A FREQUENCY SELECTIVELY SCREENED OFFICE INCORPORATING A CONVOLUTED FSS WINDOW

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The frequency selectivity of small single and double layer FSS windows built into an office enclosure and employing highly miniaturised interwoven array elements is assessed across the frequency range from 200MHz to 2GHz. The aim of providing an emergency services pass band at about 400MHz while providing isolation of at least 15dB above 600MHz is achieved.

Introduction: The electromagnetic spectrum is a finite resource and frequency reuse is essential particularly in the mobile communications bands. Signal propagation in the built environment is notoriously complex but buildings are an environment where measures can be implemented to modify their electromagnetic architecture. Multiple occupancy commercial buildings, partitioned into offices, can in principle be electromagnetically screened internally to assist frequency reuse, and large, more open structures such as theatres can be shielded by suitable construction of the outer walls. It is common practice now, particularly in new buildings, to install aluminium foil backed layers within walls, as a fire precaution measure or for insulation purposes [1]. Suitable screening can greatly reduce co-channel interference and an increase in the signal-to-interference ratio of just 10 or 15dB can decrease outage probability by an order of magnitude or more [2]. At other frequencies access through the screen is necessary, especially at the emergency services band – at 400MHz in the UK. A long-wavelength Frequency Selective Surface (FSS) intended to provide this was described in [3], based on simple square loop slot elements. An alternative approach is to reduce the array unit cell size, here by convolution of the element geometry, and interweaving adjacent elements to increase the bandwidth [4]. The purpose of this Letter is to describe the performance of such an FSS, built as a window into the wall of a small screened office-sized test cell.

FSS Design: The FSS was designed with the aid of CST Microwave Studio™: the element is a highly convoluted square loop in which the stubs of one extend beyond the unit cell and interweave with those of the adjacent element. Convolution greatly reduces the unit cell size, an advantage when the operating wavelength is large: at 400MHz the wavelength is 75 cm, but the array periodicity p is here just 2.6 cm. The width of the stubs c = 0.7mm, with w = 0.2mm. The array was etched on a copper clad polyester supporting substrate about 0.03mm thick, with $\varepsilon r = 3$.

Transmission response: To investigate the performance of FSS designs in practical application a small office-sized test cell measuring 3.0m x 2.4m x 2.1m has been constructed within the Radio Systems Laboratory in the Department of Electrical and Computer Engineering at the University of Auckland, NZ. The structure, shown in Fig. 2, has a wooden frame lined internally with drywall which is in turn completely lined with an aluminium foil surfaced flame stop product so as to provide a high degree of electromagnetic isolation between the interior and exterior fields.

For the purposes of the investigation reported here, a panel is located in the middle of one wall where the lining is provided on the outside of the frame with the aluminium shielding continuous with that on the interior surfaces. The performance of an FSS window approximately 500mm square was investigated by cutting an aperture in the aluminium foil and comparing the transmission through the FSS window completely filling the aperture (as shown in Fig. 2) normalised to that with the FSS absent. These measurements were made over a frequency range from 200MHz to 2GHz using a microwave network analyser connected to a transmitting wideband log-periodic antenna external to the test cell (located about 7m away) and a smaller receiving wideband log-periodic within the test cell. (Some electromagnetic absorbing materials were located within the test cell to reduce reflections.) With the foil completely intact and enclosing the test cell there was a high transmission loss between the antennas with the received signal being very much smaller than that measured for the open aperture or FSS window thus permitting confidence in the measured transmission coefficient results.

Both a single layer FSS window, with the FSS in the plane of the foil surface, and a double layer FSS window, with the second FSS layer spaced some distance from the first separated by polystyrene foam as shown in Fig.2, were investigated. The difficulties of undertaking measurements in an open laboratory environment are well-known. There are inevitably some short term non-stationary variations in the received signal during the frequency sweep resulting from the movement of people and objects in the vicinity, notwithstanding efforts to minimise these. To ameliorate these effects five frequency sweeps were performed consecutively and the average result recorded. Additionally, there will be a stationary multipath effect resulting from wall and other reflections which results in ripple on the measured transmission frequency response. To discern the underlying response of the FSS window, measured results were smoothed by a moving average window 100MHz wide. Measured (window-averaged) results are shown in Fig. 3 for transmission through the FSS window, normalised to that through an open aperture in the foil of the same size. The results shown are for vertical polarisation, very similar results were obtained for horizontal polarisation.

In the case of the single layer FSS window, in addition to the desired pass band around 400MHz, a secondary pass band can be observed around 1500MHz. Cascading two (or more) FSS layers serves to both modify the shape of the desired pass band, and, with the appropriate layer spacing, to significantly diminish the extent of the secondary pass band as shown in Fig 3 for double-layer FSS windows with interlayer spacing of 5cm (approximately a quarter wavelength at 1500MHz), and 10cm, respectively.

Conclusion: These in situ measurements confirm that reduced-size array elements in small FSS windows are capable of providing frequency selective isolation and thus signal-to-interference ratio improvements that in turn deliver major improvements in mobile communications reliability [2].

References

1
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Figure captions:

Fig. 1 A unit cell of the interwoven FSS Experimental variable beamwidth corner reflector antenna

Fig. 2 Screened test cell, with double layer FSS window in situ.

Fig. 3 Transmission response of single and double layer FSS windows

Figure 1

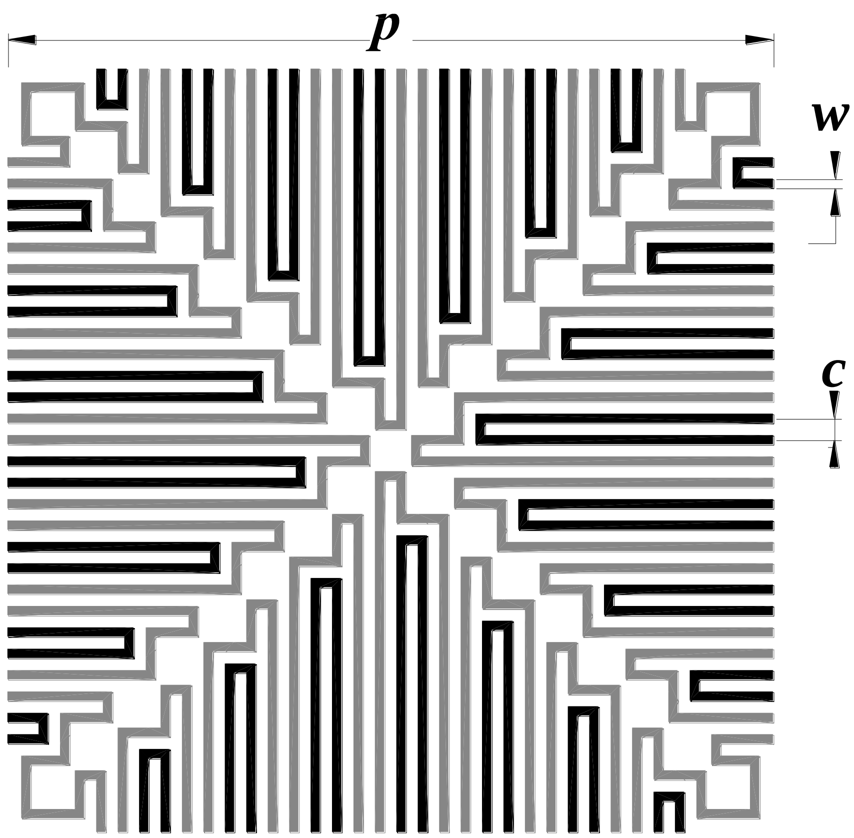
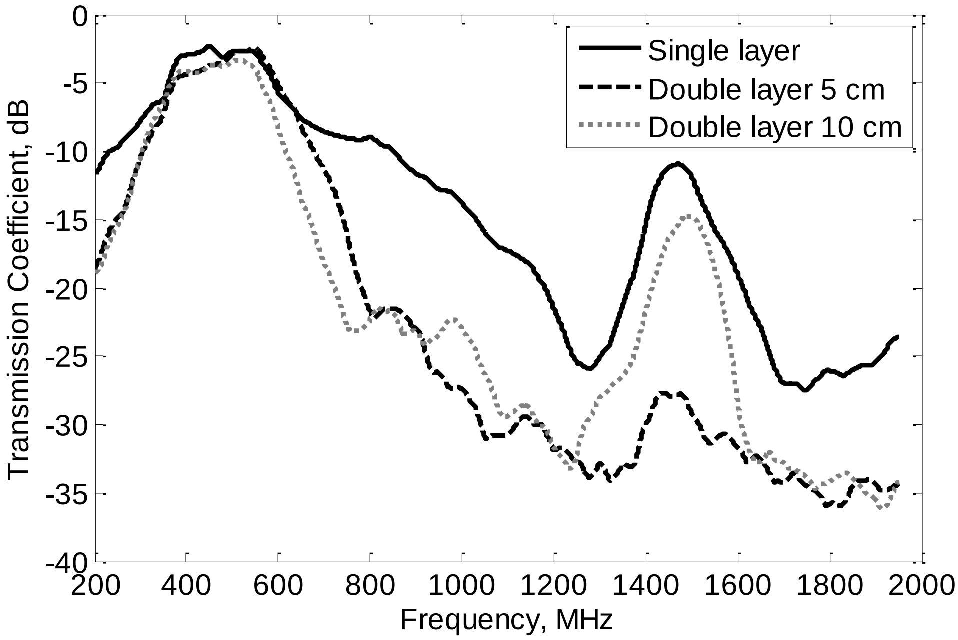


Figure 2

Figure 3


Single layer
Double layer 5 cm
Double layer 10 cm
Transmission Coefficient, dB
Frequency, MHz
0
-5
-10
-15
-20
-25
-30
-35
-40
200
400
600
800
1000
1200
1400
1600
1800
2000