Fully Printed VO_2 Switch Based Reconfigurable PIFA / T-shaped Monopole Antenna

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***Abstract*—A recent trend in frequency reconfigurable antennas is the use of a vanadium dioxide (VO_2) layer as a radiofrequency switch to operate at different frequency bands. Typically, the deposition of a VO_2 switch utilizes complex fabrication processes which result in higher costs. The ideal approach would be to use low-cost additive manufacturing techniques, such as screen printing. This work presents a novel fully screen-printed frequency reconfigurable PIFA / T-shaped monopole antenna with a printed VO_2 switch. The switch operates through thermal activation and reconfigures the frequency band. The antenna operates at 2.7 GHz band or at 3.5 GHz band for two different operational modes of the VO_2 switch. The antenna achieved 2.14 dBi gain at 3.5GHz.**

Keywords—fully printed antenna; frequency reconfigurable antenna; VO_2 switch.

I. INTRODUCTION

Fast growing of wireless communication systems requires creation of integrated multiple functions devices that operate at multiple frequency bands. Multiple antennas systems are usually designed to cover several frequency bands. The use of multiple antennas in one device is associated with complication of the device due to a large total size, volume, and coupling issues. To avoid isolation problems and reduce antenna volume, some designers use frequency reconfigurable antennas with different types of radiofrequency (RF) switches. Well-known switches are based on p-i-n-diodes, Micro-Electro-Mechanical Systems (MEMS) technology, field effect transistors (FET), and magnetic ink switches. A survey on different approaches for realization of frequency reconfigurable antennas is presented in [1].

One of the recent novel trends in RF switches is thin film vanadium dioxide (VO_2) switches [2]. The VO_2 is a material that has properties of a metal with high resistance (~5KΩ) when its temperature less than 68°C, and it has properties of a metal with low resistance (~10Ω) when it is heated to 68°C and above. Some designs of frequency reconfigurable antennas with VO_2 switches were published recently in [3-7]. A frequency reconfigurable bowtie antennas with VO_2 thin-film switch has been presented in [3, 7]. Some designs of frequency reconfigurable slot antennas have been presented in [4-7]. In papers [3-5], some external heaters were used to change the electrical properties of a VO_2 layer. In papers [6, 7], it was proposed to change the electrical properties of a VO_2 layer by passing direct current (DC) through the layer to obtain ultra-fast (on the order of several microseconds) reconfigurability.

However, some expensive and complex thin film microfabrication techniques were used to deposit VO_2 switches: pulsed laser deposition in [3], and electron beam evaporation in [4, 6]. With increasing of low cost, additively manufactured or printed frequency reconfigurable antennas, it will be beneficial to have fully printed antenna with printed VO_2 switch layer as well. In the present work, we propose a fully printed frequency reconfigurable planar inversed F antenna (PIFA) / T-shaped monopole antenna with a printed VO_2 switch to operate at two different frequency bands: 2.7 and 3.5 GHz.

II. THE DESIGN AND RESULTS

A. The Antenna Design

The geometry of the antenna is shown in Fig. 1. The antenna is designed on 100mm thick glass substrate with a permittivity of 7 and a loss tangent of 0.01 at the frequency of 1 GHz, and is fed by 50 Ohm coplanar waveguide line. The

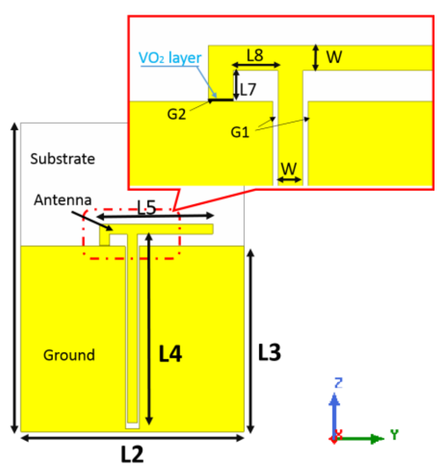


Fig. 1. The geometry of antenna.

antenna has the following dimensions (in mm): L1=50, L2=36, L3=30, L4=33, L5=18.3, L7=1.8, L8=3, W=1.6, G1=0.2, G2=0.384. The reconfigurable antenna operates in two frequency bands: 2.7 and 3.5 GHz when the switch is at "on" and "off" mode respectively. The "on" and "off" mode of the switch corresponds to 10Ω and 1KΩ resistance with parasitic capacitance of the VO_2 layer respectively. The VO_2 layer is included in the gap between the antenna arm and the antenna ground.

The prototype of the antenna was fabricated, as shown in Fig. 2, utilizing a custom VO_2 based ink for switch printing and a PE819 Silver paste from DuPont for metal traces printing. The vanadium dioxide ink has been prepared by mixing the 33 wt% VO_2 nanoparticles in 66 vol % of 2-hydroxyethylcellulose, HEC solution (2 wt % in 50:50 ratio of water and ethanol). The PE819 conductive silver paste is purchased from DuPont, as listed in their product list [8]. A total of 40um thickness of silver paste is screen printed and cured at 150 ^{0}C for 30mins. Similarly, 25 um of VO_2 film is screen printed and cured at 200 ^{0}C for 60 min in vacuum. A SMA connector is mounted to the coplanar waveguide line to feed the antenna.

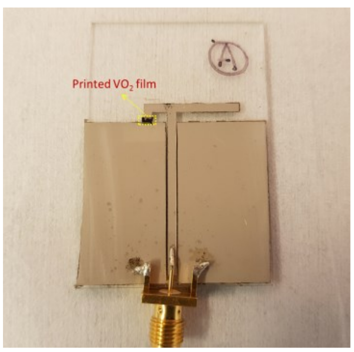
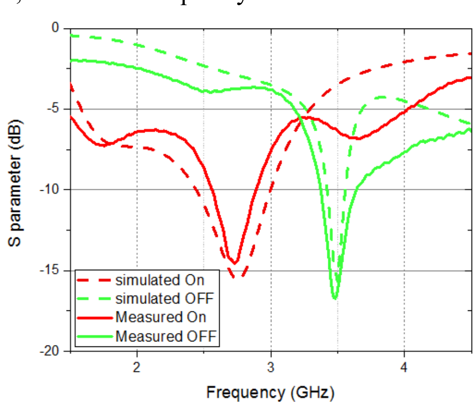


Fig. 2. Photo of the fabricated prototype.

B. Simulated And Measured Results

The antenna was simulated using ANSYS HFSS software, and the simulated and measured reflection coefficient (S_{11}) of the antenna is shown in Fig. 3. In the simulation, the VO_2 switch is modeled with taking into account a parasitic capacitance introduced by the VO_2 layer. The parasitic capacitance is 0.1 pF. The S_{11} of the antenna is less than -10 dB in the frequency band of 2.45-2.98 GHz when the switch is at "on" mode, and in the frequency band of 3.42-3.56 GHz when



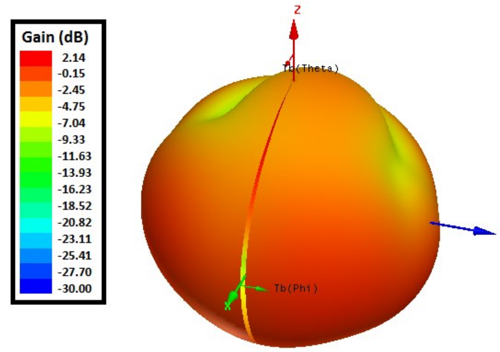


Fig. 4. The measured radiation pattern at 3.5GHz.

there is no switch or a slight shift when the switch is at "off" mode. The measured S_{11} is less than -10 dB in the frequency band of 2.56-2.88 GHz when the switch is at "on" mode. As expected, the antenna in the frequency band of 3.32-3.64 GHz when the switch is at "off" mode. The impedance bandwidth different from the Fig. 4 plots measured radiation pattern of the antenna at the frequency of 3.5 GHz. The antenna maximum gain is 2.14 dBi.

III. Conclusion

This work presents a low cost fully printed frequency reconfigurable PIFA / T-shaped monopole antenna based on innovative vanadium dioxide (VO_2) material. The antenna is able to switch between two bands with a single printed VO_2 switch layer. The antenna is matched for 2.7 and 3.5 GHz when the switch is at "on" or "off" mode.

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