Multi Wide-Band Frequency Selective Surface for Automotive Applications

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***Abstract*—A symmetrical double-layer frequency selective surface (FSS) is proposed for multi wide-band filtering applications. The structure consists of three pairs of circles on the two sides of the supporting dielectric layer. A parametric analysis concerning the frequency response versus the angle of incidence is reported, demonstrating that the structure exhibits a satisfactory response to incidence up to 45º, for both TE and TM cases. The configuration can be used for filtering in the X band for example in Automotive applications.**

Keywords—FSS; wide-band; angular insensitivity, X band.

I. Introduction

Designing Frequency Selective Surfaces for WLAN band and X band filtering has been of interest for the authors for some time now [1]. For example, a FSS based on a combination of a rectangular ring and a cross dipole has been proposed in [1] in view of applications in Automotive EMC testing. Even if in the literature works to build spatial multi band filters from FSS have been reported [2], [3], [4], the topic remains challenging when there is need to design multi wide-band ones. For instance, in [2] the FSS offers band stop response at 930 and 1720 MHz with 18 dB shielding effectiveness for a bandwidth of 100 and 173 MHz, respectively.

The present work proposes a simple structure to answer such a practical issue with final design goal on the X band, commonly used in the automotive industry. Two double-sided FSSs conceived for multi wide-band filtering applications are reported. The two considered structures are built on FR4 substrate; they consists of a set of (i) one and (ii) three circular rings on both sides, respectively. The filtering properties are assessed with a commercial solver. Parametric studies are undergone to demonstrate the stability with respect to the angle of incidence of the structure.

II. Proposed Structure

A. Initial Structure

The unit cell of the initial FSS is presented in Fig.1. It consists of a pair of circles made from copper on both sides of the substrate. The dimensions are as follows: substrate thickness: 3.2 mm, substrate relative dielectric constant: 4.4,

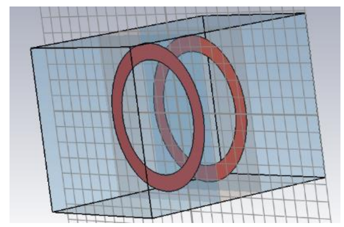

Fig. 1 Unit cell of the proposed structure

dimensions of the unit cell: d_x=d_y=10 mm, circle width: 1mm, outer radius: 4.5 mm, inner radius: 3.5 mm. The FSS results by 2D repetition of the unit cell in the x and y directions with periodicity of d_x and d_y, respectively [1], [5].

The structure with one circle on only one side of the substrate has been assessed first. Such a design resonates at a single notch frequency determined by the perimeter of the circular ring [5]. In this particular case, one notch frequency (8.38 GHz) has been obtained, for a -10 dB band in the range (6.28 – 9.36 GHz).

In Fig. 2 the band-stop properties between 0 and 20 GHz of the structure in Fig. 1, obtained using a commercial solver [6] are reported. The transmission coefficient of the structure having the outer radius equal to 3.5, and 4.5 mm have been calculated.

In the first case from Fig.2 (orange color), a wider stop-band that the one by using a circle on only on side, can be seen. It starts at 6.26 GHz and stops at 11.76 GHz, thus we obtained a stop-band of 5.5 GHz. The stop-band enlargement is motivated by the coupling between the circular resonant structures on the two sides of the PCB. In the other case of Fig. 2 (blue color) again a larger wide-band is obtained, between 9.02 GHz and 15.28 GHz. Considering the wider bandwidth, in the following, the structure with outer radius of 3.5 mm has been considered.

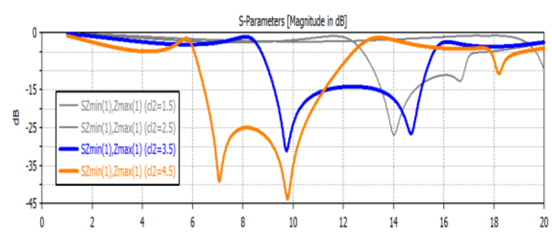

Fig. 2 Transmission coefficient for normal incidence

Moreover, the initial stop-band starting at 6.26 GHz is shifted to higher frequencies by reducing the outer radius of the circles. Both cases intersect the X band (frequency range 8-12 GHz), so this structure can be used for filtering in this frequency range. To sum up, one can conclude that by placing circles on both sides, a wide-band spatial filter is obtained.

B. Improved Structure for Multi Wide-Band filtering

A method to obtain multi wide-band filtering is reported in Fig. 3: it consists in increasing the number of resonant elements by placing two extra rings on each side of the substrate. The new parameters are as follows: outer radius of circle_1: 4.5 mm, outer radius of circle_2: 3 mm and outer radius of circle_3: 1.5 mm. Each strip has a width of 1 mm.

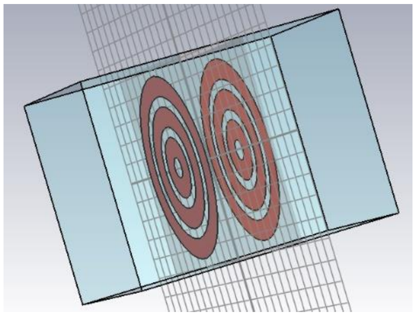

Fig. 3 Unit cell of the improved structure for multi wide-band filtering

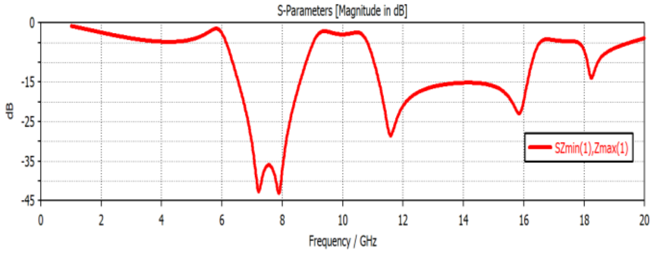

Fig. 4 Transmission coefficient for multi wide-band

In Fig. 4 we can notice the dual band-stop transmission properties of this new structure. The first wide-band extends from 6.35 GHz to 8.78 GHz (2.43 GHz) and the second one from 11.02 GHz to 16.25 GHz (5.23 GHz). The first wide-band is inherited from the outer ring (as one can see from Fig.2); the other two rings determine the second wide-band [5].

III. Parametric Analysis

To assess the sensitivity with respect to the angle of incidence of the electromagnetic plane wave, a parametric study on the structure in Fig. 1 has been performed.

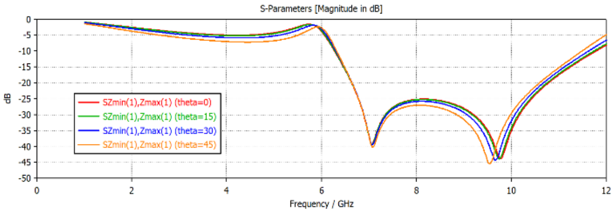

Fig. 5 Results of parametric study for different incidence angle (TE case)

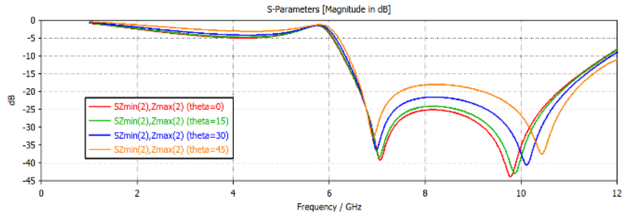

Fig. 6 Results of parametric study for different incidence angle (TM case)

In Fig. 5 and Fig. 6 results of parametric variation of the colatitude angle (theta) with azimuth phi=0 have been reported. This parameter has been varied between 0 and 45^{o} in 4 steps. Consistency for the band (6.26 GHz - 11.76 GHz) can be seen in TE mode (Fig. 5), while in TM mode the bandwidth is slightly enlarged (Fig. 6) by increasing theta, which might be considered a positive feature. The response is insensitive to azimuth due to the x and y symmetry of the design of the unit cell.

Because of space limitation, results of a more exhaustive parametric studies are not included here, but will be reported during the conference presentation. Some of them are: use of a single circle on one side of the substrate and changing the circle outer radius, changing the dimensions of the unit cell to 5 and 15 mm and assessing the influence of the substrate thickness.

IV. Conclusions

In this paper, a FSS built on a FR4 substrate, with a unit cell consisting of one pair and three pairs of metal circular rings on both sides has been proposed. The potential for applications of the FSS has been demonstrated by simulation with an electromagnetic software package. It has been established that the proposed structure can work as an X band spatial filter for Automotive applications.

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