Experimental broadband single layer PSS using reactive impedance switching

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A new experimental single-layer phased switched screen that uses a *pin* diode controlled frequency selective surface to provide reactive impedance switching is described. The new design provides increased reflectivity bandwidth and reduced thickness compared to resistively switched screens. Experimental data is presented and compared to the results from a theoretical model.

Introduction: The phase switched screen (PSS) has been proposed as a technique that can be used to dynamically control the radar cross-section of an object, and has been actively researched, both theoretically and experimentally, over the past five years [1–6]. Conventional, passive, radar absorbing materials operate either on the principle of phase cancellation, such as a Salisbury screen, or use lossy materials to absorb incident electromagnetic energy, as in a Dallenbach layer. In the PSS approach however, the energy scattered by an object is translated in the frequency domain to regions that are outside the bandwidth of detection systems. The PSS achieves this translation in frequency by imposing phase modulation onto the energy scattered from the object to produce a scattered signal with a low average energy spectral density. In a previous publication [3] we presented the results of an experimental single layer PSS and demonstrated that this system produced a single reflectivity null that was comparable to that obtained from a Salisbury screen. Larger operating bandwidths and tunable PSS absorbers can be realised by using two or more active layers as demonstrated experimentally in [4], but at the expense of increased absorber thickness. In this Letter we describe a new experimental single layer PSS that uses a *pin* diode controlled frequency selective surface (FSS) to enable reactive impedance switching. This new single layer PSS results in a significant increase in reflectivity bandwidth performance compared to a purely resistively switched PSS and also provides a reduction in absorber thickness.

Design details: A detailed theoretical analysis of a single layer PSS is given in [5] where it is shown that an ideal PSS of thickness d, consisting of an active layer which can be switched between reactance values of $\pm jZ_0 \sin \beta_0 d$ (where Z_0 and β_0 represent the impedance and propagation constant of free-space, respectively) provides zero reflectivity over an infinite bandwidth. Unfortunately, the reactance against frequency characteristics required to give this performance appear to be physically unrealisable using currently known materials. Nevertheless, the work in [5] suggests that the use of reactive impedance switching can significantly increase the bandwidth of a PSS in much the same way that reactance is used in the design of passive circuit analogue absorbers [7].

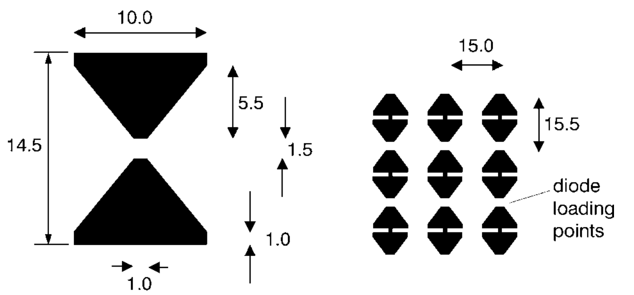

Fig. 1 *Details of active FSS geometry (all dimensions in mm)*

To incorporate reactive impedance into the active layer of a practical PSS the linear dipole topology used in [3] has been replaced by a FSS controlled by *pin* diodes. The diodes act as microwave switches that enable the topology of the FSS to be dynamically reconfigured, and hence its reactance to be switched between two states. A prototype active FSS was constructed from 0.8 mm-thick printed circuit board based on the element geometry and lattice spacing shown in Fig. 1. The FSS measures 185 × 230 mm and contains 300 elements. Surface mount *pin* diodes are soldered to each element at the locations described in Fig. 1. A loose-lay PSS was constructed by mounting the FSS above an aluminium conducting back-plane using a 4.0 mm-thick, low-loss, foam dielectric spacer ($\varepsilon_r = 1.05$, $\tan \delta = 0.0017$). The FSS circuit board is arranged ‘face-downwards’ in the assembly so that the surface mount diodes are embedded into the dielectric foam spacer, resulting in a PSS with a total thickness of approximately 4.8 mm.

Measurements: The free-space reflectivity characteristics of the PSS were measured over a frequency range of 8–13 GHz in a calibrated NRL arch using an HP 8510C network analyser. Fig. 2 shows the measured reflectivity response obtained when the PSS was modulated by a periodic square wave of frequency 10 MHz compared to the theoretical maximum bandwidth of an ideal, purely resistive, PSS designed for operation at 10 GHz. The experimental reactive PSS shows a double null response that provides a significant increase in bandwidth compared to the ideal resistance switched PSS. Furthermore, the reactive PSS is less than 5.0 mm thick compared to 7.3 mm for the ideal screen with the same type of dielectric spacer.

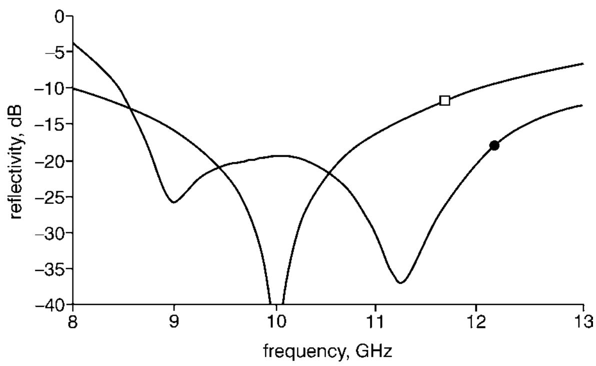

Fig. 2 *Measured reflectivity performance*

● experimental single-layer PSS
□ ideal resistance switched screen

Analysis: A transmission line analogue has been used to model the reflectivity characteristics of the reactive PSS. Using this approach a passive FSS may be represented by a fixed series equivalent circuit of inductance, capacitance and resistance; where the reactive component is determined by the FSS geometry and the resistive component models the loss in the system [7]. For the active FSS under consideration here however, the effect of biasing the diodes between high and low conductivity states is to change the FSS topology and so modify its reactive impedance. This model was used to derive approximate values for the equivalent circuit parameters of the active FSS under bias and no bias conditions as: $R_1 = 10\ \Omega$, $L_1 = 0.94$ nH, $C_1 = 51$ fF and $R_2 = 10\ \Omega$, $L_2 = 11.7$ nH, $C_2 = 58$ fF, respectively, and the corresponding predicted reflectivity characteristics are shown in Fig. 3.

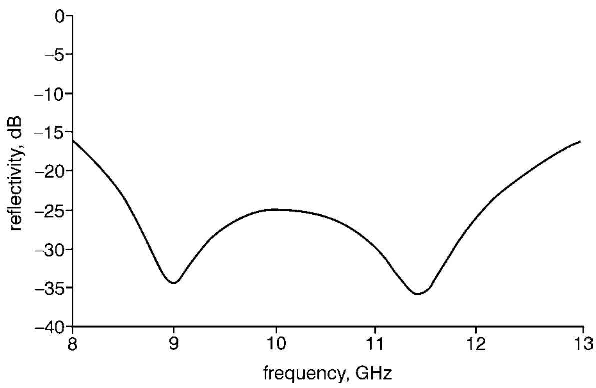

Fig. 3 *Predicted reflectivity performance of experimental single layer PSS based on transmission line equivalent model*

Conclusions: An experimental single layer PSS which uses a *pin* diode controlled FSS to provide reactive impedance switching has been described. The reactive PSS provides increased bandwidth compared to a single layer resistance switched PSS and also provides a significant reduction in thickness. A simple theoretical model based on a transmission line analogue has been used to describe the behaviour of the PSS, and to derive an equivalent circuit description of the active FSS. The theoretical model also indicates that the experimental FSS is not optimum in terms of its equivalent circuit and that further increases in bandwidth can be achieved from modified FSS topologies. Work in this area is continuing and will be reported at a later date.

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