The Study about the Effect of the Frequency Selective Surface (FSS) on the Different Material of Substrate

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***Abstract*—The Frequency Selective Surface (FSS) design structure consists of square FSS placed on the FR4 and energy saving glass (ESG). Then, the circular and square slot FSS is added on the square FSS to produce a dual band FSS. The FSS design structure is designed and simulated by using the CST Microwave Studio software at 2.4 GHz and 5.2 GHz frequency response based on industrial, scientific and medical bands (ISM) standard. The reflection (S_{11}) and transmission (S_{21}) of the design FSS structure is analyzed and the effect of the material used is studied. The material of the substrate affects the transmission and reflection signal of the FSS. The dual band FSS is designed on the ESG to improve the transmission of the WLAN signal at 2.4 GHz and 5.2 GHz.**

***Index Terms*—Frequency Selective Surface (FSS), ESG, FR4, reflection, transmission**

I. INTRODUCTION

Metamaterials have properties that may not be found in nature. It gains its properties not from their composition but from their designed structures. It consists of periodic structure and subwavelength characteristic which particle smaller than the light wavelength with which it interacts. Others are structured that exhibit the subwavelength characteristics are Frequency Selective Surface (FSS) or also known as Artificial Magnetic Conductor (AMC) or High Impedance Surface (HIS) [1]. FSS is a planar periodic structure of the identical array of patch or aperture type elements arranged in one or 2D plane. FSS have inherent inductive and capacitive properties that useful in designing to get a desired frequency response.

Filters play a fundamental role in almost electronic or RF circuit. Once being incorporated into a design, the filter acts as a device that controls the frequency content of the signal for mitigating noise and unwanted interference. Filters are categorized, based on their function, into three major groups: lowpass, bandpass, and highpass filters. A lowpass filter, for example, allows for the lower frequencies to pass through the circuitry and blocks higher frequencies. Frequency-selective surface (or dichroic) structures to space waves are the counterparts of filters in transmission lines. Once exposed to the electromagnetic radiation, a frequency selective surface (FSS) act like a spatial filter; some frequency bands are transmitted and some are reflected [2-4].

Its filtering characteristic is depending on the array element type. The frequency behavior of the FSS is entirely determined by the geometry of the surface in one period (unit cell), the size of the FSS, the way the surface is exposed to the electromagnetic wave (incidence angle of the incoming wave), substrate parameters, inter-element spacing and materials used. The frequency selective surface frequency characteristics depend solely on the dimensions of the elements and substrate properties [2-6].

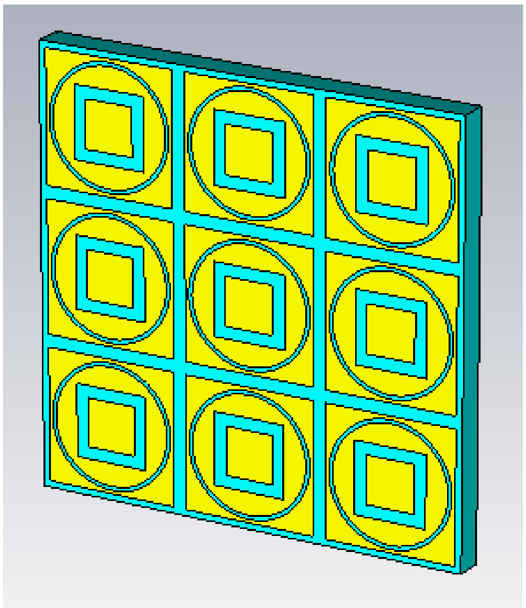
Energy saving glass (ESG), due to its low-emissivity characteristics, is being used in energy smart architect, and plays an important role in energy saving. These types of ESG are manufactured by applying a homogenous layer (0.3-0.4 micron) of pyrolytic coating (hard coating) or metal oxide/nitride (soft coating) on one or both sides of float glass. The layer can provide good thermal isolation for buildings by reflecting the infrared radiation (IR) at room temperature while transmitting visible light [7].

However, the coating layer on ESG also attenuates useful RF/microwave signals, for examples, signals from mobile phones, Wi-Fi, personal communication systems (PCS) and global positioning system (GPS) [8-10]. Usually, the coating layer attenuates microwave signals up to 30 dB. This probably will be accentuated by higher frequencies in future wireless communication system, as attenuation level increase with frequency [11-15]. To solve this problem this paper is presented the dual band FSS design. The dual band FSS is designed to improves the signals transmission of WLAN at 2.4 GHz and 5.2 GHz without affecting the IR and UV attenuation properties.

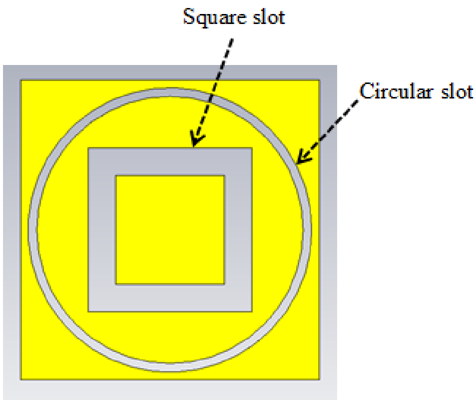
II. FSS DESIGN

The 3×3 FSS element and unit cell geometry of the proposed design square FSS structure which consists of circular and square slot that designed on the FR4 board is shown in Figure 1. The dual band FSS is made up of copper with thickness 0.035 mm. In this paper the FSS is designed on the FR4 board (100 mm×100 mm) for 3×3 elements. Then, the

FSS is designed on the energy saving glass. The dielectric constant of FR4 is 4.4 and a tangent loss of 0.019 with a thickness of 1.6 mm while the glass dielectric constant is 6.9 and conductivity is 5×10^{-4} S/m with thickness of 5 mm [16]. The material that has been used for the coating is ohmic sheet by choosing the surface resistivity of 17.95Ω/square. The dual band FSS is designed and simulated by using CST microwave studio software.



(a)



(b)

Fig.1. The design FSS structure that etched on FR4 board (a) dual band FSS (3×3) (b) unit cell of dual band FSS

The unit cell geometry of the proposed dual band FSS design structure are designed and simulated [17-18] by using CST Microwave Studio at 2.4 GHz and 5.2 GHz. The dual band FSS is chosen in this paper because of the design gave the lowest transmission losses of -0.5 dB at 2.4 GHz and 0.44 dB at 5.2 GHz compared to others designed [19-20]. The design chosen is based on the frequency response needed to achieve. The square slot produces 2.4 GHz frequency response while 5.2 GHz is produced by circular slot.

The square FSS is designed on the substrate. Then, two slots which are circular and square slots are added on the square FSS. The double slots are added to create a band-pass at 2.4 GHz and 5.2 GHz frequency response. The parameters for the design FSS structure are shown in Figure2. The values for each parameter are shown in Table 1. The parameters involved in this design are length of square (*a*), outer radius of circle slot (*b*), inner radius of circular slot (*c*), length of the square slot (*d*), length of the small square (*e*) and length of substrate (*s*).

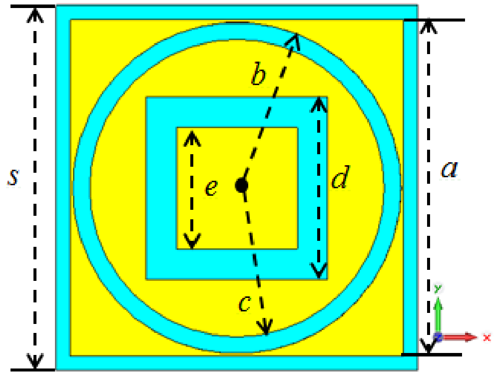


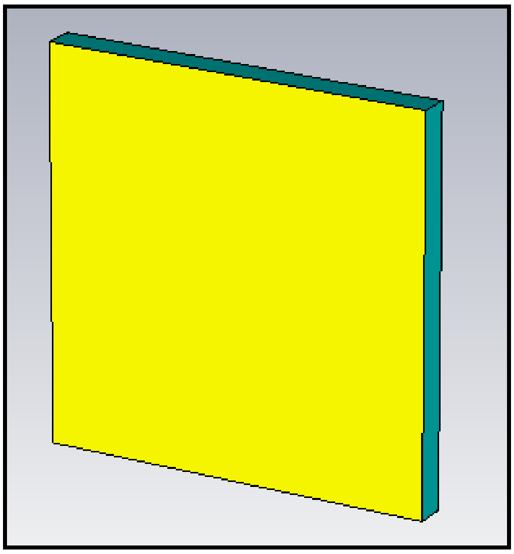
Fig.2. The parameter of the unit cell dual band FSS

TABLE I. DIMENSION OF THE UNIT CELL DUAL BAND FSS

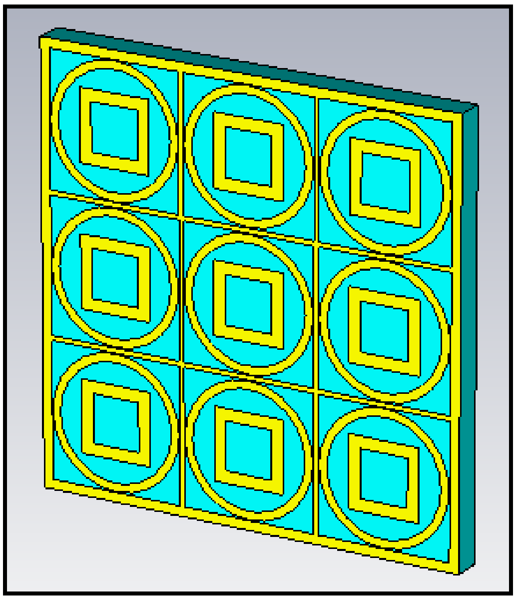
Parameter	Dimension (mm)
a	14
b	13.9
c	12.2
d	7.5
e	5
s	15

A. FSS on Energy Saving Glass(ESG)

There are two materials that have been used in this paper which are FR4 board and energy saving glass. The dielectric constant of FR4 is 4.4 and a tangent loss of 0.019 with a thickness of 1.6 mm while the glass dielectric constant is 6.9 and conductivity is 5×10^{-4} S/m with thickness of 5 mm. the ohmic sheet with resistance of 17.95Ω/square is used for the ESG coating. The dual band FSS design structure is designed on the ESG by removing certain area of the coating. The area removed by each of square and circular slot FSS is about 60%. Figure 3 are shown the full coated of energy saving glass and the dual band pass FSS.



(a)



(b)

Fig. 3. The structure of (a) Full coated energy saving glass (b) energy saving glass (ESG) with dual band pass FSS

III. RESULTS AND DISCUSSION

All configurations are simulated with the same size of the dual band FSS design structure for WLAN applications at 2.4 GHz and 5.2 GHz for ISM band applications. The results of the transmission signal (S_{21}) for each material are shown in Table 2. Firstly, the dual band FSS is designed and simulated on the FR4 board. Secondly, the ESG is designed and simulated with full resistive coating. Lastly, the dual band pass FSS is designed and simulated on the ESG. Certain area of the coated is removed by the square and circular slot FSS.

The transmission coefficients at 2.4 GHz and 5.2 GHz when the dual band FSS is designed on the FR4 is -0.99 dB and -0.66 dB. While when the full coated ESG is simulated, the average attenuation is -8.79 dB and -11.33 dB respectively. After that the dual bandpass FSS has been designed on the coated side of the glass. The transmission coefficients have been noted at 2.4 GHz and 5.2 GHz are –6.68 dB and -7.07 dB, respectively. The transmission of the FSS that designed on the FR4 is higher compared to the FSS that etched on the ESG due to the permittivity of the material. Other effect is the heat loss when by the percentage of the area removed. The transmission results of the coated glass are shown in Figure 4. The shaded area is shown the focused frequency responses which are 2.4 GHz and 5.2 GHz.

The full coated ESG affect the transmission because the coated have the characteristics that reflect or blocked the signal from passing through. When the dual band FSS is designed on the full ESG, the signal transmission is increased about -11.33 dB. After that, the dual band FSS is designed on the FR4 board, the signal transmission is -0.99 dB. The signal transmission for both frequency responses is higher when the FSS is designed on the FR4 board compared to the signal transmission when the FSS is designed on the ESG. The results shown that the material of the substrate used in the designed is affected the signal transmission.

TABLE II. SIMULATED S_{21} RESULTS FOR ALL CONFIGURATIONS

Material	Frequency (GHz)	
	2.4	**5.2**
FR4	-0.99 dB	-0.66 dB
Full Coated ESG	-18.01 dB	-15.86 dB
ESG	-6.68 dB	-7.07 dB

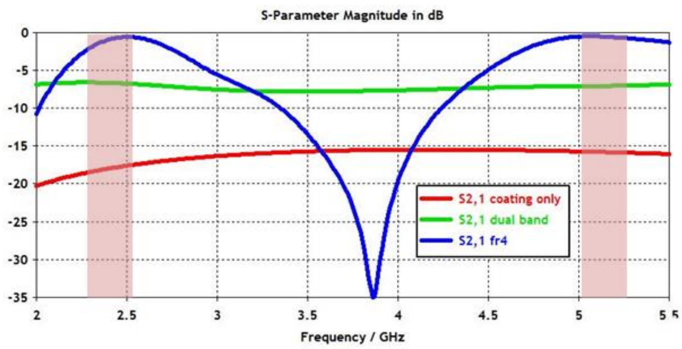


Fig. 4. Simulated transmission (S_{21}) results of the coated ESG and dual band design FSS structure

V. CONCLUSION

The dual band FSS design structure (3×3) is presented in this paper at 2.4 GHz and 5.2 GHz for WLAN applications and its performance has been demonstrated through simulation. The coated ESG attenuated the signal and the dual band FSS is designed to improve the transmission signal about -7 dB to -12 dB. So, future work is needed to increase the transmission rate due to the effect of the FSS element.

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