LOW BACKSCATTERED DUAL-POLARISED METALLO-DIELECTRIC STRUCTURE BASED ON SIERPINSKI CARPET

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Received 7 July 2003

ABSTRACT: *A novel technique for backscattering reduction for both TE and TM polarisations, employing a metallo-dielectric structure based on Sierpinski carpet fractal geometry, is reported. A reduction in backscattered power of ~30 dB is obtained for normal incidence in the X-band for the structure using the third iterated stage of the fractal geometry.* Microwave Opt Technol Lett 40: 246–248, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.11342

Key words: *sierpinski carpet; backscattering; radar cross section*

1. INTRODUCTION

Numerous results have been published in the technical literature on the scattering properties of strip gratings and microstrip patch arrays [1, 2]. All these structures employ metallisations on a dielectric substrate based on Euclidean geometry. Various designs have been tried and tested for the elimination of backscattering as well as specular reflection [3, 4]. These metallo-dielectric structures may have wide application in RCS reduction, frequency selective surfaces, and antenna design.

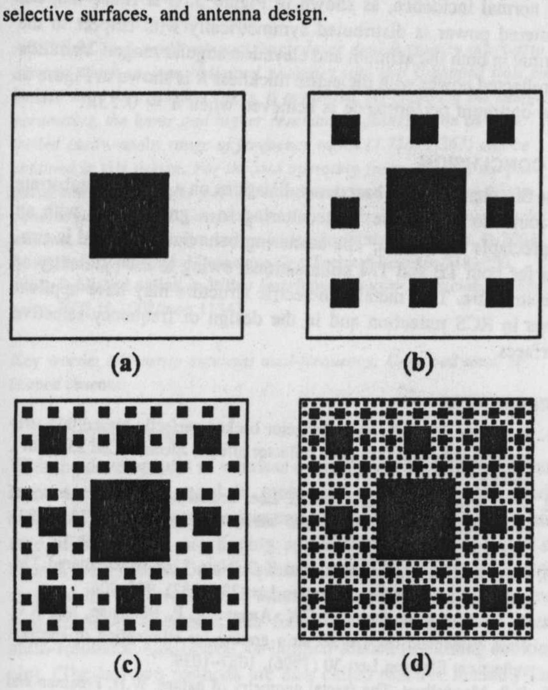

Figure 1 Iterated stages of Sierpinski carpet geometry: (a) stage 1; (b) stage 2; (c) stage 3; (d) stage 4

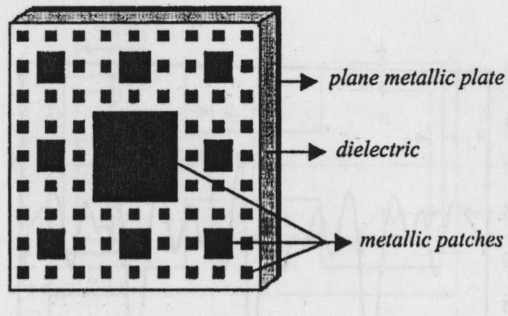

Figure 2 Schematic diagram of the reflector-backed metallo-dielectric structure of the third iterated stage

The idea of using fractal geometries rather than Euclidean geometries has received much attention in the design of electromagnetic radiating and scattering structures, which has opened a new area of research known as fractal electrodynamics. Fractal structures, which are self similar and scale invariant, are finding a wide variety of applications in electromagnetics [5–7]. Antenna designs and frequency-selective surfaces based on fractal geometries have gained considerable interest because of their inherent space filling and multiband nature [8–10]. Using the Sierpinski gasket as an example, it has been established that the paraxial Fraunhoffer zone-diffracted field of a self-similar fractal screen also exhibits self-similarity [11]. Some of the other examples of studies that relate fractals and electromagnetics are diffraction by band-limited fractal screens, the reflection and transmission properties of fractal multilayers, the side-lobe computation of fractal arrays, and the scattering of electromagnetic wave from corrugated random surface with fractal slopes [12–15]. However, studies utilising fractal geometric concepts in the design of metallo-dielectric structures for RCS reduction are not available in the literature. In this paper, the development of a dual-polarised metallo-dielectric structure based on Sierpinski carpet fractal geometry for backscattering reduction is introduced. A considerable reduction in the backscattered power over broadband frequencies is obtained using the third iterated stage of the Sierpinski carpet fractal geometry for both TE and TM polarisations.

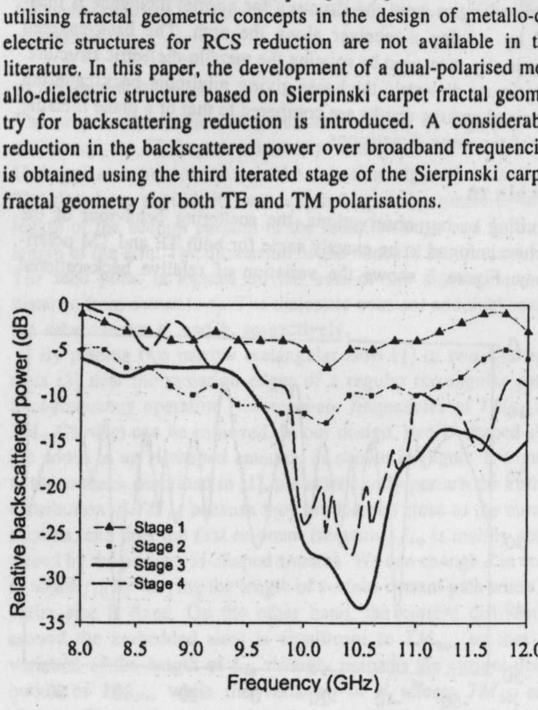

Figure 3 Variation of relative backscattered power with frequency for normal incidence

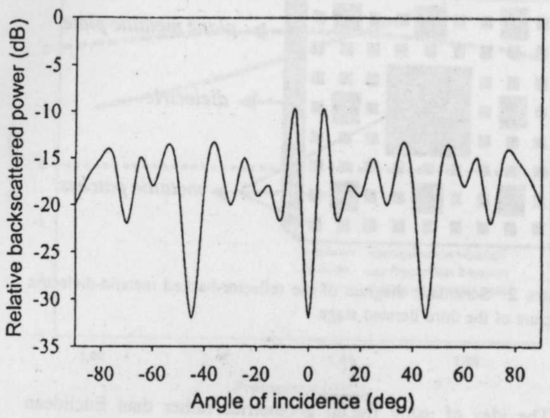

Figure 4 Variation of relative reflected power with angle of rotation at stage 3 with $h = 3.91$ mm and $f = 10.5$ GHz

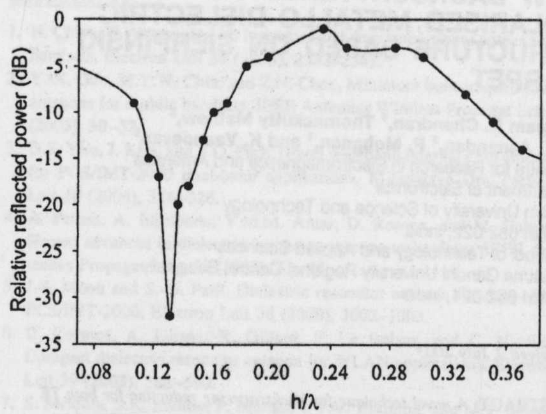

Figure 6 Variation of relative reflected power with dielectric thickness at stage 3

2. METHODOLOGY AND EXPERIMENTAL SETUP

The various iterated stages of Sierpinski carpet fractal geometry used in the present work are shown in Figure 1. The structure is fabricated by photo etching the metallisation on a reflector-backed low-loss dielectric substrate ($\varepsilon_r = 2.56$) of size 30 × 30 cm^2. Figure 2 shows the schematic diagram of metallo-dielectric structure using the third stage of the Sierpinski carpet fractal geometry.

The measurements are performed in the X-band using an HP network analyzer. The arch method is used to measure the scattering properties of the structure. The metallo-dielectric structure is placed on a turntable at the centre of the arch. The power scattered at various angles from the structure for normal incidence is measured by moving a receiver along the arch. The backscattered power is also measured by rotating the metallo-dielectric structure. An optimum dielectric thickness giving minimum backscattering is obtained and the results are compared to that of a plane metallic plate of the same dimensions.

3. RESULTS

According to our observations, the scattering behaviour of the structure is found to be exactly same for both TE and TM polarisations. Figure 3 shows the variation of relative backscattered power with frequency for different configurations of the Sierpinski carpet. It is found that the backscattered power obtained at stage 3 is much less compared to that at stages 1, 2, and 4. From the graph, it can be seen that a maximum reduction of 32 dB at 10.5 GHz is obtained for this configuration. It is also observed that, for this structure, the bandwidth is higher than at the other stages.

Figure 4 shows the variation in backscattered power with angle of incidence for the metallo-dielectric structure employing the third iterated stage of the Sierpinski carpet fractal geometry. It is found that the backscattering is minimum at normal incidence. The power scattered from the structure at various angles is measured for normal incidence, as shown in Figure 5. It is found that the scattered power is distributed symmetrically with respect to the normal in both the azimuth and elevation angular ranges. Variation of reflected power with dielectric thickness h is shown in Figure 6. The optimum performance is achieved when $h = 0.13\lambda$.

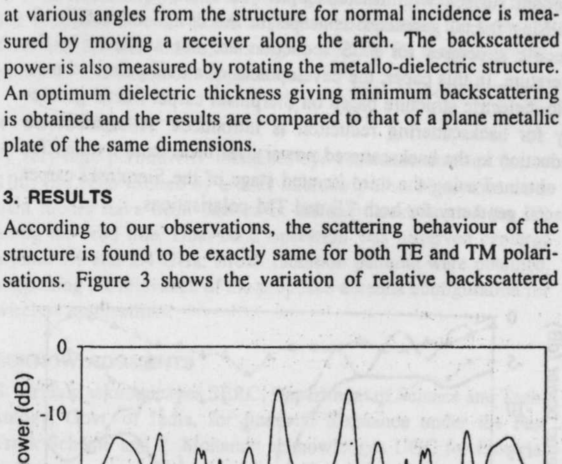

Figure 5 Variation of relative received power with scattering angle at stage 3 with $h = 3.91$ mm and $f = 10.5$ GHz

4. CONCLUSION

The Sierpinski-carpet-based metallisations on a dielectric substrate is found to reduce the backscattering to a great extent with an appreciable bandwidth. The scattering behaviour obtained is similar for both TE and TM polarisations, owing to the symmetry of the structure. This metallo-dielectric structure may have applications in RCS reduction and in the design of frequency-selective surfaces.

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