# A Flexible Printed Complementary Split-Ring Resonator based Chipless RFID

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***Abstract*—A fully inkjet-printed flexible chipless RFID is presented in this paper. It consists of a regular microstrip transmission line on the top plane that is coupled with two back "etched" slit-ring resonators called complementary split-ring resonators (CSRR) on the ground plane. The CSRRs resonate at around 2.3 GHz and 3.4 GHz, respectively. The design is characterized in both simulations (ANSYS HFSS) and experiments. The future application of this RFID will focus on sensing where one resonator will be utilized as the sensor, and another one will be used as the reference.**

***Index Terms*—Chipless RFID, complementary split-ring resonator, flexible electronics, printed electronics.**

## I. Introduction

Compared to traditional electronic fabrication methods, the flexible printed electronic (PE) technology has the advantage of low-cost, high throughput, and better bio-medical compatibility. It has already demonstrated its effective performance in numerous applications, such as thin-film transistor (TFT), biomedical sensor, antenna design, and radio-frequency identification (RFID) tag [1].

With the development of Internet of Thing (IoT), the RFID tag has become essential for logistic item tracking [2] and sensing [3]. In contrast to common RFID tags, chipless RFIDs do not have any embedded integrated circuit (IC) for the data encoding. They have the benefit of even lower cost due to the absence of ICs. They are solely based on passive components, which are more compatible with the printing technology than active elements. Finally, as they are passive, they do not need any internal power source, which makes them attractive for embedded applications.

For the application of tracking and sensing in the real world situation, bendable or flexible chipless RFID tags will be preferable due to the geometry variation of the attached/embedded objects. In this paper, a passive chipless RFID is presented. It is based on complementary split-ring resonator (CSRRs), which are coupled to a 50 Ω transmission line. The RFID is compact and produced at low-cost using PE technology. It has the potential for low-cost sensing such as food spoilage and environment monitoring.

## II. Design Methodologies

A complete block diagram of the chipless RFID system is shown in Fig. 1, where the interrogating signal is sent

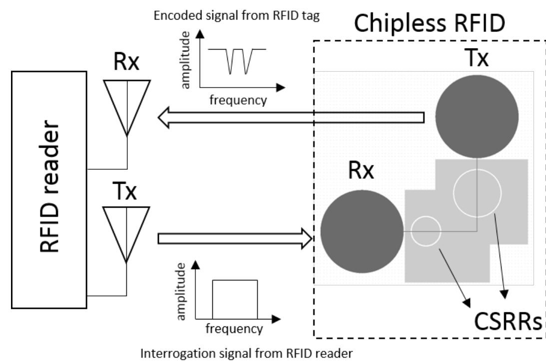


Fig. 1: A complete diagram of the chipless RFID sensing system, where $Rx$ and $Tx$ are the receiving and transmitting antenna, respectively.

from the RFID reader to the chipless RFID tag. The tag will then transmit the encoded signal back to reader for the further information processing. In this work, we focus to demonstrate the chipless RFID part without the antennas. To print flexible electronics, selection of the printing technique, substrate material and conductive ink is crucial. Among many printing methods, inkjet printing has a better resolution and ink-flow-rate control [1] that makes it a perfect candidate for this design. A 5 $mil$ Dupton Kapton Polyimide film is chosen as the flexible substrate due to its excellent electrical properties ($\epsilon_r = 3.4$ and $tan\delta = 0.002$). The flexible conductive ink ($\sigma$ = $1{\times}10^6$ $S/m$) and the inkjet printer are from *Voltera*. The inkjet printer has a supported resolution of 200 $\mu m$ and a deposited ink thickness around 50 $\mu m$. To obtain $Z_0 = 50$ Ω, the width of the microstrip line is 250 $\mu m$, which is close to the supported resolution of the printer.

CSRR is selected as the resonator topology here due to its simplicity and printing friendliness. A common single CSRR geometry is shown in Fig. 2 (a). It has been shown that CSRR behaves electromagnetically like a $LC$ resonator [4]. The resonate frequency of a CSRR is described by $f_0 = 1/(2\pi\sqrt{L_{CSRR}C_{CSRR}})$, where $L_{CSRR}$ and $C_{CSRR}$ are the inductance and capacitance of a CSRR, respectively. We proposed that CSRRs on the ground plane and the microstrip transmission line on the other. This topology works out with

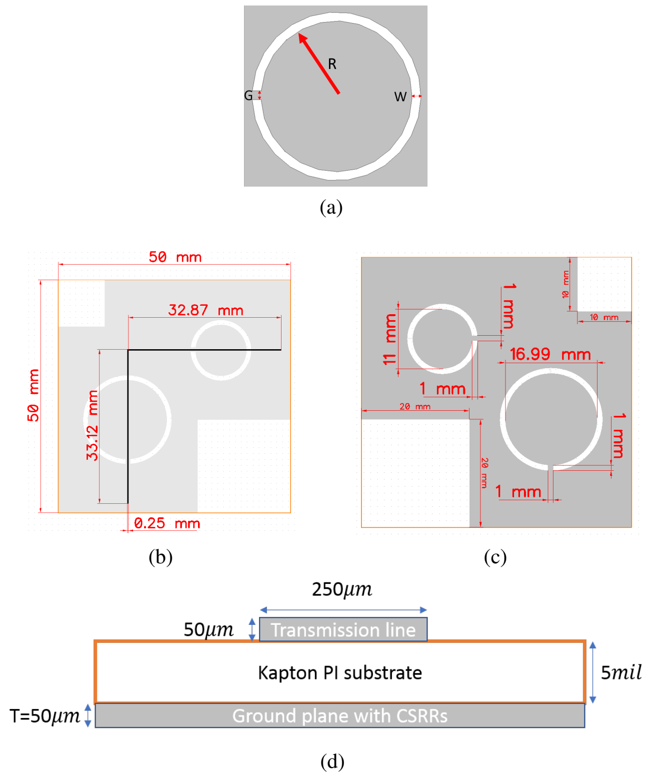


Fig. 2: Dimensions of the proposed design. The white colour represents the substrate and the grey colour represents the conductive layer; (a) a common CSRR structure; (b) the top plane, where the transmission line is aligned with the CSRRs at the ground plane in the center (the light grey colour shows the ground plane conductive layer); (c) the ground plane with the CSRRs; (d) the cross-section view.

the printer resolution while sustaining the coupling between the CSRRs and the transmission line. For sensing applications, $f_0$ of one resonator (sensing) will be varied while $f_0$ of the other resonator (reference) will not be changed with the measurand. Thus, the reference resonator will help us to have a differential sensing or identification of the tag.

## III. Simulation and Measurement

The dimensions of the resonators and transmission line are given in Fig. 2 (b)-(d). The chipless RFID was designed and simulated in ANSYS HFSS. The design was then printed and baked in an oven at 200 °C for 30 minutes to remove the solution and dispersants in the conductive ink. The final prototype is presented in Fig. 3, where the SMA connectors were cold-soldered onto the substrate by the conductive silver epoxy after the baking.

The $|S_{21}|$ parameter of the prototype is then measured by a vector network analyzer (VNA) and plotted together with the HFSS simulation curve in Fig. 4. The measured resonances of two CSRRs match well with the simulation. The decreasing of the quality factor of the resonances are mainly contributed by the dimension distortion of the transmission line during

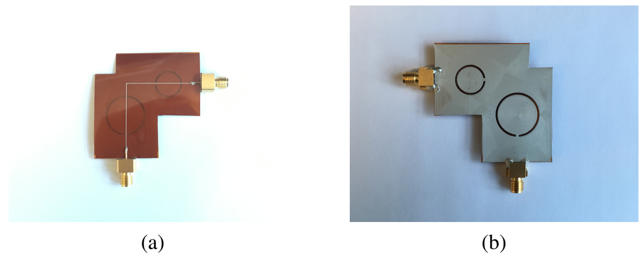


Fig. 3: (a) Top plane of the prototype; (b) ground plane of the prototype, together with CSRRs.

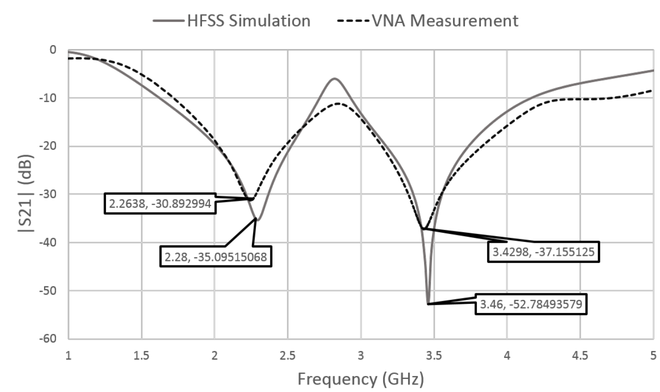


Fig. 4: $S_{21}$ response from the measurement (dash line) and HFSS simulation (solid line).

printing and the thickness uniformity issue of the printed conductive layer on the Kapton.

## IV. Conclusion

A fully inkjet printed chipless RFID is presented. Its manufacture method and flexibility make it unique compared to traditional chipless RFIDs. The agreement between the simulation and measurement result shows the reliability of the printing technology. The future work will involve incoopering sensing ability and the antennas to operate it wirelessly.

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