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A Single-Layer Tuneable Microwave Absorber Using an Active FSS

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***Abstract*—An experimental single-layer active microwave absorber in described. The absorber is a planar structure based upon the topology of a Salisbury screen, but in which the conventional resistive layer is replaced by an active frequency selective surface (FSS) controlled by pin diodes. The resulting structure has superior reflectivity-bandwidth characteristics compared to conventional passive absorbers of corresponding thickness. Measured data are presented and show that the reflectivity response of the absorber can be controlled over the frequency band from 9 to 13 GHz.**

***Index Terms*—Absorber, active, adaptive, frequency selective surface (FSS).**

I. INTRODUCTION

CONVENTIONAL passive microwave absorbers such as the Salisbury screen, or the multiple layer Jaumann absorber, use resistive sheets spaced in front of a conducting back-plane to form a structure which provides low reflectivity at chosen resonant frequencies. The reflectivity-bandwidth performance of these structures can be enhanced by adding a reactive component to the resistive layer to produce what is often termed a circuit analog absorber [1]–[3]. In these absorber designs, the reactive component of the sheet impedance is chosen to help counteract the frequency dependent variation in spacer electrical thickness in such a way as to maintain a free-space input impedance match over a band of frequencies. A practical method of achieving a reactive impedance component is to incorporate a FSS into the layered structure of the absorber, either in addition to a resistive sheet or by replacing such a sheet with a FSS which contains loss [2], [3]. Although the use of a FSS can increase the bandwidth of resonant absorbers, they remain passive structures with fixed reflectivity characteristics. However, if the impedance of one or more of the constituent layers of the absorber can be varied in response to an applied electrical or optical control signal, then it is possible to realize an active, or adaptive, absorbing structure [4]. One approach to achieving a variable impedance layer is to incorporate pin diodes in to the FSS structure, such as the scheme described in [5], which uses *two* active impedance layers, based on pin diode loaded inductive strips. In this contribution we describe a *single-layer* active absorber which uses a reactive FSS and pin diodes to provide resistive tuning of the absorber reflectivity characteristics.

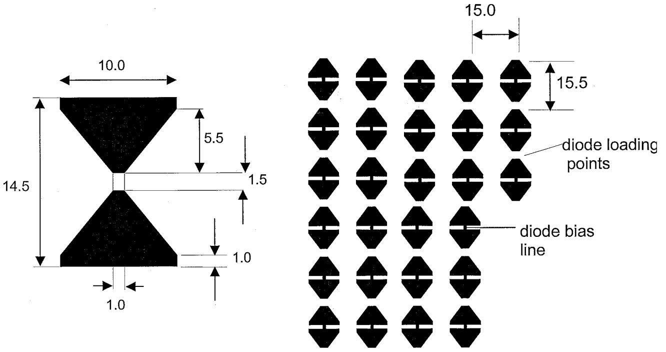

Fig. 1. Details of the active FSS geometry (all dimensions in millimeters).

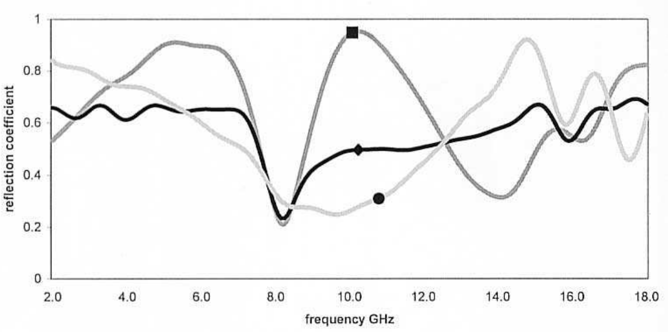

Fig. 2. Measured reflection coefficient of active FSS as a function of diode bias current. ■ $= 0.0\ \mathrm{mA}$, ♦ $= 0.1\ \mathrm{mA}$, ● $= 1.0\ \mathrm{mA}$.

II. EXPERIMENTAL INVESTIGATIONS

The FSS used in the absorber was designed for single, linear polarization and consists of a periodic grid of bow-tie dipole elements arranged on a rectangular lattice; the bow-tie dipole was chosen to provide a broadband response. Active control of the FSS impedance is achieved by loading the center of each dipole with a pin diode. To allow a control voltage to be applied to the diodes, the dipole elements are connected in parallel strings by a dc bias line which is incorporated into the FSS design, as shown schematically in Fig. 1.

Based on the design in Fig. 1, an experimental FSS was constructed from 0.8 mm thick, FR4 printed circuit board using standard photo-etching techniques. The board measures 185 mm by 235 mm and contains 180 (15 by 12) dipole elements which are loaded with commercially available surface-mount pin diodes using hand-soldering techniques. The reflectivity characteristics of the active FSS were measured over the frequency range of 2–18 GHz in a calibrated NRL arch using a Agilent 8510C network analyzer. Fig. 2 shows

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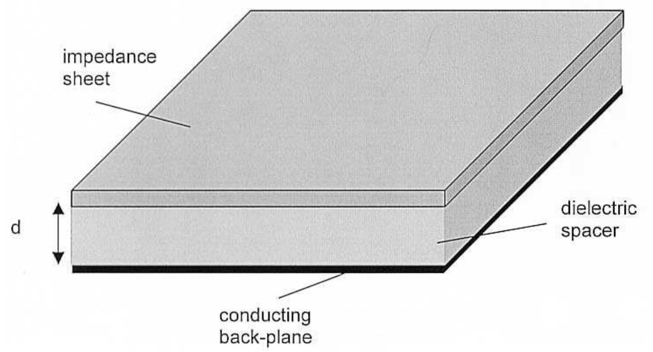

Fig. 3. Details of the active absorber construction. $\mathrm{d} = \mathrm{spacer\ thickness}$.

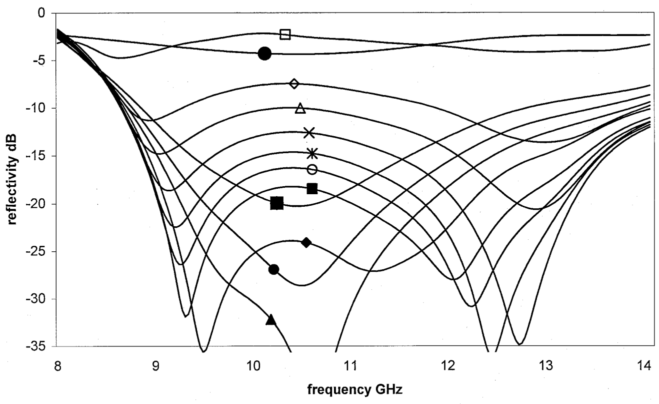

Fig. 4. Measured absorber reflectivity as a function of diode bias current. $\square = 0.0\ \mathrm{mA}$, $\diamond = 0.025\ \mathrm{mA}$, $\triangle = 0.05\ \mathrm{mA}$, $\times = 0.06\ \mathrm{mA}$, $* = 0.07\ \mathrm{mA}$, $\bigcirc = 0.075\ \mathrm{mA}$, $\blacksquare = 0.085\ \mathrm{mA}$, $\blacktriangle = 0.1\ \mathrm{mA}$, $\bullet = 0.11\ \mathrm{mA}$, $\blacksquare = 0.13\ \mathrm{mA}$, $\CIRCLE = 1.0\ \mathrm{mA}$.

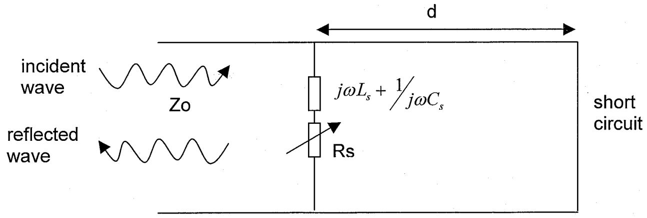

Fig. 5. Transmission line equivalent circuit of the experimental active absorber. L_S and C_S represent the inductance and capacitance of the active FSS and represents the resistance of the pin diode as a function of bias current.

the measured reflection coefficient of the FSS for diode bias currents of 0.0 mA, 0.1 mA, and 1 mA, respectively. The 1 mA bias current level represents a saturated condition, as currents above this level produced no significant change in reflectivity. From Fig. 2 it can be seen that the reflectivity characteristics of the FSS can be varied over the entire 2–18 GHz range, but that there are two "dead-spots" at approximately 8 GHz and 16 GHz which are related to the resonant frequencies of the FSS.

An active absorber was constructed by mounting the FSS above a conducting back-plane using a 4.0 mm thick, low-loss, foam dielectric spacer (Rhocell 51, $\varepsilon_r = 1.05, \tan\delta = 0.0017$) as shown schematically in. Fig. 3. The FSS circuit board was arranged "face-downwards" in the assembly so that the diodes could be embedded into the dielectric foam spacer by the application of moderate pressure, resulting in a rigid structure with an overall thickness of less than 5.0 mm. An additional advantage of this topology is that the outer dielectric layer formed by the circuit board provides increased bandwidth, as well as a protective outer skin [6]. The reflectivity characteristics of the structure were measured over the frequency range of 8–14 GHz for various applied diode bias currents, and these data are presented in Fig. 4. For zero applied bias current the structure is strongly reflecting. However, as the bias current is increased the reflectivity level reduces across a band of frequencies from 9 GHz to13 GHz and shows a double null response. At a diode bias current level of approximately 0.08 mA a reflectivity level of less than $-20\ \mathrm{dB}$ is achieved from 9.5 to 12.5 GHz. For further increases in bias current, the reflectivity curve shows a single null at around 10.5 GHz and resembles the response of a single layer Salisbury screen, but with increased bandwidth. Further increases in bias current result in a progressive increase in reflectivity until, in the saturated state ($\mathrm{bias\ current} > 1\ \mathrm{mA}$), the structure again becomes strongly reflecting. Although a detailed electromagnetic analysis is beyond the scope of this letter, initial investigations have shown that, to a good first order estimate, the behavior of the active FSS absorber may be described by the transmission-line equivalent circuit shown in Fig. 5. In this model, the reactance introduced by the FSS is represented by a series combination of inductance and capacitance and the pin diode is modeled as a variable resistor to represent the impedance of diode for varying bias currents.

III. CONCLUSIONS

A single layer active microwave absorber which uses a pin diode loaded FSS has been described. Measured results show that the structure can be tuned to provide a variable reflectivity response over a band of frequencies from 9–13 GHz. The reactive impedance of the FSS layer results in an absorber that is considerably thinner than that of a comparable Salisbury screen absorber, and also shows increased bandwidth. The bias current levels required by the active absorber are extremely small and the average power consumption is estimated to be less than $25\ \mu\mathrm{W/cm}^2$. Work is underway to investigate the increased reflectivity-bandwidth performance offered by multiple active layer absorbers. Research is also being carried out on dual polarized and conformal structures, and the results of these studies will be reported at a later date.

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