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A Sparse FSS for Control of Radio Coverage in Buildings

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***Abstract*— Frequency selective surfaces have been widely used to control radio propagation within buildings. In this paper we consider the application of a sparse FSS for improved coverage of radio signals between two isolated adjacent rooms. The scattering lobes which will occur from a sparse FSS design can therefore be exploited to alter the coverage pattern within the second room.**

Keywords— frequency selective surfaces, sparse array.

I. INTRODUCTION

Over the last decade numerous papers have been published considering radio propagation within the built environment for the improvement of performance, capacity, or security [1-8]. Such systems have been envisaged for use within buildings to limit the transmission of unwanted communications systems (e.g. Wi-Fi for SINR improvement), whilst transmitting wanted signals such as cellular, radio, TV, emergency services etc. Several authors have considered transmissive Frequency Selective Surfaces (FSS) for controlling the propagation of radio frequency (RF) signals into and within buildings including those published in [2-8]. FSS are large area filters based on periodic arrays of metallic or dielectric elements capable of operating with low-pass, band-pass, band-stop and high-pass frequency characteristics [9]. Alternative methods for controlling radio propagation within buildings have included intelligent walls [10], passive antenna based systems [11] and comb reflection FSS [12] for deployments in corridors.

In this paper we consider the application of using a sparse FSS for improved coverage of radio signals between two adjacent rooms. Classical FSS design typically uses inter-element spacing d of less than our equal to half the wavelength λ of the operational frequency. Wide incidence angle frequency response performance can be achieved when $d << \lambda$. By using a sparse FSS we exploit the scattering lobes which will naturally occur for an array of elements having an spacing of greater than wavelength. It is proposed that this technique can be used to mitigate the requirement multiple FSS panels within a wall which can be costly to install, or a large aperture which will have no frequency selectivity.

II. DESIGN & SIMULATION

This work considers two adjacent rooms separated by a perfectly isolating metallic wall. All other walls are considered as open boundaries. For analysis purposes a dual polarized inductive pass-band FSS has been considered. The FSS comprises and array of 4x4 inter-woven inductive cross elements as illustrated in Fig. 1. A standard design ($d = \lambda/2$) and sparse design ($d = \lambda$) have been considered. The pass-band region has been designed to operate at 3.695 GHz. The crosses are formed by two orthogonal slots of width W = 2mm, cut into a 1mm thick aluminium plate. Due to the effects of mutual coupling the lengths of the slots were optimized to ensure that resonance occurred at the same frequency for both designs. No further attempts to optimize the unit cell performance have been made as such techniques are widely known and are in the available literature, such as [9].

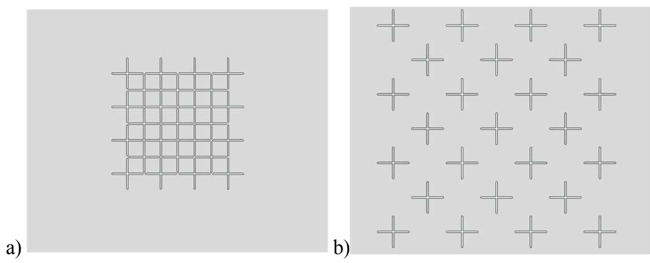

Fig. 1. Fig. 1. Illustrations of a 4x4 inter-woven simple inductive cross FSS for a) standard design $d = \lambda/2$ and b) sparse design $d = \lambda$.

Simulations have been performed using CST Microwave Studio. The unit cell designs were analysed with the Frequency Domain Solver with periodic boundaries and were performed using a tetrahedral mesh over a frequency range from 1 to 6 GHz using 1001 points, with two Floquet modes being considered. Electric field strength simulations were performed using the Time Domain solver over a frequency range of 0 to 4.5 GHz. E-Field monitors were used at the resonant frequency of the FSS at 3.695 GHz.

III. RESULTS

The characteristics of a standard $d = \lambda/2$ and a sparse $d = \lambda$ inductive cross FSS have been considered. A comparison between the transmission |T| and reflection |R| characteristics of the normal and sparse FSS unit cells are given in Fig. 2. It can be seen that the sparse design has a significantly narrower bandwidth performance when compared to the standard design. Fig. 3 shows the Electric field strength coupled between two

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perfectly isolated rooms using the pass-band FSS for both the standard and sparse designs. An increase in electric field strength of over 10 dB can be clearly seen near to the isolating wall in the sparse FSS design.

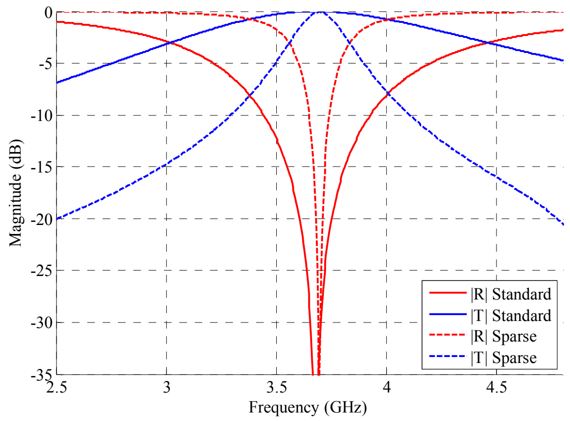

Fig. 2. A comparison of transmission |T| and reflection |R| response of standard ($d = \lambda/2$) and sparse design ($d = \lambda$) inductive cross FSS structures.

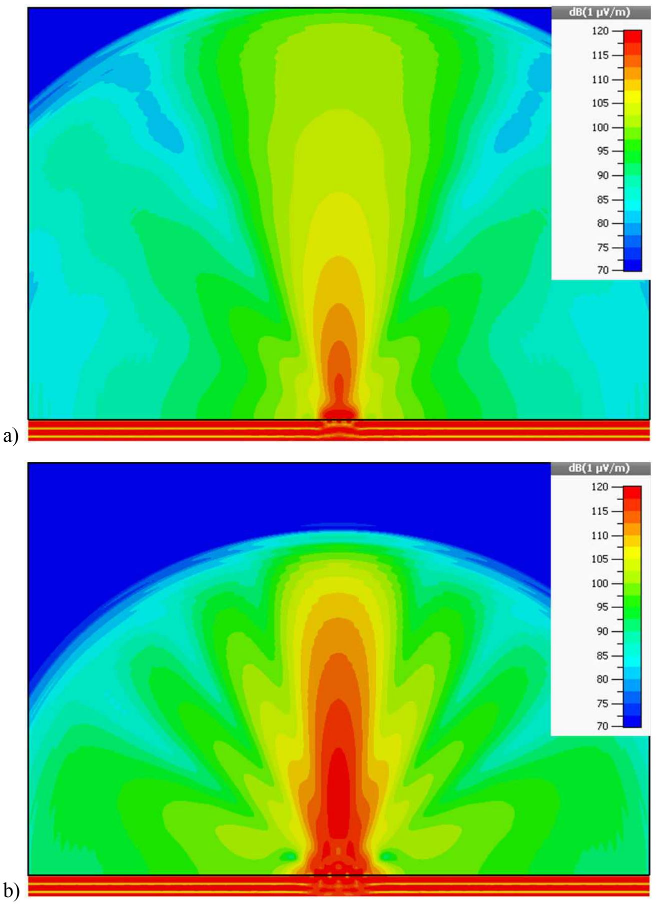

Fig. 3. Electric field strength coupled between two perfectly isolated rooms using a 4x4 inter-woven inductive cross FSS. Inter-element spacing of a) $\lambda/2$ and b) ~λ.

IV. Discussion and Conclusions

This paper has considered the application of using a sparse FSS for improved coverage of radio signals between two adjacent rooms. By using a sparse FSS we exploit changes in the radiated power pattern which will naturally occur for an array of elements having an spacing of greater than wavelength. It is proposed that this technique can be used improve coverage performance close to wall in which the FSS aperture is places. Furthermore, it mitigates the requirement of large aperture that will have no frequency selectivity, or multiple FSS panels within a wall which can be costly to install. Two isolated adjacent rooms connected by a 4x4 interspaced inductive cross FSS have been simulated. Results presented in Fig. 3 show this hypothesis to be true with an increase in electric field strength of over 10 dB being visible near to the isolating wall. Disadvantages of the proposed technique are well documented [9] and include reduced band-pass/band-stop performance for a given FSS element, although this can be mitigated by using broadband unit cell designs. It is with these in mind that the authors believe that this is an area worthy of further investigation and are not claiming that it is suitable or relevant for all practical scenarios.

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