RECONFIGURABLE ANTENNA ARRAYS USING PIXEL ELEMENTS

Eric Walton, Eugene Lee, Yakup Bayram, Andrew Duly and Brandon Salisbury
The Ohio State University ElectroScience Lab.
1320 Kinnear Road, Columbus, OH 43212

Gary Bruce and Bruce Montgomery
Syntonics LLC
9160 Red Branch Road, Columbia, MD 21045

ABSTRACT

The goal of this research is to develop an unconstrained reconfigurable programmable array antenna. The concept is to build patch arrays using individual controllable pixels. The aperture of the system is made up of a large array of small (1/10 λ_{min}) pixels. Each pixel is a small piston made up of a metal top, a dielectric shaft, and a metal base. The pistons can be moved up and down under computer control. When all pistons are in the down position, a ground plane is created. When a line of pixels is raised into the up position, a microstrip transmission line (a metal line over a dielectric substrate) is created. A patch antenna is created when multiple pixels are raised into the up position to form a larger rectangle or other shape.

In the final design, a set of feed lines and antennas can be created in any pattern within 1 millisecond. Under computer control, it is possible to change the beam direction, the beamwidth, the polarization, and the frequency of operation of the array.

Design details, theoretical models, and the behavior of test fixtures and configurations will be discussed during this presentation.

Keywords: Reconfigurable Antenna, microstrip line array antenna, patch antenna

1.0 Introduction

Research is being performed at the Ohio State University ElectroScience Laboratory to develop reconfigurable microstrip antenna arrays created using small ceramic pistons. As shown in Figure 1, each piston has a conductive top and mid-layer so that a ground plane, substrate and conductive microstrip layer can be created or removed by moving the piston up or down.

Microstrip lines and small arrays configured using such small elements (pixels) have been studied both theoretically and experimentally as part of this research. Other researchers have studied the effects of a microstrip line over perforated [1] or grid-like [2] ground planes. They showed that such geometries constrain the operational frequency band of the system, and they give techniques for analysis of such structures. Xue et al [3] also shows the effects of introducing cell-like structures in microstrip lines for the purpose of controlling the transmission line impedance.

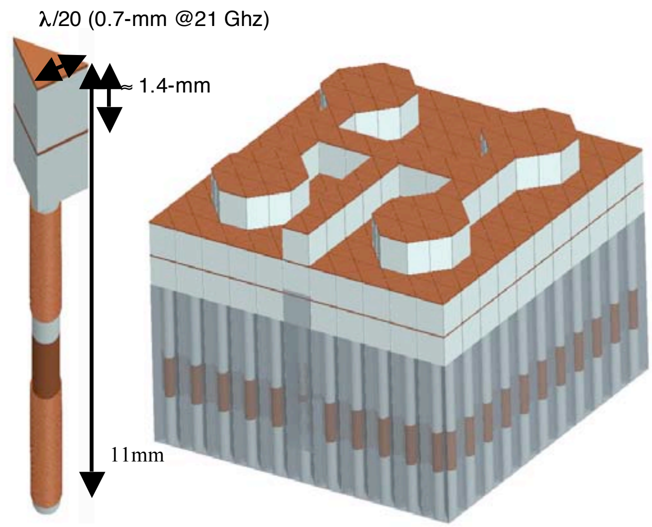

Figure 1 – Ceramic pixel microstrip concept

When a microstrip line is created using such a structure, the classical microstrip line as a metal strip over a semi-infinite dielectric and ground plane layer is modified to yield a metal strip with dielectric only under the metal. This finite dielectric type of microstrip line has been studied by Smith et al. [4], to yield curves of intrinsic transmission line impedance versus the height to width ratio of the structure as shown in Figure 2. These curves permit the design of the small pistons so as to yield a specific desired characteristic impedance.

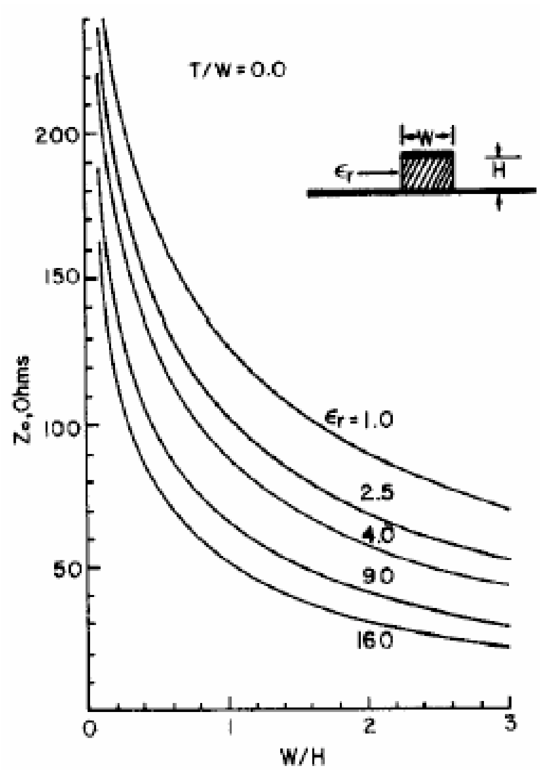

Figure 2 – Finite dielectric Microstrip lines (from [4])

2.0 Experimental Tests

A test structure was built to study this concept using a plastic grid structure with square metal patches that could be inserted to form patterns. These conductive elements could be turned on or off by simply turning the structure upside down. A picture of the structure is given in Figure 3.

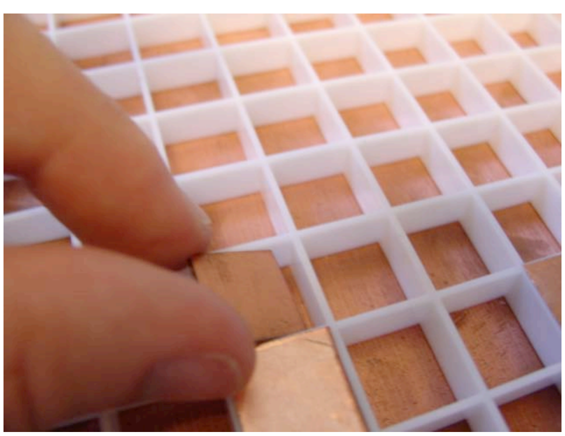

Figure 3 – Finite dielectric Microstrip lines

Note that small diamond shapes were optionally used on a dielectric top cover to increase the capacitive coupling between each small square.

Microstrip transmission lines were configured using these pixel elements as well as single patch antennas and small (two-element) patch arrays.

A plot of the transmission coefficient versus frequency for several tests of a pixel microstrip line using this test structure is given in Figure 4. Note that the transmission line works well from 3 to 4.5 GHz.

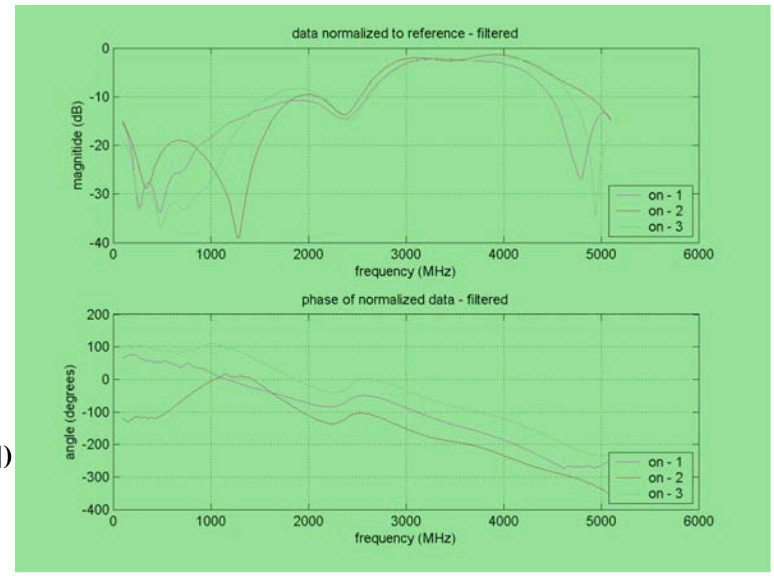

Figure 4 – Pixel microstrip line test results.

A two-element patch array was also configured using this test structure. It was demonstrated that the main beam could be tuned in frequency and shifted in pointing angle by modifying the size of the patch antenna and by changing the relative length of the feed lines.

An example set of data for the two element patch array is given in Figure 5. In this case, the antenna was sized to operate at 2.5 GHz and was pointed at an angle of minus 25 degrees from boresite.

Over the course of the testing program, it was demonstrated that we could shift the operational frequency, the pointing angle and the beamwidth by changes in the pixel configuration.

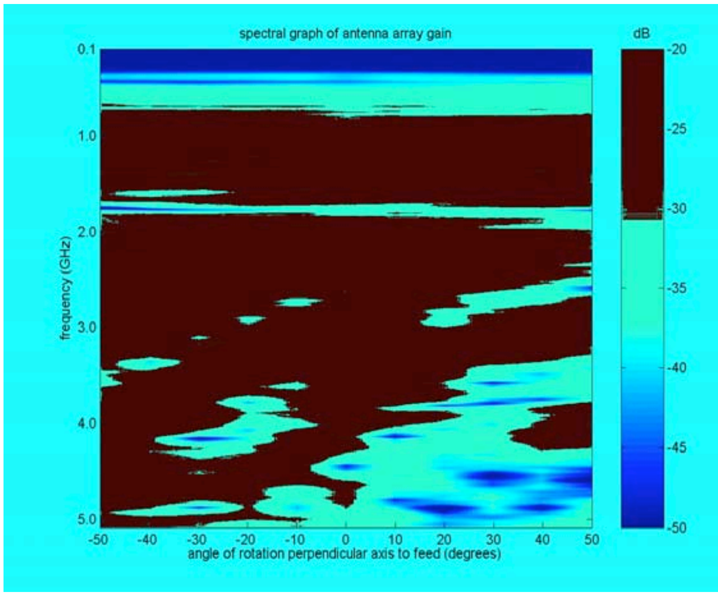

Figure 5 – Antenna pattern measurement results (amplitude versus Frequency and angle)

3.0 Theoretical studies

Theoretical analysis was used to study methods of extending the frequency band of the pixel antenna structure. In this case, Ansoft HFSS was used to model the geometry and to predict the behavior of various versions of the pixel geometry. One geometry for study is shown in Figure 6. Each pixel consists of end plates and bottom plates to form a box-like structure (side plates not used in this model). Note the serpentine-shaped lines between the pixel end plates and the pixel bottom plate in this case. These lines added inductance to the structure and made it possible to compensate for the pixel-to-pixel capacitance.

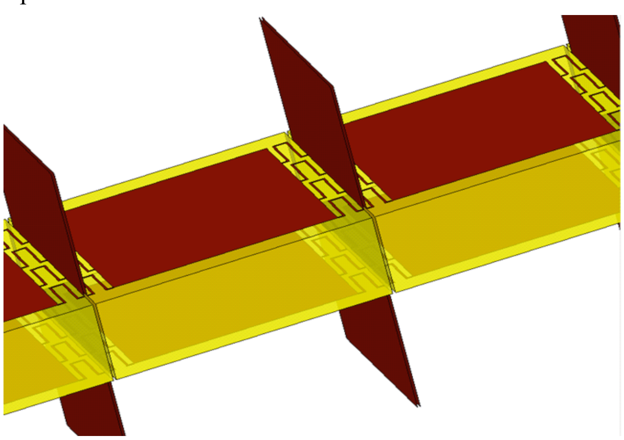

Figure 6 – Theoretical geometry with inductive tuning lines.

A plot of the resulting microstrip line transmission coefficient is given in Figure 7. Note that this pixel-based microstrip line works very well from 6 GHz to beyond 25 GHz.

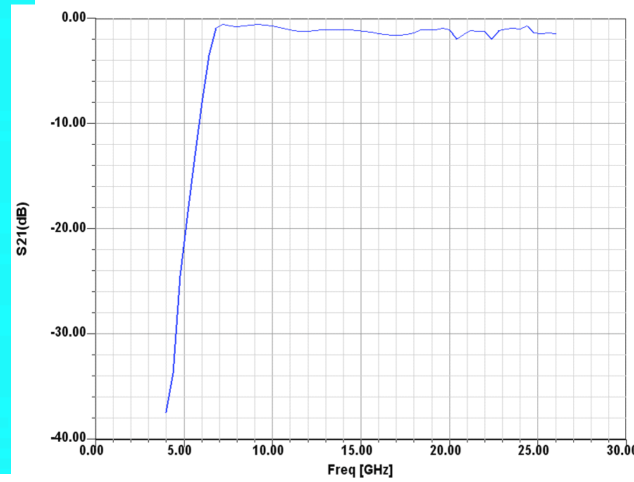

Figure 7 – Pixel-based microstrip line transmission coefficient vs. frequency

Many other geometries were studied to determine methods to extend the frequency band of such microstrip transmission lines. It was found that it is very difficult to extend the low frequency performance of the transmission lines because of the finite gap between each pixel. The mechanical engineering team predicts that a gap of 1 to 10 mils may be achieved in practice. Work on achieving lower frequency performance is on-going, mostly using direct DC coupling concepts.

4.0 Summary

This on-going research continues to develop methods to create reconfigurable antenna arrays using small dielectric and metal pistons (pixels). The result is a new class of "software antenna arrays," where the operational frequency band, polarization, pointing angle and beamwidth can be created or shifted in less than one millisecond.

We have studied various piston shapes (square, triangular, hexagonal) and sizes. We have built oversized (for convenience) models and compared our theoretical results with measurements. We have built and tested various transmission lines and antennas.

We found that it is quite practical to build microstrip transmission lines and patch antenna arrays using such arrays of pixels. The limitations are mainly at the lower frequency bands, where the pixel-to-pixel capacitive impedance becomes a problem.

5.0 REFERENCES

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9. ACKNOWLEDGMENTS

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