Backscattering Reduction of Flat Metallic Surface Using Stacked Sierpinski Carpet Fractal Arrays

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Abstract : This paper presents the backscattering reduction of metallic surfaces using fractal arrays. Different iterated stages of the Sierpinski carpet fractal arrays are stacked to achieve a 10 dB backscattering reduction of approximately 80 percent of the X band, with a 32 dB reduction at 11.08 GHz. The effect of the width of the dielectric separating the fractal arrays is studied experimentally.

***IndexTerms* – Backscattering reduction, stacking, fractal arrays.**

I. INTRODUCTION

Scattering of electromagnetic waves back in the direction of the transmitter is termed as backscattering. Most of the radars are monostatic where the transmitter and receiver are collocated. Backscattering is a measure of the monostatic radar cross section of the target. Complex targets like aircrafts, missiles, ships etc. can be modelled as combinations of flat metal plate, corner reflectors, wedges, cones etc. So backscattering reduction of these simple structures can be utilized in the monostatic radar cross section of targets of interest [1].

Different techniques are available for backscattering reduction. Corrugated surfaces with rectangular or triangular grooves with definite width and depth were used to reduce backscattering [2]. But these structures are bulky and non-planar and hence corrugated surfaces are not the ideal choice to reduce backscattering. Dielectric backed strip gratings also called Simulated Corrugated Surfaces have the property of wide angle elimination of specular reflection. [3-4].

Many of these structures reported are narrowband. Stacking of these structures is a method to improve the performance of gratings [5-6] as well as antennas [9-10]. Metallo-dielectric structure based fractal geometry can reduce backscattering to a good extent [7] Sierpinski carpet arrays were also used for reduction of backscattered power from dihedral corner reflectors [8].This paper discuss stacking of Sierpinski carpet fractal arrays for backscattering reduction of metallic targets.

Sierpinski carpet arrays of different iterated stages are stacked in the X- band. The second and third iterations are used for stacking to attain backscattering reduction. Compared to [7] and [8] the required dielectric thickness is less for attaining backscattering reduction below 10 dB for a considerable portion of X band.

II. METHODOLOGY & EXPERIMENTAL SETUP

Measurements are performed over the X band. A flat metal plate of dimension 10 λ×10 λ is selected for backscattering measurements. Sierpinski carpet fractal arrays are fabricated by photo etching an FR-4 substrate (εr =4.4) with thickness of 0.8mm. Second iterated stage of the 4×4 array of Sierpinski Carpet is shown in figure 1.

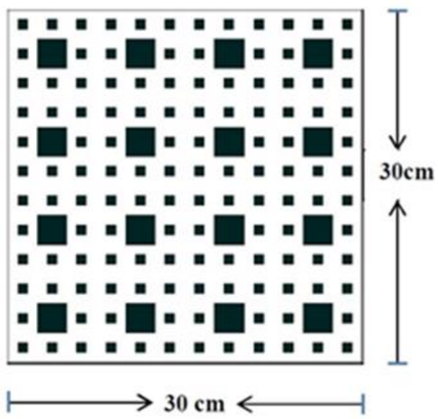
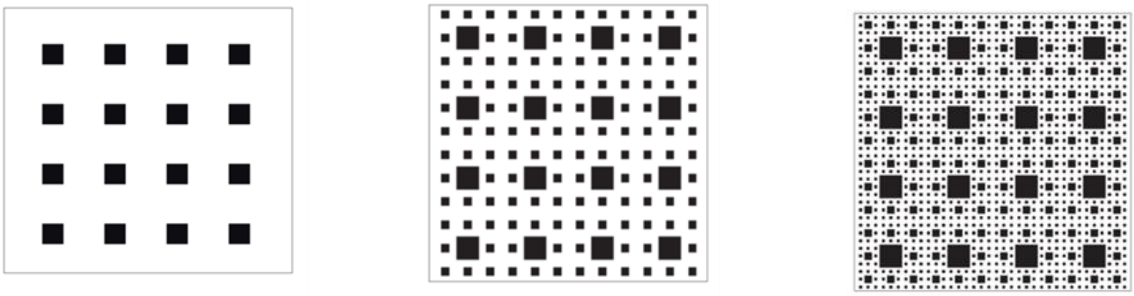


Fig 1.Second iterated stage of the Sierpinski Carpet Array.

First, second and third iterated stages of the Sierpinski Carpet array used for stacking are shown in figure 2.



(a) First iteration (b) Second iteration (c) Third iteration

Fig.2 Different iterated stages of the Sierpinski Carpet array.

Sierpinski carpet arrays are stacked with low loss dielectric sheets (thickness h) of PMMA (poly methyl methacrylate) with εr =2.5 in between as shown in figure 6. The order of stacking is important because backscattered power varies when stacking order is reversed. Measurements are repeated by varying dielectric thickness separating the two stacked fractal arrays.

The arch method is used for the measurement. Backscattered power in various angles are also measured by placing the receiving antenna at various positions along the arch. The experimental setup is shown in in figure 5. Two identical X band horns are connected to the two ports of a vector network Analyzer Rohde & Schwarz ZVB20 calibrated for a flat metal plate at normal incidence. The fractal dielectric structure is mount over the turntable at the center of the arch placed in the anechoic environment as shown.

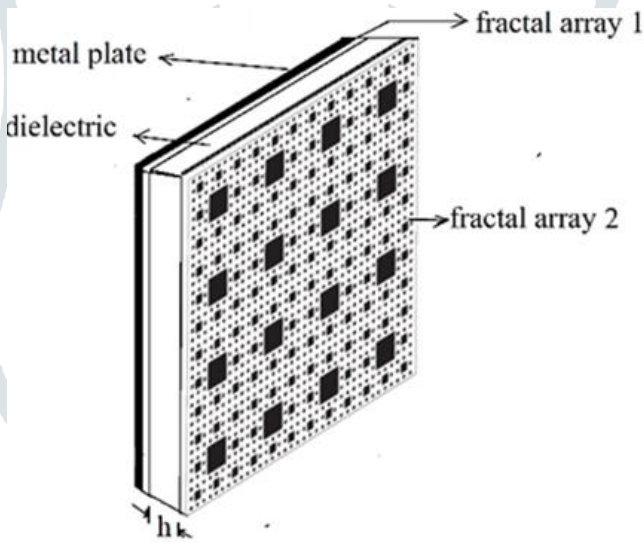


Fig. 3. 3D view of the stacked arrays.

Fig. 4 Photograph of the measurement setup

III. RESULTS & DISCUSSIONS

Backscattering measurements were done using stacking of different iterated stages of Sierpinski carpet arrays. In the experiment only two structures are used for staking in order to reduce the overall thickness.

Stacking of second and third iterated stages give better results compared to other combinations. Backscattered power obtained in the X band for normal incidence by stacking second and third Sierpinski carpet arrays fabricated over 0.8 mm FR4 sheets with varying the thickness of the separating dielectric is shown in figure 5.

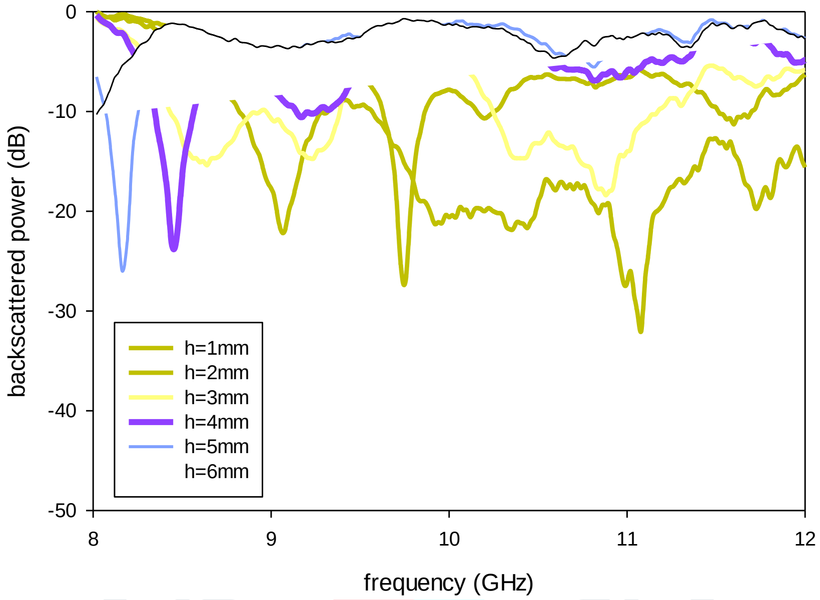


Fig 5 Variation of backscattered power with frequency for varying dielectric thickness

From figure 5 it can be seen that backscattered power is minimum when dielectric separation h=2mm .The variation of backscattered power with frequency for a dielectric thickness of 2 mm is shown in figure 8. A 10 dB reduction in backscattering is obtained over a wide band (80%). The maximum backscattering reduction obtained is 32 dB at 11.08 GHz.

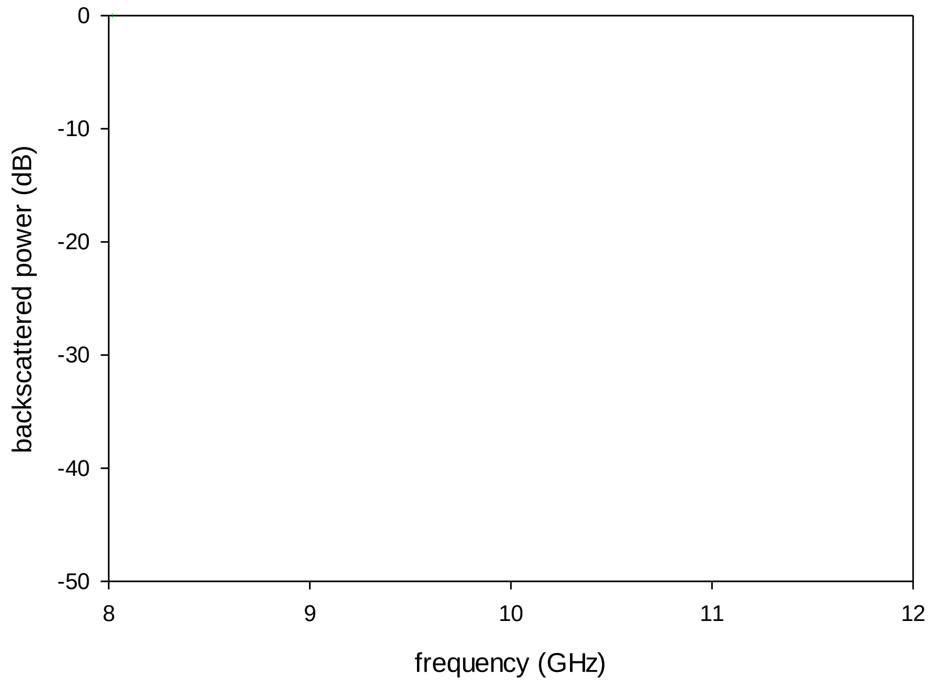


Fig 6 Variation of backscattered power with frequency for h=2mm.

Variation of backscattered power with dielectric thickness for normal incidence at a frequency 11.08 GHz is shown in figure 7.

Scattered power at various angles are measured by moving the receiving antenna along the arch. The received power at various angles are plotted in figure 8. The scattered power is maximum at an angle of ±29 degree.

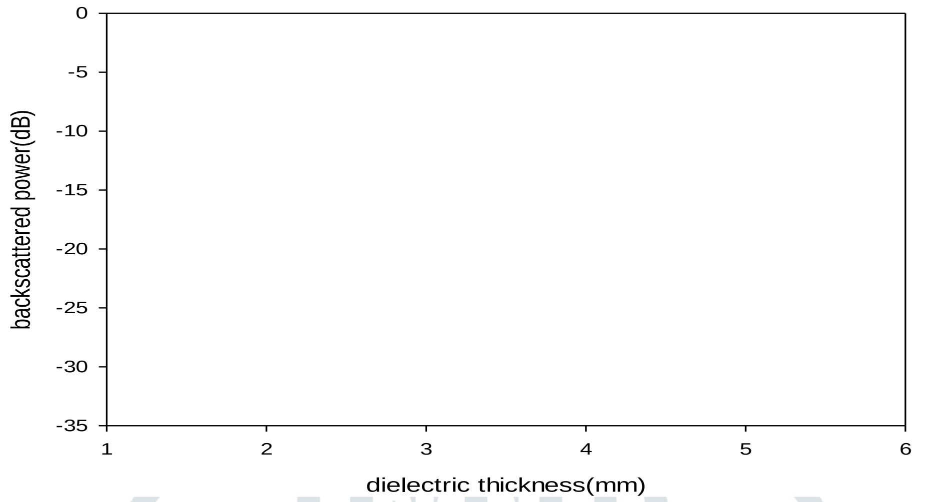


Fig. 7 Variation of backscattered power with dielectric thickness (h) at 11.08 GHz

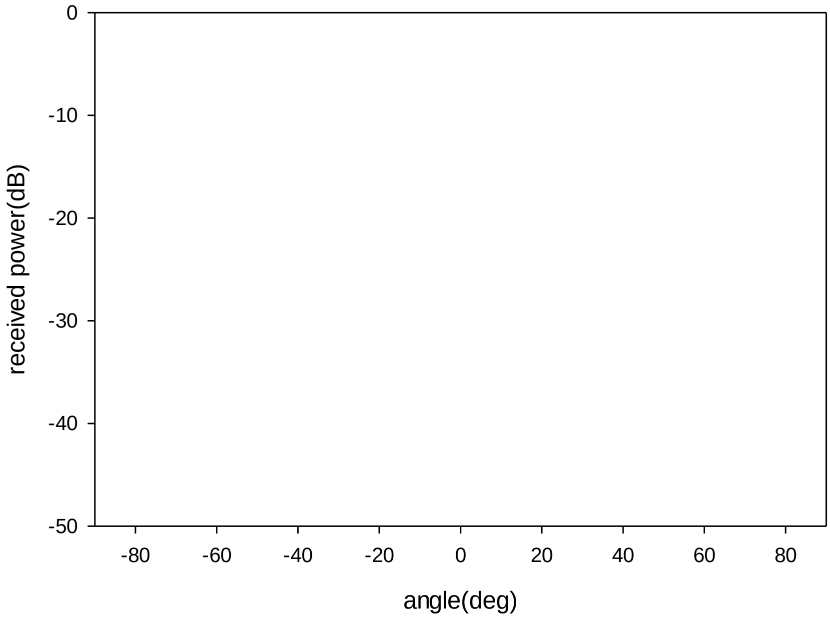


Fig. 8 Variation of received power at various angles at 11.08 GHz

IV. CONCLUSIONS

Backscattering reduction of metallic plates is demonstrated in X band by stacking second and third iterations of the Sierpinski Carpet array. 10 dB reduction over 80 percent of the X band is obtained for a dielectric thickness of 2mm with a maximum reduction of 32 dB at 11.08 GHz. The power incident on the structure is redirected towards other angles to achieve the backscattering reduction.

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