Fractal FSS:
Various Self-Similar Geometries Used for Dual-Band and Dual-Polarized FSS

John P. Gianvittorio*[1], Yahya Rahmat-Samii[1] and Jordi Romeu[2]

*[1]Department of Electrical Engineering
University of California, Los Angeles
Los Angeles, California 90095-1594
rahmat@ee.ucla.edu*
*[2]Department of Signal Theory and Communications
Universitat Politecnica de Catalunya
Jordi Girona 1-3, 08034 Barcelona, Spain*

Introduction In our attempt to design a frequency selective surface (FSS) that is resonant at two distinct bands, dual-polarized, and has a simple planar design, several self-similar elements based on fractal geometry have been investigated. In this paper these various geometries will be presented along with their characteristics.

Fractals Fractal geometries have been used in antenna applications relatively recently. There are two distinct ways to use the iteratively generated geometries. It has been shown in the past how fractals can be used to miniaturize antennas by capitalizing on their space filling ability to fit large electrical lengths into small physical volumes [1-3]. The second method uses the various scales of the self-similar geometry to design antennas that have similar properties at various frequency bands which correlate to the scaled geometry. This concept leads to the antenna looking the same physically or fairly similar at several frequency bands [4].

Fractal FSS Utilizing the self-similarity of fractal geometries for multiband frequency selective surfaces has been studied in [5, 6]. In the former reference, the authors use a self-similar patch element, while the latter studies a multi-scaled crossed dipole. The crossed dipole had the advantage of also being dual-polarized.

In this paper the concern will be to derive geometries that exhibit a multi-frequency response and are dual-polarized. The tunability of the structure should also be considered for the FSS to fit practical applications. Various patch shaped geometries and a Babinet corollary are considered here to fit these requirements.

Analysis The surfaces are simulated with infinite periodicity without a dielectric backing using a periodic moment method. The method, which includes the interaction between the elements, utilizes a periodic Green's function in the electric field integral equation (EFIE) which is solved using Rao-Wilton-Glisson functions [7]. The fields are calculated using enough modes of the periodic

Green's function for convergence. In this paper the fields are assumed to be normally incident. However, a study of the effects of oblique incidence will be carried out.

Minkowski Patch Element A square element FSS stops transmission when the elements are a half wavelength in width as shown in the plot in Fig. 1 of the transmission coefficient for square patches. By joining four of the patches at the center forming a bigger element in the form of a Minkowski fractal, the original stop band of the small squares is retained and another stop band is generated where the width of the entire four patches is half a wavelength in width. The geometry, dual-polarized due to its symmetry, is depicted on the left side of Fig. 1. The calculated transmission coefficient, plotted on the right side of Fig. 1, shows that both stop bands have 20 dB or better rejection.

Self-similar Aperture Element A dual polarized, dual-band screen can also be designed that blends apertures and patches on various scales in the same planar structure. A self-similar aperture element has been designed that superimposes small square patches over a grid of apertures. The apertures blocks transmission below 18GHz while the small patches inserts a stop band at 69GHz. The structure and the results are shown in Fig. 2. The comprising structures of just the small patches or just the larger apertures are also simulated and plotted in Fig. 2. It can be seen that the upper stop band has been shifted when the two geometries have been blended. This structure has also been printed on copper clad Duroid with a dielectric constant of 2.2. The measured transmission coefficient shows the frequency of the expected stop band when dielectric loading is taking into consideration which predicts a shift from 69GHz to 55GHz matches the measured result.

Koch Patch Element The Koch self-similar patches exhibit localized currents which generate fundamental as well as higher order resonances [8]. In a manner similar to the behavior of the Minkowski patch at resonance, the Koch element can be used to generate dual resonances. This structure can be arrayed in several grid arrangements to enhance various polarizations. Examples of these geometries are depicted in Fig. 3.

Conclusions The geometries that are investigated here are designed for two resonances. The structures presented here can be intuitively analyzed by considering the fundamental building blocks of the geometries. The Minkowski patches can be analyzed as the superposition of the smaller sub-elements and the larger element as a whole. Likewise, the self-similar aperture can be analyzed as the combination of large apertures on a large grid operating independently from the small patches on a tighter grid.

References

[1] Parker, E.A. and A.N.A. El Sheikh. "Convoluted Array Elements and Reduced Size Unit Cells for Frequency-Selective Surfaces." *IEE Proceedings-H* Feb. 1991: 19-22.

[2] Puente, C., J. Romeu, R. Pous, J. Ramis, and A. Hijazo. "Small but Long Koch Fractal Monopole." *Electronics Letters* Jan. 1998: 9-10.

[3] Cohen, N. "Fractal Antennas Part I: Introduction and the Fractal Quad." *Communication Quarterly* Summer 1995: 7-22.

[4] Puente-Baliarda, C., J. Romeu, R. Pous, and A. *Cardama*. " On the Behavior of the Sierpinski Multiband Fractal Antenna." *IEEE Transactions on Antennas and Propagation* April 1998: 517-24.

[5] Romeu, Jordi and Yahya Rahmat-Samii. "Fractal FSS: A Novel Dual-Band Frequency Selective Surface." *IEEE Transactions on Antennas and Propagation* July 2000: 1097-105.

[6] Werner, Douglas H. and Dongwoon Lee. "A Design Approach for Dual-Polarized Multiband Frequency Selective Surfaces Using Fractal Elements." *IEEE Antennas and Propagation Society International Symposium Proceedings.* July 2000: 1692-5.

[7] Barlevy, Alon S. and Yahya Rahmat-Samii. "Control of Resonant Bandwidth in Frequency-Selective Surfaces by Tilting the Periodic Elements." *Microwave and Optical Technology Letters* April 20, 1999: 114-7.

[8] Romeu, Jordi, Carmen Borja, and Sebastian Blanch. "High Directivity Modes in the Koch Island Fractal Patch Antennas." *IEEE Antennas and Propagation Society International Symposium Proceedings.* July 2000: 1696-9.
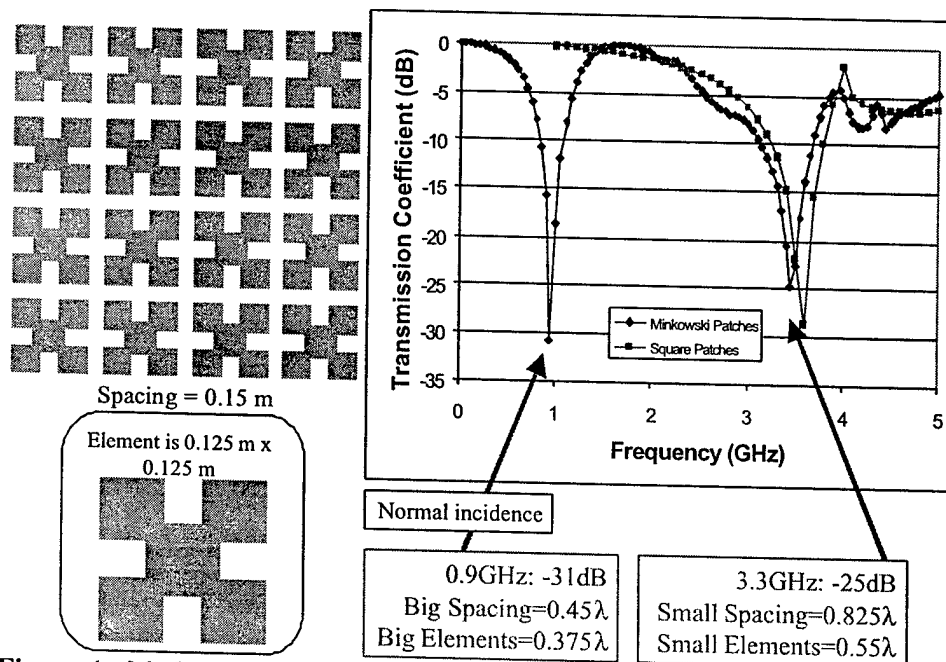
Spacing = 0.15 m

Element is 0.125 m x 0.125 m

Normal incidence

0.9GHz: -31dB	3.3GHz: -25dB
Big Spacing=0.45λ	Small Spacing=0.825λ
Big Elements=0.375λ	Small Elements=0.55λ

Figure 1: *Minkowski patches. The FSS has better than 20 dB rejection on two bands which correlate to the overall patch resonating and only the smaller sub-squares resonating. The higher band resonance is very similar to small square patches only.*
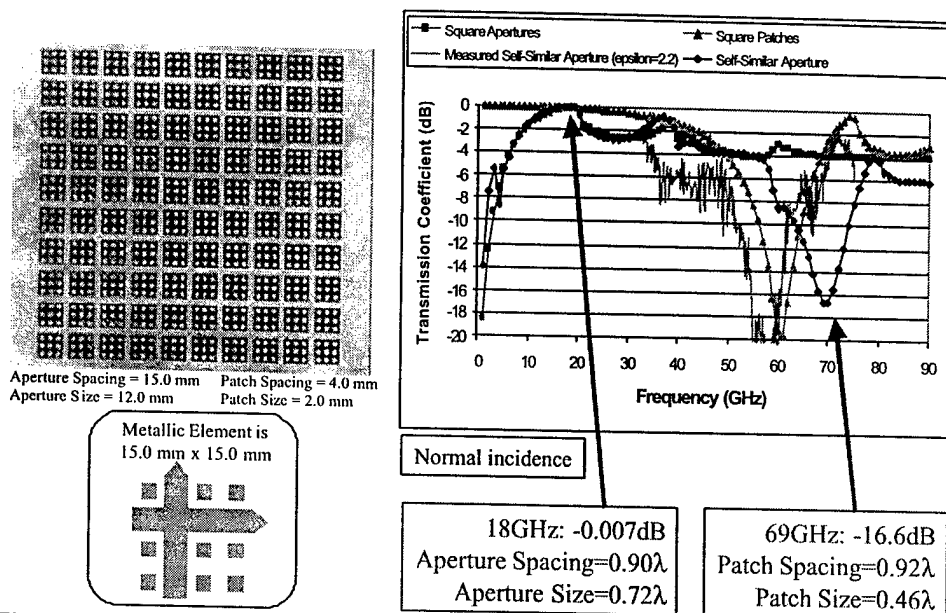
Aperture Spacing = 15.0 mm   Patch Spacing = 4.0 mm
Aperture Size = 12.0 mm   Patch Size = 2.0 mm

Metallic Element is
15.0 mm x 15.0 mm

Normal incidence

18GHz: -0.007dB
Aperture Spacing=0.90λ
Aperture Size=0.72λ

69GHz: -16.6dB
Patch Spacing=0.92λ
Patch Size=0.46λ

Figure 2: *Self-similar aperture FSS. This structure operates as a square aperture high pass FSS blocking transmission below 18GHz and blocks transmission again at 69GHz due to the inset patches in the apertures. The comprising geometries are also simulated separately. On the left is shown a fabricated FSS printed on Duroid. The measured results are shown for the upper band.*
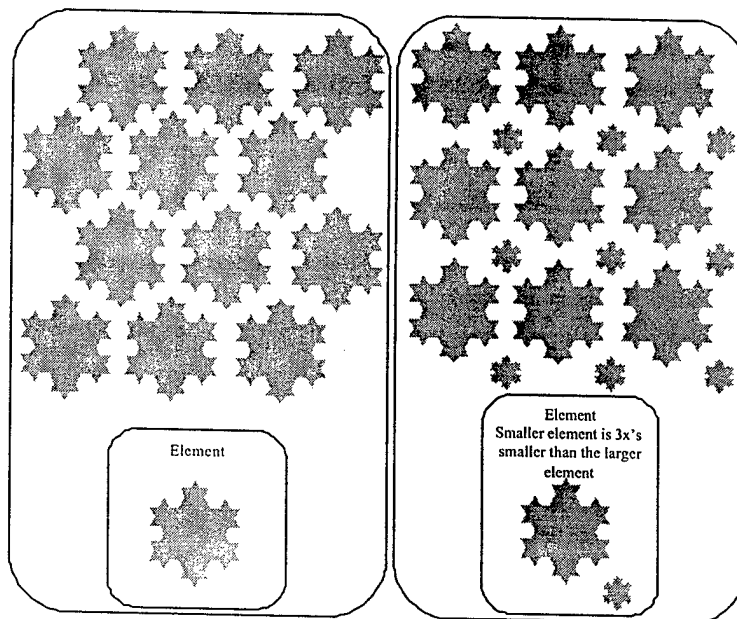

Element

Element
Smaller element is 3x's
smaller than the larger
element

Figure 3: *Koch patch elements. FSS on left uses the patches on a triangular grid. FSS on right uses miniature patches to create a lattice of the smaller patches and the higher order modes localized on the corners of the larger patches.*