Fully Printed VO_2 Switch Based Reconfigurable PIFA Antenna

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***Abstract*—Frequency reconfigurable antennas are attractive as they can cover multiple bands as well as different wireless standards in different countries. Typically, these antennas utilize complex subtractive fabrication processes which result in higher costs. For switching to different bands, generally semiconductor based devices such as PIN diode switches or MEMS switches, etc. are used, which add to the cost and pose integration and reliability issues. The ideal approach would be to use low-cost additive manufacturing techniques, such as inkjet printing. This work presents, a novel fully inkjet printed frequency reconfigurable PIFA antenna, where the switch (based on vanadium dioxide (VO2)) has also been printed. The switch operates through thermal activation and reconfigures the frequency band. In one mode of the switch, the antenna operates at 2.4 GHz band for WiFi, Bluetooth or Zigbee applications, and in the other mode, it operates at 3.5 GHz band for 5G communications. The antenna achieved 1.58 dBi gain at 3.5GHz.**

Keywords—fully printed, frequency reconfigurable antenna; PIFA; VO_2 switches.

I. INTRODUCTION

Multiple functions are increasingly integrated into the wireless communication system. To facilitate multiple operation frequency functions, multiple antennas system are usually designed. However, multiple antennas operating at multiple bands requires a large total size and volume. Moreover, multiple antennas have significant coupling issue. As a result, a signal processing module or a complex filter design is required to have high signal-to-noise ratio due to the noise introduced by multiple antennas. As compared with multiple antennas, a frequency reconfigurable antenna takes small space and allows to avoid isolation problems. With a switch is turned at “on” or “off” mode, a single reconfigurable antenna could operate at different frequencies. Also, a reconfigurable antenna may cost much less than a multiple antennas system.

Some designs of frequency reconfigurable antennas have been published in [1-7]. The switches based frequency configurable antennas with PIN-diodes switches were published in [1, 2]. However, the presence of diodes leads to a rise in the cost of design. Also, soldering and mounting of lumped diodes make a fabrication process more complex. The MEMS switches based frequency reconfigurable antenna is shown in [3], and it also requires expensive fabrication procedures. There are some works on magnetic ink switches for radio frequency reconfigurable antenna [4, 5]. However, the antenna re-configurability comes from the inkjet printed magnetic substrate. The preparation of the functional magnetic substrate is supposed to take a long time. The large size of the magnetic substrate has a high risk to crack so that its yield rate is low in mass fabricate. Paper [6] reports on frequency tunable antennas with vanadium dioxide (VO_2) switches. The VO_2 layer is a material that has properties of a metal with high resistance (~5KΩ) when its temperature less than 70°C, and it has properties of a metal with low resistance (~10Ω) when it is heated to 70°C. However, in previous papers, expensive and complex thin film microfabrication techniques were used to deposit VO_2 switches.

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. To verify the concept of a printed VO_2 switch for a frequency reconfigurable antenna, we propose a fully printed planar inversed F antenna (PIFA) like the one shown in [7] with an addition of printed VO_2 layer (acting as switch) to operate at two different frequency bands: 2.4 GHz for WiFi, Bluetooth or Zigbee applications, and 3.5 GHz for lower band 5G communications.

II. THE DESIGN AND RESULTS

A. PIFA Design

The geometry of the antenna is shown in Fig. 1. The antenna is designed on 50 um thick Kapton substrate that is fed by 50 Ohm coplanar waveguide line. The Kapton substrate has a permittivity of 3 at the frequency of 1 GHz, and a loss tangent of 0.003. This reconfigurable PIFA operates in two frequency bands: the first one is WiFi band at 2.45 GHz when the switch is at “on” mode, the second one is a 5G band at 3.5 GHz when the switch is at “off” mode. The “on” and “off” mode of the switch corresponds to 10Ω and 1KΩ resistance of the VO_2 layer respectively. The antenna has the following dimensions (in mm): L1=50, L2=60, L3=27, L4=21, L5=11.8, L6=L7=3, W=2, G1=0.2, G2=0.053. The VO_2 layer is included in the gap of antenna's arm.

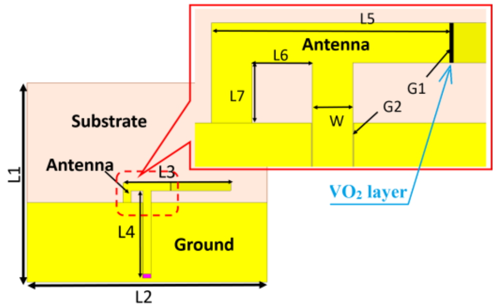

Fig. 1. PIFA design.

The prototype of the antenna was fabricated (Fig. 2) utilizing a custom VO_2 based ink for switch printing and a silver-organo-complex (SOC) ink 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 SOC metallic ink is prepared according to reported in [8]. In this particular case, a PIFA antenna is printed through SOC ink. A total of 8 layers of SOC ink is printed and cured using infrared (IR) heating for 5 min. The SMA is mounted to the coplanar waveguide line.

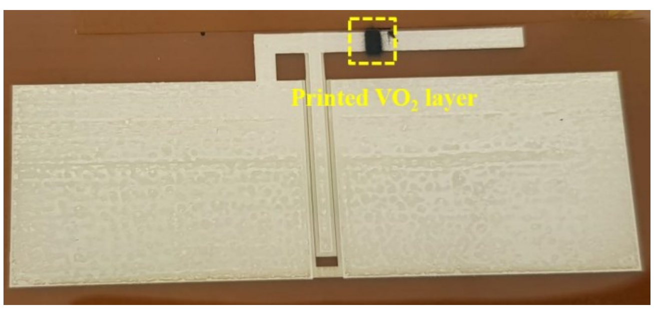

Fig. 2. Photo of the fabricated prototype.

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 without taking account of the parasitic capacitance introduced by the VO_2 layer. So that the antenna

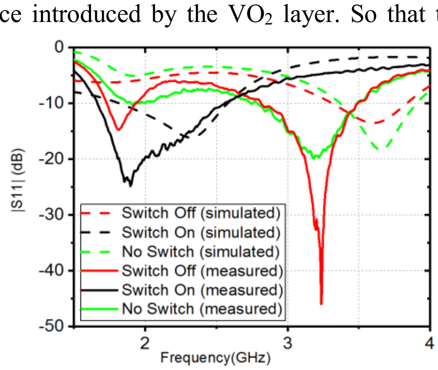

Fig. 3. The reflection coefficient of the antenna at two switch modes.

without VO_2 switch is simulated and measured as a reference. The S_{11} of the antenna is less than -10 dB in the frequency band of 1.8-2.6 GHz when the switch is at "on" mode, and in the frequency band of 3.3-3.8 GHz when 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 1.7-2.5 GHz when the switch is at "on" mode. As expected, the antenna in the frequency band of 2.75-3.5 GHz when the switch is at "off" mode as similar to the one without the VO_2 layer. Fig. 4 plots measured radiation pattern of the antenna at the frequency of 3.5 GHz. The antenna maximum gain is 1.58 dBi.

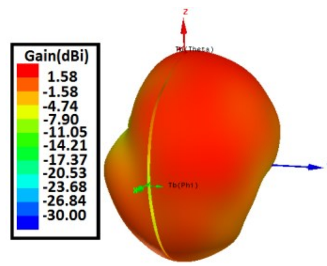

Fig. 4. The measured radiation pattern.

III. CONCLUSION

This work presents a low cost fully printed frequency reconfigurable PIFA 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 WiFi (2.45 GHz) and 5G (3.5 GHz) bands when the switch is at "on" or "off" mode. In the future work, the VO_2 switch RF characterization will be further studied and the reconfigurable antenna performance will be optimized.

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