Effect of Bias Traces and Wires on a MEMS Reconfigurable Pixelated Patch Antenna

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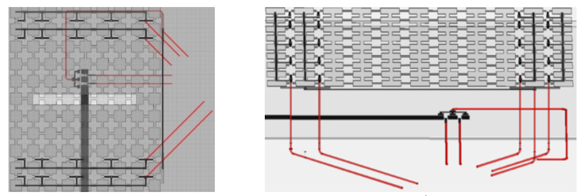
***Abstract*—The simulated studies showing the effect of DC bias lines on an aperture coupled reconfigurable pixelated patch antenna for CLAS applications is presented. The simulations show significant deterioration in S11 and gain for all operating modes when copper bias wires are introduced. A solution utilizing very high sheet resistance bias lines in place of copper traces is proposed.**

I. INTRODUCTION

Reconfigurable antennas are an active area of interest for engineers and researchers due to the potential benefits frequency reconfiguration provides [1-4]. Especially of interest are pixelated antennas [1], [4] which combine individual conducting pixels with electrically controlled switches to force physical changes to an antenna's dimensions. This ability to change the physical dimensions of the antenna makes traditionally narrowband antennas capable of broadband performance. The reconfiguration concept is especially appealing for aircraft or other electrically large platforms for which size, weight and shape are considerations. The traditional method of bolting multiple separate antennas to the structure is disadvantageous in that it can degrade the performance characteristics of the structure and weaken the structure mechanically. This is an area where embedded antennas or Conformal Load Bearing Antenna Structures (CLAS) can provide significant benefits. The CLAS concept combines the antenna and the structure into a single element which is both structurally sound, and electrically efficient [5]. Recently we proposed an aperture coupled MEMS reconfigurable pixel patch antenna for CLAS [4] and investigated the effects of superstrate loading on the antenna in [6]. In this work we investigate the practical consideration of including DC bias wires to the model for controlling the switches.

II. ANTENNA CONFIGURATION

The geometry discussed in this paper is the same as described in [6] except that the Rohacell core and superstrate have been excluded from the models for this study. Additionally, external copper wires have been attached to the DC bus bars of the antenna to observe their effect on antenna performance. These wires will be required in any physical specimen as a means to control the MEMS. The Rohacell core is modeled as a 17mm air gap in this paper. Fig. 1a shows a top down view of the aperture coupled patch antenna with the attached bias wires colored red. Fig. 1b shows a side view of the same structure.



a b

Fig.1. Geometry and wiring of antenna in HFSS model.

There are 8 separate wires required to bias the switches. 5 wires will be required to control the 36 MEMS on the patch substrate. Those 5 wires comprise of 4 positive voltage wires, each of which controls 9 switches, and 1 wire for the ground connection which is common for all switches. The 4 positive voltage wires are each attached to their corresponding DC busbar at a single point. The DC busbar then transmits the voltage to the switches in that row. The ground wire is attached to a ground busbar which runs underneath the patch substrate and makes both ground pads on the top side of the patch substrate electrically continuous. 3 additional wires will be required to bias the feedline switches. 1 wire for the switch controlling the Midband stub, 1 wire for the Lowband stub switch, and 1 wire for the ground connection for those 2 switches. The three wires for the feedline switches are located on the underside of the ground plane substrate and do not require the creation of vias or through holes. All the patch wires require through holes created in the foam core and ground plane substrates.

The wires are solid copper (σ = 5.8E7 S/m) of cylindrical cross-sections with a radius of 0.25mm. After exiting from underneath the ground plane, the routing of the wires converges towards a central location in anticipation of connection to an external source voltage. It should be made clear that these DC bias wires are a completely separate system from the RF signal and RF ground, and at no point is it intended for the DC bias signal and RF signal to become mingled.

III. RESULTS

A comparison of simulated results without, and with the DC bias wires included is shown in Fig. 2. As can be seen in

Fig. 2, including the DC bias wires in the model causes significant degradation in antenna performance. Considering S_{11}<=-10dB, the Highband decreases in bandwidth from 25% to 19%, while the Midband and Lowband become non-existent. Fig. 3 shows the realized gain radiation patterns for the three bands at their intended optimal operating frequencies.

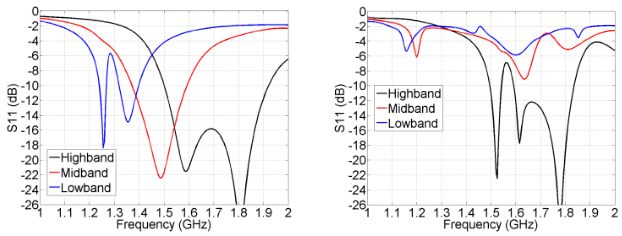


Fig. 2. Effects of including the DC bias wires in the HFSS model.

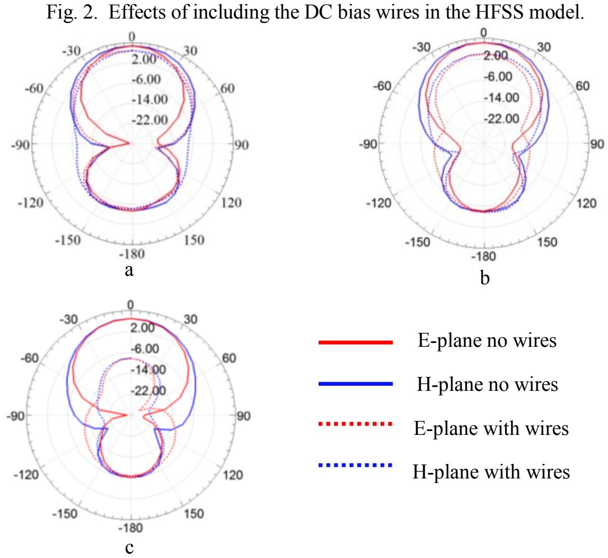


Fig. 3. Realized gain radiation patterns of the 3 bands with and without wires. a) 1.8 GHz b) 1.5GHz and c) 1.25 GHz.

The initial hypothesis as to the reason for the performance degradation was that the wires were of such a length that they created a resonance within the intended frequency range of the reconfigurable antenna. It was therefore assumed that increasing the length of the wires would sufficiently lower their resonant frequency to a value such that it would fall below the intended frequency range of the antenna. Fig. 4 shows a parametric analysis for the Highband, Midband, and Lowband with the wire length being variable. In this model, the 3 feedline wires were removed, and the 5 wires connected to the patch were routed straight downward from their connection point on the patch substrate. No bends were placed in the wires. As can be seen in Fig. 4, attaching any length of wire to the DC busbars causes an immediate degradation in S_{11}. Furthermore, this degradation is independent of wire length once any length of wire is attached, there being very little difference in the S_{11} if a 19mm wire or a 200mm wire for any of the bands.

Next, focus was placed on investigating the DC busbars made from high resistivity traces. All DC bias traces were converted from copper to a high-impedance sheet resistance model of 1000 Ω/□. The copper wires were attached to these DC busbar traces then. Fig. 5 shows the simulated S11 after this change was introduced. While not all of the S11 performance of the "No Wires" model was recovered with this change, it is a significant improvement over the results (labeled "With wires") in Fig. 2.

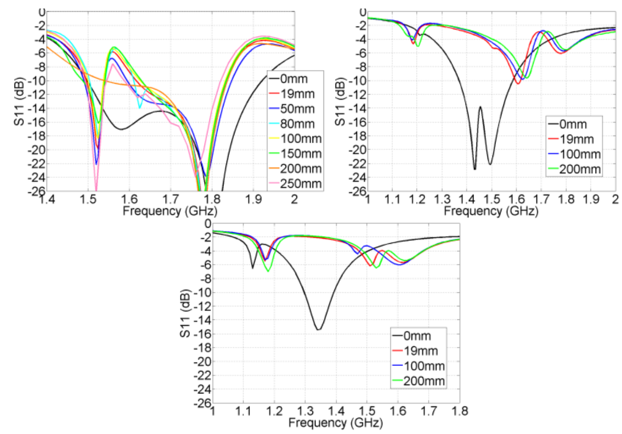


Fig. 4. Effects of variable wire length on the Highband, Midband and Lowband.

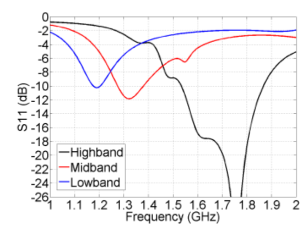


Fig. 5. S11 for the 1000 Ω/□ model with all wires attached.

Acknowledgement

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