Low-Cost Microfluidics-Enabled Tunable Loop Antenna Using Inkjet-Printing Technologies

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***Abstract*—A low-cost and disposable loop antenna is proposed, which consists of a microfluidics-enabled tunable square loop and a microfluidics-enabled tunable balun to guarantee a similar radiation pattern over a reconfigurable "liquid-controlled" frequency range. By inserting different fluids over partial sections of the loop and the balun, the proposed antenna can achieve a frequency range of 2.28 GHz for water filled channel to 2.45 GHz for empty channel. The proposed antenna is fabricated in a low-cost and non-cleanroom process by integrating inkjet-printing with laser-etching techniques. This antenna can be used as a fluid sensor for biomedical or chemical assay, as well as a tunable antenna for communication applications. The microfluidics-enabled tunable embedded balun can be applied independently as a wideband balun for various communication, sensing and biomonitoring applications.**

***Index Terms*—microfluidics, tunable antenna, loop antenna, tunable balun, inkjet printing, additive manufacturing**

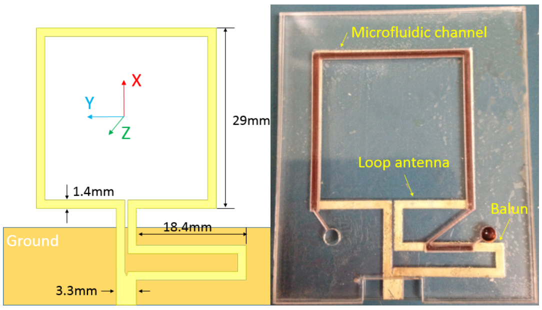
I. INTRODUCTION

Microfluidics is an emerging technology that is widely used in manufacturing control, biomedical sensing, chemical assay and lab-on-chip applications, due to its capability of manipulating extremely small quantities of liquid. Traditional microfluidics devices are fabricated with photolithography and associated technologies [1], which is environment unfriendly. However, there is an increasing number of novel and low-cost fabrication approaches. By integrating inkjet-printing microfluidics and laser etching techniques, a low-cost, zero-chemical treatment process has been developed [2]. A photo-paper substrate was originally used in additively fabricated microfluidics, which has low endurance, high dielectric loss and absorbent property. On the other hand, poly(methyl-methacrylate)(PMMA), a low-cost, transplant material with lower dielectric loss, is ideal for microfluidics fabrication.

Recently, microfluidics was embedded into electronics devices [3] [4]. While most microfluidic RF devices loading the fluids in capacitive gap to achieve reconfigurable capacitance, another way to tune the resonating frequency is changing phase velocity. Though capacitive gap sensors feature better sensitivities in general, proposed sensing mechanism have their own advantages, such as conformable shape between channel and RF pattern. Furthermore, a wideband balun is useful in reconfigurable antenna applications. An microfluidic tunable balun is introduced which can be an alternative to the conventional wideband balun in various communication and sensing applications. In summary, this work aims to demonstrate a microfluidics-enabled tunable loop antenna which is fed by a microfluidics-enabled tunable balun using low-cost additive manufacturing techniques.

II. DESIGN AND EXPERIMENT

A. Principle of operation



(a) (b)

Fig. 1: Structure of the loop antenna(a) and photo of fabrciated device(b)

Loop antenna is well-known as a magnetic dipole. A square loop is designed, as shown in Figure 1(left). The 0.5mm-height and 1.4mm-width microfluidics channel is located right on the top of loop as shown in crimson in Figure 1(right). When different fluids is filling the channel, the permittivity of the fluids will effectively control the electrical length of the loop, and thus will determine the resonating frequency of the loop. To feed the loop antenna with a coaxial cable, a balun is built with a power divider and two microstrip line with phase different. The microfluidics channel is placed right on the top of electrically longer transmission line. Similar to the working principle of the top of loop, the permittivity change in the microfluidic channel will lead to a frequency shift. The balun's frequency shift is carefully calibrated by adjusting the coverage of microfluidic channel over the balun, to guarantee the similar efficiency over the reconfigurable frequency range.

B. Fabrication

The structure consists of two pieces of 1.5mm thick PMMA sheets. An Epilog Legend 36EXT laser was used to etch the channels and feed holes into the first sheet of PMMA. A Dimatix DMP-2800 series printer was used to inkjet print 5 layers of EMD5730 SunTronic Jettable silver ink. The ink was cured by laser at 24Watts as PMMA cannot endure the high temperature normally used to cure the ink. Then, 3 layers of polymer (SU-8) were printed over the second PMMA sheet, working as an adhesive between the sheets as well as an isolation between the fluids and the metallization. After exposed to $300mJ/cm^2$ UV, the two PMMA sheets are pressed together at $10N/m^2$ and heated up to 80C for 5min.

C. Simulations and Measurements

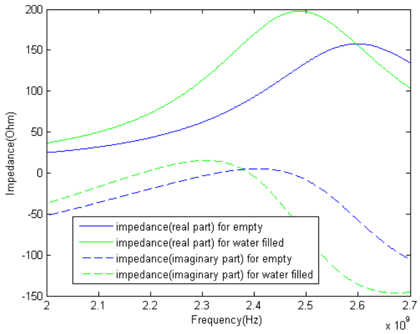


Fig. 2: Real and imaginary part of the loop antenna impedance

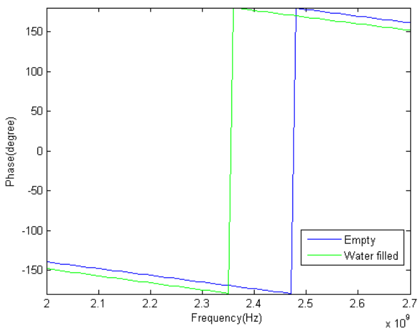


Fig. 3: Phase difference between two branches of balun

The loop antenna and the balun is simulated with ANSYS high frequency structural simulator (HFSS) independently, and then combine together to optimize the performance. In Figure 2, the zero imaginary part frequency shift from 2.42 to 2.3 GHz when permittivity change from 0 to 73, as water permittivity is 73 [5], while real part of impedance at resonate frequencies is still around 100 Ohm. The phase difference is optimized with the opening of loop to be around 175 degree and have same phase difference around resonate frequencies of the antenna for empty and water filled channel. The simulated return loss and radiation patterns are shown in Figure 4 and Figure 5, respectively, which demonstrates similar antenna radiation for empty channel and water-filled channel situations. Due to influence of the ground plane in feed circuit, radiation patterns lean up in E plane and lean to right in H plane a little as expected. The fabricated device is then measured by a VNA. A frequency shift from 2.45 GHz with empty channel and 2.28 GHz with water filled channel can be observed, showing a good agreement with simulation results.

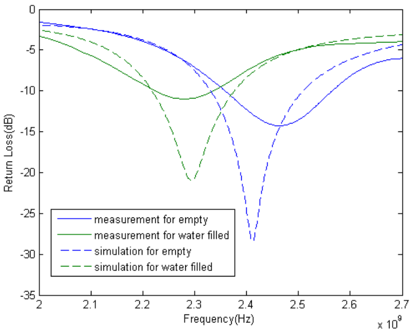
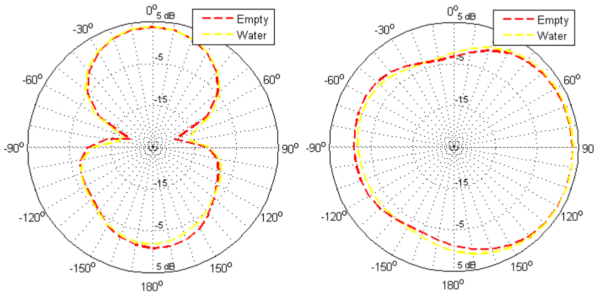


Fig. 4: Return loss



(a)

(b)

Fig. 5: Radiation pattern on E plane(a) and H plane(b)

III. CONCLUSION

A microfluidic loop antenna utilizing a low-cost inkjet-printed microfluidics platform with a frequency range of 2.28 GHz for water filled channel to 2.45 GHz for empty channel is proposed, with potential application as a fluid sensor as well as a tunable antenna. A microfluidic tunable balun is designed to guarantee effectively the similar radiation performance (radiation pattern and efficiency) over the reconfigurable frequency range.

ACKNOWLEDGMENT

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