THE GTRI PROTOTYPE RECONFIGURABLE APERTURE ANTENNA

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1. Introduction

In this paper, we describe a prototype antenna resulting from a three-year effort to design, build, and test a reconfigurable aperture (RECAP). The antenna consists of a planar array of electrically small, metallic patches that are interconnected by switches. The antenna can be reconfigured to meet different performance goals, e.g., bandwidth requirements and steering, by changing the switches that are open and closed. The switch configuration for a particular goal is determined using an optimizer, such as the genetic algorithm, with a full FDTD simulation. In previous papers, we presented the basic concept for the GTRI RECAP antenna along with several possible methods for controlling the switches. Here, we give the details for a prototype antenna that uses FET-based electronic switches with optical control.

Figure 1 shows the basic architecture for the GTRI reconfigurable aperture. A thin dielectric substrate supports an array of square, metallic patches. The patches are electrically small, that is, $l / l_o << 1$, where l is the side length of the patch, and l_o is the free space wavelength at the operating frequency. Each patch is connected to the surrounding patches by switched links, indicated by the arrows in the figure. Each switch may be open or closed depending upon the design requirements. There is a single feed point located at the center of the antenna. The aperture is formed from a printed circuit board $22.5\text{cm} \times 22\text{cm}$ in size, with the patches etched from the copper cladding on one side of the board. The spacing between the patches is equal to the side length of a patch: $l = s = 1.0\text{cm}$, see Figure 1. There are a total of 120 patches and 208 switches on the board. The frequency of operation is within the range $0.85\text{GHz} \le f \le 1.45\text{GHz}$.

2. Switch and Control System

For the RECAP antenna to be practical, a switch must be developed that can be electronically controlled, and the control mechanism must not interfere with the electromagnetic performance of the antenna. For the prototype antenna, the switches were electronic and the control was via infrared illumination.

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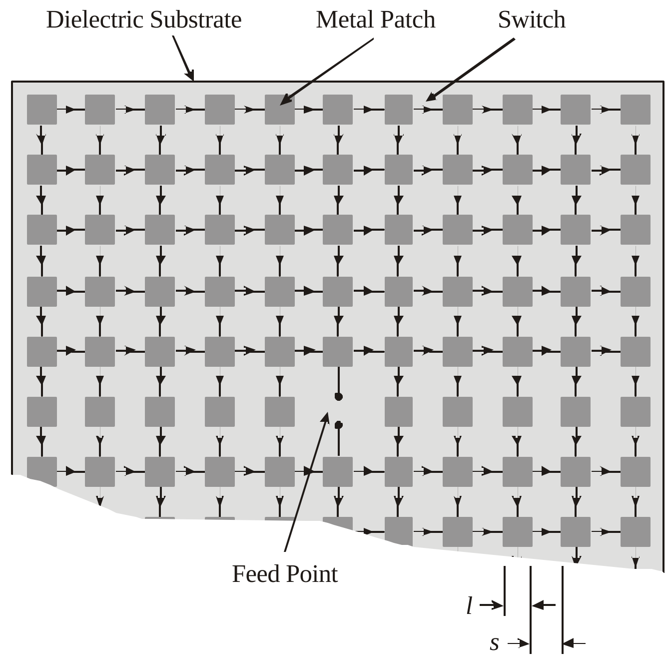

Figure 1. Schematic deawing for the RECAP antenna architecture.

Figure 2 is a schematic drawing showing the overall arrangement of the major components of the prototype antenna. Note that a metallic reflector is incorporated into the design. The reflector serves two purposes: It makes the antenna practically unidirectional, and it isolates the control circuitry from the rest of the antenna. A honeycomb dielectric spacer is placed between the reflector and the dielectric substrate containing the metallic patches.

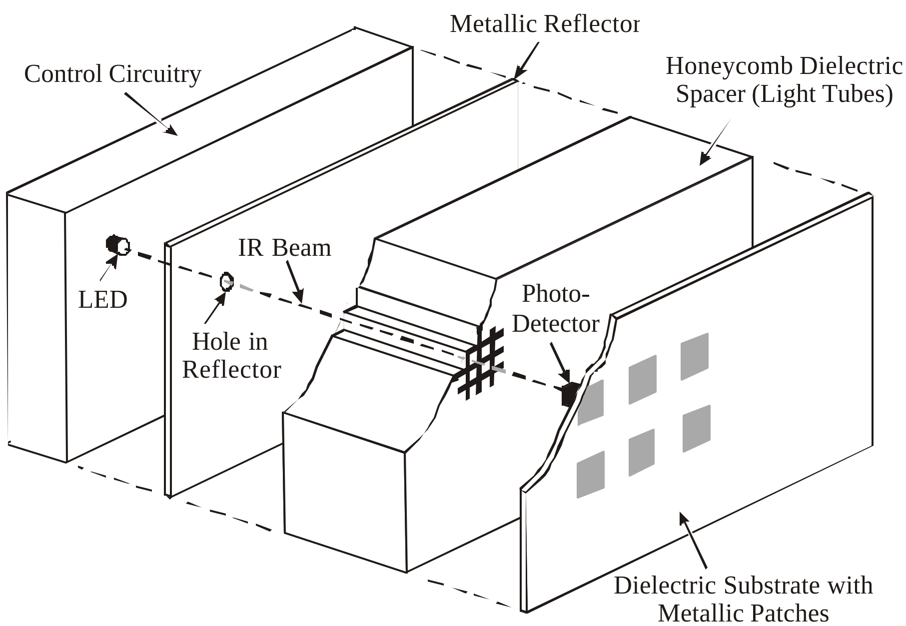

Figure 2. Schematic drawing of the major components of the prototype.

Figure 2 also shows the control path for a single electronic switch. A light-emitting diode in the control circuitry sends infrared radiation through a hole in the reflector. The beam then passes through a channel (light tube) in the honeycomb spacer. The light beam finally strikes a photo-detector located on the backside of the dielectric substrate containing the metallic patches. Here, the light beam activates an electronic switch connecting two patches

The switch itself consists of a depletion-mode FET and a bias circuit that includes a photo-detector in parallel with the gate-source junction of the FET. Neighboring metallic patches of the aperture are connected to the source and drain of the FET. The bias circuit holds a large (as compared to the pinch-off voltage) reverse bias voltage across the gate-source junction of the FET when the photo-detector is not conducting (not illuminated), so that the switch is open. When the photo-detector is illuminated, the photo-detector conducts and the magnitude of the voltage between the gate and source drops, which decreases the resistance between the source and the drain and opens the switch. The D.C. bias for the circuit is supplied through resistive lines. Resistive lines are used to reduce any scattering from the lines that might distort the pattern of the antenna.

The FET-based switch described above is far from perfect, particularly when operated at microwave frequencies. Therefore, a suitable circuit model had to be developed for incorporating the properties of the switch in the FDTD analysis. This was accomplished by measuring the FET in a test fixture, then determining the elements in the circuit by fitting the model to the measurements.

4. Performance: Comparison of Theory and Measurement

A full theoretical electromagnetic model was constructed for the prototype RECAP antenna, and FDTD results obtained with this model were used with a genetic algorithm to determine the configurations for the FET-based switches that best met specified goals. The theoretical electromagnetic model included the metallic patches and the dielectric substrate, the reflector with dielectric spacer, and the aforementioned equivalent circuit models for the FET. The theoretical electromagnetic model did not include the other circuit elements associated with the switch, e.g., the elements in the control circuit.

Figure 3 presents two measured and predicted far-field azimuthal patterns for narrow-band configurations designed for 1.25GHz operation. Fig. 3(a) corresponds to a configuration optimized for maximum realized gain at broadside, and Fig. 3(b) corresponds to a configuration optimized for maximum realized gain at 45° azimuth. Both patterns are normalized to 0 dB, and the vertical line in the center of the plot represents the orientation of the aperture surface. The measured realized gains at 1.25GHz for these configurations are 6.8 dB and 8.4 dB, respectively. Figure 4 shows the simulated and measured realized gain as a function of frequency for a broadband, broadside configuration designed with the FET switches. Results for a design with perfect switches is also shown. The difference between these results, which is about 2 dB, indicates the loss in the

FET-based switches. In the future, this loss could possibly be removed by the use of MEMS-based switches.

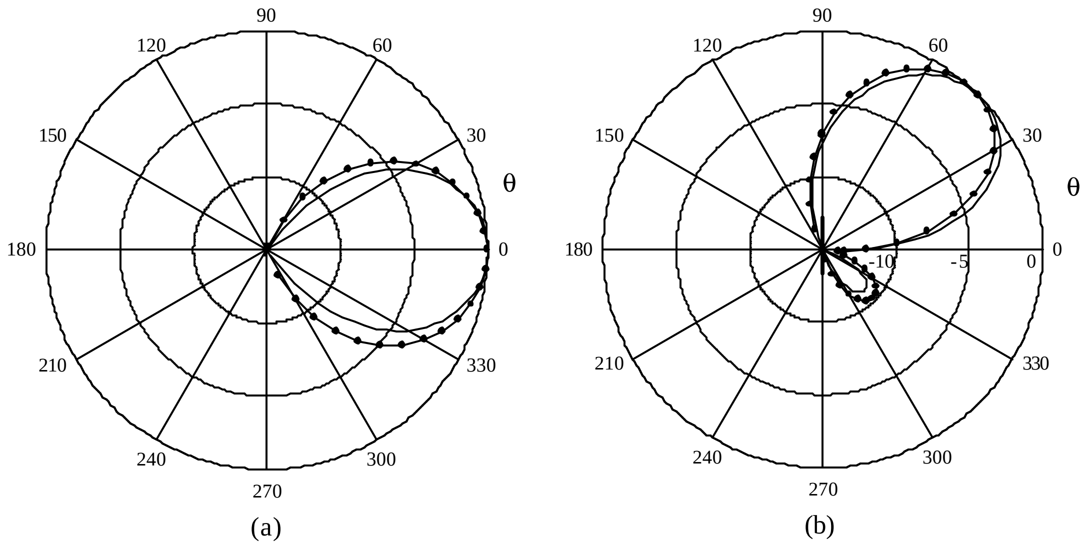

Figure 3. Measured (dots with line) and predicted (solid line) patterns for a broadside configuration (a) and a 45° configuration (b), both at 1.25GHz.

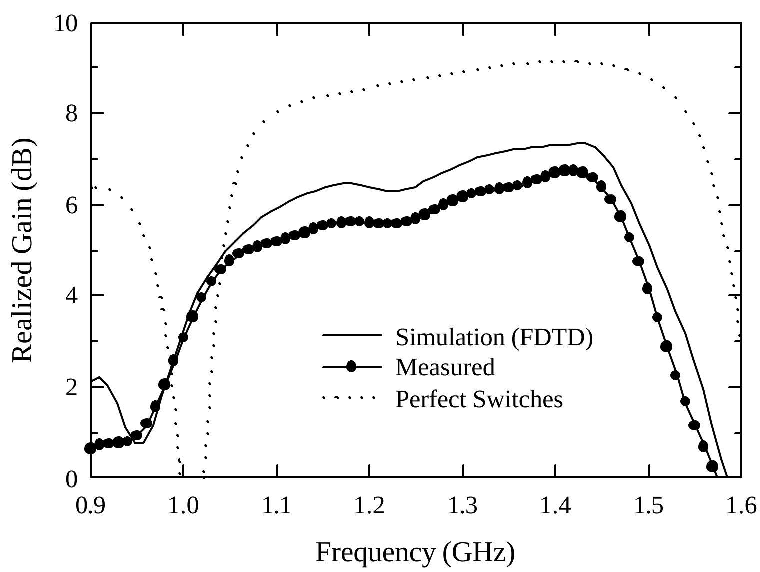

Figure 4. Measured (dots with line) and predicted (solid line) realized gain for a broadband configuration, and comparison with predictions for perfect switches (dots).

Acknowledgment

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