A Reconfigurable Antenna with Software Controlled Ground Plane

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***Abstract*—This paper discusses an antenna design that achieves tuning of its frequency response by changing the height and angular position of its ground plane. The antenna is composed of a simple patch and three ground planes. Two ground planes are fixed while a third part moves and tilts based on the user's demand. The antenna's moving ground plane is controlled by an arduino board and two linear actuators. The antenna is simulated and measured. Good analogy is found between measured and simulated data.**

I. INTRODUCTION

Antenna designers have resorted to various reconfiguration techniques to achieve antenna adaptability and function tuning. The incorporation of RF MEMS [1], p-i-n diodes [2] and varactors [3] as RF switches to connect and disconnect different antenna parts and elements has revolutionized reconfigurable antennas and led to a wide range of new antenna designs. Although these electrical reconfiguration techniques have been widely implemented and have attracted some attention, they have some undesired performance characteristics.

Mechanical reconfiguration techniques, although they achieve slower tuning time for reconfigurable antenna functions, present a robust reconfiguration method with better reliability and higher control of the antenna topology. In [4] a reconfigurable square ring patch antenna based on a movable parasitic plate within the ring patch is discussed. Small variations of the height of the parasitic plate can significantly alter the antenna radiation pattern while maintaining reasonable impedance matching. Antenna frequency tuning by varying the antenna's substrate height is also presented in [5] where different instances of substrate heights are discussed for antenna tuning.

In this paper we present a new mechanically reconfigurable antenna. This antenna tunes its frequency based on elevating and tilting its ground plane. The radiating patch remains stable while the position and angle variation of the ground plane is software controlled.

II. ANTENNA STRUCTURE AND DESIGN

The antenna structure shown in Fig.1 is composed of three layers. The top layer is a rectangular patch of 4.13 cm x 4.85 cm. Two rectangular slots are etched on the patch. The first slot (Slot 1) has a width of 0.2 cm and a length of 2.4 cm. The second slot (Slot 2) is rotated 90 □ from slot 1 with a width of 0.1 cm and a length of 1.88 cm. The patch is microstrip fed with a line of length 1.435cm and width of 0.12 cm. The feeding line length and width are optimized to reflect good matching. The middle layer constitutes the substrate which is Rogers Duroid 5880. The substrate is square with a 7 cm side, a height of 0.16 cm and a dielectric constant ε_r=2.2. The bottom layer constitutes the ground plane. This antenna's ground plane is composed of three sections: two stationary ground planes (ground planes 1 and 2) and a moving ground plane as shown in Fig.2.The two stationary ground planes are positioned as indicated in Fig.2 and are of 7 cm x 0.5 cm dimensions for ground plane 1 and 7 cm x 1 cm for ground plane 2. The moving ground plane is rectangular with dimensions of 6 cm x 5 cm. The moving ground plane is controlled by two actuators that allow its vertical movement as well as its titling position. The actuators used in this work are the Miniature linear motion series L12 by Firgelli Technologies with a positional accuracy up to 0.1 mm. The actuators are powered by 4x1.5 V batteries to supply 6 V with a maximum of 400 mA of current each. The actuators are pulse width modulated with software control by an arduino board. The arduino board used in this work is an Arduino Uno R3 with a 5 V voltage supply from a USB port. The antenna system is equipped with a parallax 5-position switch. The switch is used to control and drive the ground plane's movement through the arduino microcontroller. A guide rail links the moving ground to the actuators. This rail is made of nylon with a dielectric constant of 3.2 and the hooks connecting the actuators to the rail are made of delrin material with a dielectric constant of 3.7. An ultra dense foam chassis with a dielectric of around 1 is chosen to constitute the solid frame that encloses all these different system components. The chassis that encloses the antenna system is of 17 cm height with a 9.5 cm^2 area. The chassis and the rails are included in the simulation as shown in Fig.3.

III. ANTENNA RESULTS AND APPLICATIONS

The reconfigurable antenna is designed to allow frequency tuning between 2 GHz and 6GHz. The antenna system can be used for operation in applications such as satellite communications, wireless aviation communications, ISM, TV

auxiliary broadcasting, private land mobile, earth exploration satellite, radio navigation, WI-FI and Wimax.

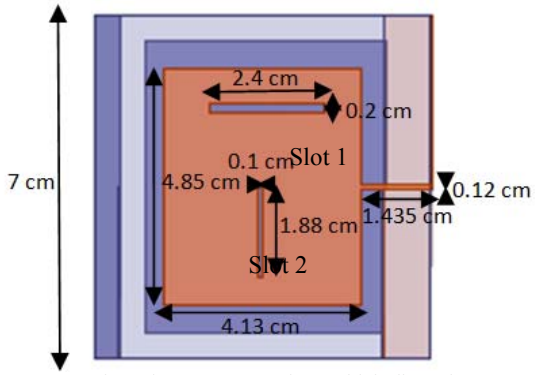

Fig.1 The antenna's top layer with is dimensions

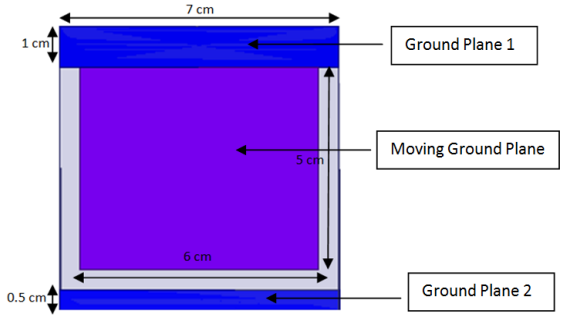

Fig.2 The antenna's bottom layer with thedimensions of the different ground planes.

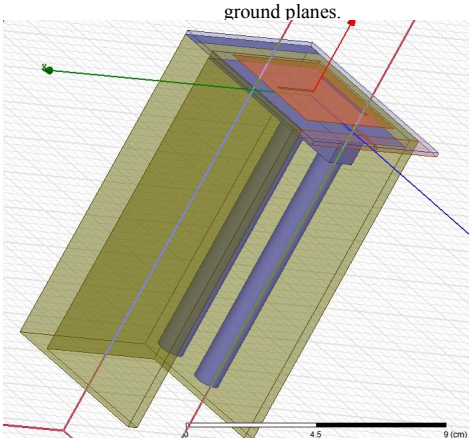

Fig.3 The whole antenna systems with rail and chassis as included in Ansys HFSS simulation

The measured reflection coefficient of the reconfigurable antenna is for five different ground elevation positions and tilt angles is shown in Fig.4 for five different ground plane elevation positions and tilt angles. The comparison between the measured and simulated radiation pattern at F=2.4 GHz in the x-z plane is shown in Fig.5 when the ground plane at original position.

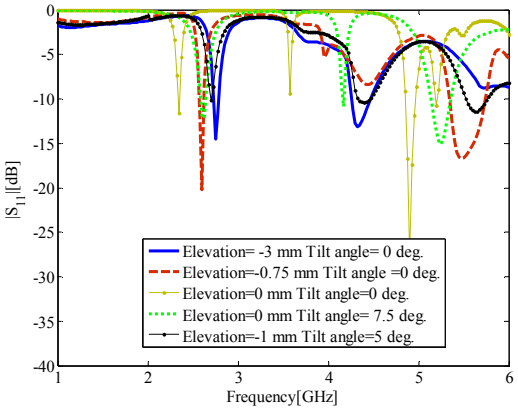

Fig.4 Tuning of Antenna frequency response for various ground position and tilt angles

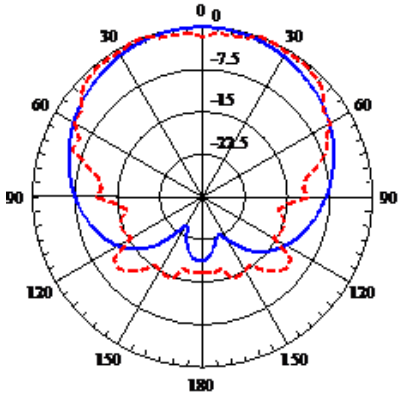

Fig.5 Comparison between measured and simulated radiation pattern in the x-z plane for F=2.4 GHz, Elevation=0 mm, Tilt angle=0 deg

IV. CONCLUSION

In this paper a new reconfigurable antenna with a software controlled ground plane is presented. The antenna control system is based on an arduino board and two linear actuators. The whole system is packaged into a one compact foam based chassis allowing its portable capability.

REFERENCES

[1] A. Grau, J. Romeu, M. Lee, S. Blanch, L. Jofre, and F. De Flaviis, "A dual linearly polarized MEMS-reconfigurable antenna for narrowband MIMO communication systems," *IEEE Transactions on Antennas and Propagation,* vol. 58, no. 1, pp. 4-16, Jan. 2010.

[2] Z. H. Hu, P.S. Hall, J. R.Kelly, P. Gardner " Novel Wideband Pyramidal Monopole Antenna with Wide Tunable Frequency Band-Notch" *Fifth European Conference on Antennas and Propagation*, pp.3509-3512, 2011

[3] Y. Tawk, J. Costantine, and C. G. Christodoulou, "A varactor based reconfigurable filtenna," *IEEE Antennas and Wireless Propagation*, vol. 11, pp. 716-719, 2012

[4] S. Jalali Mazlouman, M. Soleimani,A. Mahanfar, C. Menon, and R. G. Vaughan, " Pattern reconfigurable square ring patch antenna actuated by hemispherical dielectric elastomer," Electron. Lett., vol. 47, no. 3, pp. 164–165, Feb. 2011.

[5] K. Kitatani and S. Yamamoto, "Coaxial feed-type microstrip patch antenna with variable antenna height," *Electron. Commun. Jpn. (Part I: Communications)*, vol. 87, no. 2, pp. 10–16, 2004.