Fully Inkjet-printed Tunable Flexible Microfluidic Chipless RFID Sensor

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***Abstract*—In this paper, a tunable flexible microfluidic-based sensor is proposed. The sensor is fabricated using fast, cost-effective, and environment friendly multilayer inkjet printing techniques. Three spiral resonators with microfluidic channels are designed in three different frequencies, each resonator can be tuned individually to encode 3bits information by changing the liquid in the microfluidic channels. The proposed flexible microfluidic RFID sensor can be used for applications such as liquid analysis, healthcare monitoring and wireless sensing.**

***Keywords*— flexible electronics, inkjet printing, microfluidics, resonator, RFID.**

I. Introduction

Nowadays, the desire for chipless Radio Frequency Identification (RFID) have continuously growing due to it's low cost, reduced complexity, and fully passive features [1]. However, a main disadvantage of traditional multi-resonator RFID tags usually have fixed resonate frequencies that cannot be modified or individually tuned. Microfluidics is an emerging technology that has wide range of applications in biological analysis and chemical synthesis [2]. Introducing microfluidic channels into multi-resonator chipless RFID sensors enables unprecedented capabilities for individual frequency tunability that makes the sensor reconfigurable or "encodable". Usually microfluidic channels are fabricated with photolithography and associated technologies. However, these techniques are primarily subtractive and expensive. Inkjet printing is an additive manufacturing technique featuring no material waste, fast prototyping and low equipment cost. So it becomes a promising alternative to fabricate chipless RFID and microfluidics.

This paper builds on the previous research of [3] by introducing a compact design and improved fabrication process. This new RFID sensor has better repeatability, more accuracy and easier to fabricate. The presented RFID sensor has three slot spiral resonators resonate at frequency 3.4 GHz, 4.5 GHz and 5.9 GHz. Each resonator has an embedded microfluidic channel. By filling or removing the liquid in each channel, three resonate frequency can be tuned independently which enables 3bit encode capability.

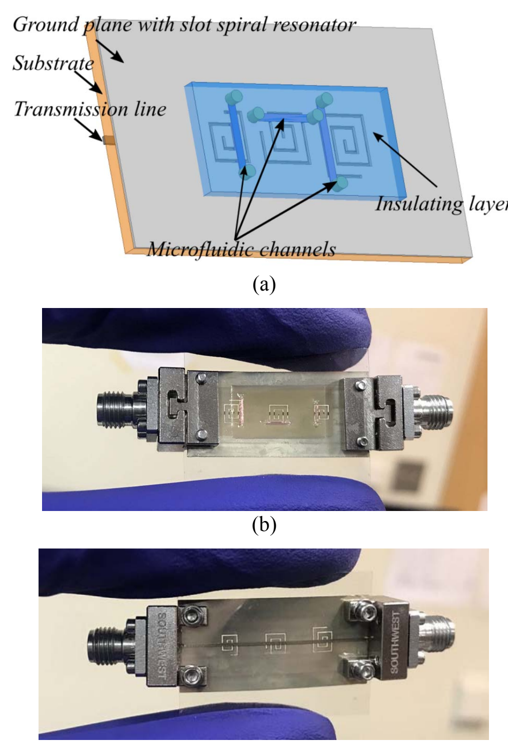

Fig. 1. (a) Design of the microfluidic RFID sensor, (b) Fabricated sample (front), and (c) Fabricated sample (back).

II. Design and Experiment

A. Theory of Operation

The design of the microfluidic RFID sensor is shown in Fig. 1(a). A fabricated prototype is shown in Fig. 1(b) and Fig. 1(c). Three slot spiral resonator has different size, so they resonate at different frequency. Microfluidic channels are placed in the spiral's gap between adjacent turns, and they are filled with air in idle status. When a liquid such as water is added to a channel, the change of dielectric constant from 1 (air) to 80 (water) [4] on top of the resonator will cause a frequency decreasement due to capacitance variation. Three idle resonate frequencies represent code '000'. Each frequency shift caused by filling liquid will change the bit from 0 to 1 respectively.

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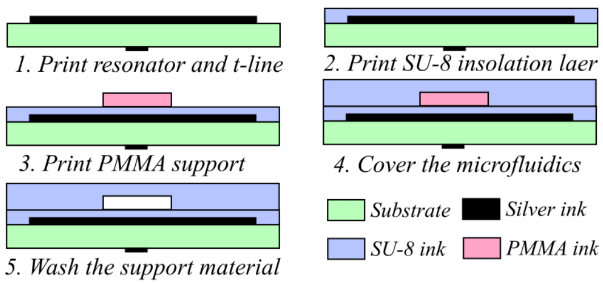

Fig. 2. Fabrication process for the microfluidic RFID sensor.

B. *Fabrication Process*

The fabrication process is shown in Fig. 2. The sample was printed on a MELINEX ST505 PET substrate using Dimatix DMP-2800 inkjet printer. First, the ground plane with slot spiral resonator was printed on top, the transmission line was printed on the bottom with SunChemical EMD5730 silver nanoparticle ink, and sintering at 150^{o}C for 1 hour. Then 3 layers of SU-8 was deposited to insulate silver traces from the test fluids. After cross-linking the SU-8 with UV light and heat, a 65-um-high 500-um-wide PMMA traces are printed as microfluidic support material. After drying the PMMA at 120^{o}C for 1 hour, another 3 layers of SU-8 was printed on top to cover the PMMA traces. Finally the sample was immersed in anisole solution for 2 hours to remove the PMMA traces.

Compare to the fabrication process in [3], the substrate only sintered once in the new process, this reduces the substrate shrinkage caused by high temperature, so the chance of damage the microfluidic channel during sintering is dramatically reduced. Meanwhile, reduced number of layers will increase fabrication accuracy because less alignment was performed during the printing. Also, the transmission line is placed on the back side away from the microfluidic channels, this eliminates the error caused by accidently spread liquid onto transmission line when filling the microfluidic channel.

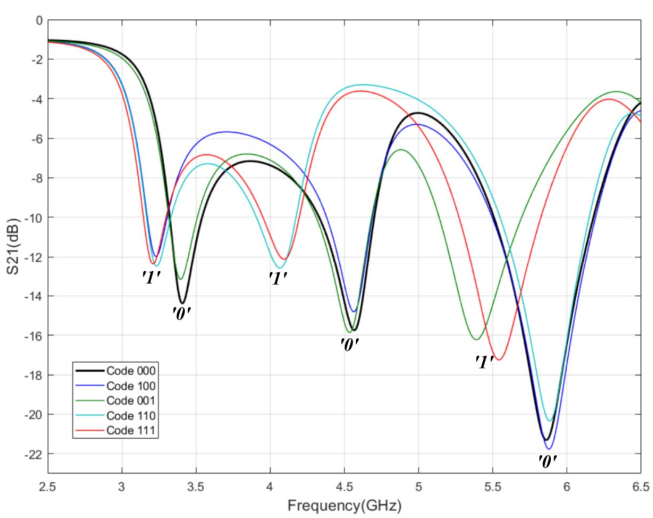

Fig. 3. Simulated insertion loss vs frequency.

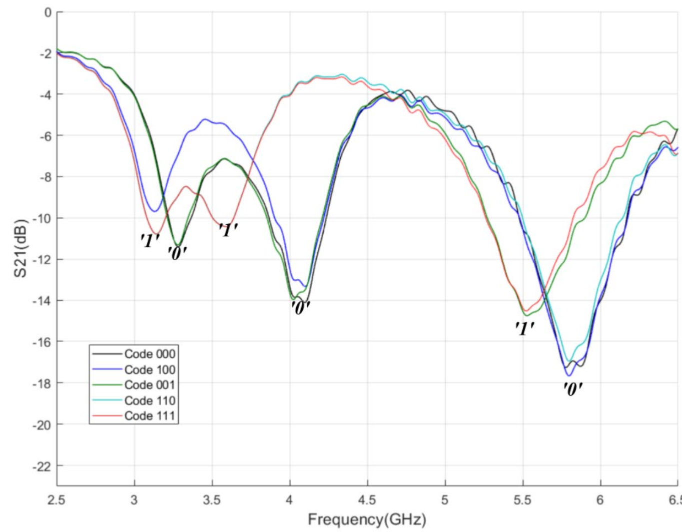

Fig. 4. Measured insertion loss vs frequency.

C. *Simulation and Measurement Results*

The design was simulated in Ansys HFSS. An Anritsu 37369A vector network analyzer was utilized to measure the insertion loss. As shown in Fig. 3, Fig. 4, the measurements verify the simulation results. The code of the RFID sensor can be tuned by selectively add or remove liquid from microfluidic channel. The channel can be adjusted individually, in pair as well as in triplet.

III. Conclusion

This work propose a novel fully inkjet-printed tunable flexible microfluidic chipless RFID sensor with encode capability. The improved design and process decrease the chance of failure while speed up fabrication cycle. This RFID sensor can find applications in liquid analysis, healthcare monitoring and wireless sensing, etc.

Acknowledgment

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