An FSS Structure Based on Apollonius Circles with Stable Resonance Frequency for WLAN Applications

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Abstract

In this study, the fractal structure of the Apollonius Circle previously used for array antenna structures is modified and used as a stable resonance element on frequency selective surfaces (FSS) operating at the WLAN band. The proposed structure designed using a low-cost Taconic-RF35 substrate resonates at 5 GHz and has a bandwidth of 3.52 GHz. The performance of the design is simulated using CST Microwave Studio in terms of surface current on the proposed structure and the dependence of the FSS resonant frequency on the angle of the incident plane wave. From the result, the FSS design provides stable performance as a band stop filter at different angles ranging from 0° to 55° in TE and TM modes.

1. Introduction

The rapid development of communication technologies in recent years has increased the data traffic in the WLAN (Wireless Local Area Network) band significantly. Since there are many devices working on WLAN band such as several types of remote controllers and baby monitors, unintended electromagnetic (EM) interference possibility should be considered at the design stage. In addition, the usage of WLAN band is increasing dramatically and electromagnetic compatibility (EMC) issues must be handled using filters, different kind of absorbers or proper decoupling, grounding and shielding equipment [1-2].

Frequency Selective Surfaces are periodical structures that have a selectivity according to frequency of the electromagnetic wave. Characteristic response of the frequency selective surfaces depend on the design parameters such as size, inter element spacing, the material and thickness of the substrate and the shape of the designed FSS (e.g. slot, patch, inverted F, etc.). In literature, there are a lot of studies about FSS to be used as band pass or band reject EM filter [3-4]. In [5], it is proposed that an FSS structure may be used as band stop filter working at 5GHz WLAN band in order to prevent undesired signals. Once the usage of the FSS structures and dramatic demand in using the WLAN band are taken into consideration, it is obvious that a properly designed FSS, which is used as an absorber in WLAN frequency range, can increase the quality of the signal while preserving EMC and provide wireless security [1-2].

In this study, the fractal structure used for antenna array in [6] is modified to be used as FSS's resonance element at WLAN band frequency range. The proposed FSS has a wide band stable response with different incident angles (*0°-55°*). The simulation results such as transmission coefficient response, surface currents on resonance frequency and characteristic at TE and TM mode for different incident angles are examined in detail. The designed structure blocks four different frequency ranges covering 3.6 GHz, 4.9 GHz, 5 GHz, and 5.9 GHz bands in the WLAN band specified in the IEEE 802.11 protocol.

2. Design and Analysis of FSS Structure

2.1. Previously Proposed Apollonius Structure for Antenna Arrays

The previously proposed Apollonius structure (PPAS) in [6] is shown in Fig.1 and was applied as a defected ground on an antenna element. This structure consists of three different conductors produced from copper; one of them is the structure obtained by removing Apollonius Circle from the copper plate covering the substrate surface and the other two structures are obtained by subtracting Apollonius Circles from their reference triangles. The fractal structure and geometric ratios of the Apollonius Circle have been studied in detail.[6]The substrate is Taconic RF-35 that have ε_r=3.5 as a permittivity with a thickness value of 0.51 mm. R_1, R_2 , and R_3 are determined radius of the inner circles and D is the side length of the unit cell.

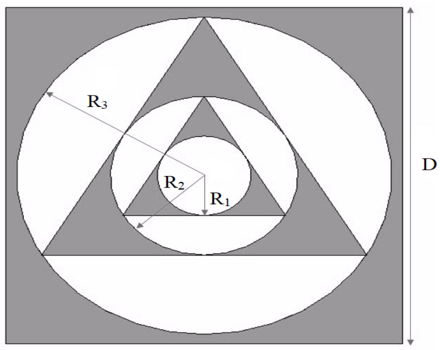


Fig. 1. Previously Proposed Apollonius Circle(PPAS). Dimensions of the structure are D=8.832 mm R_1=1.043 mm R_2=2.0865 mm and R_3=4.173 mm.

2.2. The proposed modified Apollonius Structure (PMAS) FSS structure

As depicted in Fig.2, the PPAS is modified by replacing the outermost conductive part shown in Fig. 1 with an Apollonius circular ring and changing its dimensions to resonate in the desired frequency band. Firstly, the Apollonius inner circle with radius R_1 is nested with copper triangle in order to adapt the previously proposed design. The same process is applied to the radius of R_2 and then outer circle is added. R_1, R_2 and R_3 are radius of the inner circles, R_4 is outer radius of the single copper ring. The values of the design parameters are shown in Table I. Actually, the PPAS used for antenna array operates in multiband at high frequencies and the classical circular ring FSS structure with a thickness of R4 – R3 has a narrow bandwidth. By modifying the PPAS, the PMAS operating at the WLAN band provides stable performance as a band stop filter at different angles and has a wide bandwidth as shown in Fig. 3.

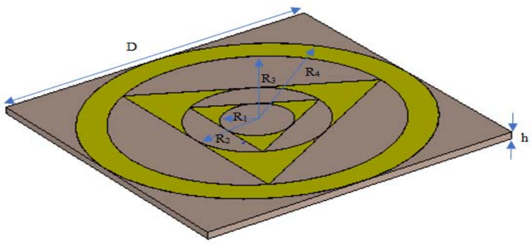


Fig. 2. The Proposed Modified Apollonius Circle(PMAS) FSS

Table 1. Dimension of modified FSS with Apollonius Circle (mm)

D	h	R_1	R_2	R_3	R_4
20.174	0.51	2.086	4.173	8.346	10.072

3. Simulation and Results

The modified FSS structure with Apollonius Circles simulated with Computer Simulation Technology Microwave Studio (CST MWS) by using unit cell boundary conditions and floquet port excitations. The S-parameter (S-11) results which represent transmission through the PMAS is shown Fig. 3. The transmissions of both modes are almost identical due to quasi symmetrical structure of proposed FSS element. The resonance frequency is 5 GHz, as seen from the S-11 of about -64 dB and it is observed that The -10 dB bandwidth of the proposed structure is 3.3–6.8 GHz. Therefore, the PMAS blocks four different frequency ranges covering 2.4 GHz, 3.6 GHz, 4.9 GHz, 5 GHz, and 5.9 GHz bands in the WLAN band specified in the IEEE 802.11 protocol.

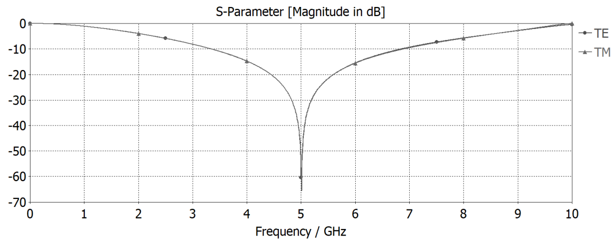


Fig. 3. Transmission coefficient of PMAS at TE and TM mode normal incidence angle.

Surface current distribution at the resonance with the plane wave Floquet mode TE(0,0) and TM(0,0) is seen in Fig. 4. Since the triangular elements are not symmetrical with respect to the x axis, the current densities are not similar in the TE and TM modes while on the single copper ring are same. In addition, the current densities increase at the corners of the triangular elements.

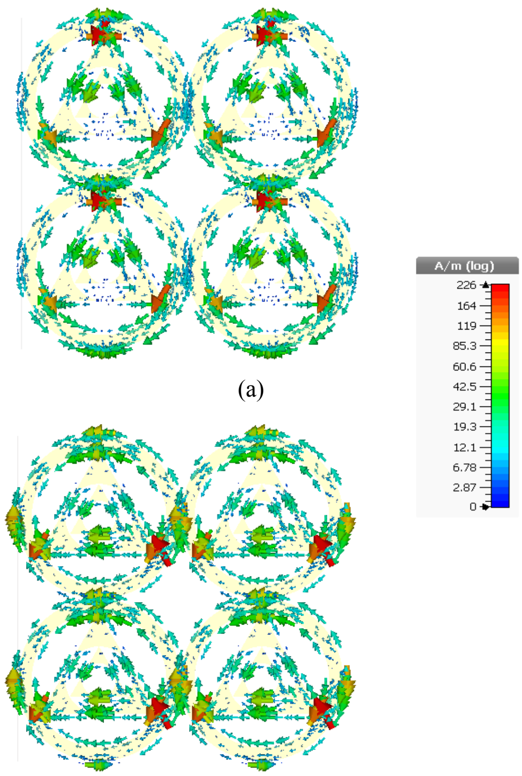
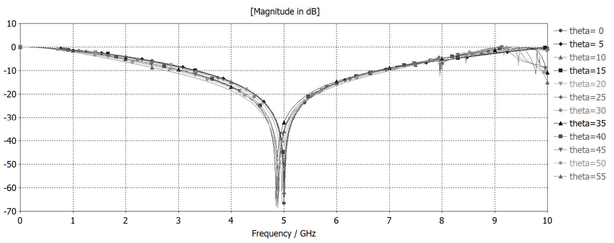
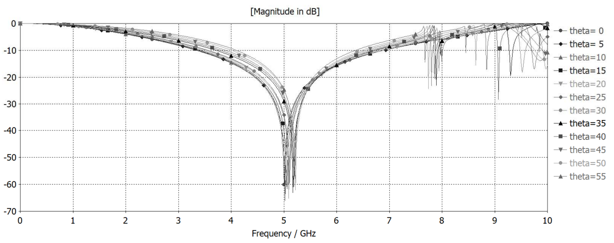


Fig. 4. Surface current at resonance frequency f=5 GHz (a) TE mode, (b) TM mode



(a)



(b)

Fig. 5. Characteristic response of FSS at different incident angles **(**a) TE Mode, (b) TM Mode

Characteristic response of the PMAS at different incident angles at TE and TM mode is depicted in Fig. 5. It seems that the proposed structure has a stable performance at different incoming wave angles range from *0°* to *55°* for both TE and TM polarizations. As the incident wave angle increases, the resonance frequency decreases at TE mode; but the case is vice versa at TM mode. The resonance frequency is about 4.8 GHz at $\theta=30^\circ$ at TE mode, while the resonance frequency is about 5.2 GHz at the same angle at TM mode. Moreover, some distortions occur after 7.6 GHz frequency band at TM polarization while the incident wave angle changes. However, it can be said that the proposed FSS structure is appropriate for different incident angles in the IEEE 802.11 WLANs operating in 3.6 GHz, 4.9 GHz, 5 GHz, and 5.9 GHz bands.

4. Conclusions

In this paper, the fractal form generated by Apollonius Circle, which was previously used in antenna arrays, is modified to be used as FSS's resonance element at WLAN band frequency range. The proposed FSS structure has a wide band stable response with oblique incident angle variations between 0˚ to 55˚ in the transverse electric and the transverse magnetic modes. It is considered that this structure can be used as a filter in the WLAN band. Such as the PMAS blocks four different frequency ranges covering 3.6 GHz, 4.9 GHz, 5 GHz, and 5.9 GHz bands in the WLAN band, permits the data transmission at 2.4 GHz frequency band in the communication.

5. References

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