# An Active Square Loop Frequency Selective Surface

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**An active frequency selective surface incorporating PIN diodes as switches is discussed. Waveguide simulation studies show that the frequency response of the surface can be electronically switched from that of a reflecting structure to a transmitting structure. A semi-empirical model based on a series connected LC equivalent circuit approach gives agreement with measurements.**

## I. Introduction

THIS LETTER reports the results of a theoretical and experimental study of an active frequency selective surface (FSS). Such a surface is capable of changing its frequency transmission response from a resonating or reflecting structure, to one which is virtually transparent except for a small insertion loss. This change in response, which is electronically controlled, could find applications in areas including RCS reduction, reconfigurable reflector systems and active waveguide horns.

Fig. 1 shows a section of the active FSS which is discussed here. The array element consists of segmented half-squares with PIN diodes mounted to link the segments, thus forming a full square when forward biased. Alternative configurations considered hitherto include dipoles or Jerusalem crosses linked end to end to form inductive strips [1]. In contrast to these two elements, the square geometry has the property of reducing the overall equivalent capacitance of the structure when the diodes are inserted, since the element and diode capacitances are now connected in series and not in parallel in the equivalent circuit of the array. The incident electric field is parallel to the arms containing the diodes as shown. With the diodes forward biased (on), this load is removed, leaving a low resistive path connecting the square sides, and the surface now looks like an infinite periodic array of squares. The squares resonate at a frequency $f_r$. When the diodes are reverse biased (off), they act predominantly as an extra capacitive load between the half squares and the array resonates at a higher frequency, but at $f_r$ the surface is now transmitting. Hence it can be made either reflecting or transmitting, according to the applied bias. Harmonic generation by nonlinear effects is a question which is being addressed in a parallel program.

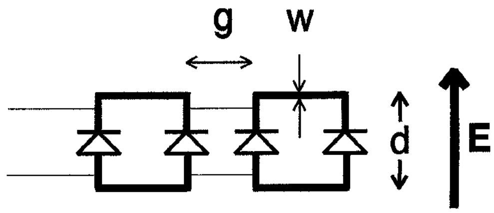


Fig. 1. Active square loop array geometry including bias lines.

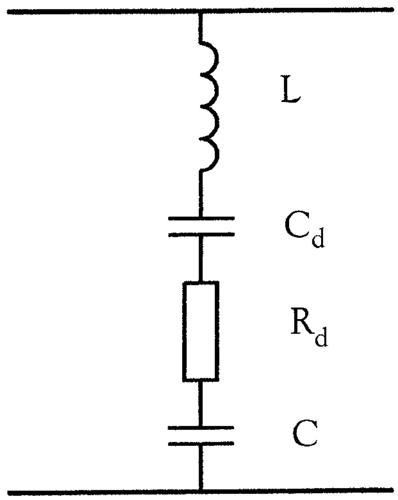


Fig. 2. Equivalent circuit for active array.

## II. Modeling

The equivalent circuit of the square loop is a series LC circuit [2] where L is due to the vertical sides of the square parallel to the electric field and C is the capacitance between the horizontal sides. Expressions for the values of components L and C are given in [2] with the inclusion of an effective substrate. The equivalent circuit of the PIN diode switch is taken from reference 3 to be a resistance $R_d$ (typically 10–100 Ω) in series with a capacitance $C_d$ (0.01–0.05 pF) when the diode is reverse biased, and a series resistance $R_d$ when it is forward biased. The model for the structure of Fig. 1 is the *series* equivalent circuit shown in Fig. 2. $C_d$ is short circuit when the diodes are forward biased. Devices with $R_d \sim 10$ Ω and $C_d \sim 0.01$ pF are readily available and in the off state give substantially higher resonant frequencies $f_r$ than the complete square loop array. The element capacitance C in the equivalent circuit is larger—0.05 pF or more—and so the smaller capacitance $C_d$ dominates the resonance.

## III. Results

To demonstrate the principle of operation a section of the array, as shown in Fig. 1, was fabricated and tested in a waveguide simulator. A simulator was used here to avoid incurring the costs of producing large active arrays. The

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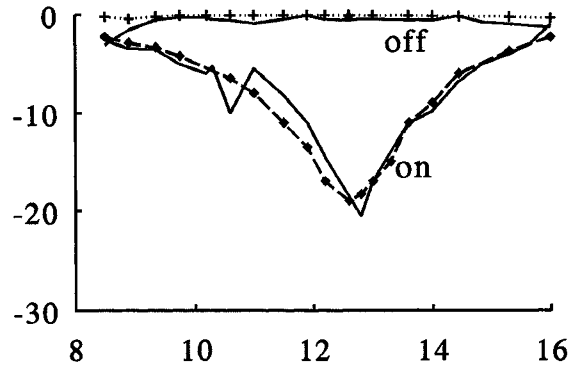


Fig. 3. Transmission response for active square loop array. Measured: ——— diodes on or off. Model: —■ — ■— diodes on, +· · ·+· · ·+ diodes off.

penalty paid for adopting this method was at polarization and angle of incidence effects could not be studied at this stage. The dimensions of the surface were approximately $d = 7.0$ mm, $w = 1$ mm and $g = 3.2$ mm and the elements were printed on the RT Duroid substrate 0.25-mm thick with $\varepsilon_r = 2.3$. The array was first measured in the simulator without diodes attached. Diodes were then bonded across the gap between the loop segments and suitable biasing wires included. The simulator had a calibrated frequency range from 7.5 to 16 GHz, giving a TE wave incident at an angle of 42° at the resonant frequency $f_r$ of the structure.

In Fig. 3, the experimental transmission characteristics of the active surface are plotted for forward and reverse bias of the surface. All measurements were carried out using a Wiltron 360 Network analyzer. The small resonance at about 10.5 GHz was due to the diode bias lines, and could be eliminated using different bias methods. Computed results from the model are shown by the broken curves and closely agree with the measurements. The active segmented square had a measured resonance 20 dB deep at about 12.6 GHz with the diodes forward biased at 1 V. A comparative measurement on a full passive square array gave a similar result although the null was deeper, about 40 dB. When the diodes were reverse biased (off) the resonance moved to a far higher frequency (36 GHz) and consequently there was virtually full transmission for the array at 12.6 GHz. The measured transmission loss at this frequency was about 0.5 dB and the switching of the transmission response from reflection to transmission is clearly demonstrated. Again the transmission response for a segmented square array without diodes was similar to the reverse bias response in Fig. 3.

## REFERENCES

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