Radar cross-section enhancement of dihedral corner reflector using fractal-based metallo-dielectric structures

A.R. Chandran, M. Gopikrishna, C.K. Aanandan, P. Mohanan and K. Vasudevan

Effective use of fractal-based metallo-dielectric structures for enhancing the radar cross-section (RCS) of dihedral corner reflectors is reported. RCS enhancement of about 30 dBsm is obtained for corner reflectors with corner angles other than 90°. This may find application in remote sensing and synthetic aperture radar.

Introduction: Complex targets such as missiles and aircrafts can be represented as collections of basic geometric elements such as cylinders, cones and flat plates. Studies of the backscattering cross-section of corner reflectors are important for many radar applications and are often used as a radar cross-section (RCS) standard. Corner reflectors are inadvertently formed on ships and military vehicles wherever flat surfaces meet at an angle and act as the major scattering centres of these targets. A right-angled dihedral corner reflector provides a large RCS over a wide angular range in a plane normal to its wedge. These large echoes from these targets arise from multiple reflections between the two mutually orthogonal flat surfaces dominating the backscattered pattern in the forward region [1–4].

In recent years several researchers have studied the backscattering properties of perfectly conducting as well as loaded dihedral corner reflector structures [5–7]. It has been reported that the RCS of dihedral corners can be reduced by altering the mutual orthogonality of the flat surfaces [8]. This technique involves changes in the original engineering design of the target. The consequences of non-orthogonality on the scattering properties have been analysed in [9].

The large RCS of the 90° dihedral corner over a wide angular range makes it a suitable reference target in remote sensing and synthetic aperture radar applications. The RCS of dihedral corner reflectors with acute and obtuse corner angles is very small. A slight variation from the 90° corner angle reduces the RCS drastically. This is a major drawback in designing corner reflectors for the aforementioned applications.

The use of Sierpinski carpet fractal-geometry-based metallisations on a dielectric substrate for reducing the backscattered power from a plane metallic plate and the frequency tunability of this structure have been proposed recently [10, 11]. In this Letter, use of fractal-based metallo-dielectric structures (MDS) for enhancing the RCS of a dihedral corner reflector with corner angles other than 90° is presented.

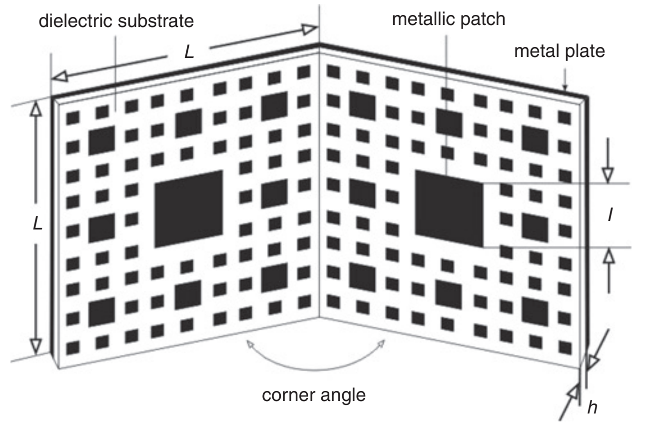

Fig. 1 *Dihedral corner reflector loaded with metallo-dielectric structure based on Sierpinski carpet fractal structure*

$L = 30$ cm, $l = 10$ cm

Methodology and experimental setup: The dihedral corner reflector is formed by attaching two square metallic plates of side $L = 30$ cm on a hinge arrangement. The structure is specially designed so as to vary the corner angle precisely from 0 to 180°. The metallisation based on the third iterated stage of Sierpinski carpet fractal geometry is fabricated on a dielectric substrate of $\varepsilon_r = 2.56$ and is inserted in the corner reflector, as shown in Fig. 1. The target under test is mounted on a support, which is attached to the turntable kept at the quiet zone of the anechoic chamber. A set of X-band horn antennas is used to illuminate the target and to measure the backscattered field. The measurements are performed for TE and TM polarisations using an HP 8510C vector network analyser with appropriate time gating. A metallic dihedral corner reflector of the same dimensions is used as the reference target.

Results: Fig. 2 shows the variation of RCS against frequency for a dihedral corner reflector with 80° corner angle, loaded with metallo-dielectric structure. Compared to an unloaded corner reflector, a large value of RCS (above 20 dBsm) is obtained in the frequency range 9.15–10.33 GHz for an optimum substrate thickness of $h = 3$ mm, the peak (31 dBsm) being at 9.55 GHz. Fig. 3 shows the backscattered cross-section against angle of incidence at this frequency.

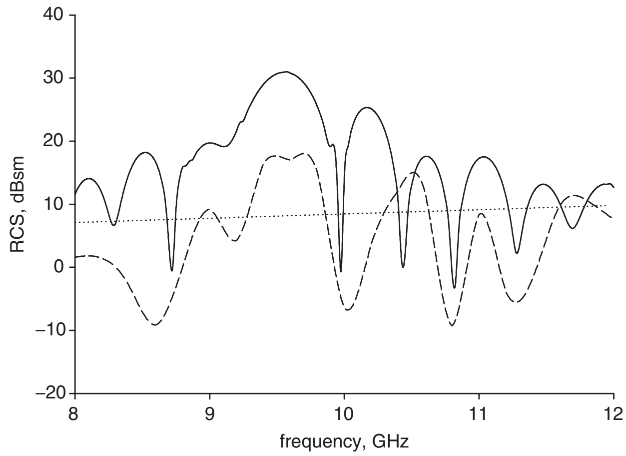

Fig. 2 *Variation of RCS against frequency for dihedral corner reflector*

Corner angle = 80°, $h = 3$ mm
—— MDS loaded, TM polarisation
– – – MDS loaded, TE polarisation
.... plain dihedral corner reflector

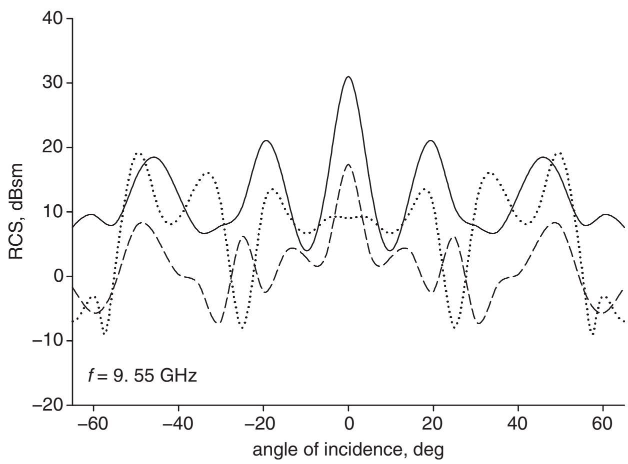

Fig. 3 *Variation of RCS with angle of incidence*

Corner angle = 80°, $h = 3$ mm
—— MDS loaded, TM polarisation
– – – MDS loaded, TE polarisation
.... plain dihedral corner reflector

From the experiments, it is found that the RCS enhancement can be obtained at other corner angles also. The optimum value of dielectric thickness depends on the corner angle. For example, for 120° corner angle, a maximum enhancement of RCS is obtained in the frequency range 9.13–9.7 GHz for an optimised substrate thickness of $h = 2$ mm.

Maximum enhancement in RCS is obtained for TM polarisation for the above cases. RCS variation with corner angle for TM polarisation for a particular substrate thickness is shown in Fig. 4. It is clear from the Figure that RCS is enhanced at certain acute and obtuse corner angles and reduced at 90° corner angle.

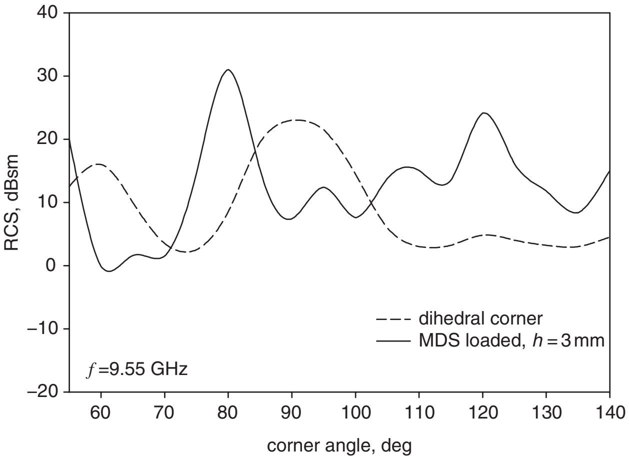

Fig. 4 *Variation of RCS with corner angle for TM polarisation*

Conclusions: The method of loading metallo-dielectric structure based on Sierpinski carpet fractal geometry is found to be effective in enhancing the radar cross-section of a dihedral corner reflector for corner angles other than 90°. RCS enhancement of airborne vehicles has a number of applications, including increasing the viability to track remotely piloted vehicles with radar, using small unmanned air vehicles as tactical decoys for physically larger aircraft, etc.

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