Deficiencies in Printed FSS Intended for Application in Smart Buildings

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***Abstract*—Errors occur in the process of digital printing of frequency selective screens using conductive inks. This paper describes some of the defects observed during the printing process and investigates their effect on the resonance frequencies of arrays that might be fabricated in practice. The elements are simple linear dipoles. The presence of the classes of error described would be serious in the case of elements with complex geometries.**

I. Introduction

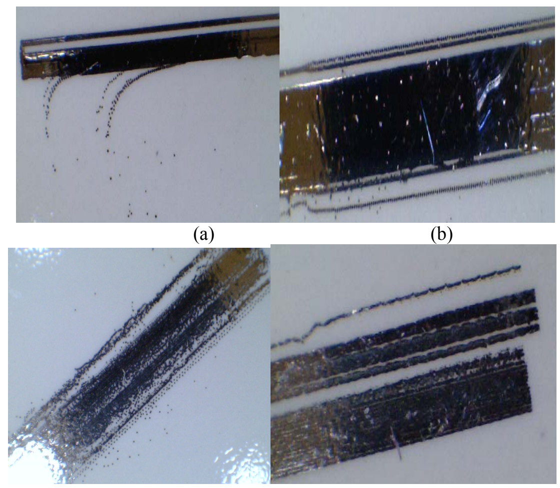
The spread of wireless technology which in the majority uses congested un-licenced bands has led to deterioration in signal quality, and there are concerns over privacy of the information within and outside buildings. Frequency selective surfaces have been known for many years for applications such as multiband reflectors and as spatial filters used in side lobe suppression and beam forming. Recently, frequency selective surfaces have been proposed for use in buildings providing enhancement to the wireless communications by decreasing co-channel interference and physically increasing communications security by screening [1].

The emergence of digitally fabricated FSS panels using inkjet printing has given a potential method of providing low-cost panels in large-scale production, compared with the conventional copper etching process. The additive drop-on-demand technology controls the amount of ink deposited and have been used in producing UHF electromagnetic structures. Low-cost FSS screens with a satisfactory level of isolation of about -20 dB have been demonstrated where the number of deposited ink layers, dot-spacing and different sintering process have been optimized [2]-[4] . Inkjet technology has also another distinction over conventional copper etching techniques with the ability to print on cheap organic substrates such as paper.

Nevertheless, producing low-cost screens may lead to some imperfections in the printed elements which could degrade the performance and result in compromised isolation levels. Errors such as absent elements and clusters of elements have been reported previously and it was concluded that randomly distributed errors in printing of 15-20% of the elements could be accepted while achieving a required -20 dB null depth, while in the case of clustered faults, about 10% faulty elements could be tolerated [5], [6].

The purpose of this paper is to focus on errors that have been observed during the printing process and seeks to understand their effects should they be mass produced. Issues resulting from fully or partially blocked print nozzles are investigated.

Fig.1 shows some of the errors observed during the production of FSS printed onto PEL sheets. Some of those errors led to the dipoles being divided into 2 or more elements, as a result of either horizontal or vertical cuts. Figs.1 (b) and (d) show the effect of a spurious line generated by ink spray resulting from a partially blocked nozzle.



(a) (b) (c) (d)

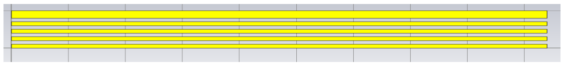
Fig.1 Defective dipole elements: (a) dipole with a slot, (b) dipole with two sprayed edge lines, (c) dipole with Horizontal gaps and (d) misaligned dipole with horizontal gaps.

II. Modelling Printing Errors

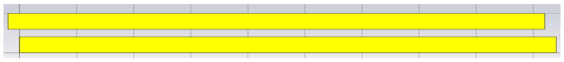
Dipole elements with defects observed were modelled in CST Microwave Studio™ and in order to simplify the simulation, periodic boundaries were used so that all elements suffered the same defect. This represents a worst case scenario. Dipoles with 9.4mm length, 1mm width were arranged in a square lattice geometry with a periodicity of 10.4. Fig.2 shows some of the modelled printing error scenarios.

III. Results

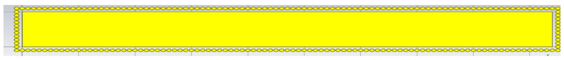
The simulated resonance frequency (f_r) of the perfect dipole FSS array was about 11.42GHz. The introduction of the *horizontal* gaps of widths of 0.1, and 0.2 mm in Figs.2 (a) & (b), which may result from a blocked nozzle, results in increasing f_r by 30 and 60 MHz respectively.



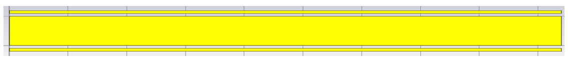
(a) Dipole with 0.1mm *horizontal* gaps



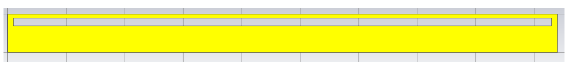
(b) Dipole with 0.2mm *horizontal* gap and misallignment



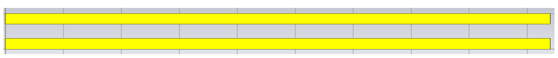
(c) Dipole with dots caused by edge spray



(d) Dipole with two edge lines caused by spray



(e) Dipole with a slot (slot width varies from 0.1 to 0.7mm)



(f) Dipole with *horizontal* gap; (gap width 0.01 to 0.8 mm)

(g) Dipole with *vertical* gap; (gap width 0.005 to 1 mm)

Fig.2 Modelled dipole FSS printing errors

Figs.2 (c) & (d) represent the ink spray effect as a result of partially blocked nozzles. The two narrow edge lines and the dots around the dipoles caused a modelled decrease in f_r of 350 and 550 MHz respectively. This is a consequence of the capacitive loading that was produced by those lines.

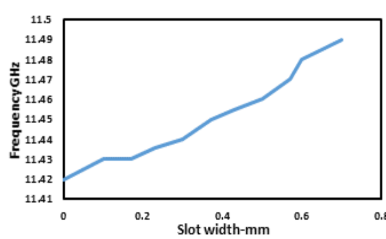


Fig.3 Resonance frequency vs. Slot width

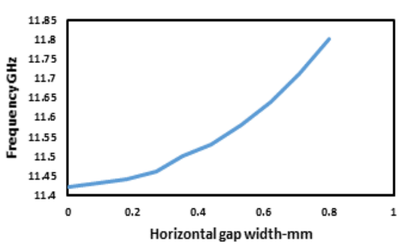


Fig.4 Resonance frequency vs. *horizontal* gap width

Fig.3 shows the effect of having a slot in the elements as depicted in Fig.1 (a) and Fig.2 (e). The impact of the horizontal and vertical gaps (Figs.2 (f) & (g)) is shown in Figs.4 and 5, respectively.

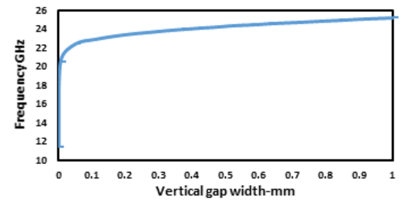


Fig.5 Resonance frequency vs. *vertical* gap width

IV. Conclusion

Simulations show that in the case of dipole FSS, printing errors causing *vertical* gaps have, as might be expected, a greater impact on the resonance frequency than *horizontal* gaps and enclosed horizontal slots within the dipoles. A tiny vertical gap of about 0.005mm in the dipole centres led to an increase in frequency of about 9 GHz (Fig.5) compared with less than 400MHz in the cases of horizontal gaps and enclosed horizontal slots – the current distribution was seriously affected, as to be expected. In [5] it was reported that dipoles with vertical gaps could be tolerated if the defected elements are less than 20% of the total number of elements, where the FSS still provides an acceptable level of reflection in the desired band of operation. However, all of the errors presented could have a severe impact on highly convoluted elements as the two dimensional nature of these designs means that horizontal defects could also disturb the current flow.

References

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