New UWB Shielding with Frequency Selective Surfaces

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***Abstract*- In this paper a Frequency Selective Surface (FSS) as a UWB electromagnetic shield is introduced. The proposed FSS comprises a quasi-J.C-Jerusalem Cross- and a copper ring, which are located at both sides of a FR4 substrate and can represent a S.E -Shielding Effectiveness- better than 20dB in 90% bandwidth of Ultra Wide Band frequency. This structure is compact and thin. Each cell comprises J.C elements and a ring at two sides of a FR4 board with 3.2mm thickness, dielectric constant of 4.4, and loss tangent of 0.02. The structure has a 24×36 elements with dimensions of 288×432mm. Also the simulation and measurement results are in good agreement.**

***Index Terms*-** FSS, Shielding Effectiveness, UWB.

I. INTRODUCTION

Complexity and sensitivity of electronic and computer systems and their increasing application in administrative, industrial and medical environments have attracted attentions towards safety and performance of such systems and it is tried to elevate their reliability. Some problems of applying such facilities are caused by interference of unfavorable signals, performance perturbation and desolation of equipment's. This phenomenon might cause economical or industrial detriments and injuries [1]. The most important way of opposing this phenomenon is electromagnetic shielding [2]. Shielding has some other applications as well, among which we can name construction of electromagnetic testing rooms for antennas and other facilities [3]. At first glance, using a metal plate such that it filters the whole frequency band might seem the best option for electromagnetic shielding but in real, sometimes it is needed that a particular frequency band is eliminated or passed. One way for realizing such shielding is to use frequency selective surface or FSS. FSSs are spatial filters with periodic structure which are in EBG category [4-17] which can represent band pass [4-7] and band stop [8-15] characteristics. FSSs can be a suitable option for shielding applications because they are easy to fabricate and low profile. Even some FSSs have transparency and printing on fabric advantages [8]. Thus, by using such structures we can prevent intervening electromagnetic waves in

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intended bands to enter specific buildings and environments in frequency bands. These plates can be mounted on walls, windows, glass doors of microwave ovens and etc. FSSs can be employed in radome antennas such that radiations of antenna in the intended frequency passes with minimum loss and radiations which are out of band are eliminated.

In addition, this type of radome can decrease cross radar area of antenna by improving characteristics of antenna such as reducing SLL, reducing surface wave and cross polarization [19]. In [20] a method of using frequency selective surface (FSS) to dynamically control beamwidth of antenna is proposed. The unit cell is composed of a two-layer periodic H-shape structure loaded with varactor diodes. By tuning the bias voltage applied to the varactor diodes, the unit cell has two different states that are transparent and absorptive to the incident wave at a certain frequency, respectively. Using this method, antenna's pattern can change from 13.2 to 30.1 degrees by changing voltage. FSSs can also be employed in arrays. For example, in [21] efficiency and bandwidth of the array is increased by improving SLL. Or in [22], FSS has enhanced the characteristics of a reconfigurable array. Among other attractive applications of FSSs, conversion of a wave with linear polarization into a wave with circular polarization can be indicated [23-24]. Decreasing cross radar section of targets [25] and construction of Salisbury screens is another application of FSSs. In order to change or control characteristics of FSS structures, active elements can be used [4, 7, 20, 22]. As mentioned, shielding electromagnetic sources is a major challenge for preventing unintended interferences, performance perturbations and threatening human's health. Nowadays, increasing usage of communication facilities like cell phones, WLAN, WiMAX and etc. in houses and administrative building, people are subject to different radiations emitted from self-gadgets and adjacent buildings. This issue along with the problems caused by unintended interferences might reduce quality of human's health. On one hand, complete electromagnetic shielding with ordinary sorbents or metals eliminates other systems' waves like cell phones which is not favorable. One of the best and most effective methods for conquering these problems is effective and selective shielding by using frequency selective levels. For example, shielding GSM mobile network frequencies and GPRS is proposed in [9-10, 27]. In these papers, SE better than 20 dB in GSM900 and GSM1800 frequencies is achieved. In [12], a Salisbury structure is used obtain appropriate shielding in WLAN. In this paper, effects of multipath fading are reduced by absorbing WLAN wave. Shielding by frequency selective levels in high frequencies have also been attractive. For example, EMI-Shielding in [11] using a cross-slot element in 12.2- 12.7 GHz frequency band is achieved. One of the major problems in FSS structures is their narrow bandwidth. In some applications, it is required to increase the elimination band of a FSS so that structure can eliminate a wide range of channels and intervening waves and an appropriate shielding is achieved. For example, [13] has used an array of square rings and Crossed Dipole to achieve $|S21|$<-10dB and bandwidth of 59.15%. Recently, [30] has used a single layer array FSS to achieve a bandwidth of 73.1% for UWB applications. In this article, a crossed dipole and a ring are combined SE has reached

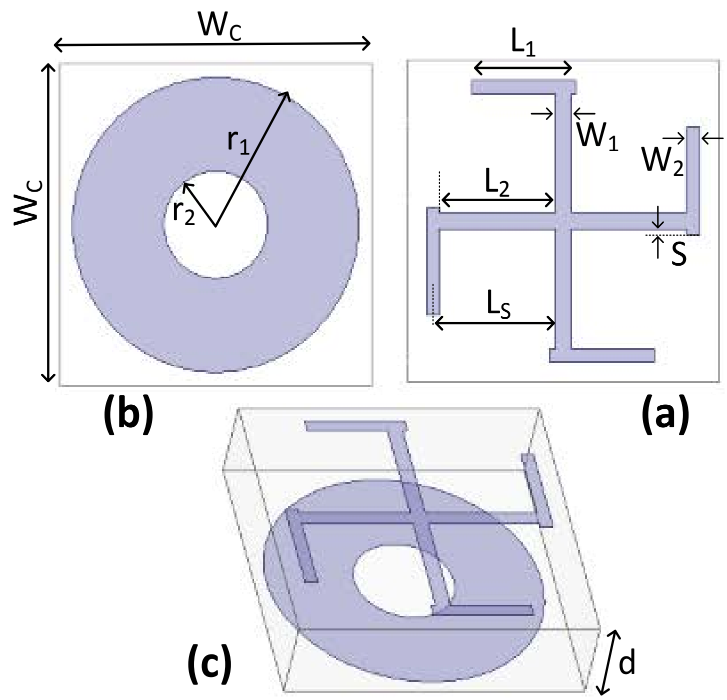

Fig. 1. The proposed unit cell. (a) Top view (b) Bottom view (c) The 3D view.

more than 20 dB in 6.5-14 GHz frequency range. Decreasing operating frequency of the shield and increasing its bandwidth for better coverage of UWB frequency band can be an optimization method [30]. Thus in this article, the above structure is optimized and crossed dipole is replaced with a similar structure like JC. A wider bandwidth is covered compared to [30]. The proposed single layer structure with 90% bandwidth coverage in 4.9-13.8 GHz frequency band can be a better option for achieving S.E better than 20dB for UWB shielding compared to [30]. Thus according to the author's knowledge, considering the single layer structure, obtained bandwidth is the maximum obtained bandwidth so far. This article is organized in four sections. After introduction, in section II FSS cell structure is proposed. In this section, after simulation effectiveness of the cell's shielding and the total FSS plate, parameter analysis is proposed. In section III, construction and simulation results are presented. Finally, in section IV conclusion is presented.

II. FSS CELL DESIGN

Structure of the proposed FSS cell is shown in Fig. 1. Each cell comprises J.C elements and a ring at two sides of a FR4 board with 3.2mm thickness, dielectric constant of 4.4, and loss tangent of 0.02. The cell's dimensions are 12*12mm in X-Y plane. Dimensions of the proposed cell are listed in table 1.

In order to design and simulate the structure, first the cell is evaluated. Magnitude and phase of scattering parameters of the J.C structure and the ring which are simulated with HFSS are shown in

Table I. Dimensions of the proposed cell in mm.

d	S	W_2	W_1	W_C	r_2	r_1	L_S	L_2	L_1
3.2	0.2	0.5	0.6	12	2	5.5	4.7	4.45	4

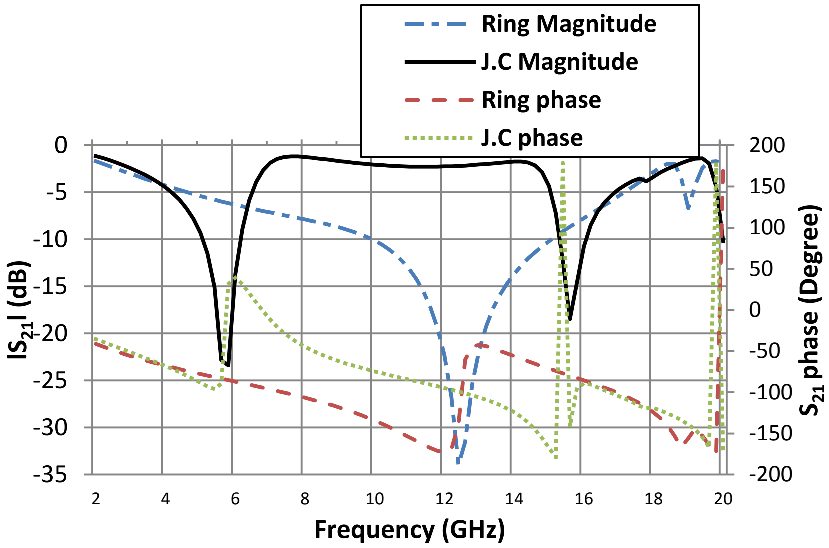

Fig. 2. Magnitude and phase of S-parameters of the J.C structure and the ring.

Fig. 2 [31].

Fig. 2 shows that prohibited bandwidth of $|S_{21}| < -10$dB for resonance frequencies of 5.6GHz and 15.6 GHz are equal to 800MHz and 600MHz respectively and for 12.4 GHz resonance frequency it is equal to 5GHz. Combining these two structures, a wide prohibited bandwidth can be achieved. But placing these structures on both sides of a board can perturb the final structure because of the mutual coupling. In order to oppose the increase in mutual coupling, a substrate with higher thickness is required. Thus a board with 3.2 mm thickness is chosen. Any ways, mutual coupling can change the structures' resonance frequencies and reduce the elimination amplitude of passing wave. Magnitude and phase of scattering parameters of the final cell are shown in Fig. 3.

According to Fig. 3, bandwidth of the final cell is 5.3-16.1GHz. Mutual coupling can shift resonance frequency from 12.4 GHz to 11.8 GHz and change S_{21} from -33dB to -31dB, resonance frequency of J.C structure from 5.6 GHz and 15.6 GHz to 5.4 GHz and 16.1 GHz respectively and changes S_{21} from -23dB to -25.6dB and from -18.5dB to -11dB.

The most important parameter is to measure the quality of an appropriate shielding. This parameter is defined as (1) [2].

$$S.E_{dB} = 20Log\left|\frac{E_{incident}}{E_{transmit}}\right| \tag{1}$$

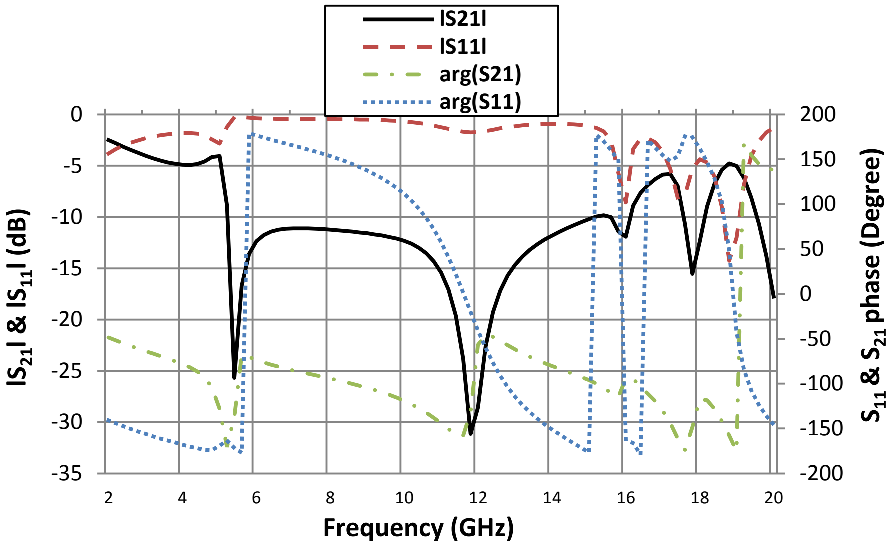

Fig. 3. Magnitude and phase of S-parameters of the final cell.

According to the definition, the smaller the wave that passes a structure is, compared to the radiation wave, SE is higher and effectiveness of shielding is more suitable. The purpose of this article is to propose a shield with the ability to cover UWB frequencies. There are two types of losses at the incidence of electromagnetic wave with a surface. A portion of the radiation wave is reflected to the transmitter which is called reflective loss and is shown with R. Another portion of the wave which enters the shielding plate is lost in the thickness of the layer which is called absorptive loss and is shown with A. Some of the wave that has entered the substrate is reflected subsequently before it passes the shielding plate, these losses are shown with B. According to [2], effectiveness of shielding structures can be written like (2):

$$S.E_{dB} = A + R + B \quad (2)$$

In the formula above, R is determined by S_{11} and A+B is determined by S_{21}. In addition, impact of J.C and ring in producing resonance frequency through simulating surface current density can be seen. For example, in resonance frequencies of 5.6GHz, 11.8GHz and 15.6 GHz current distribution is simulated on both structures and the results are shown in Fig. 4. This figure shows that 5.6GHz frequency of ring is not effective and the effective element for absorptive loss of passing wave is JC. In 11.8GHz and 15.6 GHz effect of ring increases greatly and JC is effective in eliminating the passing wave.

For simulation of total FSS, plane have been plotted in HFSS and then periodic boundary conditions be defined. Next ports be defined in top and bottom of plane and S21have been simulated. At the end simulation results have been converted to S.E curve. One of the advantages of the proposed

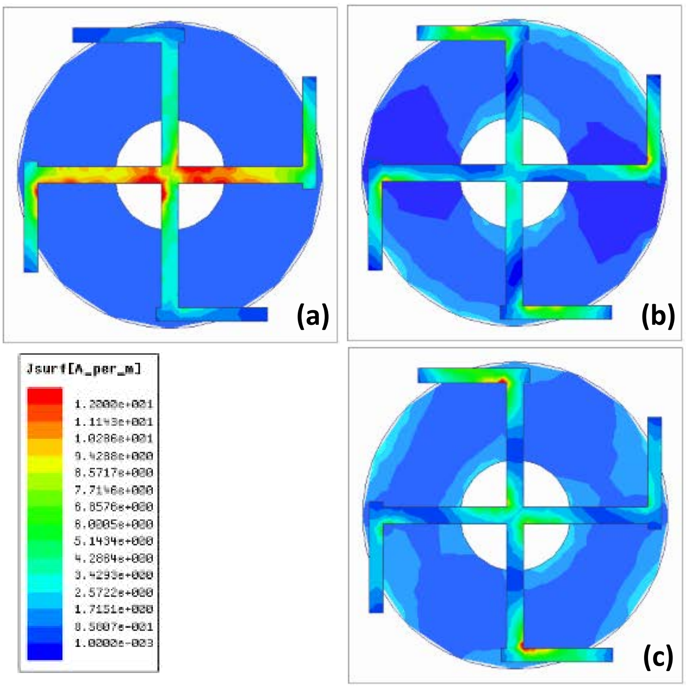

Fig. 4. The surface current density on the J.C and the ring in the proposed cell (a) 5.6GHz (b) 11.8GHz (c) 15.6GHz.

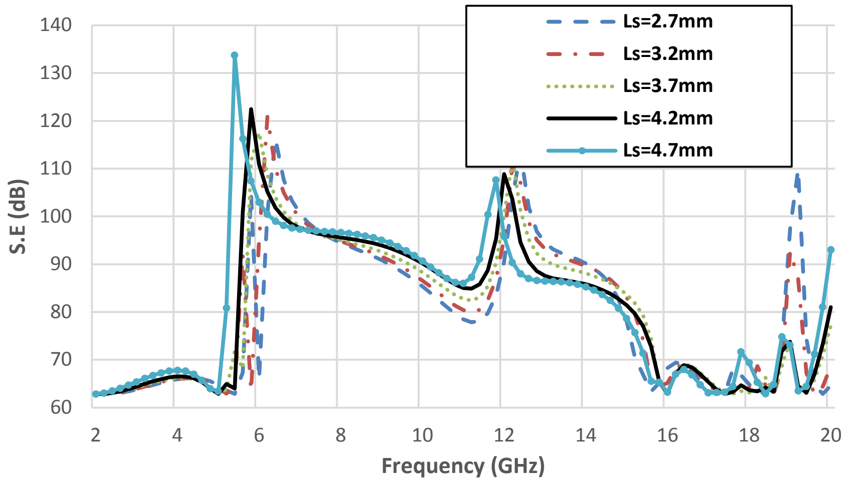

Fig. 5. The Shielding Effectiveness of proposed FSS Cell by changing L_S.

FSS is the ability to tune and change the bandwidth of the proposed shielding plate by changing L_S, such that the user can construct a plate with intended shielding bandwidth. In Fig. 5, changes of SE cell by changing L_s is plotted. By changing this parameter, elimination band of the cell can be shifted. Results of Fig. 5 obtained with 12GHz solution frequency in HFSS.

As shown in Fig. 5 with changing L_S from 2.7-4.7mm, frequency bandwidth shifted approximately 1GHz.

III. MEASUREMENT RESULTS

In Fig. 6, the constructed FSS plate which is an array of the proposed FSS cell is shown. This

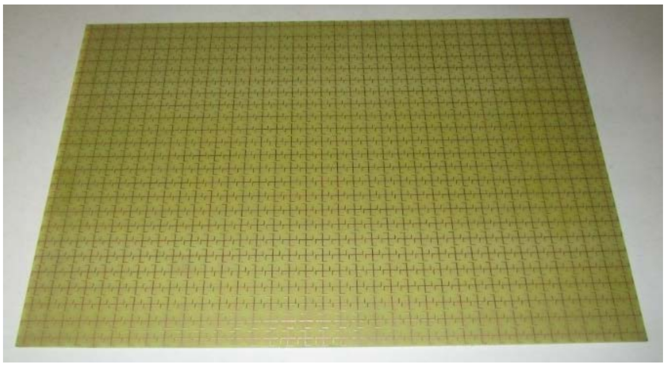

Fig. 6. The fabricated FSS.

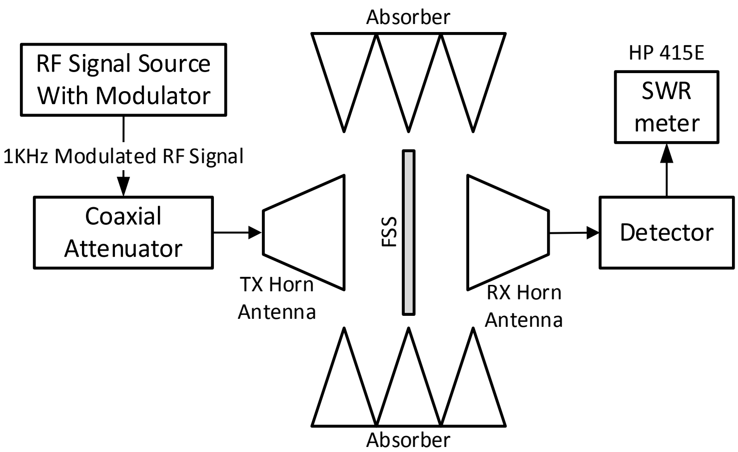

Fig. 7. The block of measurement setup.

array is a 24×36 element array with dimensions of 288×432mm.

Many useful microwave parameters, such as Standing-Wave Ratio (SWR), substitution loss, insertion loss, attenuation, and gain, are ratios of two signal levels. The relative power levels which determine these parameters an often be measured most conveniently and accurately by means of a versatile audio-frequency instrument known as a standing-wave-ratio meter. The SWR meter consists of a high gain (over 100 dB) audio amplifier which has a selective band pass frequency response, followed by an indicating meter which is calibrated for SWR and relative power measurements [32]. The 415E VSWR meter may be used for high resolution insertion loss measurement simply by inserting the device to be measured between signal source and detector and noting the change in DB indication on the 415E. The continuous coverage of the Expand scales allows any attenuation measurement to be made on Expand scales. For accurate results, both the signal source and the detector should be well matched. Impedance match of source and detector have been improved by an attenuator. The block diagram used for testing SE by [32] is plotted in Fig. 7.

According to this figure, first losses between two Horn antennas are measured without FSS plate and the obtained loss is subtracted from the loss obtained after inserting FSS plate. In Fig. 8, a

Fig. 8. The photograph of the S.E measurement test setup.

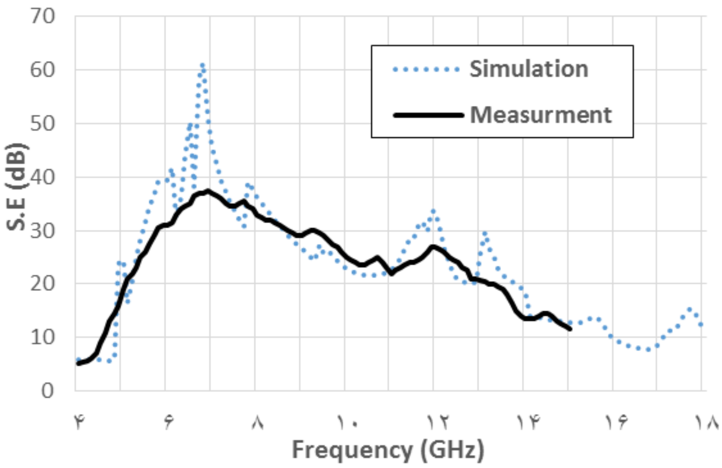

Fig. 9. The simulated and measured SE of the final FSS plate.

profile of the test bench is shown. In the performed measurement, an HP415E SWR meter and a HP 8672A Synthesizer is used.

In Fig. 9, simulation results and SE measurement of the final FSS plate are shown. It can be seen in this figure that there is a good agreement between simulation and measurement results. Test results show that this plate can achieve SE better than 20dB in 90% bandwidth in 5.1-13.3 GHz frequency range. Comparing this plot with the simulated SE frequency band of the cell shown in Fig. 5, it can be seen that it is shifted down and its amplitude is reduced. It might be because of mutual coupling and test condition. Test results also show that the proposed FSS plate can be used for UWB shielding. To reach more precise simulation results, simulation data in Fig. 5 obtained with 18GHz solution frequency in HFSS.

IV. CONCLUSION

In this article a FSS with the ability of electromagnetic shielding is designed and constructed in a wide range of UWB with a cheap substrate. Measurement results show that this structure has a SE better than 20 dB in 5.1-13.3 GHz frequency range. Simulation and measurement results are in good agreement also.

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