

Elliptically polarized frequency agile antenna on ferroelectric substrate

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Abstract: A low-profile, compact and frequency-tunable antenna made on ferroelectric substrate is presented. It is designed as a planar dipole antenna with an IDC varactor integrated in the signal line. Antenna is fed through a coplanar waveguide matched to 50 Ω. The center frequency can be tuned from 6.895 GHz to 7.050 GHz. It exhibits elliptical polarization and omnidirectional radiation pattern.

Keywords: Frequency-tunable antenna; ferroelectric thin films; (Ba,Sr)TiO₃

Eliptično polarizirana in frekvenčno nastavljiva antena na feroelektrični podlagi

Izveček: Predstavljena je frekvenčno nastavljiva planarna antena z majhnim profilom izdelana na feroelektrični podlagi. Zasnova antene temelji na planarnem dipolu z interdigitalnim varaktorjem, ki je integriran v signalni liniji. Napajana je skozi koplanarni valovod z imedanco 50 Ω. Resonančna frekvenca antene je prilagodljiva v območju med 6.895 GHz in 7.050 GHz. Antena ima eliptično polarizacijo in omni-smerni diagram sevanja.

Ključne besede: Frekvenčno nastavljiva antena; feroelektrične tanke plasti; (Ba,Sr)TiO₃

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1 Introduction

Nowadays Earth and space communication modules provide multiple services on different frequencies with constant demand for reduced dimensions of the communication devices. Reduced dimensions of the chassis often result in either compact antennas with narrow bandwidth or in complex multiband design. Frequency-agile antennas, on the other hand, are attractive as they are small and can at the same time seamlessly cover a wide frequency range [1, 2].

A simple way to tune antenna is to load it with varactors. In the past years thin-film ferroelectric varactors have been extensively studied for possible

use in frequency-agile microwave devices [3, 4]. Lumped-element microwave circuits based on ferroelectrics are advantageous over the competing technologies, i.e., semiconductor varactors and micro-electro-mechanical systems (MEMS), in terms of space-radiation stability, reliability and their rapid response [5, 6]. High-density integrated circuits based on ferroelectric thin films with thicknesses below 1 μm can be produced on a single substrate, which increases the fabrication output and reduces the cost.

This paper presents a novel antenna architecture with integrated ferroelectric varactor, which was designed to manufacture a simple yet efficient tunable antenna

for satellite communications at frequencies between 6.875 and 7.050 GHz. In addition to tunable center frequency it is characterized also with elliptical polarization and good cosmic irradiation hardness [7]. Antenna is fed through a coplanar waveguide (CPW) loaded with an interdigital (IDC) varactor made on $Ba_{0.3}Sr_{0.7}TiO_3$ thin-film substrate. Biasing of the varactor is achieved through the CPW signal line, with RF signal and bias separated with 1 MΩ resistor.

2 Antenna fabrication and design

Resonant frequency of the antenna can be effectively changed by adding a variable capacitor (varactor) at its feed point. Polycrystalline ferroelectric film, with the composition of $Ba_{0.3}Sr_{0.7}TiO_3$, was deposited by cost-efficient Chemical Solution Deposition on ~250 μm-thick polished polycrystalline Al_2O_3 substrate (CoorsTek Inc., Golden, USA, $\epsilon = 9.9$). Thickness of the film was increased by several deposition-heating steps to 240 nm and the final annealing was performed at 900 °C [8]. Dielectric permittivity ϵ and losses $\tan\delta$ of the films were measured at 9.6 GHz using split-post dielectric resonators (QWED, Warsaw, Poland) and were found to be 640 and 0.02, respectively.

Dipole antenna fed by a coplanar waveguide with integrated BST varactor was found to give the best compromise between the requirements, i.e., working frequency range, and its characteristics, i.e., dimensions and efficiency. The structure was patterned by lift-off photolithography and top Cr/Cu electrodes with 15 nm of Cr and 2 μm of Cu were deposited by DC sputtering (Balzers Sputron, Oerlikon Balzers, Liechtenstein). Its configuration is shown in Fig. 1. Width and spacing of the 50 Ω CPW feed line are 1050 μm and 250 μm, respectively. The IDC fingers are 185 μm long, 10 μm wide and have a 5 μm gap between them. Magnified view of the 12-fingered IDC varactor is shown in the inset of Fig. 1.

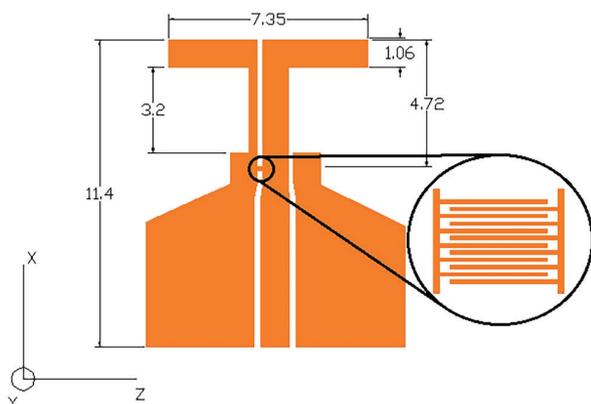


Figure 1: Configuration of the proposed tunable dipole antenna. Dimensions are given in mm.

To facilitate the measurement, an SMA connector was mounted at the edge of the CPW. The photography of the fabricated antenna and the optical micrograph of the IDC varactor are shown in Fig. 2(a) and (b), respectively.

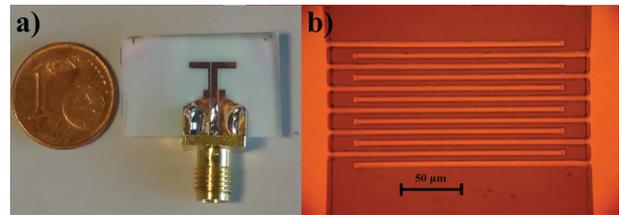


Figure 2: (a) fabricated tunable dipole antenna and (b) IDC varactor.

3 Measurement results and comparison with existing solutions

Return loss S_{11} of the tunable dipole antenna measured at applied bias voltage up to 50 V is shown in Fig. 3. The resonant frequency changes between 6.875 GHz for 0 V bias and 7.050 GHz for 50 V bias, which translates into tuning range of approximately 3 %. Higher voltages detune the antenna to the point where it is no longer viable for space communication.

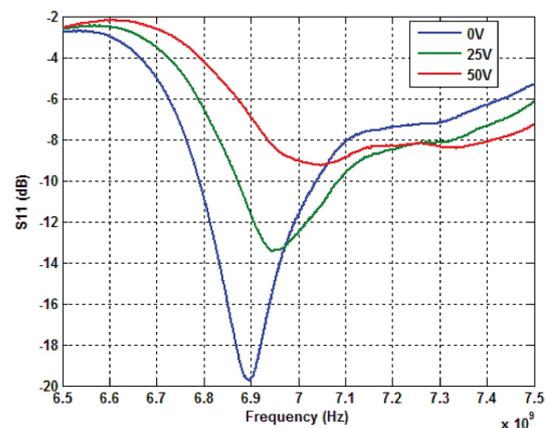


Figure 3: Measured return loss S_{11} of the tunable dipole antenna.

Far-field radiation patterns were measured in the MVG Satimo StarLab (MVG Industries, Villebon-sur-Yvette, France) near field measurement chamber (Fig. 4). Currents flowing on the outside of the coaxial cable shield were suppressed as much as possible with the use of ferrite chokes, which can be seen as white cylinders near the antenna in Fig. 4. The radiation patterns at 6.875 GHz under 0 V bias are presented in Fig. 5, while the Axial Ratio (AR) is shown in Fig. 6. In X-Y plane antenna has an almost omnidirectional

pattern. In the Z-X plane antenna has maximum gain in X axis and minimum in Z axis, which is typical for dipole antenna radiation pattern, although it is not perfect. It has a higher gain in -X direction compared to +X direction (Fig. 5a) and higher gain in X-axis compared to Y-axis. This can be explained with the current flowing on the antenna between the horizontal arms and ground plane shown in Figure 7. Maximum gain is 1.6 dBi. AR measurement shows that antenna is linearly polarized in Z-X plane but has a significantly lower AR in X-Y plane, i.e. it is elliptically polarized in Y axis (Fig. 6).

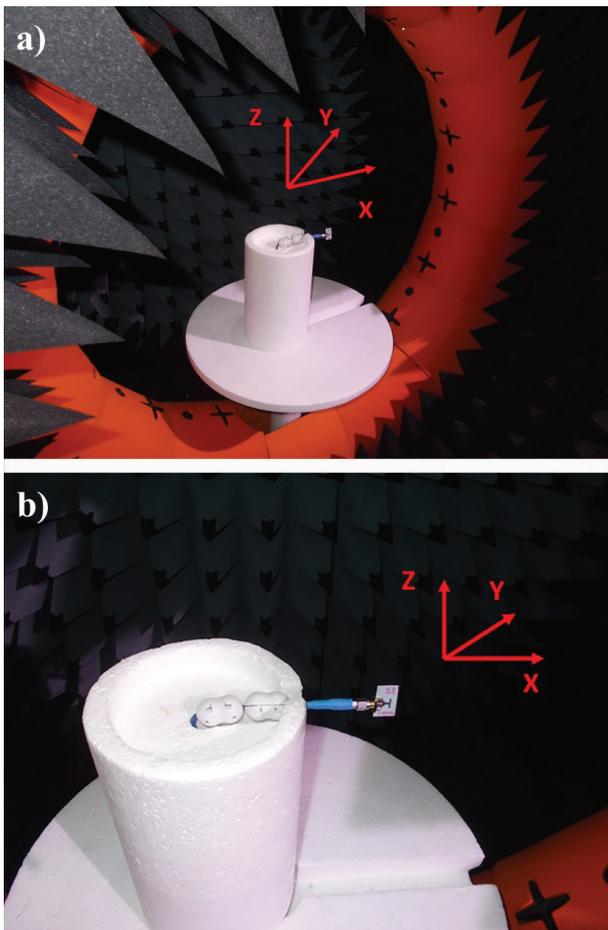


Figure 4: a) Measurement set-up for far-field radiation measurements with mounted antenna. b) Detailed view of the same set-up.

Elliptical polarization and irregular radiation pattern can be explained by examining the current distribution on the antenna, which was simulated with Sonnet Software 3D planar high-frequency electromagnetic software and is shown in Fig. 6. Vertical parts of the antenna between horizontal dipole and ground plane are electrically far apart. Consequently, currents flowing into the antenna through the signal line and out of the antenna through the ground plane do not cancel each other out. Antenna is therefore radiating not only from its horizontal parts, as could be expected for a dipole antenna, but also from

its vertical parts. This induces vertical component into the radiated electromagnetic field.

Compared to the existing literature data on tunable antennas based on BST-film varactors, the 3 % tuning of resonant frequency at 50 V exceeds the values reported for slot loop antennas, for which either 3 % or 1 % tuning was achieved with 200 [9] and 40 V bias

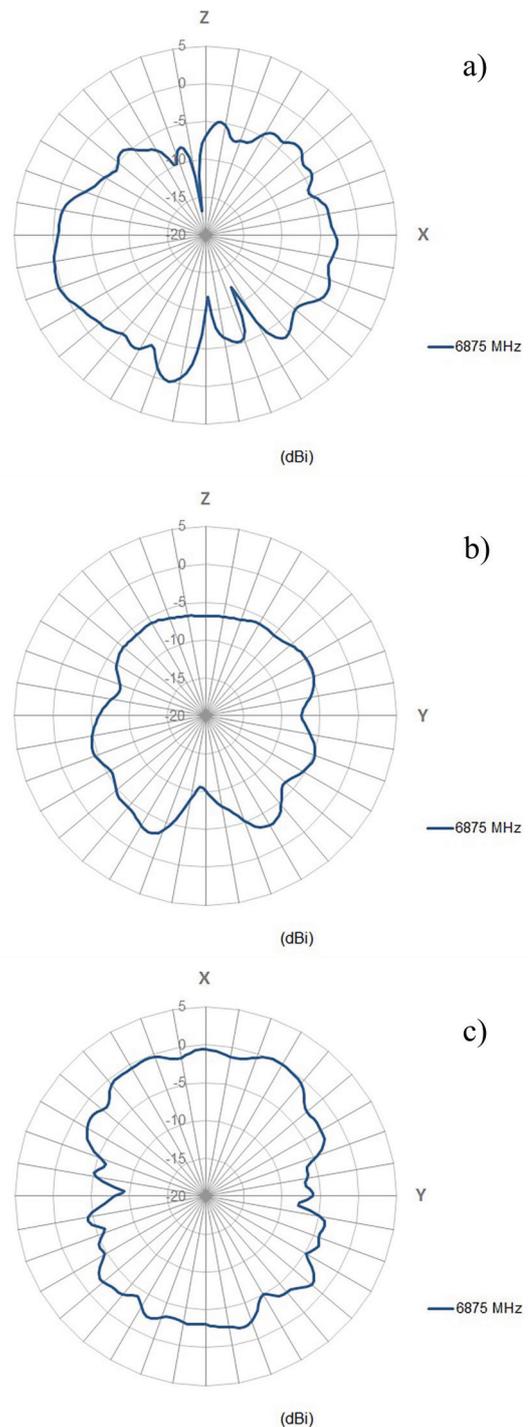


Figure 5: 2D radiation patterns measured at 6.875 GHz. a) Z-X plane, b) Z-Y plane and c) X-Y plane.

[10], respectively. However, it is inferior to the 8 % tuning achieved with 10 V in Bowtie antenna with three IDC varactors integrated in the feed line [11].

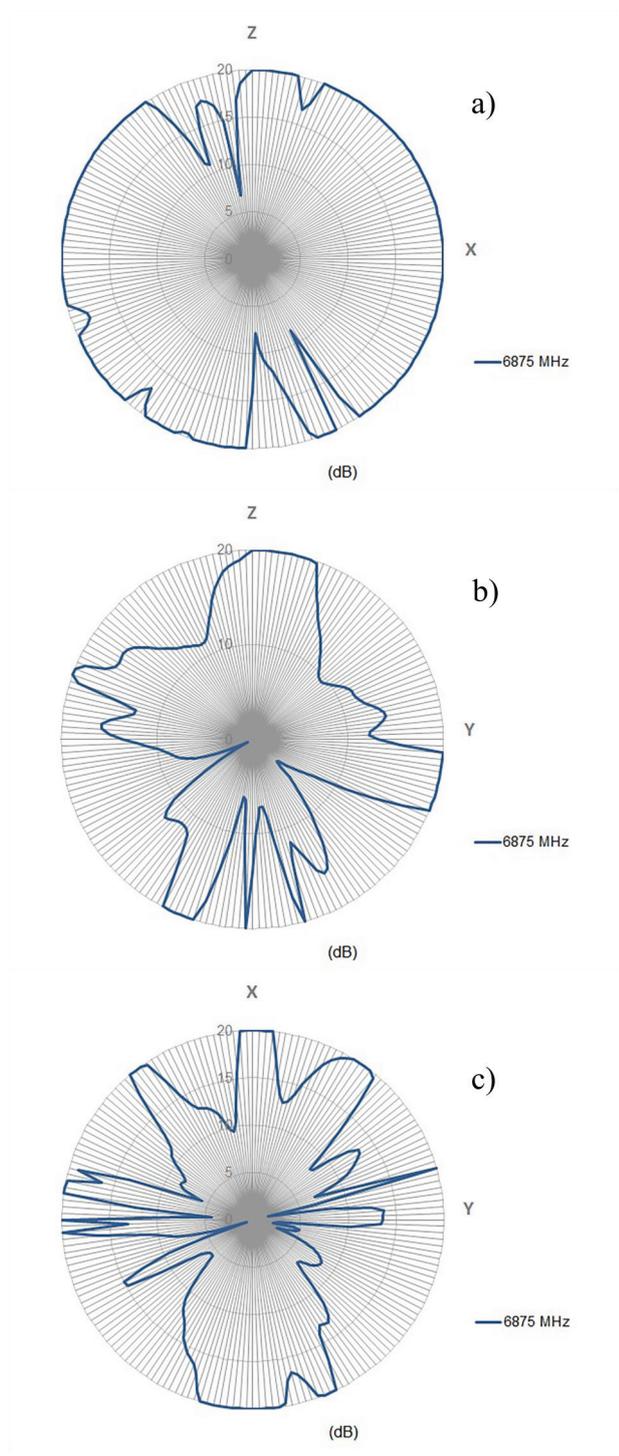


Figure 6: Axial Ratio diagrams measured at 6.875 GHz. a) Z-X plane, b) Z-Y plane and c) X-Y plane.

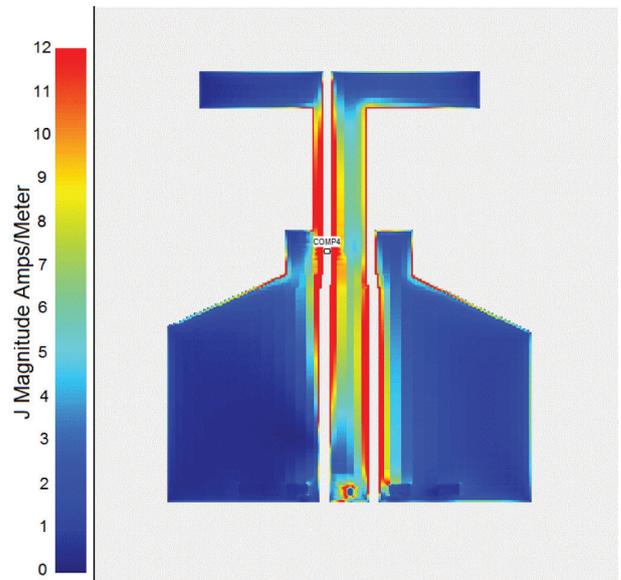


Figure 7: Tunable dipole antenna current distribution at 6.875 GHz.

4 Summary

A low-cost and compact frequency agile antenna on ferroelectric substrate was made and measured. An IDC varactor integrated in the antenna can shift its resonant frequency by 3 % when bias voltage of 50 V is applied. In Y-axis antenna exhibits elliptical polarization with low axial ratio, which is desirable in Earth and satellite communication as it reduces fading of the signal. Design allows a compact, lightweight and low cost manufacturing, which is anticipated for space applications.

5 Acknowledgments

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