MINIMAL SIZE FSS FOR LONG WAVELENGTH OPERATION

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Abstract: The properties of small finite size FSS for use particularly at long wavelengths are summarised. The intended use is the modification of the EM architecture of buildings at mobile radio frequencies.

Introduction: At microwave and millimetre wave frequencies the physical sizes of Frequency Selective arrays are, in virtually all practical applications, large enough for the structures to be adequately modelled in design work as if they are electrically infinite in extent. Nevertheless, studies of finite sized FSS have been made, and reported in the open literature. References 1 and 2 are examples. It emerged from that work that the currents induced in the array elements by incident electromagnetic waves are not uniform – they are often highly dependent on the location of the element in the array, with the greatest non-uniformity being in the edge region [3]. With the increasing interest in the application of FSS at the frequency bands used for mobile communications, and in particular their application to buildings, in effect to modify their Electromagnetic Architecture, the implications of the much longer operating wavelengths for the design of practical frequency selective structures are significant. The arrays become correspondingly much larger – scaling in proportion to typical operating bands implies large increases in their areas, by a factor of almost 1000 if a design for near 12 GHz were scaled to 400 MHz, for example.

One question that immediately arises is how many array elements are required to generate useful frequency selectivity? The smaller the number, presumably the lower are the costs of production, particularly if active devices were to be included in the structure. In mobile communications and wireless local area networks, a comparatively small reduction in signal interference can give very significant reductions in the system outage probability. Translated into the built environment, an improvement in the carrier-to-interference ratio of about 15dB has been demonstrated to give a reduction by a factor of almost 30 in the outage probability [4]. Furthermore, with an inverse square law of power approximation, a signal attenuation of just 10dB provided by a suitable intervening screen can reduce the separation required for frequency reuse by a factor of 3. The cell size can therefore be proportionally reduced, resulting in cell sizes appropriate to office buildings and with a consequent improvement in the efficiency of spectrum use. This letter describes measurements to demonstrate that simple small finite frequency selective structures are capable of providing those levels of isolation while simultaneously allowing signal access at other long wavebands. The arrays were measured in situ, in a wall.

The array structure: The array sizes were 3 x 3, ie 9 elements located on a square lattice, 2 x 2, and also just a single element. Square loops [5] in slot form were chosen for their dual polarised property and for simplicity. For most single layer FSS consisting of arrays of resonant elements, the roll-off rate between the transmission and reflection bands in the transmission/frequency response is low. Typically, the band edge ratio, taken at the – 0.5dB and – 10dB levels, is almost 3. To improve on this, and more specifically to create a passband at the 400 MHz region of the spectrum, the TETRA band, in the work summarised here two identical layers have been cascaded, to produce a group of minimal double layer FSS. Fig. 1 illustrates the 3 x 3 element version. The sides of the squares (D) were 19.7 mm in length, and the slot width w was 1 mm. In this instance the elements were not closely packed: the array periodicity p was 30cm. The slots were etched into copper foil on a polyester substrate approximately 0.1mm thick, the two layers being separated by low density polystyrene foam.

Swept frequency measurements at these relatively long wavelengths present challenges that are less severe at the higher frequencies where FSS have more commonly been employed: scattering around array edges and signal interference are more significant now. In the present case, the FSS was inserted into a cement block wall approximately 4m high and 5m wide, separating the two rooms. Metal sheets contiguous with the array foil extended the shield by a metre on all four sides, but beyond that, the wall was unshielded, and consequently transmissive. A signal source was placed 1.5 metres from the centre of the FSS. The signal received on the opposite side was recorded at distances up to 4 metres. The antennas were variously simple dipoles and log periodic Yagis. Swept frequency transmission responses were calibrated against the signal received when the FSS were entirely covered with a layer of metallic foil.

Results: Fig. 2 plots the transmitted power measured between 200 MHz and 1 GHz for the 3 x 3 array, at distances of 1.5, 3 and 4m from the wall. There is a strong ripple generated by scattering via other propagation paths, but there is also a clear passband, about 100 MHz wide between the -3dB points, and 150 MHz at the -10dB points, with an isolation of between about 15dB and 20dB at other frequencies across this wide 1 : 5 frequency range. Calibration against the metal covered aperture case does not remove the effects of receiver distance. Were a simple inverse square law to apply, the power near 400 MHz would fall by 6dB between 1.5 and 3m. In the presence of the scattering the precise change is obscured. In Fig. 2 all that can be said is the level fell by a few dB. Comparison with the signal levels recorded for the aperture alone, ie with the FSS removed, indicated that the insertion loss in the passband was small – less than 2dB.

The transmission response for what is almost the ultimate minimal FSS, two single cascaded elements separated by s = 100 mm, is shown in Fig. 3. There is again an obvious passband.

These results are particularly encouraging, as they suggest that a passband can indeed be inserted in an otherwise reflective, or, perhaps, an absorbing wall, through the use of very few array elements.

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Figure captions:

Fig. 1 Double layer 3x3 element FSS

Fig. 2 Measured transmission response for the 3x3 double layer FSS, at receiver distances of 1.5, 3.0 and 4.0m

Fig. 3 Transmission response of the single element double layer FSS

Figure 1 Double layer 3x3 element FSS

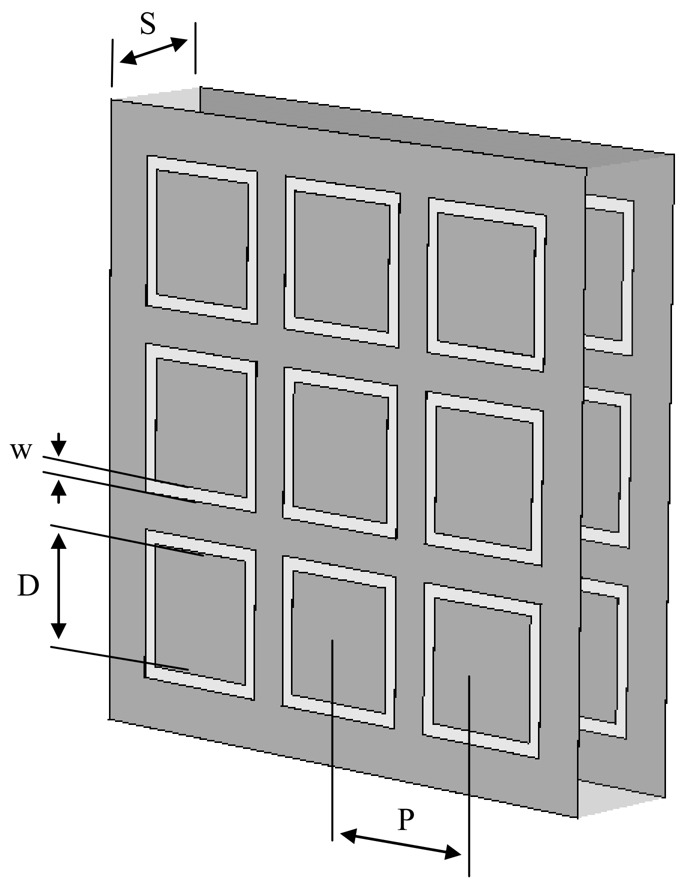

Figure 2 Measured transmission response for the 3x3 double layer FSS, at receiver distances of 1.5, 3.0 and 4.0m

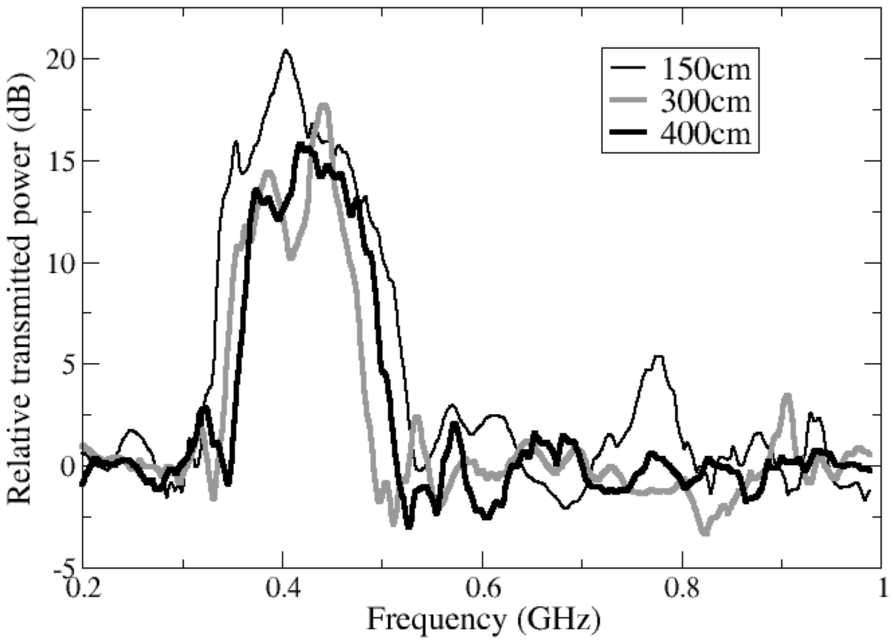

Figure 3 Transmission response of the single element double layer FSS