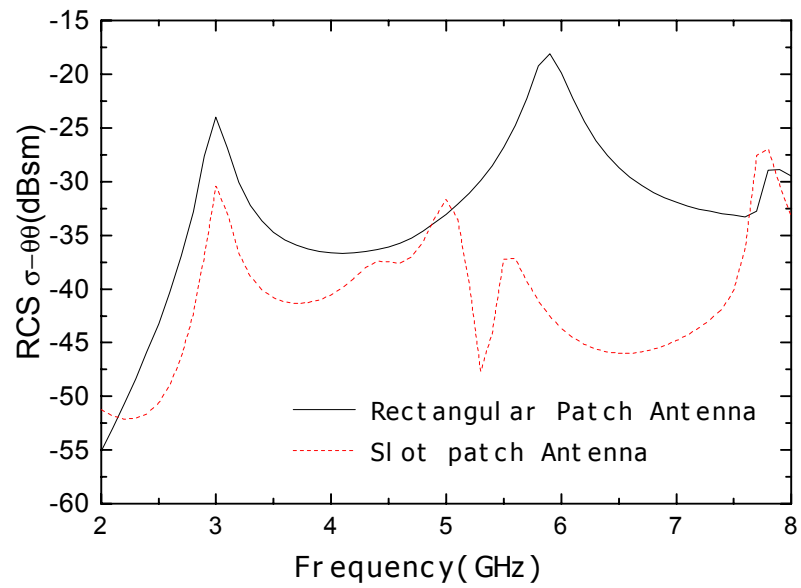


Fig.4 RCS comparison between two antennas