A MEMS Reconfigurable Pixel Microstrip Patch Antenna for Conformal Load Bearing Antenna Structures (CLAS) Concept

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***Abstract*— A four by four pixelated microstrip patch antenna is reconfigured in three frequencies using RF MEMS switches. The proposed antenna can be integrated within a physical structure under the CLAS concept which can replace bolt-on antennas. Structural testing of the antenna clearly demonstrates the structural robustness of this CLAS reconfigurable antenna.**

I. Introduction

In the literature considerable efforts have been placed on reconfigurable antennas because a single aperture can be reconfigured in frequency, pattern, and polarization with the help of switches. DARPA sponsored the Reconfigurable Aperture (RECAP) program in the 1990s where Georgia Tech. Research Institute (GTRI) worked on reconfiguring elements of metal patches to form broadside and endfire patterns [1] with the help of GaAs semiconductor switches. In [2] the authors used MEMs switches to reconfigure small spiral and microstrip patches. In [3] PIN diode switches were used to reconfigure a stacked microstrip patch antenna for operation in two frequency bands resulting in broadside and endfire beams. A Sierpinski gasket antenna was reconfigured using switches by Anagnostou *et al.* [4]. Recently work has been reported in [5] to reconfigure a multiple pixel patch antenna for operation from 4-7 GHz where RF MEMS switches were monolithic to the patch. In this work we focus on a MEMS reconfigured pixelated microstrip patch antenna that can be used in a structural platform under the Conformal Load Bearing Antenna Structure (CLAS) concept [6]-[7]. The CLAS concept, originally introduced for air vehicles allows the antenna and the structure to become one entity thus significantly reducing protrusion and drag. It also saves space and weight compared to a bolt on external antenna that is difficult to integrate into a structure without major modification and performance degradation. Our proposed MEMs integration adopts a hybrid circuit approach where RF MEMs switches are integrated into a pixel patch substrate which can be finally assembled inside a structural sandwich.

II. Antenna Configuration

The proposed reconfigurable pixel patch antenna shown in Fig. 1 consists of four by four conductive pixels each measuring 7 mm by 7 mm. The pixels were printed on a 1.6 mm thick RO4003 substrate (ε_r=3.55, tanδ=0.002). Several experimental reconfigurable pixel patch prototypes were built on 200 mm by 200 mm substrates. Each antenna was fed using a coaxial probe feed at the location shown in Fig. 1. Each pixel is separated from its neighbor pixel by a distance of 2.5 mm to accommodate an rmsw 101 MEMs switch [8].

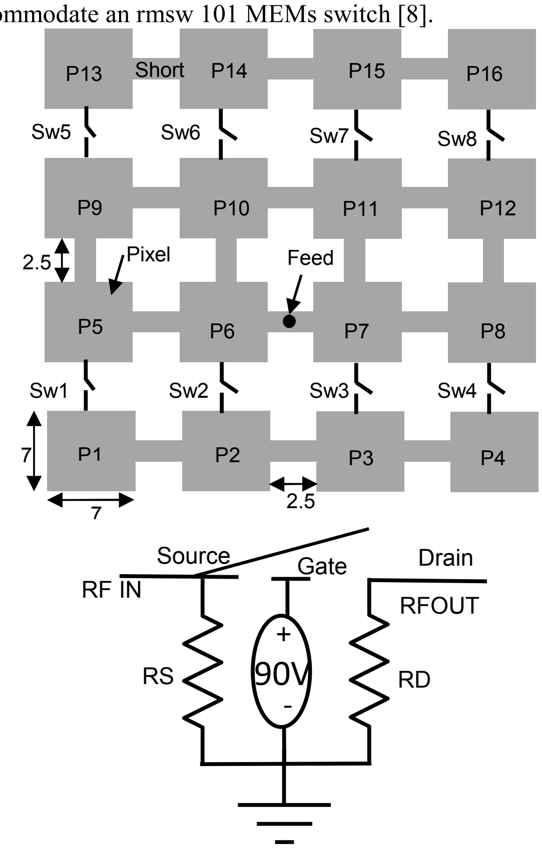
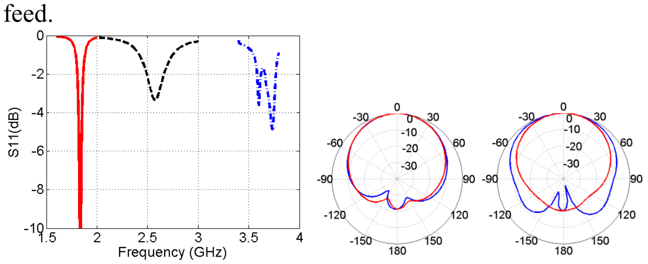


Figure 1. Reconfigurable pixel patch configuration and switch circuitry.

A total of 24 switches could be placed in order to control two adjacent pixels. However, for the present configuration two rows of switches were used as indicated (Sw1, Sw2, etc.) At all other switch locations a 2 mm wide conducting trace was used to bridge the adjacent pixels. To provide DC bias path and to isolate the RF from the DC each row of switches contained two 40 kΩ resistors. The pixel patch has three distinct resonances governed by the switch states: (1) when all switches are OFF the two central rows of pixels are activated that results in the highest resonant frequency, (2) when switches Sw5, Sw6, Sw7, and Sw8 are ON the patch operates at an intermediate frequency, and (3) when all switches are ON the patch operates at its lowest frequency of resonance.

III. Results

For the simulation models a substrate and ground plane size of 100 mm by 100 mm was considered. The On and OFF states of the switches were represented using short or open. To create the short a 2 mm wide and 2.5 mm long conducting trace was used. Simulations were conducted in HFSS where the feed was modeled using a lumped port. All conductors were modeled using copper. A summary of the simulation results are shown in Fig. 2 which show three distinct resonances at 1.836, 2.6, and 3.73 GHz. The peak realized gain at the three resonances are 5.3, 3.7, and 5.1 dBi. The impedance matching can be improved by increasing the substrate thickness and or utilizing an aperture coupling type feed.



1.836 GHz 3.73 GHz

Figure 2. Simulated S11(dB) vs. frequency and patterns. Red trace – H plane, blue trace - E plane.

To evaluate the feasibility of the proposed reconfigurable pixel patch antenna idea several antennas were fabricated and tested. A 90V DC power supply was used to activate the switches. Photograph of a reconfigurable pixel patch antenna is shown in Fig. 3. Measured S11(dB) data for three cases are shown in Fig. 3. As expected, for Case 1 (when all switches are ON) the antenna operates at the lowest frequency which is around 1.5 GHz. For Case 2 (when only the top row of switches are ON) the antenna operates at an intermediate frequency, 2 GHz and for Case 3 (when all switches are OFF) the antenna operates at the highest frequency, 3.1 GHz. The measured operating frequencies are somewhat lower than the simulated frequencies most likely due to the presence of the DC bias wires below the antenna.

After the RF performance tests Antenna specimen1 was experimented with structural load test using an experimental setup shown in Fig. 3. The reconfigurable pixel antenna test board was placed and secured on a specimen holder. The antenna test board was connected to a 90V DC supply and all 8 switches were turned ON. The antenna test board was also connected to a vector network analyzer to observe any change in the antenna resonance property. To monitor the amount of strain on the test board two strain gauges were placed on it. After 3,500 microstrain of static load no noticeable change was observed on the antenna resonance property.

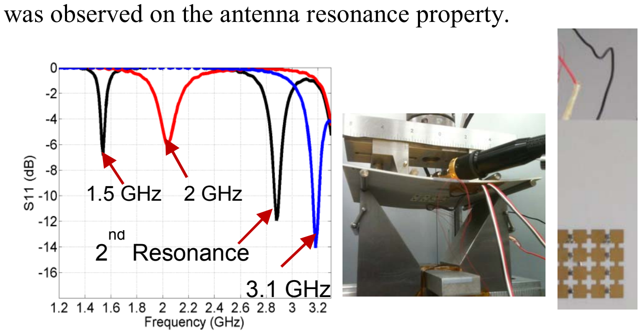


Figure 3. Measured S11(dB), structural test photo, and photograph of the four by four reconfigurable pixel patch antenna.

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