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RESEARCH ARTICLE **OPEN ACCESS**

FSS SPACE FILTERS WITH INDOOR POLAR ELEMENTS FOR WLAN APPLICATIONS

***[1]Rômulo R. de M. Bezerra, [1]Elder Eldervitch Carneiro de Oliveira, [2]Pedro C. de Assis Júnior and [3]Paulo Henrique da Fonseca Silva**

[1]Computation Department, State University of Paraíba, Rua Alfredo Lustosa Cabral, S/N, Cep: 58706-560, Patos – PB; [2]Phisics department, State University of Paraíba, Rua Alfredo Lustosa Cabral, S/N, Cep: 58706-560, Patos – PB; [3]Telecomunication Department, Federal Institute of Paraíba, Av. Primeiro de Maio, 720, CEP: 58015-430, João Pessoa - PB

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****Corresponding author: Rômulo R. de M. Bezerra.***

ABSTRACT

This article presents a project of an FSS for applications in wireless local area network (WLAN). Two dielectric substrates were used in the process of manufacturing FSS filters, such as: Fiberglass (F-R4) and glass. The dielectric properties of the substrates were experimentally characterized. Simulated and measured results for the proposed structures were presented and discussed, where a good agreement between them was observed. The results showed that the two FSS projected covered the WLAN frequency range (IEEE 802.11a and IEEE 802.11b). From these results it was possible to observe the results as a function of the incident angle of the developed prototypes, where they presented a good stability in frequency.

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INTRODUCTION

The increased use of wireless local area networks (WLAN) has led to the emergence of new techniques that seek to improve the performance of this technology in offices, homes, commercial buildings, etc. One of the techniques that have stood out in this context is known as "wireless building", i.e., physically modifying the indoor propagation environment, by means of changes in the structure and materials of the buildings, so that they exhibit specific electromagnetic properties (Nóbrega, 2013). In this sense, space filters are being used in building projects. It is possible to prevent indoor propagation to desired frequencies. These space filters can be inserted into the walls or windows of a building as electromagnetic shielding to protect environments from unwanted interference (Sung, 2006; Gustafsson, 2006; Raspopoulos, 2011 and Kiani, 2011). In (Dewani, 2018) it's proposed to install a FSS printed screen in windows of buildings and offices, besides investigating the effect of shielding on the propagation of radio waves through the structures used. A frequency selective wall is presented in (Sung, 2006). On the wall was attached a frequency selective surface as reject-band filter, customized as a wall surface. The measurements showed that this frequency selective wall filtered signals operating at 5.4 - 6.0 GHz. A proposal for an FSS using several modified elements to blocking mobile phone signals in public premises is described in [8]. Filters are inserted into the outer and inner parts of the glass used in the window. In this article, consists of the design of frequency selective surface (FSS) with polar spires for WLAN applications in 2.4 GHz and 5.8 GHz. FSS were designed with two different types of dielectric substrates, glass and fiberglass (F-R4). This article is divided into the following sections: in section II the design of the space filters is presented; in section III the measured and simulated results are presented and discussed; in section IV the final considerations are performed.

Frequency selective surface with polar elements

The polar elements were obtained from Equation (1), initially proposed by the botanist Johan Gielis (Gielis, 2003) with the help of CAD tools (Computer-Aided Design) from the implementation of algorithms in MATLAB®. This element is converted to a DXF (Drawing Exchange Format) file through an appropriate library. This conversion makes it possible to import this file into the Ansys Designer^{TM} environment, complete wave analysis software used to extract resonant parameters, resonance frequency and bandwidth, from the transmission coefficient of the proposed prototypes.

$$r(\theta) = \frac{1}{\left\{\left[\left(\left|\frac{1}{a}cos\left(\theta\frac{m}{4}\right)\right|\right)^{n_2}+\left(\left|\frac{1}{b}sen\left(\theta\frac{m}{4}\right)\right|\right)^{n_3}\right]^{1/n_1}\right\}} \quad (1)$$

The proposed elements in the form of polar spires is well suited to the design of FSS project, enabling the development of these space filters for use in different parts of a building, such as windows, doors, walls, partitions, etc. The two prototypes were designed with two polar spires, for each spire to resonate at a certain frequency. The highest spires in 2.45 GHz and the lowest in 5.5 GHz. In the first project the two elements were obtained considering the following Equation parameters (1): $n_1 = 1$; $n_2 = 1$; $n_3 = 1$; $m = 8$; $a = 1$; $b = 1$. The spire bigger containing 15.5 mm of radius and the spire smaller 8.8 mm. The FSS 1 unit cell with two concave polar turns proposal is demonstrated in Figure 1.

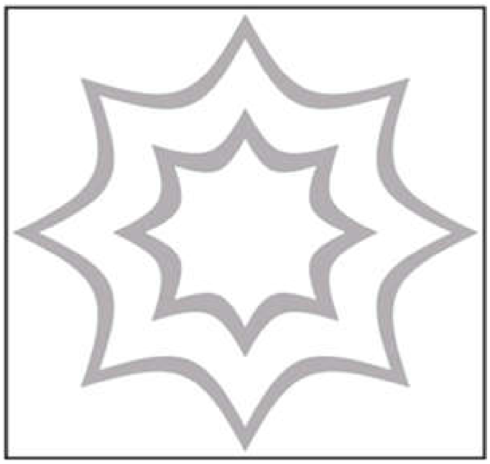


Figure 1. FSS 1 unit cell with two concave polar turns

The second FSS proposed in this work was also generated from Equation (1). Two types of elements were combined with distinct shapes, following the idea of each element resonating to a given frequency, as already mentioned. The largest polar element was obtained with the parameters $n_1 = -1$; $n_2 = 1$; $n_3 = 1$; $m = 8$; $a = 1$; $b = 1$ with radius equal to 12.9 mm. The smallest with $n_1 = 1$; $n_2 = 1$; $n_3 = 1$; $m = 8$; $a = 1$; $b = 1$ with radius equal to 7.3 mm. The FSS 2 proposedwith two polar turns - concave and convex is displayed in Figure 2.

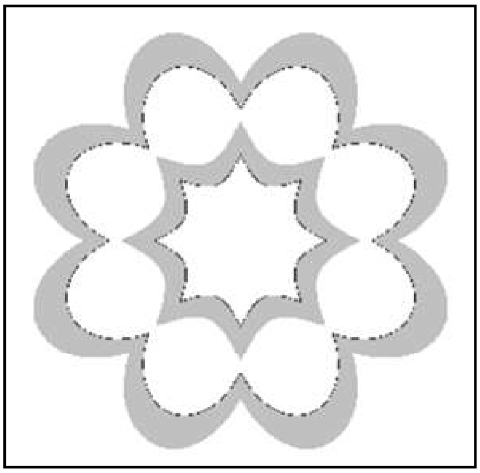


Figure 2.FSS 2 unit cell with two polar turns - concave and convex

As already mentioned, the prototypes were designed considering two types of dielectric substrates, F-R4 and glass. The choice of glass is aimed at the application of FSS in indoor propagation environments, acting as a frequency selective window. Thus, it was necessary to perform the experimental characterization of its properties, such as the relative electrical permittivity and the loss tangent. The dielectric substrate was characterized in the vector network analyzer (VNA) of Agilent Technogies model S5071C (300 kHz – 20 GHz), in the Laboratory of Telecomunications of the Federal Institute of Paraíba (IFPB). The result of the experimental characterization of the glass substrate for electrical permittivity can be seen in Figure 3 and for the loss tangent in Figure 4. For the frequency project, the relative electrical permittivity, ε_r = 6,1, and loss tangent, tang (δ) = 0,083. The FSS was designed considering a glass substrate of 2 mm thickness and a conductive adhesive laminated copper material, generally used for electromagnetic shielding of musical instruments that can be visualized in Figure 5.

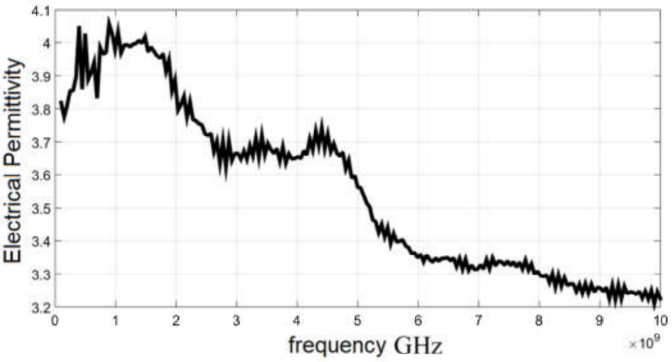


Figure 3. Relative electrical permittivity of glass

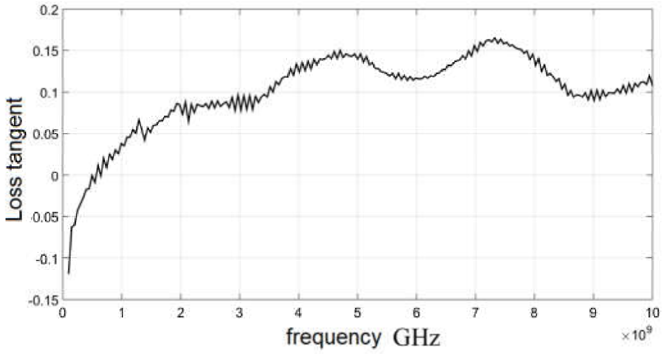


Figure 4. Tangent loss of glass

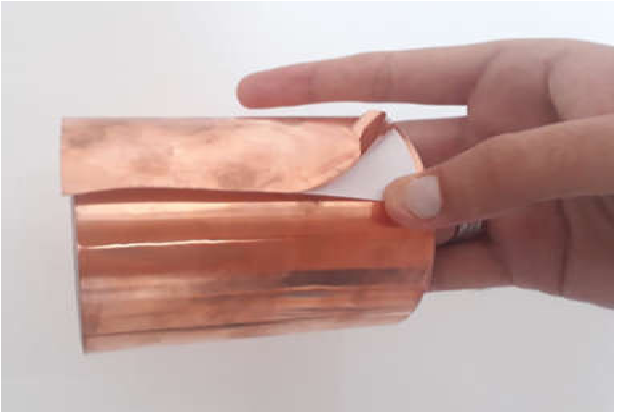
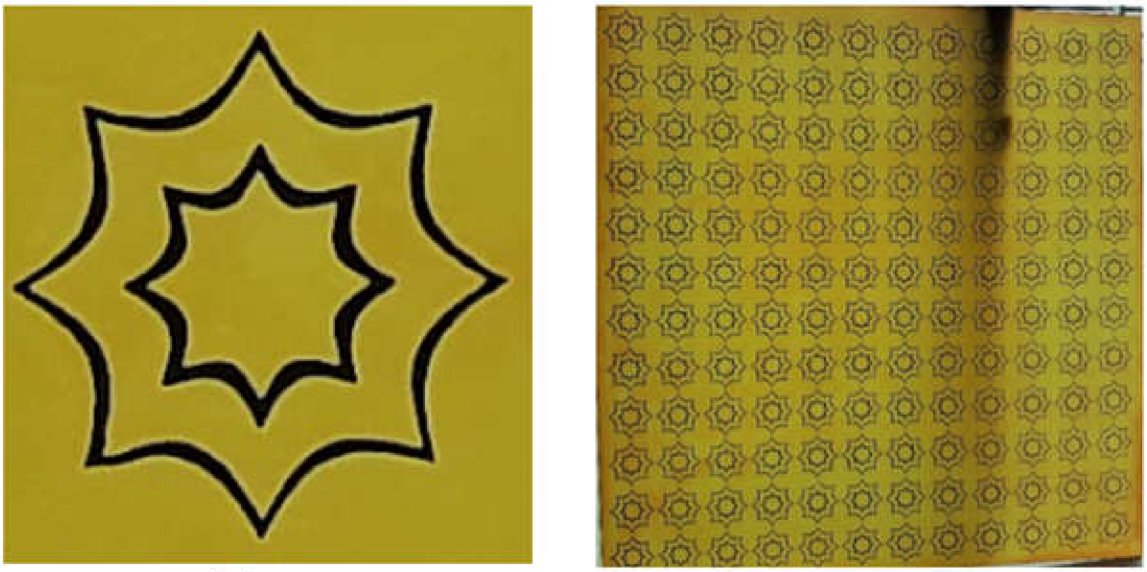
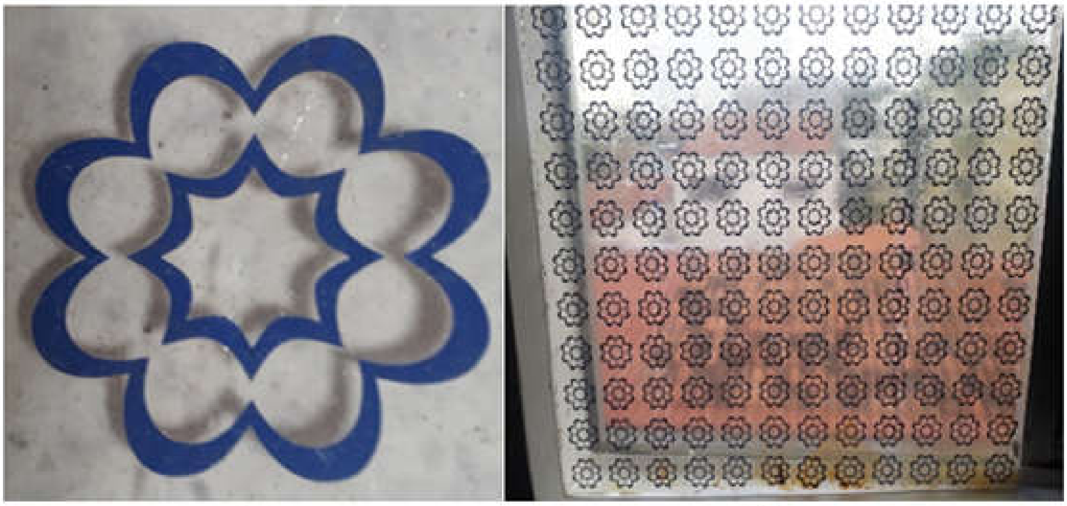


Figure 5. Copper adhesive laminate



(a) (b)

Figure 6. FSS 1 with two concave polar turns prototype with F-R4 substrate: (a) unit cell; (b) FSS manufactured



(a) (b)

Figure 7. FSS 2 with two polar turns - concave and convex prototype with glass substrate: (a) unit cell; (b) FSS manufactured

(a) (b)

Figure 8. Measurement setup for the proposed FSS

The process of manufacturing the elements of each FSS was by the method of corrosion with iron perchloride. The printed adhesive is glued to the copper laminate and placed in the corrosive solution. For the first design it was considered a low cost material F-R4, with 1,5 mm thickness, dielectric constant $\varepsilon_r = 4.4$ and loss tangent of 0,02.

The FSS has a total number of 144 cells, 12 x 12 elements, each one with 32 mm x 32 mm, which corresponds to a total size of 384 mm x 384 mm. Figure 6 shows the manufactured prototype. The second FSS proposed (manufacturing of glass substrate) has a total number of 144 cells, 12 x 12 elements, each one with 33 mm x 33 mm, corresponding to a total dimension of 396 mm x 396 mm (see Figure 7). Measured results of the prototypes were obtained in the Telecommunications Measurements Laboratory using the vector network analyzer, which can be visualized in the measurement arrangements in Figure 8.

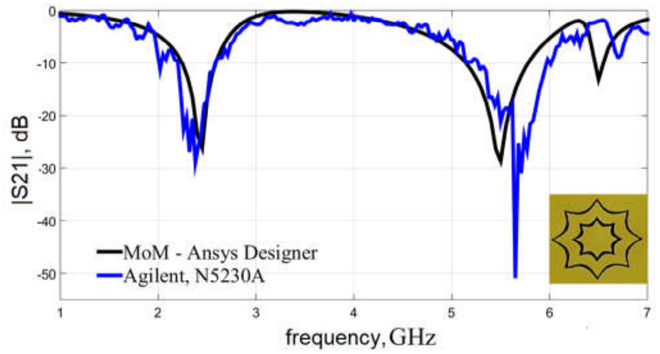


Figure 9. Comparison of FSS frequency responses with glass substrate in terms of simulated and measured transmission coefficients|S21| in dB

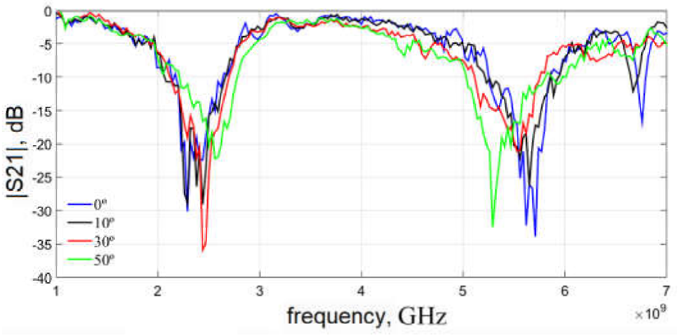


Figure 10. Measured results of |S21| with F-R4 substrate as a function of incidence angle

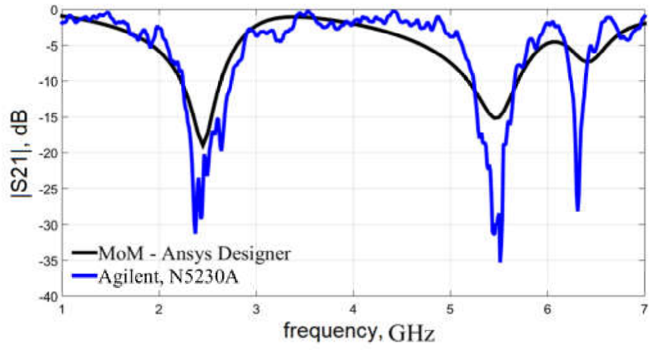


Figure 11. Comparison of FSS frequency responses with glass substrate in terms of simulated and measured transmission coefficients|S21| in dB

Simulated and measured results: The results obtained for selective areas in frequency for indoor applications will be presented below. The results of the parameter |S21| simulated and measured from FSS with F-R4 substrate can be seen in Figure 9. A good agreement between the results can be observed. The first resonance frequency obtained -2.90% displacement when compared to the simulated result, the second frequency 2.65%. The comparison between the measured and simulated resonance values are presented in Table 1. Measurements were made for the proposed FSS varying the incidence angle from the normal incidence up to 50 degrees. The results obtained are shown in Figure 10.

Table 1. FSS with substrate F-R4: comparison between simulated and measured results

PARAMETERS	SIMULATED	MEASURED	ERROR%
F_1	2450 MHz	2379 MHz	-2.90
F_2	5500 MHz	5655 MHz	2.65
BW_1	350 MHz	506 MHz	44.57
BW_2	600 MHz	621 MHz	3.50
$\vert S_{21}\vert_1$	-26.13 dB	-28.89 dB	10.56
$\vert S_{21}\vert_2$	-22.41 dB	-50.91 dB	12.18

It is observed that up to 30 degrees there is stability in the frequency in relation to the angle of incidence, this occurs in the first resonance frequency as well as in the second one.

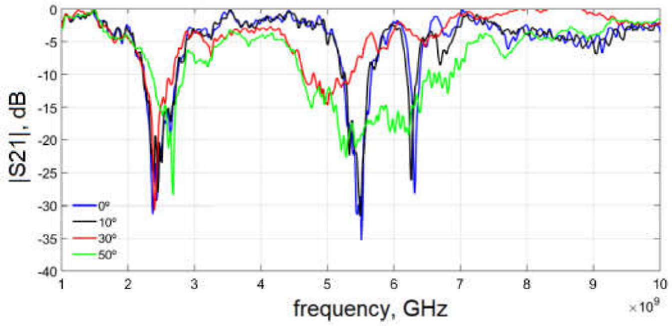


Figure 12 . Measured results of FSS transmission coefficient with glass substrate as a function of incidence angle

For example, for frequency 2.37 GHz, up to 50 degrees, The FSS presented a maximum deviation in resonance frequency of 7.59% compared to normal incidence, while for frequency of 5.65 GHz, up to 30 degrees, it was observed a maximum deviation of 2,12%, however, when compared to the angle of 50 degrees the deviation increases to 6.54%. The results of the parameter | S21 | simulated and measured of FSS with glass substrate can be seen in Figure 11. The values showed an excellent agreement around the desired frequencies (2.45 GHz and 5.5 GHz). The lower order frequency (2.45 GHz simulated) obtained a displacement of 0.24%. The higher order (5.5 GHz simulated) displaced 0.27%. The comparison between measured and simulated values is shown on Table 2.

Table 2. FSS with glass substrate: comparison between simulated and measured results

PARAMETERS	SIMULATED	MEASURED	ERROR%
F_1	2450 MHz	2456 MHz	0.24
F_2	5500 MHz	5515 MHz	0.27
BW_1	450 MHz	485 MHz	7.77
BW_2	550 MHz	400 MHz	-27.27
$\vert S_{21}\vert_1$	-18.95 dB	-32.92 dB	73.72
$\vert S_{21}\vert_2$	-14.07 dB	-35.15 dB	149.82

Aiming at analyzing the stability in frequency of FSS with glass substrate, the measurement was also performed varying the incidence angle from the normal incidence up to 50 degrees. This factor is of extreme importance, mainly in indoor applications of local wireless networks, due to the propagation of the waves in various directions. Figure 12. shows the obtained results. Notice on the graph that for the first frequency of the project (2.45 GHz) there is a good stability in the resonance frequency, with maximum deviation of 10.6%. The same stability is also demonstrated in the second frequency of the project (5.5 GHz), the maximum deviation was 9.09%.

Conclusion

Aiming at analyzing the stability in frequency of FSS with glass substrate, the measurement was also performed varying the incidence angle from the normal incidence up to 50 degrees. This factor is of extreme importance, mainly in indoor applications of local wireless networks, due to the propagation of the waves in various directions. Figure 12. shows the obtained results. Notice on the graph that for the first frequency of the project (2.45 GHz) there is a good stability in the resonance frequency, with maximum deviation of 10.6%. The same stability is also demonstrated in the second frequency of the project (5.5 GHz), the maximum deviation was 9.09%.

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REFERENCES

Dewani, A. A., Member, S., Keefe, S. G. O., Thiel, D. V, Member, L. S. and Galehdar, A. (2018) Window RF Shielding Film Using Printed FSS, vol. 66; pp. 790–796.

Gielis, J. (2003) Generic geometric transformation that unifies a wide range of natural and abstratic shapes. American Journal of Botany. pp. 333-338.

Gustafsson M., Karlsson, A., Rebelo, APP and Widenberg, B. (2006) Design of frequency selective windows for improved indoor outdoor communication. IEEE Transaction Antennas Propagation.

Kiani, GI., Olsson, LG., Karlsson, A., Esselle, KP and Nilsson, M. (2011) Cross-dipole bandpass frequency selective surface for energy-saving glass used inbuildings. IEEE Transaction Antennas Propagation.

Kim, D., Yeo, J. and Choi, J. (2008) Compact spatial triple-band-stop filter for cellular/PCS/IMT-2000 systems. ETRI Journal, vol. 30; pp. 735–737.

Nóbrega, C. D. L (2013). Análise e projeto de superfícies seletivas de frequência com elementos pré-fractais para aplicações em comunicações indoor. Tese de Doutorado, Programa de Pós-Graduação em Engenharia Elétrica e Computação da Universidade Federal do Rio Grande do Norte, Natal (RN), Brasil.

Raspopoulos, M., Stavrou, S. (2011) Frequency selective buildings through frequency selective surfaces. IEEE Transaction Antennas Propagation.

Sung, G. H. H., Sowerby, K. W., Neve, M. J. and Williamson, A. G. (2006) A frequency-selective wall for interference reduction in wireless indoor environments. IEEE Antennas Propag. Mag., vol. 48; pp. 29–37.

Sung, GHH., Sowerby, KW and Williamson, AG. (2006) Modeling a low-cost frequency selective wall for wireless-friendly indoor environments. Antennas Wirel. Propag. Lett. 2006.

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