Non-Uniform Bias Enhancement of a Varactor-Tuned FSS used with a Low Profile 2.4 GHz Dipole Antenna

David Cure* and Thomas M. Weller
Dept. of Electrical Engineering
University Of South Florida
Tampa, FL, 33620
E-mail: dcure@mail.usf.edu

Félix A. Miranda
Antenna and Optical Systems Branch
NASA John H. Glenn Research
Cleveland, OH 44135
E-mail: felix.a.miranda@nasa.gov

***Abstract*—In this paper a low profile antenna using a non-uniformly biased varactor-tuned frequency selective surface (FSS) is presented. The tunable FSS avoids the use of vias and has a simplified DC bias network. The voltages to the DC bias ports can be varied independently allowing adjustment in the frequency response and enhanced radiation properties. The measured data demonstrate tunability from 2.15 GHz to 2.63 GHz with peak efficiencies that range from 50% to 90% and instantaneous bandwidths of 50 MHz to 280 MHz within the tuning range. The total antenna thickness is approximately λ/45.**

I. Introduction

Herein an end-loaded planar open sleeve dipole (ELPOSD) antenna backed with a non-uniformly biased varactor-tuned frequency selective surface (FSS) is presented (Fig. 1). This work builds upon the design presented by Cure, et al. [1] with the goal of achieving broad tunable bandwidths. The antenna has a total thickness (excluding the feed layer) of ~λ/45 at the center of the operating band.

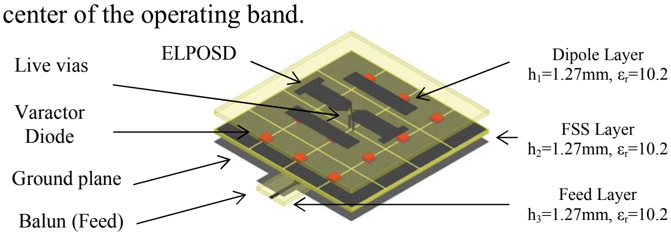

Figure 1. Schematic of ELPOSD antenna illustrating the multi-layer substrate with feed layer, tunable FSS layer, and dipole.

The main features of this antenna are the use of an FSS that does not include via connections to ground, its low profile and potentially conformal nature, its high radiation efficiency and high front-to-back radiation pattern ratio, and the ability to dynamically adjust the center frequency. The significance of these features stems from the intended use of the antenna for biomedical radiometric sensing applications where characteristics such as light weight, conformability, simple integration, adjustment in response to adverse environmental loading, and the ability to block external radio frequency interference to maximize the detection sensitivity are highly desirable.

Previous works [2-5] have demonstrated that dipole-type antennas above tunable FSS ground planes can achieve broadband bandwidth. In [4] and [5] broad tunability range is obtained for a total antenna and FSS thickness of ~λ/25 and ~λ/15, respectively. In this paper, similar performance is achieved with an FSS that not only has the ability to dynamically adjust the antenna center frequency but also allows for varying the impedance match of the antenna to create broadband or multi-resonance responses. In addition, the absence of interlayer wiring on the electronically-tuned FSS minimizes the fabrication complexity and facilitates the potential use of flexible substrates for future works.

II. Antenna Design and Performance

The antenna was designed to operate at a center frequency of 2.4 GHz and built using a 1.27 mm-thick Rogers RT6010 substrate, with a dielectric constant of 10.2. It has a planar size of 120 x 133 mm^2, including the bias network. It consists of 56 tunable hybrid unit cells and 56 varactor diodes. The network is distributed in 8 rows, each containing seven diodes in series. It has eight independent DC voltage lines, on which each total voltage is divided evenly between the seven diodes per row. A 1 KΩ resistor was used at the ends of each row to block RF leakage onto the bias lines. Fig. 2 shows the antenna assembly which integrates the ELPOSD, DC bias, FSS and ground plane. The antenna thickness (excluding the feed layer) is λ~/45 at 2.4 GHz.

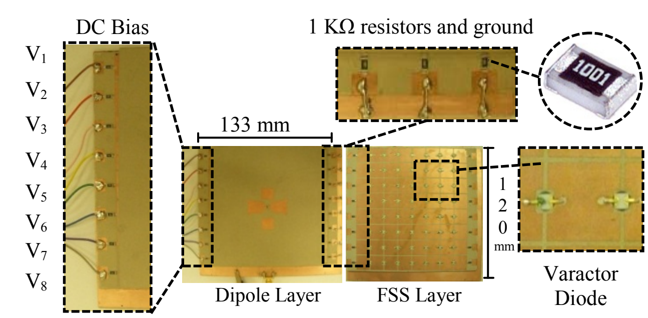

Figure 2. Antenna assembly showing the dipole layer and the tunable asymmetric FSS ground plane with 8 independent voltage ports and resistors to isolate the RF leakage from the bias lines.

Measured S_{11} data for the antenna when applying a common bias voltage of 0 V and 70 V to all DC bias ports are shown in Fig. 3 (left). Using the 10 dB return loss criterion, there is a 510 MHz span between the low end of the response with 0 V and the high end of the response using 70 V. The radiation patterns of the antenna with bias voltage of 30 V at 2.4 GHz shown in Fig. 3 (right) demonstrate cancellation of back radiation and low cross polarization. The performance of the antenna using a common voltage to all ports is summarized in Fig. 4. Here, the bandwidth is defined as the band over which the return loss is greater than 10 dB and the gain is more than 3 dBi. The shaded region shows tunability from 2.15 GHz to 2.63 GHz (i.e. BW ≈ 480 MHz) with efficiencies greater than 50%. The efficiency was determined using a Wheeler cap.

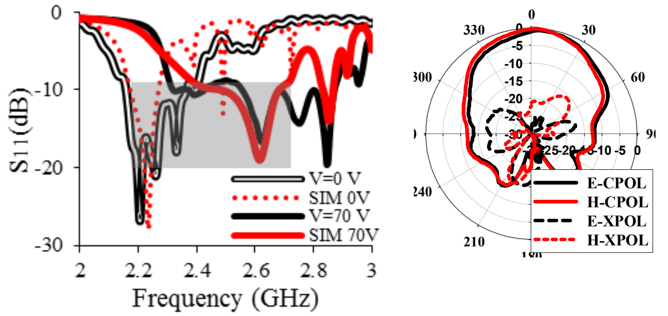

Figure 3. Measured and simulated S_{11} when 0 V and 70 V is applied to all DC bias lines (left) and radiation patterns for the antenna with bias voltage of 30 V at 2.4 GHz (right) respectively.

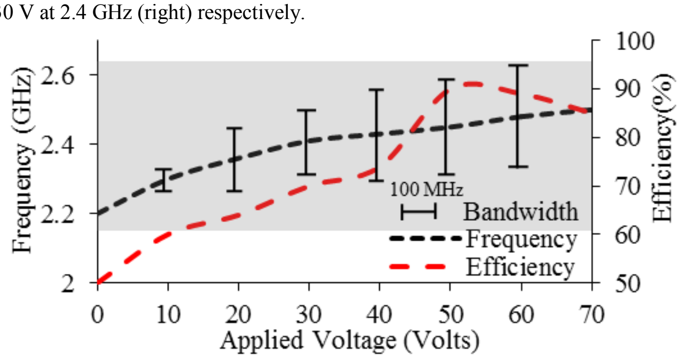

Figure 4. Performance of the antenna versus bias voltage.

The antenna performance can be enhanced by using different voltages in the external lines. The results presented in Fig. 5 and Fig. 6 compare the measured performance of the antenna using different FSS bias configurations (Table I). With a uniform voltage of 30 V on all rows (Configuration A), the antenna exhibits more than 3dBi gain and broad bandwidth from 2.3 GHz to 2.5 GHz, however at 2.57 GHz the gain drops and the surface wave effects are noticeable in the radiation pattern. For Configuration B, the four external rows are biased at 70 V and rows below the dipole are biased at 30 V. In this configuration, the return loss is strongly affected creating a dual resonance response with high gain. A variation to Configuration B, where 70 V is uniformly applied to all DC bias lines, is shown in Fig. 3; in this latter case, the antenna exhibits broad bandwidth from 2.5 GHz to 2.63 GHz.

TABLE I. MULTIPLE BIAS CONFIGURATION

Configuration	*V_1, V_2*	*V_3*	*V_4,V_5*	*V_6*	*V_7, V_8*
A	30 V	30 V	30 V	30 V	30 V
B	70 V	70 V	30 V	70 V	70 V

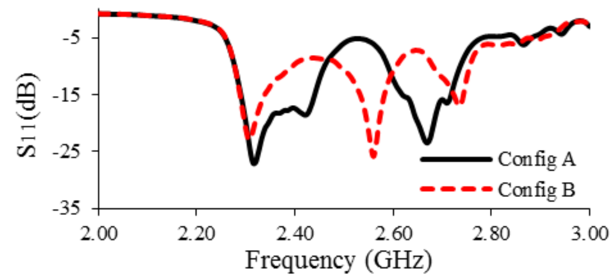

Figure 5. Measured S_{11} when non-uniform bias is applied to the diodes.

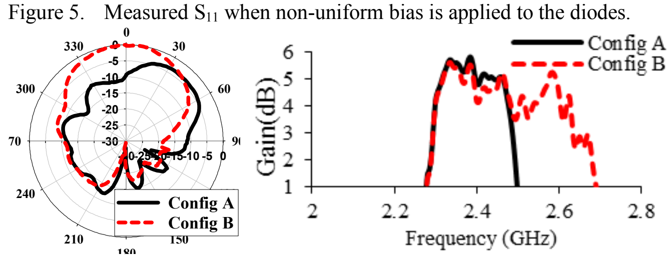

Figure 6. Measured E-plane radiation patterns at 2.57 GHz (left). Measured gain of the antenna for voltage configurations A and B in table I (right).

III. CONCLUSION

An ELPOSD antenna backed with a non-uniform bias varactor-tuned frequency selective surface (FSS) has been presented. The measured data demonstrate that the antenna has the ability to dynamically adjust the center frequency and vary the impedance match of the antenna to create broadband or multi-resonance responses. The antenna is ultra-thin (~λ/45), immune to external radio frequency interference, and avoids the use of vias which makes the design amenable to biomedical radiometric sensing applications and facilitates the potential use of flexible substrates for future works

ACKNOWLEDGMENT

The authors thank Rogers Corporation for donating the substrates used in this work. This work was partially supported in by NASA Glenn Research Center's Graduate Student Researcher Program (Grant # NNX10AL41H) and by NSF Grant #ECS-0901779.

REFERENCES

[1] D. Cure, T. Weller, F.A. Miranda and P. Herzig "One dimensional capactive loading for low profile antenna applications," IEEE International Symposium on Antennas and Propagation Spokane, USA, July 2011.

[2] D. Sievenpiper, et al., "Electronic Beam Steering Using a Varactor-Tuned Impedance Surface," *Proc. IEEE Antennas and Propagation Society Int. Symp*.,vol. 1, Boston, MA, 2001, pp 174-177.

[3] V. C. Sanchez, R. E. Diaz, and W. E. McKinzie, "Broadband Antennas Over Electronically Reconfigurable Artificial Magnetic Conductor Surfaces," *Proceedings of the Antenna Applications Symposium*, Robert Allerton Park, Monticello, IL, Sept. 19-21, 2001.

[4] F. Costa, A. Monorchio, S. Talarico, and F. M. Valeri, "An active high impedance surface for low profile tunable and steerable antennas," *IEEE Antennas Wireless Propag. Letters*, vol. 7, pp. 676–680, 2008.

[5] M. G. Bray and D. H. Werner, "A Broadband Open-Sleeve Dipole Antenna Mounted Above a Tunable EBG AMC Ground Plane," Proceedings of the 2004 *IEEE Antennas and Propagation International Symposium*. Monterey, CA. June 21-26, 2004. Vol. II, pp. 1147 – 1150.