Wideband EM architecture of buildings: a six-to-one dual-passband filter for indoor wireless environments

B. Sanz-Izquierdo, I. T. Ekpo, J.-B. Robertson, E. A. Parker, and J. C. Batchelor
Department of Electronics, University of Kent, Canterbury CT2 7NT

Wideband EM architecture of buildings: a six-to-one dual-passband filter for indoor wireless environments

B. Sanz-Izquierdo, I. T. Ekpo, J.-B. Robertson, E. A. Parker, and J. C. Batchelor
Department of Electronics, University of Kent, Canterbury CT2 7NT

Abstract: The application of closely packed elements to obtain wideband isolation at mobile phone frequency bands while allowing transparency at the emergency TETRA and the Bluetooth bands is proposed. The intention is to modify the EM architecture of buildings over a very wide frequency range, permitting access at these two very separated bands. In particular, we have in mind buildings with restricted mobile phone usage such as public libraries, theatres and secure offices. Experimentally validating the design required scaling the operating frequencies by a factor of 10.

Introduction: With the recent and ever increasing number of communication applications using the frequency spectrum between about 300 MHz and 5 GHz, owing to the favourable balance there between range and bandwidth, there is a need for the capability to establish "electromagnetic zones" in the built environment, between which communications, or the interference level, can be managed [1]. As a result, there is an interest in Frequency Selective Surfaces (FSS) and their use in buildings to establish the necessary electromagnetic architecture. A major challenge for FSS design for such applications at these wavelengths are the high proportional frequency ranges that may have to be covered, the factor of 6 for example between the 400MHz emergency service band and the 2.4GHz Bluetooth band.

The design of suitable FSS for a specific application is similar to that of antennas: while a number of parameters can be varied (eg. the spacing between elements, type and amount of dielectric in hybrid or multi-layer FSS), the most significant difficulty is generally associated with the generation of elements with geometries that would fit the specific application at hand. There is no obvious general methodology to choose one particular element configuration suited to dual-band filter applications at selected frequencies.

FSS made of the simplest patch elements are generally reflective in a single frequency band (and, to a lesser extent, at harmonic frequencies) and suffer from a relatively slow roll-offs, with a typical edge ratio of 1:3 between the frequencies corresponding to the -0.5dB edges of the low frequency transmission band and the reflection band. An extreme example of such behaviour is that of superdense FSS [2] made of tightly packed elements disposed on a skewed lattice, which give reflection bands which can greatly exceed an octave in width, but with very slow roll-off rates. Using the Fabry-Perot technique described in [3] and [4], faster roll-offs can be produced, by correctly spacing two layers of the densely packed structure. As a guide to a way forwards to meet the challenge posed by the need for wideband operation, in this letter we describe a *singly* polarised FSS that is transparent in both the TETRA (around 400MHz) band and in the unlicensed wireless land band (2.4-2.5GHz), and mostly opaque at frequencies in between.

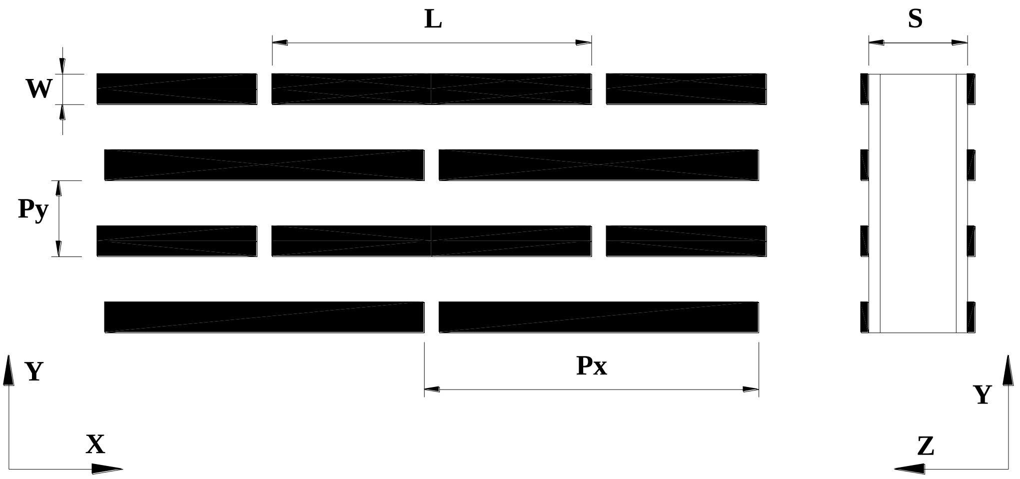

Fig. 1 *Elements and lattice of the 2-layer superdense FSS*

Design and results: Floquet modal software and the frequency domain solver of CST Microwave studio™ were used in the computational modelling. The simulated plane wave response for such an FSS is shown in Fig. 2. The dimensions of the structure as given in Fig.1 were: L = 168mm, W = 8mm, Px = 172mm and Py = 20mm. The space S between the two layers was 48mm which could be implemented in a thin partition wall in a building, or further tuned to thicker wall structures. In the simulations there are two clear passbands, one at around 400MHz and the other at 2.4GHz. At the lower band the resulting widths between the -1dB points are 40MHz and 130MHz at the higher band, while the -5dB bandwidths are about 130MHz and 180 MHz respectively.

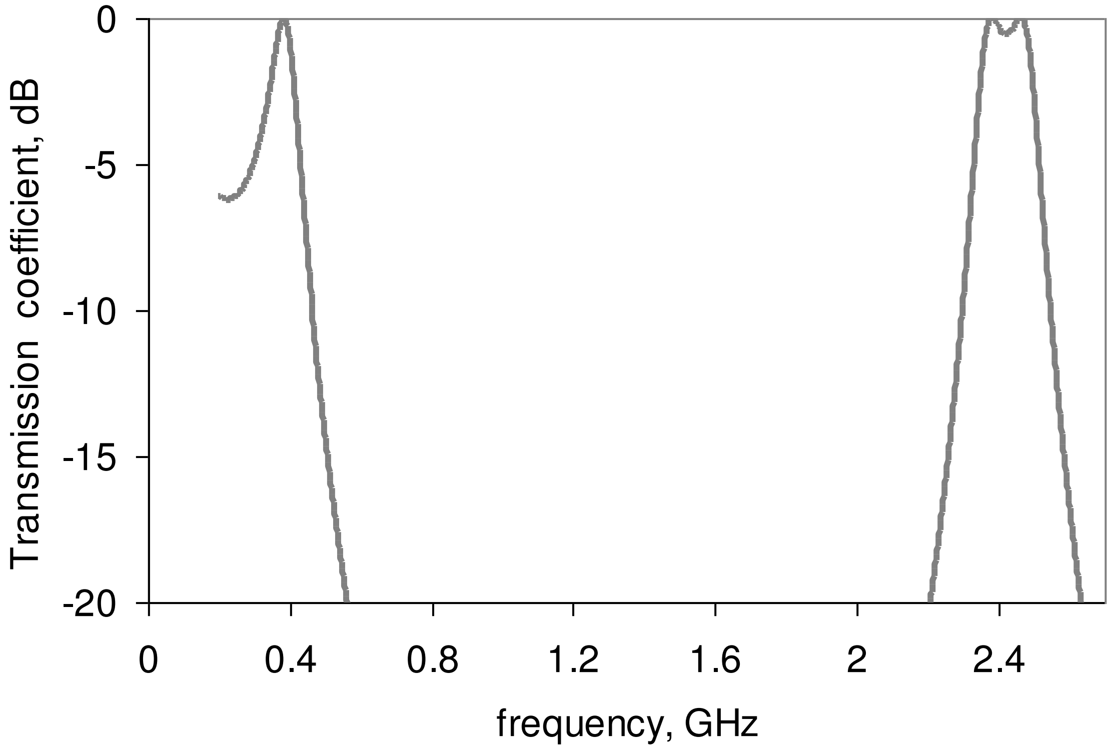

Fig. 2 *Computed transmission response of 2-layer superdense FSS at normal incidence*

Measurements at frequencies as low as 400MHz are too often perturbed by secondary issues such as multipath signal leakage, so the dimensions of the experimental FSS were scaled by a factor of 10, resulting in the transmission response in Fig. 3. The elements were etched into a copper clad polyester supporting substrate 0.03mm thick, the two layers being separated by a foam spacer. There is very good agreement between the simulated and measured results, with two clear passbands at 3.9GHz and 23.4 GHz, which corresponds to the required 6:1 ratio. The measured passband insertion loss was about 1.5dB at 4GHz and 3dB at 24GHz, very consistent with the concept of a loss-bandwidth product discussed in reference 5, and in close agreement with the data given there for the materials used to fabricate these FSS. The two fractional bandwidths are about 30% and 8% respectively. Narrow passbands have higher insertion losses.

The transmission responses of all FSS depend on the angle of incidence of the illuminating EM waves, and are lattice dependent [6]. Bands drift in frequency. For widely spaced lattices there is sometimes very little overlap of the bands for normal and 45^{o} incidence. This could obviously be even more apparent with narrow bands. In the present case there is little drift at 45^{o} for TE incidence, but in TM an additional peak appears at 14GHz.

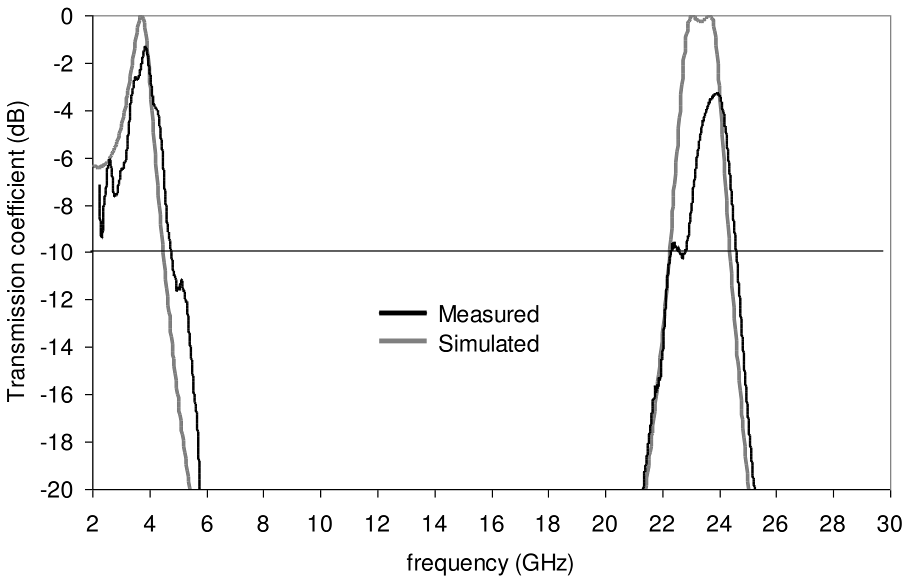

Fig. 3 *Simulated and measured transmission response of the scaled version*

Conclusions: A wide band FSS with two passbands spaced in frequency by a factor 6 has been presented. Such an FSS makes it possible to screen an electromagnetic zone in a building from much of the activity in the UHF band while permitting access to the TETRA and wireless LAN channels. Reducing the passband loss requires higher quality materials for fabricating the FSS, which conflicts with a need to keep costs low for some building situations, but may not be true for one-off high-tec buildings.

Acknowledgements

This work was funded by the UK Engineering and Physical Sciences Research Council and by the National Policing Improvement Agency.

References

1 Parker, E.A., Robertson, J.-B., Sanz-Izquierdo, B., and J.C. Batchelor: 'Minimal size FSS for long wavelength operation', *Electron. Lett.,* 2008, **44**, (6), pp. 394 - 395

2 Schneider, S.W., and Munk, B.A.: 'The scattering properties of superdense' arrays of dipoles', IEEE Trans. Antennas Propag., 1994, 4**2**, pp. 463–472

3 Lima, A.C. de C., and Parker, E.A.: 'Fabry-Perot approach to the design of double layer FSS', IEE Proc. Microw. Antennas Propag., 1996, **143**, pp. 157–162

4 Savia, S.B., and Parker, E.A.: 'Superdense FSS with wide reflection band and rapid roll-off', *Electron. Lett.,* 2002, **38**, (25), p. 1688

5 Callaghan, P. and Parker, E.A.: 'Loss- bandwidth product for frequency selective surfaces', *Electron. Lett.,* 1992, **28**, (4), p. 365

6 Hamdy, S.M.A., and Parker, E.A.: 'Influence of lattice geometry on transmission of electromagnetic waves through arrays of crossed dipoles', IEE Proc. H, Microw. Opt. Antennas, 1982, **129**, (1), pp. 7–10

Figure captions

Fig. 1 Elements and lattice of the 2-layer superdense FSS

Fig. 2 Computed transmission response of 2-layer superdense FSS at normal incidence

Fig. 3 Simulated and measured transmission response of the scaled version

Authors' affiliations

B. Sanz-Izquierdo, I. T. Ekpo, J.-B. Robertson, E. A. Parker, and J. C. Batchelor

Department of Electronics, University of Kent, Canterbury CT2 7NT UK

Corresponding author: E.A. Parker   E-mail: e.a.parker@kent.ac.uk