THE SOFTWARE DEFINED ANTENNA™; PROTOTYPE AND PROGRAMMING

E. Walton[1], J. Young[1], E. Lee[2], S. Gemeny[2], D. Crowe[2], C. Bryant[1], C. Harton[1], J. Dule[1]

[1]The Ohio State University ElectroScience Lab.
1320 Kinnear Road, Columbus, OH 43212
[2]Syntonics LLC
9160 Red Branch Road, Columbia, MD 21045

ABSTRACT

The goal of this research is to develop an unconstrained reconfigurable programmable array antenna that we call the Software Defined Antenna™. We create patch arrays using individual controllable pixels. The aperture of the array is made up of a large group of small (<1/10 λ) pixels. Each computer controlled pixel is a small piston made up of a metal top, a dielectric shaft, and a metal base. When a line of pixels is raised into the up position, a microstrip transmission line 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 to form an antenna array 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.

Theoretical results, experimental results and the implementation of a working prototype will be shown

Keywords: array antenna, microstrip, patch antenna, reconfigurable antenna

1. Introduction

Research is being performed at The Ohio State University ElectroScience Laboratory to develop a Software Defined Antenna™. Microstrip antenna arrays are created using small computer-controlled 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 by moving the piston up or down.

In the past, researchers have studied microstrip lines over perforated [1] or grid-like [2] ground planes. The effect on the operational frequency and impedance of the associated structures was shown. Xue et al [3] for example, showed the effects of introducing cell-like structures in microstrip lines for the purpose of controlling microstrip transmission line impedance.

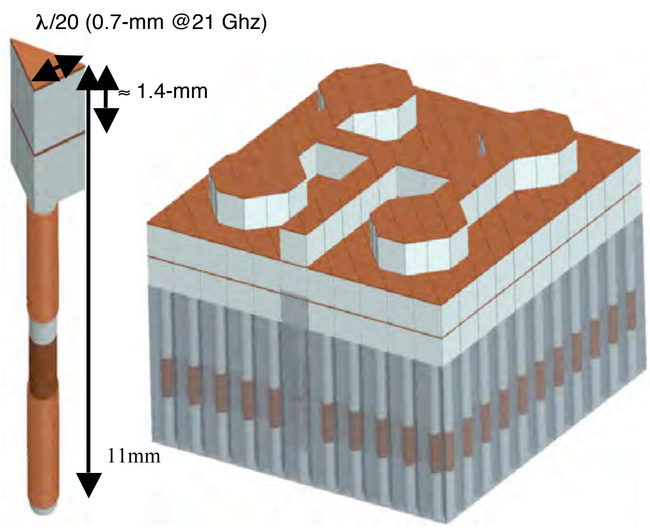

Figure 1. Ceramic pixel microstrip concept

The microstrip transmission lines and the patch antennas created using this technique are therefore made up of metal over a dielectric, but there is no dielectric in other locations. 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 specific desired characteristic impedances.

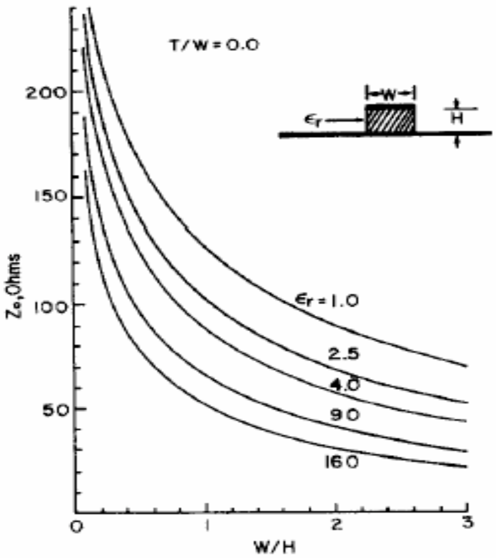

Figure 2. Finite dielectric Microstrip lines (from [4])

2. Experimental Tests

Earlier tests of the theoretical behavior of such lines were done using steel hexagonal nuts glued on top of similar nylon nuts. These could be moved around on a ground plane to form transmission lines and antennas. Effects of geometrical shape and pixel-to-pixel gap size were studied.

The new testing is being done using ¼ inch square pixels because that is the size of the prototype that is being constructed. A photo of a patch antenna using such square pixels is shown in Figure 3.

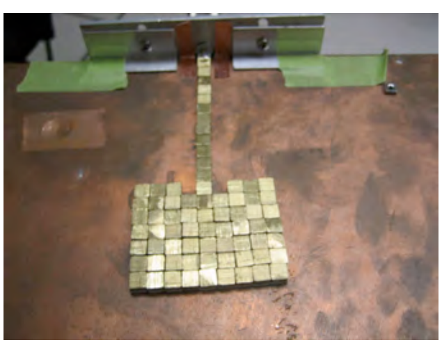

Figure 3. Patch antenna from ¼ inch square pixels

A number of tests were done using such structures. An example is shown in Figure 4. For this plot, a set of S_{11} data was taken over a fairly large frequency band, but this band was truncated to the 3-5 GHz band and the data was time gated to eliminate effects due to the coupling between the coaxial cable and the pixel microstrip line. This permits us to plot the behavior of the antenna alone. Three different tuning results are shown. The curves show results for the case where the microstrip line is attached to the patch antenna with no tuning, then with removal of 1 pixel on either side of the patch attach point (inset transmission line tuning) and then with the use of tuning stubs. Note that very good efficiency of coupling between the transmission, line and the patch antenna can be achieved. In fact. an extensive study of tuning available using tuning stubs constrained by the size and geometry of the individual pixels shows that stub tuning can be very effective.

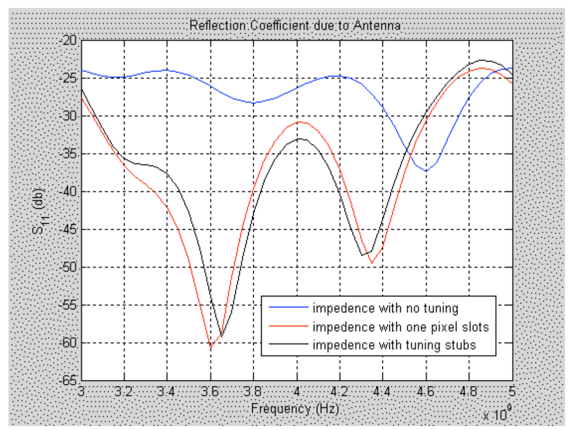

Figure 4. Pixel patch antenna S_{11} values.

3. Working Prototype Development

Simultaneous with the study of the behavior of pixel-based microstrip transmission lines and pixel-generated patch antennas, Syntonics Corporation has been developing a computer controlled prototype.

The prototype is made up of a large number of small pixels as shown in Figure 5. The pixels are raised and lowered using very small (1/4 inch diameter) solenoids. A USB-based interface permits computer control of the array of pixels. The overall solenoid control concept is summarized in Figure 6. Note that the small solenoids are layered so that they can be placed in an overlapping configuration and thus control the ¼ inch square pixels.

The working prototype will consist of 256 of the ¼ inch diameter solenoids fabricated on 4 printed circuit cards.

Each card will be an 8x8 array of 64 such pixels controlled over a USB interface. The cards are designed to be edge mounted in groups so that a working array of 16 by 16 pixels can be created. This will be a 4 inch by 4 inch prototype aperture where various antenna configurations can be created under computer control.

A vendor created the individual pixel pistons based on CAD drawings as shown in Figure 5. A two step process was used to create layers of conductive and dielectric polystyrene. The individual pixel has a travel limiting captive stem and a molded-in metal rod ("tail") for the push-rod.

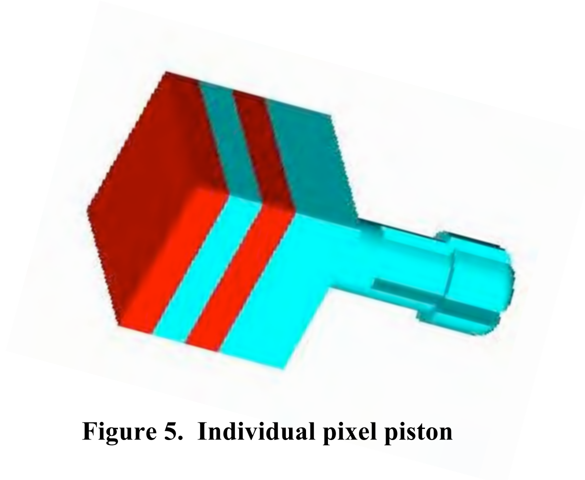

Figure 5. Individual pixel piston

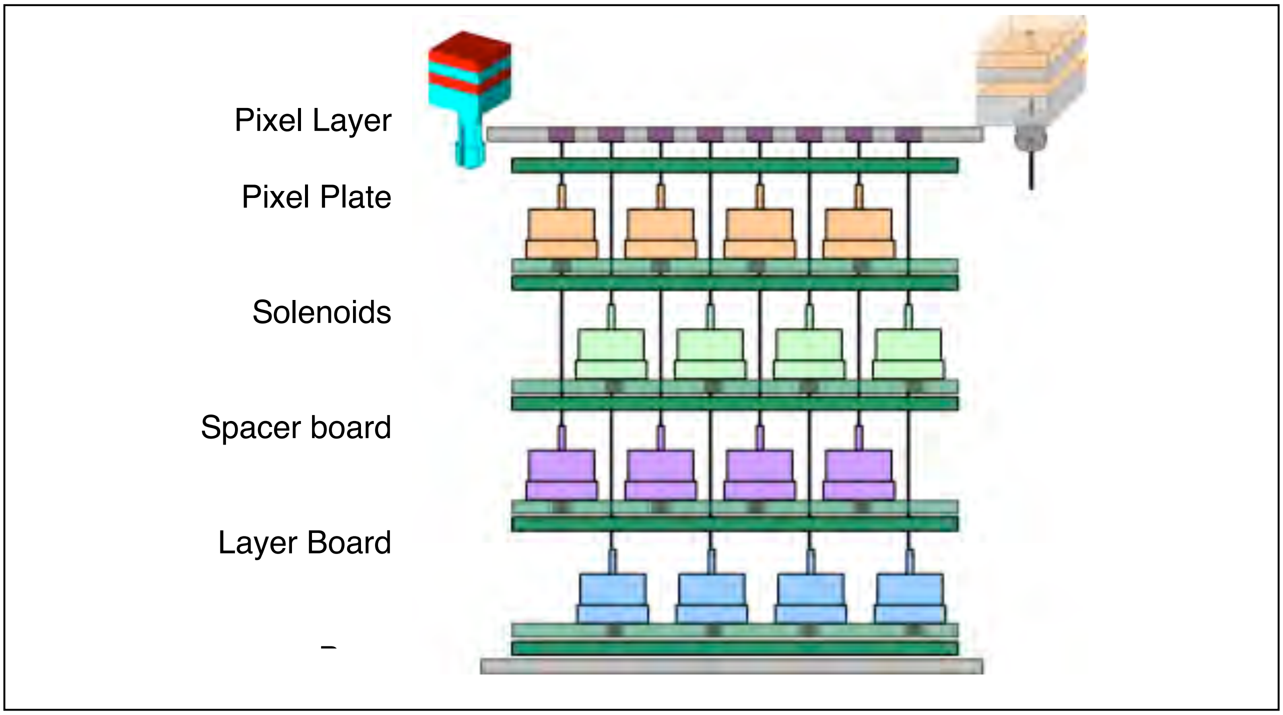

Figure 6. Solenoid configuration on 4-layer PC boards.

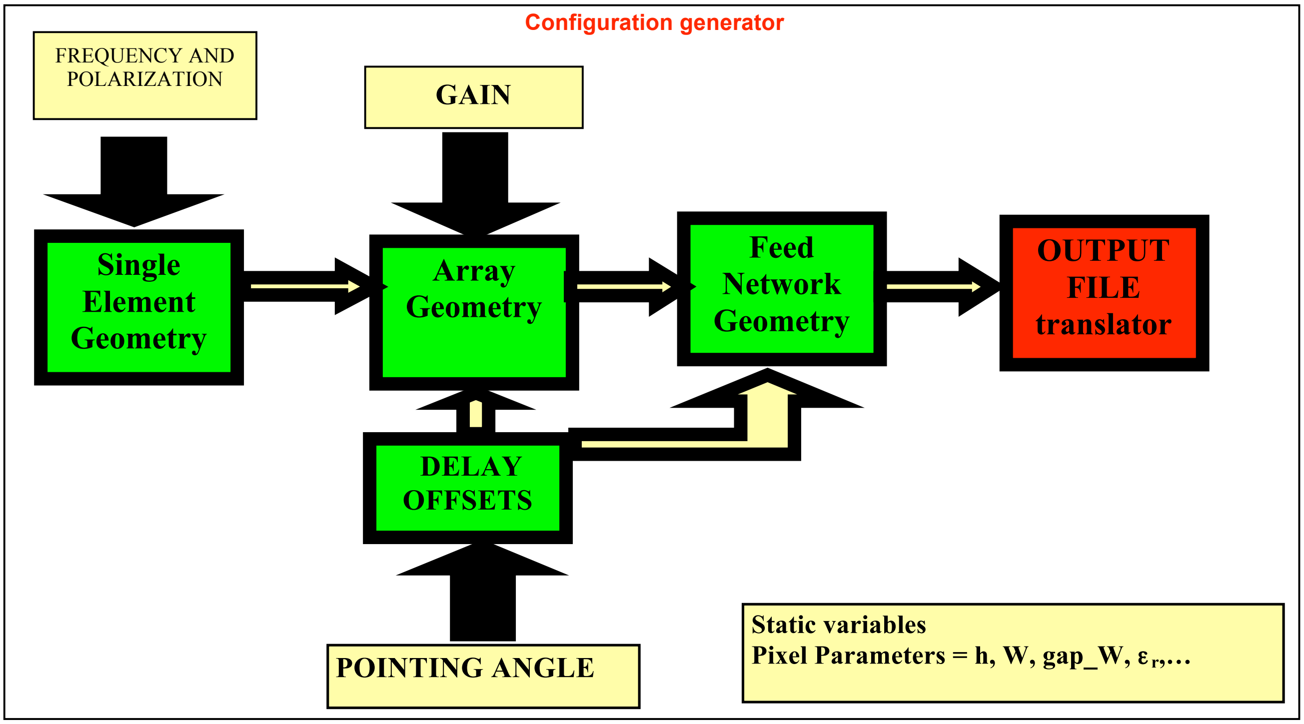

Figure 7. Logic flow diagram for automatic antenna array generation using pixels.

4. Software Pixel Layout Control

As the experimental data on the behavior of the pixel transmission lines and patch antennas was being developed along with the working prototype to demonstrate the system, it was also necessary to develop the software to configure the pixels to perform the antenna function.

We have developed a computer program that takes as input the desired operational frequency, polarization, beam gain and pointing angle and creates a pixel pattern to yield the antenna array.

The automatic array generation software block diagram is shown in Figure 7. Note that we start with the polarization and frequency requirements and design the individual patch element. The array design is then derived from the total required gain. Finally, the transmission lines are adjusted to yield the desired pointing angle based on true-time delay theory. Of course some requirements may be impossible given the pixel size and the total aperture size. These requirements are flagged and rejected on input.

5. Summary

We have designed a Software Defined Antenna ™ where the radiating elements, transmission lines and matching networks are made up of computer programmable pixels. We have theoretically studied this concept and built a large number of test setups to evaluate its behavior. Finally, we have built a prototype system so that the overall system can be tested.

We expect prototype system test results to be available soon.

6. References

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7. Acknowledgments

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