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Skewed Frequency Selective Surface Absorber*

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ABSTRACT

In this paper, a skewed Frequency Selective Surface (FSS) absorber based on cross-dipole elements is presented. The proposed FSS design provides good frequency stability for oblique incidences. It provides better absorption rate for 5-GHz WLAN frequency band and allow other communication bands to pass through it. Also, the absorption in the stop-band reduces multipath fading of additional WLAN signals which occurred due to the placement of conducting/reflecting FSS. The FSS design consists of two layers; first layer consists of conducting cross-dipole and second layer consists of resistive cross-dipole placed in-front of the first layer. The periodicity of both elements is same. Asymmetric property is applied to FSS elements by taking a reference of central element. This technique leads to achieve a maximum stability in the stop-band. Simulated results demonstrated that the proposed FSS design has a stable frequency response for 5-GHz frequency band for both horizontal (TE) and vertical (TM) polarizations when the incident wave angle varied from 0^0 to 45^0.

Keywords : Frequency Selective Surface (FSS); Skewed Configuration; Oblique Incidences; WLAN; Horizontal Polarization; Vertical Polarization

1 INTRODUCTION

FREQUENCY Selective Surfaces (FSSs) are used as a spatial filter for electromagnetic related problems. It is first demonstrated by Ben A. Munk which was the guru of presented technology [1]. Many applications associated with the designs of FSS, in which the most commonly used applications are radar and circuit analog absorbers [2], [3], radome design [4], telecommunication [5], etc. The FSS structure could be used as a High Impedance Surface (HIS) to provide maximum angular stability for horizontal and vertical polarizations to the phase of resonant frequency [6], [7]. Mosly, HISs are designed and used to enhance the bandwith and gain of an antenna, because HIS provides maximum reflection to the fringing waves as compared to conventional ground plane [8], [9]. In [10], authors proposed a two dimensional Photonic Bandgap (PBG) structure with the conventional microstrip line to obtain wide stop-bandwidth. The presented structure is also associated with the band-pass FSS. In [11], [12], authors presenetd band-pass behavior of FSS to transmit GSM signals through energy efficient windows. The stable frequency response is achieved by designing simple and compact designs.

In this paper, we are presenting the FSS absorber technique for 5-GHz WLAN security. The design configuration of FSS absorber was first presented by Salisbury and Jaumann [13], [14]. These design configurations are much easier to model, but the problem associated with them is that, it provides an unwanted attenuation to the out-of-band communication signals. Many schemes and designs are proposed by researchers to minimize the above mentioned problem [15], [16].

One of the major problems with the FSS design is to get stability for resonant frequency at oblique incidences. Many researchers presented FSS designs for oblique angle stability [17], [18]. The proposed designs offer good frequency stability characteristics, but this leads to most difficult modeling and fabrication. An optimization technique is applied to FSS design, but its practical implementation is not yet available [19]. Also, the above mentioned designs are associated with band-stop characteristics.

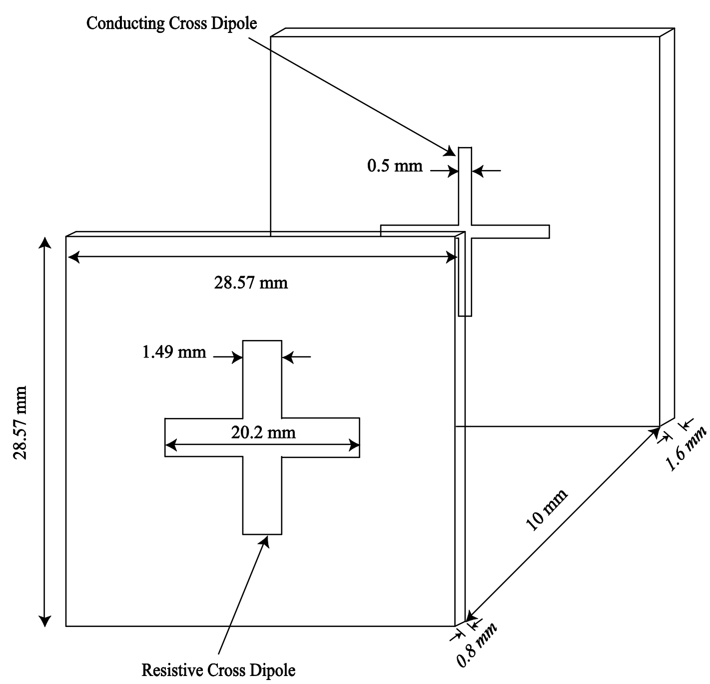

Fig. 1. Geometry and dimensions of proposed dual-layer FSS absorber.

Ghaffer *et. al.*, [15] and Umair *et. al.*, [16] proposed a novel and compact design to obtain stable frequency response by absorbing 5-GHz WLAN signals. Both presented designs provide oblique angle stability for perpendicular (TE) and parallel

(TM) polarizations up to 45^0 oblique incidences. The problem associated with the designs is that, at TM 45^0 oblique incidence, the absorption is not band limited.

In this paper, a stable cross-dipole based skewed FSS absorber is presented to provide security by absorbing 5-GHz WLAN signals. The proposed FSS design has a potential to provide maximum absorption rate. Also, by applying the skewed technique, a stable frequency response is achieved up to 45^0 angle of incidence which is better than the previous reported data [15], [16].

The remainder of the paper is organized as follows. Section 2 presents the design and configuration of proposed FSS absober. Section 3 presenets the simulated results and discussion on the results. Finally, we conclude the paper in Section 4.

2 DESIGN AND CONFIGURATION OF FSS

This section describes the design and configuration of proposed FSS absorber. The overall design parameters and configuration is shown in Fig. 1. First of all, a conducting cross-dipole element is designed to demonstrate the reflection properties of FSS element. To obtain maximum stability from the design, the periodicity of the elements is skewed to an angle of 45^0 by taking a reference of central element. Skewed means to place the elements in asymmetric plane by providing it a sufficient angle. The skewed or asymmetric design configuration is shown in Fig. 2. This technique allows FSS element to provide maximum stability characteristics within a desired band. In skewed configuration, the unit cell length remains the same which is along x-axis on the coordinates system, but the width of the unit cell is skewed by multiplying the width with cosine function. It can be calculated as:

$$\textit{Width (along y-axis)} = \textit{Width of unit cell} \times \cos\theta_s \quad (1)$$

where, θ_s is the skewed angle. After that, second layer which consists of resistive cross-dipole element is palced in-front of the conducting layer to achieve absorption characteristics. The distance between the two layers is 10 mm. This design configuration strictly follows the principle of Salisbury and Jaumann absorber design [13], [14]. The resistive layer dimensions are also shown in Fig. 1. Also, the skewed dimensions of the resistive layer are same as that of conducting layer. The surface resistance of the resistive layer is chosen to be 50Ω/square. The design is then simulated to demonstrate the absorption characteristics for 5-GHz frequency band. The dielectric used for the design purpose is FR-4 having relative permittivity (ε_r) 4.4. The thickness of the conducting sheet is 1.6 mm, while thickness used for the resistive layer is 0.8 mm which is also shown in Fig. 1. Both the materials are easily availbale in the market. The simulation results corresponding to the design are described below.

3 SIMULATION RESULTS

This section describes the simulation results of proposed FSS absorber design for oblique incidences. The simulation has been done by applying the configuration and dimensions of proposed FSS design using CST Microwave Studio.

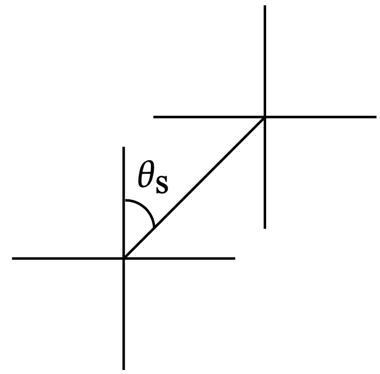

Fig. 2. Skewed or asymmetric configuration of FSS element.

3.1 Conducting FSS Layer

As discussed in Section 1 that the FSSs are spatial filters so, the frequency response should be stable when the angle of incident wave is changed from normal to oblique incidence [20]. Fig. 3 shows the stability chracteristics of the conducting layer for horizontal (TE) polarization. For 0^0 and 45^0 angles of incidence, the noted resonant frequencies are 5.25-GHz and 5.29-GHz, respectively. The transmission coefficients corresponding to the resonant frequencies are -29.6 dB and -32.5 dB. Also, the reflection coefficient at the resosnat frequencies is almost 0 dB.

Fig. 4 shows the simulated stable frequency response for vertical (TM) polarization. For 0^0 and 45^0 angles of incidence, the noted resonant frequencies are 5.25-GHz and 5.28-GHz, respectively. The transmission coefficients at the resonant frequencies are -29.6 dB and -23.6 dB. Also, the reflection coefficnet is 0 dB at the resosnant frequencies. In TM propagation mode, some attenuation noted at 4.6-GHz. It is due to the skewed configuration and functionalilty problem of FSS element.

From the above described results, it is noticed that the proposed FSS design has a stable frequency response up to 45^0 angle of incidence compared to previous reported data [15], [16].

3.2 Resistive FSS Layer

After the simulation of conducting FSS layer, resistive sheet is placed in-front of the conducting sheet at a distance of 10 mm to achieve absorption characteristics. The surface resistance of the resistive layer is chosen to be 50Ω/square. FR-4 with different resistance values is also available, but the disadvantage associate is the unwanted attenuation occurred for the out-of-band communication signals [21].

Fig. 5 shows the simulated results of dual-layer FSS absorber for horizontal (TE) polarization. The resonant frequencies for 0^0 and 45^0 angles of incidence are 5.25-GHz and 5.27-GHz, respectively. The transmission coefficients noted at the resonant frequencies after the placement of resistive layer are -30.8 dB and -32 dB, and the reflection coefficients noted are -37.6 dB and -13.4 dB, respectively. The reflection coeffcients in this case are absorption coeffcients, because we are demonstrating the absorption characterisitcs after placing the resistive layer.

Fig. 6 shows the simulated results of dual-layer FSS absorber for vertical (TM) polarization. In this case, the resonant frequencies for 0^0 and 45^0 angles of incidence are 5.23-GHz and 5.24-GHz, respectively. The transmission coefficients noted at the resonant frequencies are -30.6 dB and -23.3 dB, and the absorption coefficients are -36.8 dB and -13.3 dB, respectively.

From the above presented results, it can be demonstrated that the proposed FSS design has great potential to absorb WLAN signals and has a stable frequency response for both horizontal and vertical polarizations. Maximum stability is achieved from the previous results, where the absorption is not band limited and out-of-band signals are attenuated [15], [16]. Also, the presented FSS design is much simple, compact and easy to fabricate than [15], where the conducting FSS element is sandwiched between two dielectric layers which increases complexity of design. Also, the FSS element is not able to function properly. Also, the distance between the two layers is approximately equal to $\lambda_o/6$ which to equal to the previous reported data [16].

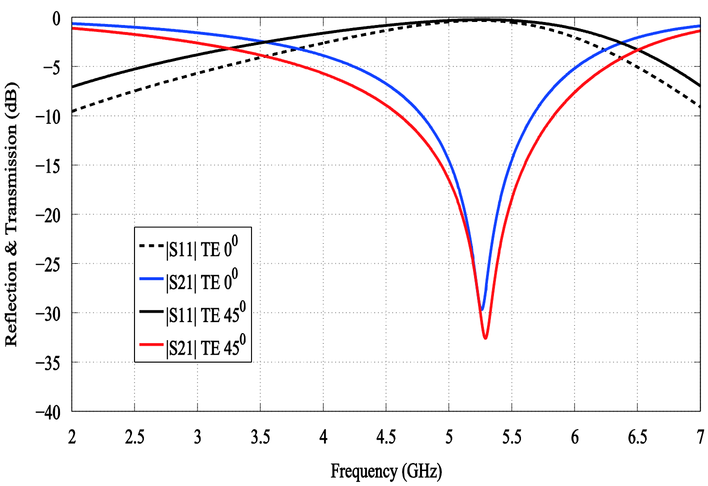

Fig. 3. Reflection and transmission coefficients of reflecting FSS for TE polarization.

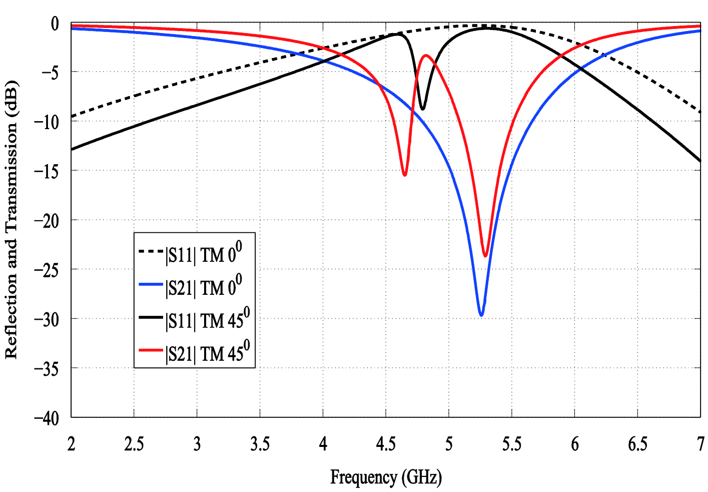

Fig. 4. Reflection and transmission coefficients of reflecting FSS for TM polarization.

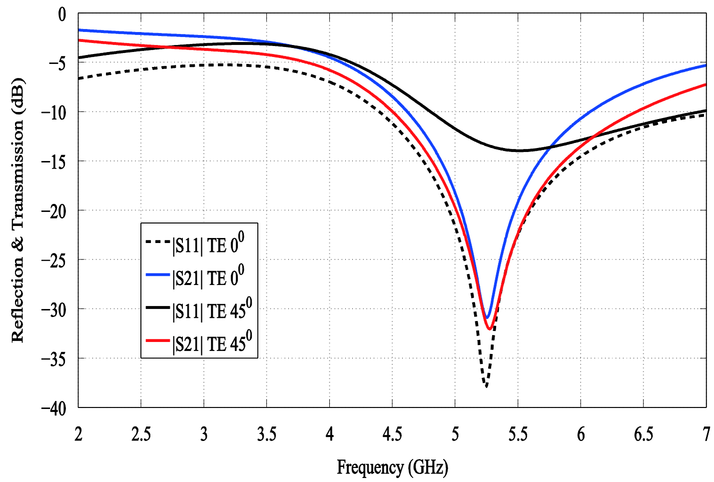

Fig. 5. Reflection and transmission coefficients of dual-layer FSS absorber for TE polarization.

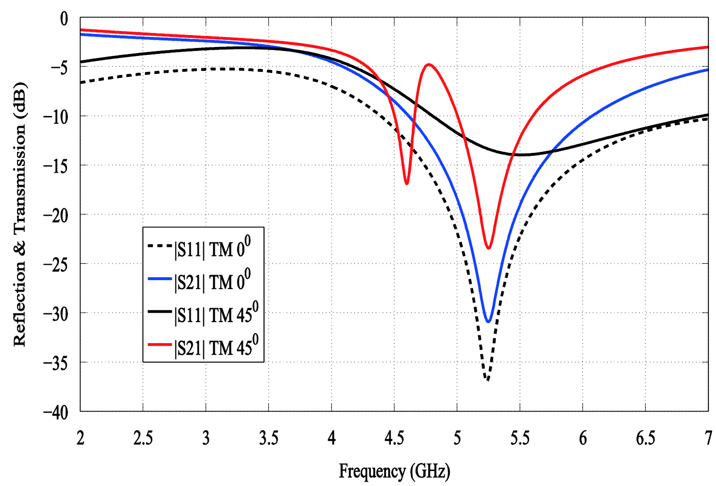

Fig. 6. Reflection and transmission coefficients of dual-layer FSS absorber for TM polarization.

4 Conclusion

A dual-layer FSS absorber based on cross-dipole elements is presented for 5-GHz WLAN security. Maximum stability is achieved for the desired WLAN frequency band with the skewed configuration of the FSS elements for both perpendicular (TE) and parallel (TM) polarizations from 0^0 to 45^0 oblique incidences. Improved chracterisitcs and proposed technique ensures that FSS will be able to absorb desired frequency band for the wide incidence angles. Research is in progress to achieve stability up to maximum angle of incidence with the reduction in distance between two layers.

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