Inkjet Fabrication of Frame Dipole FSS

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Abstract—**Digital fabrication techniques gives the possibility of producing elements with very thin and precise features which could allow the modification of UHF structures to reduce ink usage while still achieving similar performance. This paper investigates the case where dipole elements are modified into *Frame Dipoles* by removing areas where the surface current tends to be very low.**

Keywords; Frequency selective surfaces; Inkjet printing; Indoor radio propagation;Electromagnetic architecture; security.

I. Introduction

Wireless communication in indoor environments endures degradation in performance due to over use of the radio spectrum, especially in the unlicensed bands. Frequency selective surfaces have been considered as a means of improving wireless communication within indoor environments and have been shown to reduce co-channel interference by rejecting the interfering signals [1-2].

Inkjet printing technology is considered as a potentially useful future means of manufacturing electromagnetic designs with very fine details, especially as new printers are introduced capable of producing pico-Litre and femto-Litre sized droplets. The drop-on-demand (DoD) technology allows printing of very thin traces, in the order of a few tens of micrometers that could not be achievable with chemical etching. Repeatable droplets (on demand) are deposited to achieve the required design dimensions which could lead to a reduction the amount of waste associated with the chemical etching process. It also allows the use of inexpensive recyclable substrate materials, which cannot be used with the conventional etching technique [3].

The performance of frequency selective screens in indoor environments has been reported in [4-5] and the performance of inkjet printed FSS showed signal rejection levels very similar to equivalent copper etched FSS [6].

This paper utilizes the thin precise features that can be achieved by inkjet printing, and introduces printed *frame* elements where conductors are deposited *only* where the surface current is likely to be maximum, at the dipole edges. The solid and frame elements are arranged on a skewed lattice geometry [7].

II. Design Methodology

The FSS arrays contained 374 patch dipoles in total, arranged in a skewed lattice format with length L and periodicity P equal to 9 and 10.4mm respectively, with horizontal spacing $Dx = 1\text{mm}$, and vertical spacing $Dy = 2\text{mm}$, as shown in Figs. 1 and 2. The dipole width w was 1mm and conductor thickness was 0.01mm.

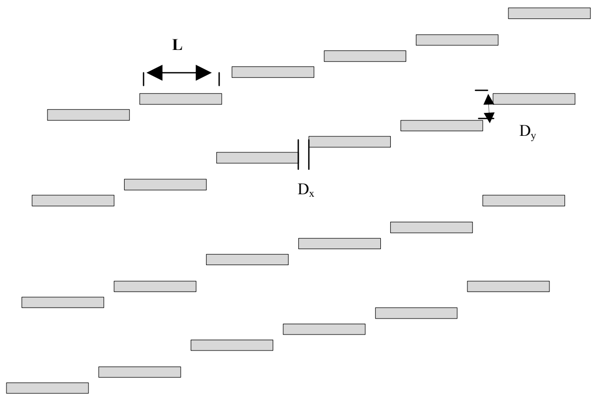


Fig.1 Skewed lattice solid dipole FSS

Two equivalent *Frame dipole FSS* were made with frame widths of $Fw = 0.2$ & $0.15\ mm$ respectively.

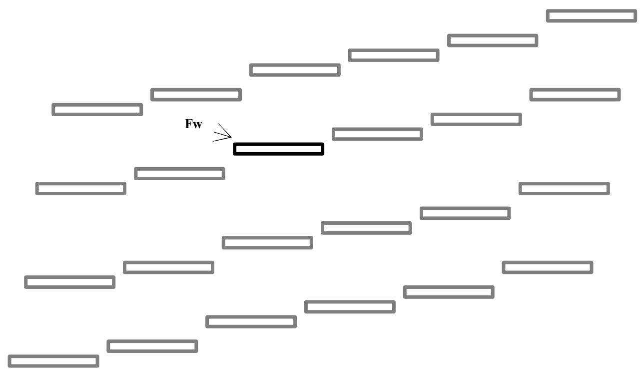
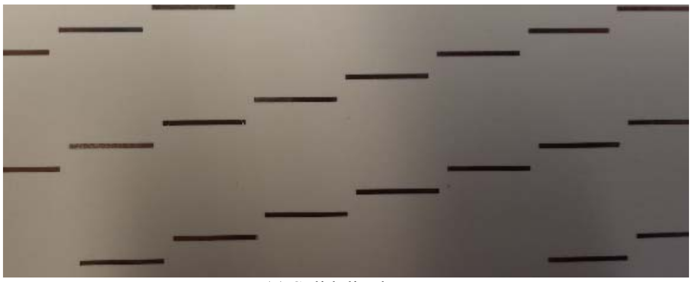


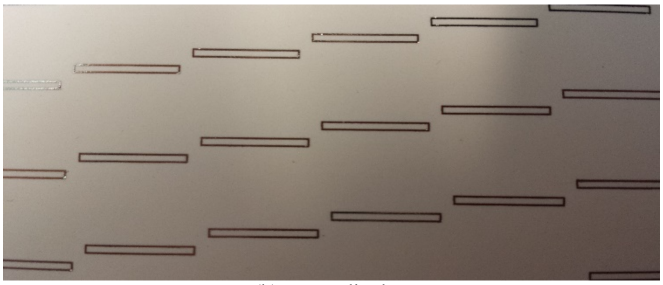
Fig.2 Skewed lattice frame dipole FSS

The FSS was etched onto a polyester substrate of 0.045mm thickness and relative permittivity $\epsilon_r = 3.5$ with loss tangent $= 0.02$. The physical size of the array was $280 \times 190\ \text{mm}^2$.

In addition, 2 FSS screens were also produced by inkjet printing using a nanoparticle silver ink: 1 Solid and 1 Frame, with the same *L* and *P,* and vertical and horizontal spacing, but with dipole width *w=0.4mm and Fw=70 µm,* as shown in Fig.3 (a and b).



(a) Solid dipoles



(b) Frame dipoles

Fig.3 Inkjet printed FSS

III. RESULTS

A. Transmission response (S_{21})

The measured transmission responses (S_{21}) of the chemically etched and inkjet printed FSS are shown in Fig.4 and Fig.5 respectively.

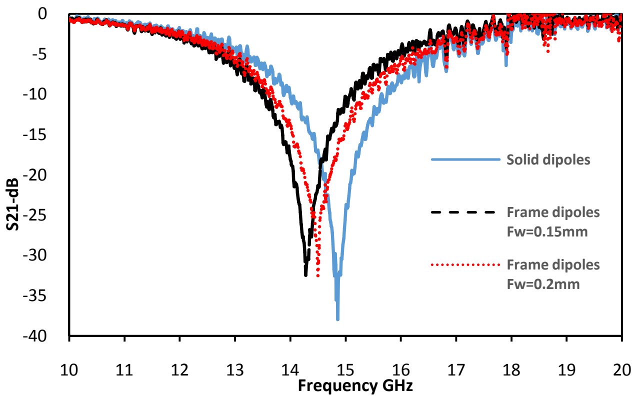


Fig.4 Chemically etched FSS; Transmission response (S_{21})

The resonant frequency of the frame dipole FSS is less than the solid dipole FSS by about 300 and 450MHz for frame widths of 0.2 and 0.15 mm respectively.

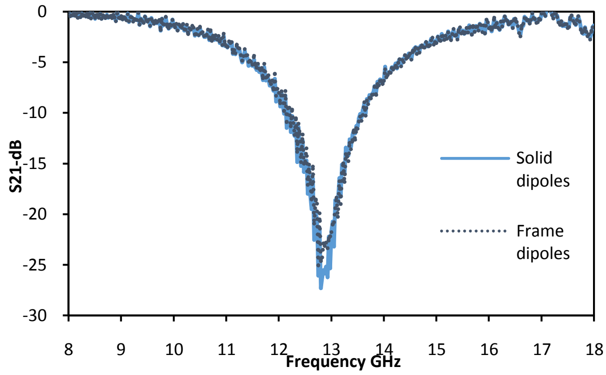
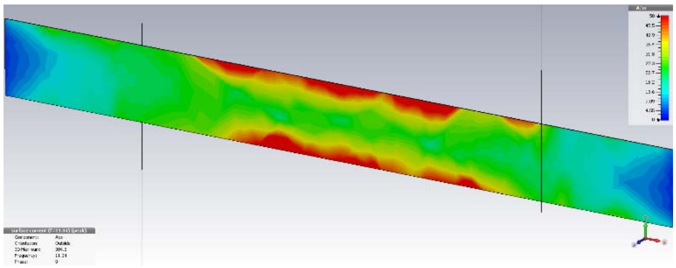


Fig.5 Inkjet printed FSS; Transmission response (S_{21})

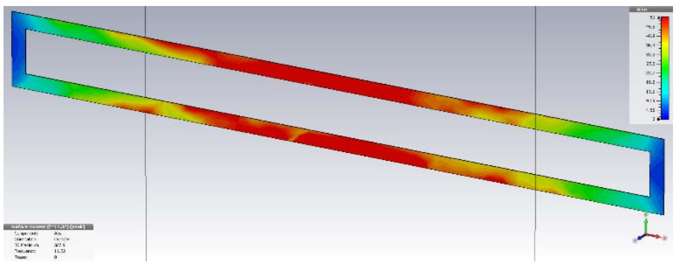
The resonant frequency of the inkjet printed frames is less than the inkjet solid dipoles by only 50MHz, as shown in Fig.5.

B. Current distribution

Fig.6 shows the surface current across the solid and frame dipoles; red shows that current is maximum and blue is minimum.



(a) Solid dipoles



(b) Frame dipoles

Fig.6 Surface current across the dipole elements; red shows that current is maximum and blue is minimum.

IV. Discussion and Conclusions

Inkjet printing costs for producing large FSS arrays could be reduced by printing only dipole elements as outer frames where the current is maximum. This could save up to 50% of the amount of ink used compared to the solid complete elements, while still achieving a very good reflectivity of more than the 20dB benchmark within the operating frequency band [8]. With some design modification, the resonant frequency could be adjusted to meet the solid counterpart, while still saving ink.

The difference in the resonance frequency is less in the case of the printed FSS, as the ratio between dipole width and frame width is greater for the etched FSS.

ACKNOWLEDGMENT

The authors wish to acknowledge the contribution of the UK EPSRC in funding this research through grant EP/J000086/1.

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