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Research Paper

FREQUENCY SELECTIVE TRANSPARENT FRONT DOOR FOR MICROWAVE-OVEN

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Microwave oven generates a harmful Electromagnetic Wave at 2.4 GHz of 1000 Watts. The generated microwave has to be confined within the cavity of the oven for efficient heating and secured operation. To prevent the microwave leakage through the front glass door, a special construction of Faraday Cage being involved. In this paper, Faraday Cage is replaced with Transparent Frequency Selective Surface Front Door is proposed, this provide better visibility and to avoid microwave energy to escape from the oven. Band pass response has been achieved for 10 GHz by printing array of Greek cross aperture (FSS) on the front glass door. Design of FSS array and the simulation results were discussed.

Keywords: Frequency selective surface, Greek cross, Electromagnetic shielding

INTRODUCTION

A Microwave oven is a Microwave Generator used for heating food, which works by passing non-ionizing microwave radiation, at a frequency of 2.45 GHz through the food. Microwave is generated by the Magnetron and fed to the metal cavity (cooking compartment) through waveguide. The metal cavity (size≈ 33.6 x 22.5 x 34.9 cm^3) is closed with solid metal plates on five sides and Faraday Cage incorporated glass plate on the sixth side. Since all the six faces are reflecting the microwave, the energy is confined inside the oven for heating.

The Front Glass window design is important, because it should see through and should not allow the microwave to pass through. To achieve this Faraday Cage is placed inside the glass plate. Faraday Cage is conducting mesh screen which blocks out external static and non-static electric fields. Its operation depends on the fact that an external static electrical field will cause the electrical charges within the cage's conducting material to redistribute themselves in order to cancel the field's effects in the cage's interior. The hole size the in the mesh should smaller than the wavelength of the microwave signal so that it

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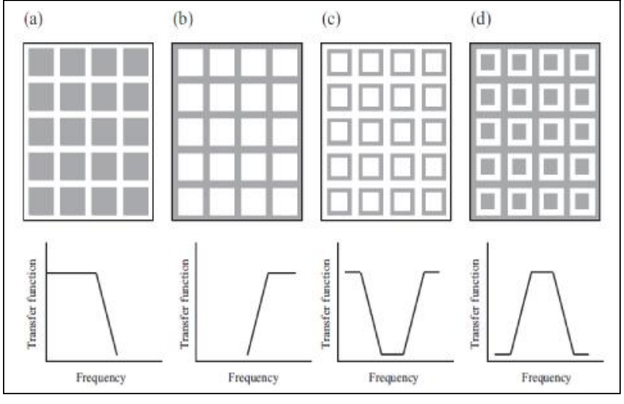
can't penetrate. In this paper Faraday Cage is replaced with Frequency Selective Surface to provide improved visibility and Microwave radiation blocking capability.

FREQUENCY SELECTIVE SURFACE (FSS)

FSS is the periodic structure of conductive elements or apertures in either one or two dimensions that provide a filter operation when they are illuminated with EM wave. When illuminated by an electromagnetic wave, FSS exhibits total transmission/reflection around the resonance frequency. This spatial filter behavior of FSS is used in designing the FSS Shield. The filter behavior (low-pass, high-pass, band-pass and band-stop) of the FSS depends on the shape of the element (Munk, 2000). In this paper Greek Cross element is considered for FSS design. Figure 1 shows various arrays of FSS and the frequency response.

The major application of FSS is selective shielding. By carefully choosing the element shape and size, desired frequency response can be obtained. FSS has already applied to block/allow Wi-Fi band 2.4 GHz.

Figure 1: FSS Types and Response (a) Solid Patch Array-Low Pass, (b) Slot Array-High Pass, (c) Patch Looped Array-Band Stop and (d) Slot Looped Array-Band Pass



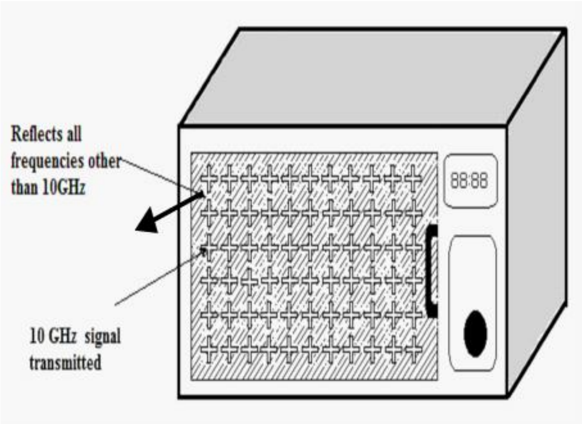
In Cheng-Nan Chiu *et al.* (2008) Band pass Shielding Enclosure has been designed to allow the 2.4 GHz band and block the remaining frequencies. Here the size of the enclosure considered in 10x16x2.1 cm3, and array of Jerusalem cross apertures has been made. The design objectives of a practical BPSE are - high transmittance in the specified wireless-signal band and high shielding outside that band. Also several works has been proposed to block the Wi-Fi inside the building. In Taylor (2011) a Frequency Selective Surface (FSS) of square loops printed on both sides of a dielectric substrate is used to allow/block 2.4 GHz band inside a room. This FSS structure is printed on the walls to control the Wi-Fi band.

In Raspopoulos (2011) also FSS wall has been designed to stop penetration of Wi-Fi inside the building. Here square loop patch is printed on the walls to achieve the band stop response. In Mias (2006) transparent FSS box has been designed to place Microwave oven. The microwave oven measurements in the presence of the FSS box demonstrated that there is a satisfactory attenuation, around 20 dB. In all the above literatures FSS is printed on substrate which is either transparent or not transparent for blocking or allowing the Wi-Fi signal. But so far FSS design approach has not been applied to design the front doors of microwave oven.

DESIGN OF FSS FRONT WINDOW

Design Objective: To design a Frequency Selective Surface (i) blocking the radiation

Figure 2: Microwave Oven with FSS Wall (FSS Slots are Embedded on the Front Door)



of 2.4 GHz and (ii) providing the transparency in FSS wall so that light pass through the window and user can see through the oven. So FSS has to be designed to block 2.4 GHz, i.e., a band stop response at 2.4 GHz. But for safety reasons, in this paper FSS has been designed for allow 10 GHz band. This design will block till 5 GHz strongly. Array of Greek Cross apertures will be made on the conductor and this FSS will be placed above the glass. The model is simulated with Feko 5.5 Lite Version. Microwave oven with see through FSS window has been shown in Figure.2.

Table 1: Literatures on FSS Shelding

Ref. Paper	FSS Element	Frequency Response	Frequency Band	Application
[1]	Center connected, Loop type and all possible combinations	Band pass, Band stop, High pass and Low pass	As per the necessity based upon stopping or passing the wavelength	Hybrid Radome, Band-stop filters, Dichroic sub reflectors, Dichroic main reflectors, Circuit Analog absorbers, Meander line Polarizers, etc.
[2]	Slot arrays, Tripole-slot arrays, and Cross-slot arrays	Band pass	IEEE 802.11 b/g (2400-2484 MHz)	High transmittance in the IEEE 802.11 b/g band and High shielding effectiveness outside this band, together with minimal effect on the radiation characteristics of the internal antenna.
[3]	Ring element	Band pass	2.45 GHz WLAN band	Controlling the electromagnetic architecture of buildings, Offering good performance in terms of all polarizations affected and good angular stability. The two states offered by the surface enable it to be either transparent or reflective at the frequency of interest.
[4]	Cross slots with and without loading	Selective radio band control, band stop	Wi-Fi, 2.4 GHz	FSS in indoor wireless environments and investigates their effect on radio wave propagation. FSS can be deployed to selectively confine radio propagation in indoor areas, by artificially increasing the radio transmission loss naturally caused by building walls.
[5]	Circular patches, Tripole element and Tripole element within triangular element	Band stop	10 GHz, 1.9 GHz and 2.4 GHz	Designing transparent films for windows that can shield at some desired frequencies. Either 2.45 GHz for wireless Local Area Network (LAN) applications or 1.9 GHz for Personal Hand-phone System (PHS) applications. They also indicate that their product does not disturb mobile phone communication bands at 900 MHz and television frequency bands.

DESIGN OF FSS UNIT ELEMENT

First the single unit cell of the FSS array should be decided. The length of the Greek Cross aperture should be of approximately/2 which the resonance length of the aperture pole. Since band pass response is expected the at f = 10 GHz (= 3 cm), the half wavelength is 1.5 cm. The single element is shown in Figure 3.

For Simulation Feko 5.5 Lite version is used. As the FSS is infinite periodic array, Periodic Boundary condition is applied. Unit cell meshed view is shown in Figure 4. This Greek Cross aperture shaped unit cell is place above the Glass. The white part of the cross will be the transparent part and remaining are metal. As the array is backed by glass the resonance frequency curve is shifted to few hundred megahertz.

Figure 3: FSS Unit Element

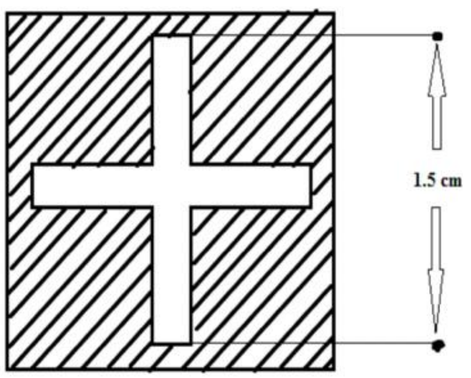
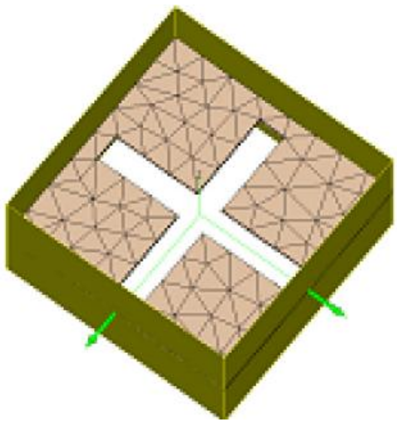


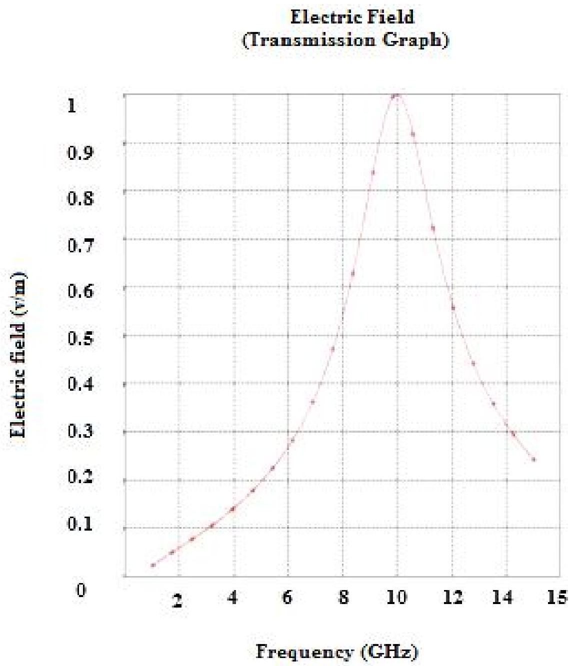
Figure 4: Unit Cell Meshed View



RESULTS AND CONCLUSION

From the simulation we observed that, this FSS screen possess band pass response at 10 GHz and high attenuation at 2.4 GHz band.

Figure 5: Response Curve Between Electric Field vs Frequency



In this paper Frequency Selective Surface is designed to block the Microwave energy from the Microwave oven front glass window. For this purpose a FSS layer which consist of array of greek cross shaped apertures were made on the conducting surface and this is printed on the glass front window of the microwave oven.

To provide further attenuation one more layer of FSS has been inserted. This provides improved transparent area over the conventional Faraday Cage based oven door. So simultaneously transparency and electromagnetic shielding were achieved.

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