Design of Window Applicable Blind-type Frequency Selective Surface

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Abstract – In this paper, we presented the window applicable blind-type frequency selective surface to control the coverage area of wireless communication in secure building or conference room. The proposed frequency selective structure has the reconfigurable frequency range depends on its blind rotation angle. To verify the proposed structure, we fabricated the window blind-type frequency selective surface with four-legged loaded element and ring-type element as a unit cell and performed measurements of the transmission characteristics for different blind rotation angles to prove the feasibility. The measurement results show good agreements with the simulation results. One of the advantages is that the proposed structure does not need to have a bias circuit, so it is very easy to implement at low cost and also can be applied to any planar surface for wireless security applications.

Keywords: Frequency selective surface, Four-legged loaded element, Wireless security

1. Introduction

To improve communication service for shadow zones which may be caused by a complicated structure inside the building, the additional installation of equipment such as repeaters or strong wireless signal from outside not only costs a lot, but also causes more interference in the external communication environment and weakens wireless security as the leakage or unwanted radio waves increases. For the communication environment in a secure building or a conference room, it is required to provide the limited radio communication service coverage and achieve wireless security from outside the building or room using complete electromagnetic wave shielding structure [1]. Therefore, it is necessary to find a way to ensure both the efficiency and security of limited radio resources by preventing the leakage of radio waves inside the building or the infiltration of unwanted wireless signal from outside at relatively low cost.

In order to meet those demands, there have been studies that apply frequency-selective surfaces(FSS) structures which act as a band-stop filter reflecting certain frequency band [1-3] for building. Recent studies have mainly conducted with focus on implementing FSS on windows [4], and there have also been studies of attempts to install FSS structures on the walls [5]. However, most of the previous studies are limited to single frequency band and had a difficulty in adapting to arbitrary rooms or buildings. We proposed the window blind-type FSS using the concept of a light-blocking blind to overcome these. Recently, there has been some research on propagation effects of window blinds [6-7]. But there are considerable errors between simulation and experimental results and did not present the polarization and incidence angle characteristics.

The proposed window blind-type FSS is easily applicable to a variety of different building or room environments because it is not need to design any separate window or wall that requires a special design like placing an FSS on the window or wall. Also, this proposed structure can provide the reconfigurable operation frequency band according to the angle of blind. Unlike active FSS structures which are generally used for frequency reconfigurable structure, the new proposed window blind-type of FSS structure does not need to have any complicated bias circuit and enables complete shielding or complete opening simply by adjusting the angle of blind. For the validation of this paper, we designed the window blind-type FSS which is composed of four-legged loaded element and ring-type element as a unit cell for band stop application. Also, the transmission characteristics of the designed structure are simulated using the commercial electromagnetic software. We fabricated the designed window blind-type FSS and presented the compared results between simulated and measured performances.

2. Design and Measurements

In this study, we designed four-legged loaded element and ring-type element FSS to have band-stop characteristics at 7 GHz for normal incidence wave. We just choose the 7 GHz because of experimental convenience due to absorber property used in measurement setup. Those FSS structure are designed with unit cell arranged on Taconic RF-35 which have $\varepsilon_r = 3.5$, $\tan\delta = 0.0018$ and 0.726 mm as substrate dielectric thickness.

To simulate the proposed structure, we used the Floquet mode analysis of Ansoft’s HFSS which is the commercial electromagnetic simulator. Fig. 1(a) and Fig. 1(b) show the
Fig. 1. (a) Reconfigurable four-legged loaded element; (b) ring-type FSS with the change of blind rotation angle; (c) 10×10 four-legged loaded elements; (d) ring-type FSS structure to simulate and fabricate

Fig. 2. (a) Fabricated window blind-type reconfigurable FSS and (b) free space measurement setup for measuring transmission characteristics of FSS structure

Fig. 3. Transmission characteristics comparisons between measurement and simulation results
form of reconfigurable FSS with the change of blind rotation angle of four-legged loaded element and ring-type element, respectively.

From Fig. 1(a), we established the design parameters with the variables of gap, length and width. From the parameter sweep simulation, 20 mm of gap, 14.8 mm of length and 4.8 mm of width are determined as design parameters. For ring-type element, 20mm of gap, 15.4mm of outer radius and 1.585mm of width are obtained from the optimized simulation as shown in Fig. 1(b). Figs. 1(c) and (d) represent the whole structure made of proposed window blind-type FSS, which have $10 \times 10$ elements and the size of $200 \, \text{mm} \times 200 \, \text{mm}$.

Figs. 2(a) and Fig. 2(b) shows the front view of the proposed window blind-type FSS and the free space measurement setup for measuring the transmission characteristics of FSS for the different angle of blind. For the measurement of transmission characteristic of FSSs, the standard wideband horn antennas are used.

Figs. 3(a-c) and (d) presents comparisons between the measurement results and the simulation results of transmission characteristics of the proposed four-legged loaded elements FSS. Because of similar results, we didn’t present the results for ring-type elements FSS. The results show that there are good agreements between measurement and simulation. Figs. 3(a-c) and (d) shows the transmission characteristics for $0^\circ$, $15^\circ$, $30^\circ$ and $45^\circ$ of blind rotation angle, respectively. For $0^\circ$ of blind angle, the resonant frequency is measured at 7 GHz as designed. For $15^\circ$ and $30^\circ$ of blind angle, the resonant frequencies are measured at 7.3 GHz and 7.6 GHz. We performed the measurement for another blind angle like $60^\circ$ and $75^\circ$, either. But above $60^\circ$ of blind angle, there are no noticeable frequency change compared to below $60^\circ$ of rotation angle.

That is the why when we investigated the current distribution on the conductor, we found that there are no induced current for the resonance above $60^\circ$ of rotation angle as shown in Fig. 4.

We also presented the TE and TM mode transmission responses for different incident angle $0^\circ$, $15^\circ$, $30^\circ$ under fixed $30^\circ$ rotation angle in Figs. 5(a) and (b), respectively. These results show that TM mode is better than TE mode for the angle stability of incident wave and improvement of angle stability using different unit cell should be considered for future research.

### 3. Conclusion

We proposed the design of new window blind-type reconfigurable FSS structure to control the communication signal in building or conference room and ensure wireless

![Fig. 4. Field distributions for different rotation angle](image)

![Fig. 5. TE and TM mode transmission characteristics for different incident angle](image)
In-Gon Lee and Ic-Pyo Hong

security. For the validation, we fabricated the simulated FSS structures with four-legged loaded element and ring-type element as a unit cell and measured the transmission characteristics using free space measurement setup. Compared results show good agreements between measurement and simulation results for different angles of blind. We also investigated the TE and TM mode transmission characteristics for different angles. The stability weakness of the angle of incidence can be improved if we adopt the different unit cell with the insensitivity of incident angle. The proposed structure has strong advantages for building or room secure application compared to windows or walls including FSS in previous studies, because it is very simple to control frequency range, by angle of blind, and is easy to make because of no bias circuit for frequency reconfigurable function.

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References


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