A Novel 3D and Inkjet Printed Pressure-sensing Button-shaped Resonator

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***Abstract*—In this paper, a novel 3D and inkjet printed pressure-sensing button-shaped resonator is proposed. The button is fabricated using fast, cost-effective, flexible and environment friendly stereolithography (SLA) 3D printing and inkjet printing techniques. The resonant frequency of the button can be tuned from 2.7 GHz, for idle status, to 1.6 GHz, for a hard press. This design can be used for applications such as gesture detection for Internet of Things (IoT) devices and wireless pressure monitoring for buildings and constructions.**

I. INTRODUCTION

In recent years, additively manufactured electronic sensors have attracted an increasing amount of attention due to their low-cost, fast prototyping, and potential for large-area applications such as Internet of Things (IoT) [1]. Under this concept, different manufacturing methods have been developed, including stereolithography (SLA) 3D printing and inkjet printing techniques. SLA is an optical-based 3D printing technology that uses laser as energy source to cure light sensitive resin layer-by-layer to realize 3D structures. This technique has large number of printable materials with high optical resolution, thereby making it a superior candidate for electronic applications compare to other 3D printing technologies such as Fused Deposition Modeling (FDM) [2]. Inkjet printing technology can create complex conductor patterns in a fast, low-cost manner. It doesn't require a clean room and complex procedures as conventional circuit fabrication process need. Combining inkjet printing with SLA 3D printing technology can achieve a great design flexibility on substrate shape as well as conductor patterns for electronic applications.

Generally, to interact with an IoT device through a button will only provides two options: on and off. This paper proposed a button shaped pressure sensitive resonator that can detect gestures from a gentle touch to a hard press. The frequency response can vary from 2.7 GHz (idle status) to 1.6 GHz (a hard press), enabling numerous potential applications on control a device such as brightness adjustments, volume control, pressure monitoring, etc.

II. DESIGN AND EXPERIMENT

The design of this pressure sensitive resonator is shown in Fig.1. The sensor itself is a spiral resonator projected onto a 'bulge' to form a button-like structure. The resonator is fed by a transmission line with a extended branch to enhance coupling that improves return loss performance [3].

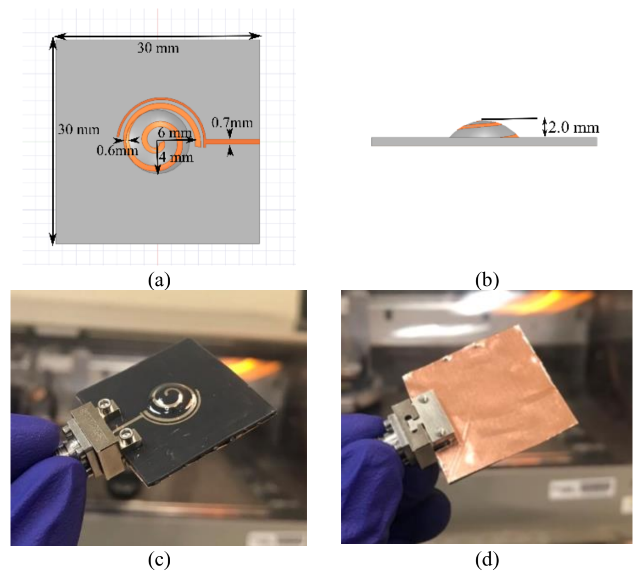


Fig. 1. Design of pressure sensitive button slaped resonator: (a) dimention of the design, top view, (b) dimention of the design, side view, (c) fabricated sample, top view, (d) fabricated sample, bottom view.

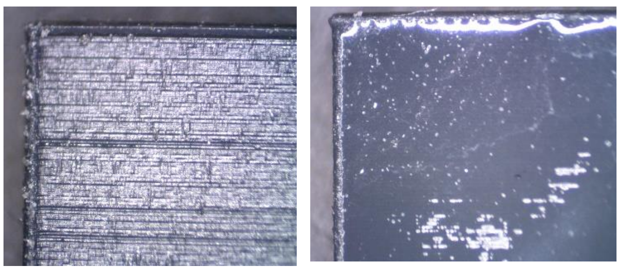
A. *Theory of operation*

When the bulge is pressed, distance between the spiral resonator and the ground plane will reduce respect to the pressure intensity. The reduced distance will change the capacitance between conductor layer and the ground plane, as a result, resonate frequency should decrease with the pressing force.

Meanwhile, when the spiral resonator is pressed with human finger, the contact area between the skin and resonator will increase with the pressing force. Human finger typically has a dielectric constant close to water, the change of dielectric from 1.0 (air) to 60 (finger) on top of the resonator will also cause a frequency decreasement. Combining the capacitance and dielectric constant variation, the resonate frequency should decrease dramatically respect to the pressure.

B. Fabrication Process

The substrate is 3D printed using Formlabs Form 2 SLA printer. The utilized material is Formlabs Flexible (FLGR02) resin. This flexible material is a rubber-like elastomer with 7.7-8.5 MPa tensile strength and 80% elongation [4]. The characterized dielectric constant is 2.78 with loss tangent 0.06. The layer thickness during this process is 50 um. The printed substrate is post processed with isopropyl alcohol (IPA) washing and UV curing system. The IPA washer will remove extra resin left on printed samples. While the UV curing system with heater will further cure the photopolymer to ensure the best structure strength. The utilized wash time is 10 minutes with 99% IPA, the cure time is 15 minutes at 60°C.



(a) (b)

Fig. 2. Surface modification results: (a) 3D printed substrate without surface modification. (b) smoothed substrate surface after modification.

Surface roughness of 3D printed substrate needs to be improved before printing the spiral resonator. The 50um resolution of 3D printed substrate is still a rough surface compare to 0.8um thickness of one layer printed silver nanoparticle (SNP) conductor. The cured substrate will be manually coat a thin layer of photopolymer resin, and cure in UV crosslinker for 30 seconds to get a smoothed surface (Fig. 2).

The conductor is fabricated using SunChemical EMD5730 silver nanoparticle (SNP) ink with Dimatix 2800 inkjet printer. 20um drop space (1270 dpi) is adopted for this process. To improve the SNP ink adhesion, 90 seconds of ultraviolet (UV) ozone treatment is performed before printing conductor patterns [5]. The SNP ink is sintered using a low temperature sintering process to prevent 3D printed substrate damaged by heat. The sample was place on a hot plate at 90°C for 30 minutes to dry the pattern completely. Then increase the temperature to 120°C, hold for 15 minutes to sinter the pattern without breaking substrate.

C. Simulation and Measurement Results

The design was simulated in Ansys Electronics Desktop 19.1 with HFSS. In order to measure the reflection coefficient of the sample, a Anritsu 37369A vector network analyzer was utilized. As shown in Fig. 3, the measurements verify the simulation results. By pressing the resonator with gentle force, harder force and finally press it all the way down, the frequency response shift from 2.7 GHz to 1.6 GHz, thus demonstrating a good sensitivity of the device. There are some mismatch between simulated and measured results, the mismatch can be improved by accurately characterize the permittivity of 3D printed material and human finger in future works.

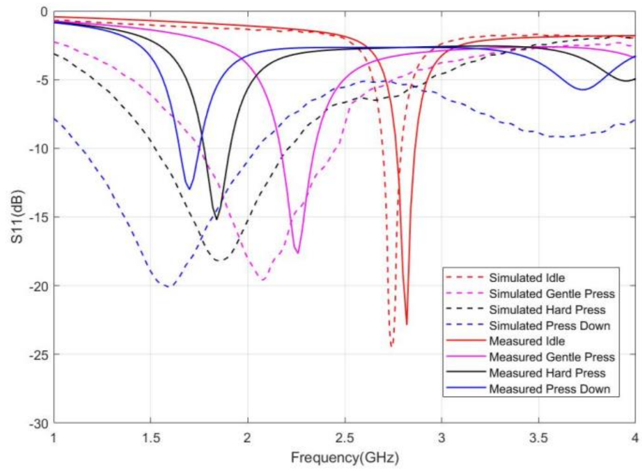


Fig. 3. Simulated and measured reflection coefficient vs frequency.

III. Conclusion

This work propose a novel printed pressure-sensing button-shaped resonator which demonstrates a high range of frequency tunability as well as excellent pressure sensing performance. The results shows a good approach to make low-cost, flexible, environment friendly electronic devices by combining 3D printing and inkjet printing technologies.

Acknowledgment

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