The Software Defined Antenna: Measurement and Simulation of a 2 Element Array

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Abstract

The goal of this research is to develop an unconstrained reconfigurable programmable array antenna. The concept is to build microstrip patch antenna arrays using individual controllable pixels. The aperture of the system is made up of a large array of small (1/10 λ) 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.

This paper will compare measurements of a test array against electromagnetic simulation. The construction and programming of a prototype array is also discussed.

1 Introduction

Current systems must select transmitters and antennas to cover expected frequency ranges prior to deployment. They are unable to adapt to a new configuration once deployed in the field. Advances in transmitters provide multi-octave coverage from a single high power amplifier. It is difficult to design a conventional antenna to cover such a wide frequency due to the physics involved.

Mechanically steered systems require pointing the entire antenna system in order to point the beam and electronically steered systems are costly to implement. Beam steering and dynamically adjusted polarization is an important attribute for mobile platforms, such as aircraft or ground vehicles.

The goal of this research project is to develop an array of pixel microstrip patch antennas that can be reconfigured through software control of individually addressed pixels, see Figure 1. Each pixel is made up of a dielectric substrate sandwiched by two layers of conductor. A known limitation of microstrip patch antennas are the narrow bandwidth [1]. Microstrip antennas at different frequencies and polarizations can be created in less than a millisecond to meet changing requirements.

This approach allows us to develop an array of microstrip patch antennas that can scan in both frequency and angle by varying the size of the antennas or the feed network structure [2] [3].

This paper demonstrates the behavior of a 2 element patch array fed by a pixelated transmission line. A tuning stub is used to improve the impedance match. This is compared against predicted results. Beam steering is also performed by adjusting the feed network.

2 Design

This implementation uses a micro-scale piston to drive a pixel up and down. Each pixel is fabricated from a low loss tangent ceramic with metal conductive layers above and below, see Figure 1. When the piston is down, its top is part of the ground plane. When the piston is up, its top is part of the radiating structure and an intermediate conductive layer completes the ground plane. This geometry is similar to a microstrip circuit geometry with a few critical differences.

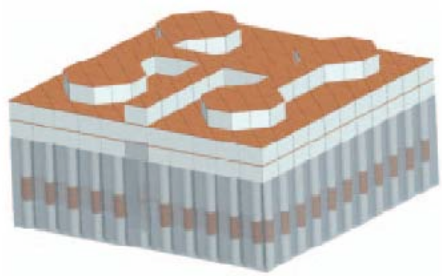


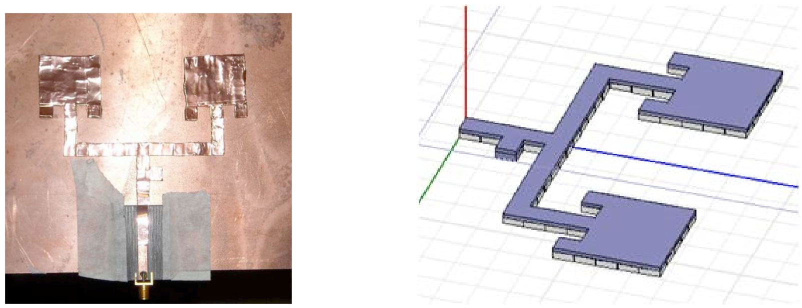
Figure 1: Software Defined Antenna Design

The presence of air gaps in both the substrate and conductive layer create design challenges that are not accounted for in the traditional microstrip design equations. Gaps in the dielectric result in a decrease in the bulk dielectric constant. Gaps in the conductive layer result in a capacitive effect and result in a cutoff frequency for the transmission line and an increase in the operating frequency of the patch antennas [2] [3].

The pixels move up and down based on commands from control application. The software allows for individual pixel configurations to be selected. A sequence of pixel geometries for beam steering can also be activated. A pixel pattern geometry generator is also used to chose the most appropriate pixel geometr based on pointing angle, desired gain, and polarization [5].

3 Measurements

A pair of microstrip patch antennas were made using brass and polystyrene pixels. The two antennas were fed using a pixel transmission line feed network, see Figure 2a. These antennas were covered with copper tape to reduce the capacitive effect and to reduce pixel movement. The gap size is critical determining the size of the capacitive effect. The final prototype for the Software Defined Antenna will involve much smaller gaps (2 to 3 mils) than can be obtained with the lab prototype (7 to 10 mils).



(a) measured (b) simulated

Figure 2: 2 element array on finite substrate

The microstrip patch is 5 pixels by 5 pixels. The feed network uses a short tuning stub for impedance matching. The measured radiation pattern at 3.15 GHz is shown in Figure 3. The first null location and half power beamwidth are as expected from array theory. A simulation of the antenna array in Ansoft HFSS was performed, see Figure 2b. The results are also shown in Figure 3 and demonstrate good agreement with the measured results.

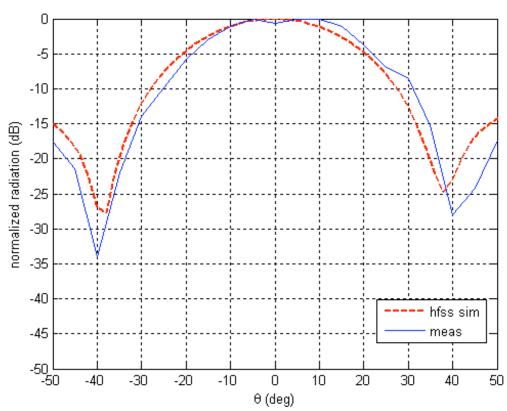
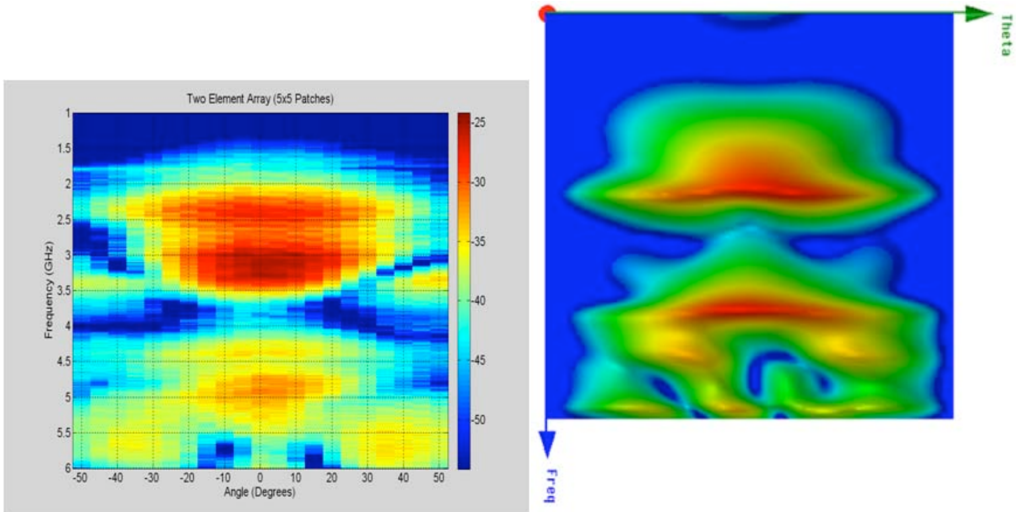


Figure 3: Radiation pattern at 3.15 GHz for a 2 element finite substrate microstrip patch array

The radiation intensity for a two element microstrip patch array with respect to frequency and angle is shown in Figure 4. Note that the radiation intensity at boresight with respect to frequency is consistent between the measured (Figure 4a) and predicted (Figure 4b) results.

4 Conclusion

An array of pixelated patch antenna has been demonstrated. This array was fed by a pixelated feed network with a tuning stub. The measured radiation patterns were consistent with predicted results.



(a) measured

(b) simulated

Figure 4: Radiation intensity vs. gain and elevation

A prototype board with 256 mechanically positioned pixels is expected to be completed in February 2009. This prototype will have fully software controlled pixels along with a pixel configuration generator. Full testing on the prototype Software Defined Antenna will be performed in an anechoic chamber and explore the full beam steering and dynamic configuration capabilities of the system.

References

[1] R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, *Microstrip Antenna Design Handbook*. Artech House, 2001.

[2] E. Walton, E. Lee, Y. Bayram, A. Duly, B. Salisbury, G. Bruce, and B. Montgomery, "Reconfigurable antenna arrays using pixel elements," in *29th Annual Symp. of the Antenna Measurement Techniques Association*. St. Louis, MO: AMTA, Nov. 2007.

[3] E. Walton, J. Young, E. Lee, S. Gemeny, D. Crowe, C. Bryant, C. Harton, and J. Duale, "The software defined antenna; prototype and programming," in *30th Annual AMTA Symposium*, Boston, MA, 2008.

[4] C. Smith and R. S. Chang, "Microstrip transmission line with finite width dielectric," *IEEE Trans. Microw. Theory Tech.*, vol. 28, no. 2, pp. 90–94, Feb 1980.

[5] *Pixel Perambulator Help Files*, v1.0 ed., Syntonics, LLC, Columbia, MD.