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Investigation on Dielectric Layer Effect for Multilayer FSS Design

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ABSTRACT

In this paper, an investigation on Multilayer Frequency Selective Surface, using different types of dielectric materials, is proposed. The structure investigated is obtained using two FSS screens separated by a dielectric material layer. The influence of a dielectric layer between two simple FSS structures forming a multilayer FSS (cascaded or coupled FSS), using different dielectric materials with different values of thickness is presented. The results were compared with the results presented when an air gap layer is used. An improvement in frequency response in terms of bandwidth was observed.

Keywords: FSS, Multilayer structure, Dielectric, Filter, Transmission coefficient.

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1. INTRODUCTION

Frequency Selective Surfaces (FSS) can be defined as periodical structures consisting of conducting patch or aperture elements with an arbitrary shape generally embedded in or supported by a dielectric substrate layer. FSS can be designed to exhibit different filtering responses for the incident electromagnetic waves, that is, they can act as filters that operate on free-space waves, presenting band-stop or band-pass characteristics, which depends primarily on the geometry of the structure on one period called unit cell, the periodicity and the properties of the dielectric substrate [1-3].

FSS have been investigated and studied by several researchers over the years for a wide variety of applications, e.g., increasing communication capabilities of satellite platform, modern military applications such as aircrafts, ships, and missiles. FSS are used as radomes and sub reflectors integrated with antennas systems, this last one is applied to separate electromagnetic waves into different frequency bands. FSS can, also, be used in the civil sector such as isolation in hospitals, schools and domestic environments for unwanted and harmful radiation [1-6].

One of the most important problems in the FSS theory is the question of the operating bandwidth offered, a closer look at a FSS in a single layer, for example, shows that it is very difficult to improve bandwidth behavior. To solve this problem, it is necessary to use elements with very complex geometries or the use of multilayer structures, that is, cascade structures. It is preferable the use of the second option in terms to increase to single resonance bandwidth [7].

Applications using multilayer FSS (cascaded FSS or coupled FSS) have been special attention in the last years, a high-efficiency wideband FSS backed for 20/30 GHz dual-band circularly polarized reflect array antenna is presented in [8] and can be used for satellite communication applications at Ka band. A multilayer FSS is used as wall in a low-mutual-coupling 60 GHz MIMO antenna system to reduce the free-space radiation [9]. A new band-pass FSS with tightly coupled elements for ultra-wideband (UWB) applications, based on the multilayer concept, is proposed in [10].A novel class of circular polarization selective surface using a coupled split-ring resonator is proposed in [11]. FSS with highly selective tri-band band-pass by cascading three layers of periodic arrays is presented in [12]. In [13] a novel polarization-reconfigurable converter is proposed based on a multilayer FSS. The design of a flat lens which uses multilayer FSS to realize the desired radially varying phases delay without unduly compromising the magnitude of S_{12} is proposed in [14]. A second-order reconfigurable multilayer FSS based on tunable plasma is presented in [15].

This paper presents an investigation on the influence of a dielectric layer between two simple FSS structures forming a multilayer FSS (cascaded or coupled FSS), using different dielectric materials with different values of thickness. In this work was analyzed a multilayer FSS structure, using conducting Koch fractal elements. This structure was first proposed in [16], in this case was used as dielectric layer between the structures an air gap (air gap layer), and consists of two FSS called structure 1 and structure 2 mounted on a dielectric isotropic layer, separated by a dielectric layer. The dielectric substrate used was the RT/Duroid 3010^{TM}, with 1.27 mm of height and relative permittivity equal to 10.2 and unit cell periodicity (Tx = Ty) equal to 10 mm. A comparison with results obtained using an air gap layer is performed to validate the influence of the dielectric materials, in terms of the frequency response for the transmission coefficient of the multilayer structure.

2. MULTILAYER FSS AND DIELECTRIC MATERIALS

The proposed multilayer FSS used in this work consists of two FSS screens called structure 1 and structure 2, respectively, each one using Koch fractal patch elements printed on a dielectric substrate separated by a dielectric layer with thickness *d*. The first structure with Koch fractal level 1 is defined as structure 1 and the second FSS screen with Koch fractal level 2 is defined as structure 2, as can be seen in Table 1 with their respective resonant frequencies (f) and bandwidths (BW).

Table 1: Single FSS Identification

Structure	FSS structure and its operating parameters		
	FSS Element	Frequency – *f* (GHz)	Bandwidth – *BW* (GHz)
1	Koch fractal level 1	9.115	1.951
2	Koch fractal level 2	8.333	1.618

The element shapes and the multilayer structure considered in this investigation are shown in Fig. 1 and Fig. 2, respectively.

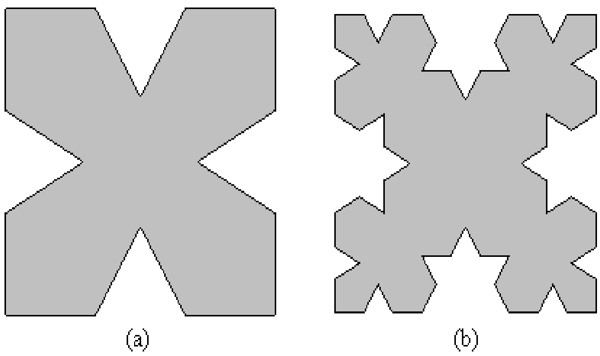

Fig. 1: Elements: (a) Koch fractal level 1 and (b) Koch fractal level 2.

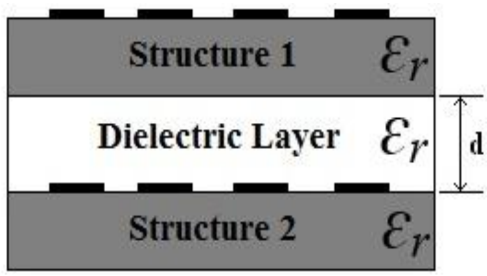

Fig. 2: Multilayer FSS structure.

Table 2 presents a list of dielectric materials used in this work and their respective relative permittivity values.

Table 2: Dielectric materials

Relative Permittivity	Materials					
	RO3203	RO4003	RT/Duroid 5880	RT/Duroid 6010	TMM4	TMM6
ε_r	3.02	3.55	2.20	10.7	4.70	6.30

The RO3203™ high frequency circuit dielectric material is a ceramic-filled laminate reinforced with woven fiberglass, and offer exceptional electrical performance and mechanical stability. The RO3203 dielectric constant is 3.02 with a dissipation factor of 0.0016 and frequency range beyond 40 GHz. The RO4000®ceramic laminates are designed to offer superior high frequency performance, the result is a low loss material with low dielectric tolerance, ideal for broadband applications. RT/Duroid® 5880 glass microfiber PTFE composite was designed for exacting strip line and microstrip circuits applications, such as, commercial airline broadband antennas and military radar systems. The RT/Duroid® 6010 is a ceramic-PTFE composite designed for electronic and microwave circuit applications requiring a high dielectric constant. TMM® thermoset microwave materials are ceramic, hydrocarbon, thermoset polymer composites designed for microstrip applications, e.g., RF and microwave circuit, patch antennas, filters and satellite communication systems [17-21].

3. RESULTS

In order to investigate the influence of the material dielectric layer on the composition of the multilayer FSS or coupling between two single FSS structures, in terms of transmission characteristics, the structure was simulated using each one the materials described previously. The obtained results are compared with the results obtained when the multilayer FSS is designed with an air gap layer as dielectric layer as seen in Fig. 1.

The structure was simulated for each one material informed on the Table 2, and for different values of thickness represented by the parameter *d* in Fig. 1.The results were obtained for values of thickness (*d*) equal to 1.0 mm, 5.0 mm and 10.0mm. The structure was simulated using Method of Moments (MoM) and the obtained results are presented in Figures 3 – 5.

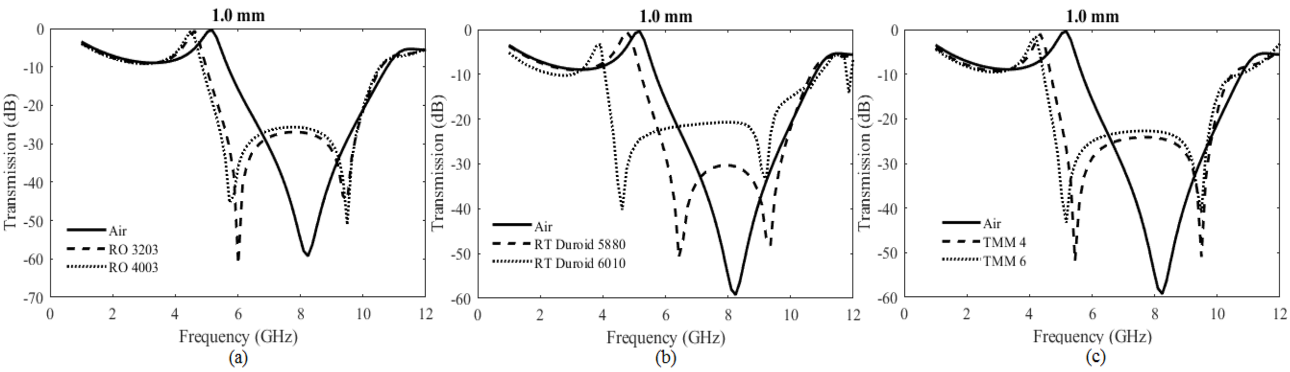

Fig. 3: Transmission coefficient for the multilayer FSS with a dielectric layer thickness equal to 1.0 mm: (a) RO3203 and 4003, (b) RT/Duroid 5880 and 6010 and (c) TMM 4 and 6.

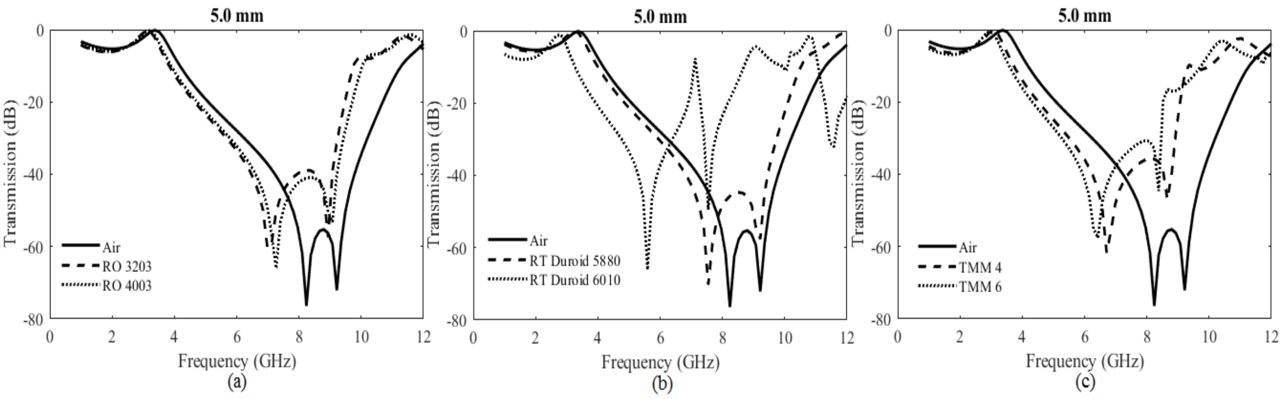

Fig. 4: Transmission coefficient for the multilayer FSS with a dielectric layer thickness equal to 5.0 mm: (a) RO3203 and 4003, (b) RT/Duroid 5880 and 6010 and (c) TMM 4 and 6.

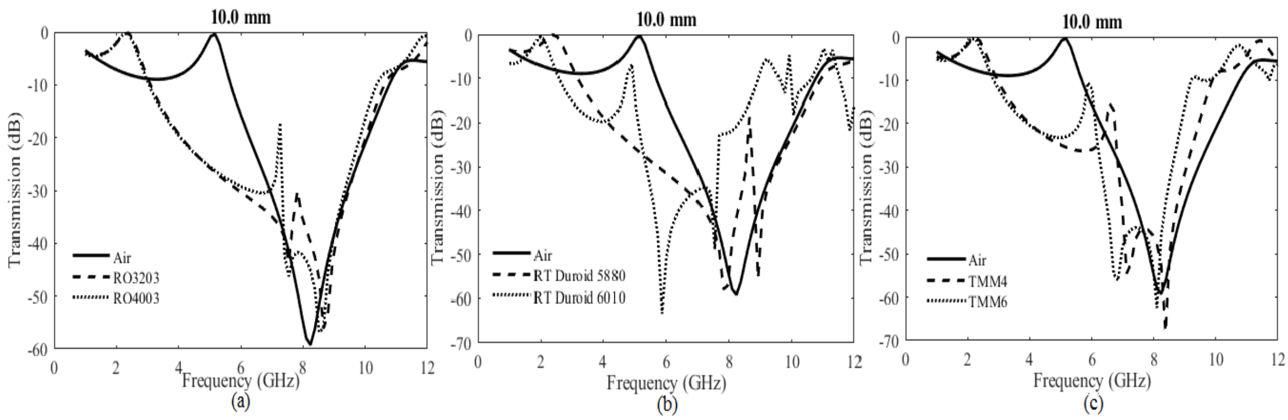

Fig. 5: Transmission coefficient for the multilayer FSS with a dielectric layer thickness equal to 10.0 mm: (a) RO3203 and 4003, (b) RT/Duroid 5880 and 6010 and (c) TMM4 and 6.

Fig. 3 shows the transmission characteristics for the proposed multilayer structure using the dielectric layer materials for a thickness equal to 1.0mm. When compared with the results obtained with an air gap layer of 1.0 mm, it is possible to observe for all the results an increase in the bandwidth for a 10 dB insertion loss reference level. Fig. 4 illustrates the transmission characteristics for the multilayer FSS using the dielectric layer materials for a thickness equal to 5.0 mm. It is possible to observe a reduction in the bandwidth for all the results when compare with an air gap layer and for the RT/Duroid 6010 it is possible to observe a multiband behavior, for a 10 dB insertion loss reference level. The transmission characteristics for the multilayer FSS using the dielectric materials for a thickness equal to 10.0 mm can be observed in Fig. 5. In these results, there was also an increase in the bandwidth and in this case presenting the highest values for this parameter (*BW*), except for the material RT/Duroid 6010. It can be observed that, in the case of this material, the transmission coefficient presents multiband behavior.

A graph showing the values of the bandwidths for each dielectric material used and their respective thickness can be seen in the Fig. 6.

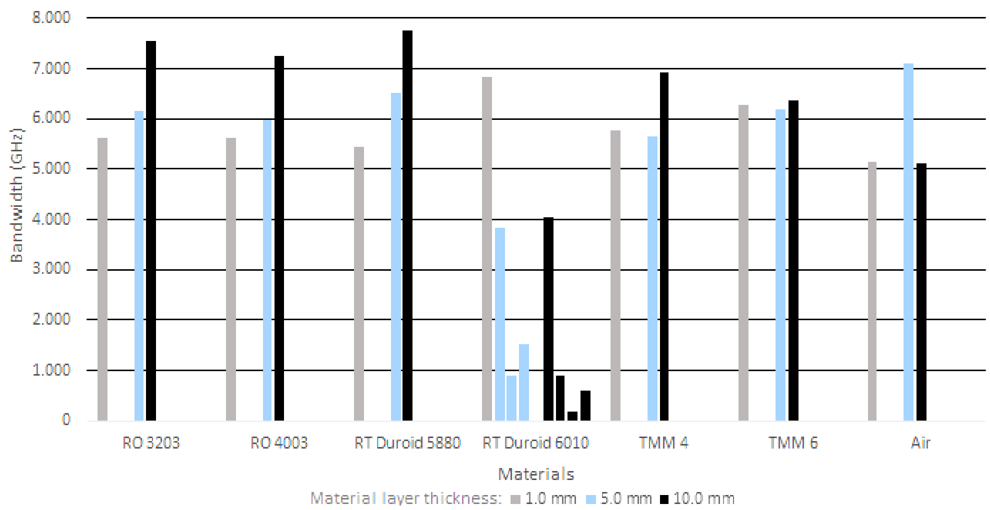

Fig. 6: Values of the bandwidths obtained for each material used

CONCLUSION

A compact band-stop multilayer FSS is proposed in this paper using different dielectric materials. Two FSS screens separated by a dielectric material layer formed this multilayer structure. Each FSS screen using a conducting patch element with fractal geometry in the unit cell. The effect of the dielectric layer on the coupling between two single stranded structures was investigated. In the simulated cases for the thickness values of 1.0 and 10.0, for the materials used in the study, most of the results obtained showed an increase in terms of bandwidth (rejection band) for the transmission coefficient, when compared with the results obtained using an air gap layer and presenting a broadband behavior. In some cases, the dielectric material caused the structure to exhibit multiband behavior. This study served to know the effect of the dielectric material in the design of a multilayer FSS in terms of frequency response for the transmission coefficient.

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