Cascaded Frequency Selective Surfaces Using Dürer's Pentagon Pre-Fractals Patch Elements for Licensed 2.5 GHz and 3.5 GHz Bands

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***Abstract*—This work presents an analysis of frequency selective surfaces (FSSs) with with Dürer's pentagon pre-fractals patch elements. The proposed FSSs are composed by a 2-D periodic array of metal pre-fractal patch elements printed on a dielectric substrate. A parametric analysis is performed using Ansoft Designer commercial software in terms of the thickness of the layer of air between the FSSs and the fractal iteration number used in the FSS. The structures are proposed to behave like stop-band spatial filters and exhibit interesting features to be used in the design of compact FSSs for licensed 2.5 GHz and 3.5 GHz bands**.

***Index Terms*—Frequency selective surfaces, fractals, microwave propagation, filtering.**

I. Introduction

Frequency Selective Surfaces (FSS) are two-dimensional arrays of periodic metallic elements on a dielectric layer or bidimensional arrays of apertures within a metallic screen. The frequency response of these structures is entirely determined by the geometry of the structure in one period. They are used for a variety of applications, such as radomes and dichroic subrelfectors, bandpass and bandstop spatial filters, absorbers, and artificial electromagnetic bandgap materials [1]-[3]. Several types of fractal elements have been used, such as Koch, Minkowski, and Sierpinski patches [4]-[9].

Recently the design of multiband frequency selective surfaces has received a great attention from researchers in electrical engineering and telecommunications. Therefore, different approaches are available in literature related to the analysis and development of multilayer frequency selective surfaces, including fractal geometries. For instance, the effects of using different element types and array periodicities have been investigated. Lately, a growing interest has been observed in the analysis and development of new FSSs based on the concept of the modern theory of fractal geometry.

An analysis of frequency selective surfaces with Dürer's pentagon pre-fractals patch elements is shown in [4]. A parametric analysis is performed in terms of the FSS periodicity and of the fractal iteration number used in the FSS elements.

Numerical and experimental investigations are presented for a cascaded frequency selective surface with Koch fractal conducting patch elements in [5]. The FSS are cascaded and separated by an air gap layer to improve the bandwidth behavior.

An experimental investigation is made using cascaded Frequency Selective Surfaces with perfectly conducting fractal patch elements in [6]. For this case, the structures are cascaded using Teflon spacers and screws to obtain the air gap.

A fractal Y aperture FSS has been designed using recursive technology and the periodic method of moments (PMoM) to characterize the transmission properties of FSS as band-pass filters in [7]. The frequency response to the structural parameters is presented considering an electromagnetic wave incident with different angles and polarizations.

A novel type of miniature bandpass frequency selective surface based on fractal antenna–filter–Antenna (AFA) array is proposed In [8]. The AFA-based FSSs exhibit superior frequency selectivity and have lower profile than conventional FSSs. Fractal geometries are utilized in this letter to reduce the unit cell of AFA based FSSs. The iteration order and iteration factors of the utilized fractals including Minkowski island-shaped transmit/receive patches and fractal cross-shaped coupling aperture are analyzed.

In [9], a new miniaturized bandpass fractal frequency selective surface (FSS) with excellent angular stability performance is proposed. The miniaturization has been achieved by scheming out a symmetric fractal pattern of continuous slots from the surface of a square-shaped patch, in which each periodic cell consists of incurved slot resonator for reducing the cell size.

In the generation of the fractal element considered in this work, we begin with a pentagon element with side *L*. The method used to generate the FSS element geometry is similar to those of fractal curves construction.

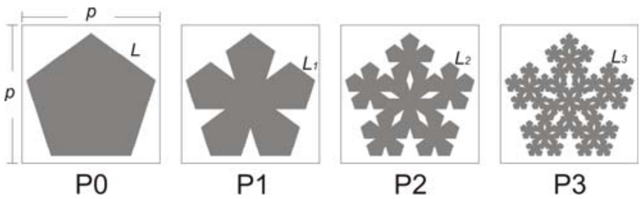
In Section II, the generation of Durer's pentagon fractal element is described. Simulated results are presented and discussed in Section III.

II. Structure of the Proposed Cascaded FSS and Fractal Elements

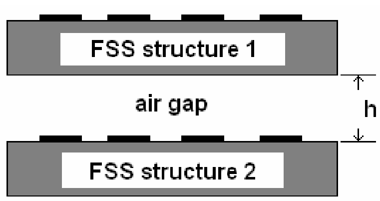
The structure of the proposed FSS structure consists of a periodic array of patch elements printed on a fiberglass substrate (FR-4), with thickness 1.5 mm and dielectric constant equal to 4.4. A parametric analysis is performed using Ansoft Designer commercial software in terms air gap between the FSSs and the fractal iteration number. The format of the patch elements are designed using the Dürer's pentagon fractal geometry that is generated from iterated function system. From a regular pentagon of side L, that corresponds to the generator element (P0), we use a scale factor of 0.382 for the generation of Dürer's pentagon elements at levels k = 1, 2, and 3, with

$$L_k = L \times 0.382^k \tag{1}$$

For each fractal iteration five copies are generated in small-scale (Fig. 1a). The proposed structure consists of two cascaded FSS screens, separated by an air gap layer, that are called structure 1 and structure 2 respectively, each one using a level of fractal iteration patch element mounted on a dielectric isotropic layer. The proposed FSS structure is shown in Fig. 1b.



(a)

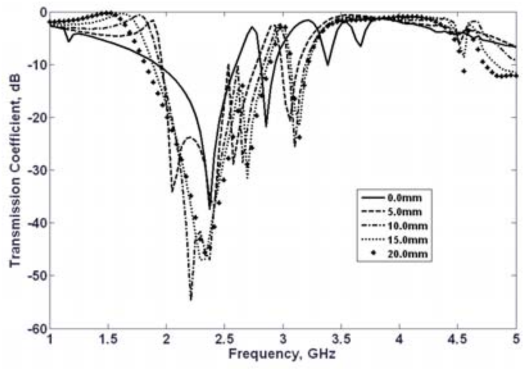


(b)

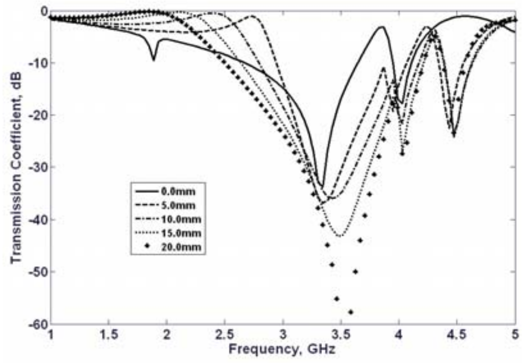
Fig. 1. Proposed Dürer's pentagon (a) pre-fractal patch elements for FSS design, (b) cascaded FSS geometry.

III. Simulation, Results and Conclusion

In this section, the effect of using different elements on the FSS performance is investigated. Four different types of elements are considered that are the pentagon generator (P0), and Dürer's pentagon fractal levels 1, 2 and 3 elements. The parametric analysis of the proposed FSS structures (Fig. 1) was performed for the number of the fractal iterations and of the air gap layer between the FSSs (0.0 mm ≤ air layer ≤ 20.0 mm). The periodicity considered for cascaded P1 and P2 is p = 64mm. For cascaded P2 and P3, the periodicity considered is p = 36mm. Dürer's pentagon pre-fractals patch elements were used to design FSS stop-band filters with dual-band responses. A dual substrate structure was used to generate stop-band characteristics. It was shown that the use of Dürer's pentagon pre-fractals patch elements allows the design of FSSs with dual-band responses and higher bandwidth. The simulated structures found practical applications in 2.5 GHz licensed band coupling structure P1 and structure P2, and 3.5 GHz licensed band coupling structure P2 and P3 (Fig. 2).



(a)



(b)

Fig. 2. Simulated results for Dürer's pentagon pre-fractal patch elements: (a) applications in 2.5 GHz licensed band, (b) applications in 3.5 GHz licensed band.

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