Design Chipless Textile Tag for RFID Application

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Abstract. This paper presents a chipless textile tag for RFID application. The CST microwave studio was used to design the chipless textile RFID tags which consist of three, four, and five slotted ring resonators nested in the circular patch. The RFID tag also fabricated using shieldit super fabric as conductive patch plane and the polyester fabric as substrate. The designed tags can operate over 1 GHz to 3 GHz frequency ranges. Each of the slot ring resonators are generate different reflection coefficient spectrum. The larger the slot ring create a resonate frequency at lower frequency. The measured and simulated results of the different slot ring chipless textile RFID tags are discussed.

1. Introduction
RFID is an abbreviation for Radio Frequency Identification. It is one of the encouraging technological innovation. It uses radio frequency to identify and locate certain objects or persons. RFID can be used in many applications such as asset tracking, military, human rescue, healthcare, etc. [1], [2]. Nowadays, consumers want to use light, small and thin items in their daily life so that they can easily bring it to anywhere they want. RFID tags will be placed on the assets or items that want to be tracked. RFID tag is not only can track items but it also can be used on the wildlife and person that want to track. Due to this application, RFID tag also are demand in small size, light and thin [3]. RFID technology is not widely used in the grocery shop and mall due to the cost of RFID tag. Barcode is still an option to grocery shop and mall as a medium to identify items and obtain information of the items that have been encoded in the barcode. RFID tag consist of a silicon chip that store its unique identification and an antenna to receive and transmit back the signal [4]. Therefore, many researches have been conducted and focus to decrease the cost of RFID tag. Thus, chipless RFID tag have been proposed as a one of solution [5].

Chipless RFID tag is a microstrip based device. It consists of two layers which is known as patch and substrate layer. The materials used for patch and substrate layer in RFID tag is same as other microstrip based device. The material for patch layer is copper while the material for substrate layer
are FR-4, Roger and Taconic [6]. In the patch layer, resonators are nested in the patch so that it can encoded the signal coming from the reader and transmit back. The encoded signal represents the unique identification of the chipless RFID tag. Due to the use of resonator that replace the function of silicon chip in the conventional RFID tag, the cost of chipless RFID tag can be reduced [7].

In order to make a RFID tag which meet all this requirement demand by the consumers, a chipless RFID tag is proposed. A chipless RFID tag is microstrip based tag. The material used as its substrate plane play the important role to meet the requirements. For chipless RFID tag, the material usually used for substrate plane is FR4, Taconic and Rogers. This material is light but it is not thin and flexible for the use of human tracking and wearable purposes. Textile is chosen to replace the FR-4, Taconic and Roger as the substrate material. The design of the chipless textile tag must be small in size, thin, and light so that it is comfortable to the wearer and can be easily used in RFID application.

2. Material of chipless textile tag
Two material have been chosen for the patch and substrate plane. One is the Shieldit super as conductive fabric for patch plane. The Shieldit super fabric is a high-quality flame-retardant fabric plated with conductive nickel and copper for radio frequency and microwave shielding. Figure 1 shows the Shieldit Super fabric.

![Figure 1. Shieldit super fabric.](image1)

Another material is polyester fabric use as substrate plane shown in Figure 2. Polyester fabric is used due to its chemical resistant, easily to retain shape and have low moisture absorption. The feature of polyester is critical for comfortless of the wearer. Fabricated three slotted ring and four slotted rings of chipless RFID tags shown in Figure 3. Table I shows the properties of the Shieldit super (patch plane) and polyester fabric (substrate).

![Figure 2. Polyester fabric.](image2)
Figure 3. Fabricated chipless RFID tag (a) three and (b) four slotted ring.

Table 1. Parameter of patch and substrate

| Type                  | Parameter        | Value          |
|-----------------------|------------------|----------------|
| Shieldit Super        | Thickness        | 0.17 mm        |
| (patch plane)         | Conductivity     | $1.18 \times 10^5$ s/m |
| Polyester fabric      | Thickness        | 0.39 mm        |
| (substrate)           | Dielectric       | 1.90           |
|                       | Constant[8]      |                |
|                       | Loss Tangent[8]  | 0.0045         |

The conductivity of Shieldit Super is referring to its datasheet while the dielectric constant and loss tangent of polyester fabric is measured by open ended coaxial probe. The value of dielectric constant and loss tangent of polyester is measured by using Portable Network Analyzer (PNA) [9], [10]. The dielectric properties of polyester fabric are measured five times, and the average values are used to define the value of dielectric constant and loss tangent of the polyester fabric.

3. Design of the tag

The chipless textile RFID tag consists of two planes that is substrate and patch plane. This type of RFID tag did not have ground plane due to the design is slot resonator based [11]. The substrate plane has a reasonable size which is 10 cm x 10 cm. A circular-shaped patch made from Shieldit Super is designed above the substrate plane. Slot resonators which represent the ID of the chipless textile RFID tag will be nested in the circular-shaped patch. Figure 4 shows the design of the three chipless textile RFID tag.

Figure 4. Design of the chipless textile RFID tag.
The circular shape patch has a diameter of 88 mm and 5 slots nested in it. Each slot has a width of 2 mm. Overall thickness of the chipless textile tag is 0.56 mm. Table 2 shows the dimension of chipless textile tag. The outer slot is the biggest slot. The slot will become smaller when it comes to origin point of the circular-shaped patch. The outer slot is the first slot and define as S1, the second slot is defined as S2 and so on.

| Parameter                  | Value (mm) |
|----------------------------|------------|
| a (width of slot)          | 2          |
| Radius of S1 (first slot)  | 40         |
| Radius of S2 (second slot) | 35         |
| Radius of S3 (third slot)  | 30         |
| Radius of S4 (fourth slot) | 25         |
| Radius of S5 (fifth slot)  | 20         |
| Circular patch             | 44         |
| Thickness of substrate     | 3.7        |
| Thickness of patch         | 1.9        |

4. Results and Discussion

The chipless textile RFID tag is measured by using monostatic radar method. A broadband horn antenna A-INFOMW P/N:LB-8180-NF which can support from 0.8 GHz up to 18 GHz where used as transmitter. It can cover the operation frequency of the chipless textile RFID tag over 1 GHz to 3 GHz frequency range. The broadband horn antenna connected to Performance Network Analyzer (PNA) using coaxial cable. Figure 5 shows the illustration of the measurement setup. The chipless textile tags are placed in front of the broadband horn antenna. The distance of the chipless textile tags from the broadband horn antenna is 10 cm. A polystyrene board is used as a supportive material to hold the chipless textile tag in front of the broadband horn antenna due to its low reflective capabilities [12].

![Figure 5. Illustration of measurement setup.](image)

4.1. Simulated results of the chipless textile RFID tag

The identification of the chipless textile tag is represent by the presence of dips in reflection coefficient (S\textsubscript{11}) graph. The presence of dips is determined by the slot resonator nested in the circular patch of the chipless textile RFID tag. This is a phenomena where there have a gap between conductive material allows the proper elements to perform like a narrow band-pass filter [13]. The slot resonators will be produced dips at certain frequency in reflection coefficient (S\textsubscript{11}) graph. Figure 6 shows the design of chipless textile RFID tag which hold its unique ID. The frequency that the dips
fall is depend on the size of the slot resonators. Slot resonator with bigger size will generate dip at lower frequency. The smaller the size of slot resonator, the higher the frequency of generated dips. The spectrum in reflection coefficient graph will represent bit 1 and 0. Bit 1 symbolize by the existence of dip while bit 0 symbolize if there is no existence of dip. Figure 8 shows the relationship between the spectrum and tag ID.

Figure 6. The designed chipless textile RFID tags represent unique ID.
4.2. Comparison between the simulated and measured result of the chipless RFID textile tag

The measured dips for all the chipless textile tags that had been tested occurred shifting in their spectrum from the simulated dips. This can occur from the fabrication error. After the fabrication process, the dimensions of the chipless textile tag is slightly changed. The change in dimensions after the fabrication process is quite minor. Although it is minor, the results will greatly change as it depends on the dimensions of the tag. The value of dielectric constant of the polyester fabric is not so accurate because the value is not obtained by measured process. Every fabric has its own value of dielectric constant. Different value of dielectric constant can affect reflection coefficient ($S_{11}$). The value of dielectric constant has been measured using Portable Network Analyzer (PNA). The measured and simulated results are slightly difference, but the resonate of the measured results is close to the simulated performance. These measured results show frequency shifted compare with the simulated results, this error may cause by the free space measurement.

Figure 7. The relationship between the spectrum and tag ID.
Figure 8. Simulation vs Measured result of chipless textile tag with ID of (a) 11111, (b) 10111 and (c) 10101

5. Conclusion
As a conclusion, the slot ring resonators play an important role to the chipless textile RFID tag in order to generate the unique identification of the tag. From the measured and simulated results, the relationship between the slot ring resonators and the reflection coefficient ($S_{11}$) spectrum can use as a guideline for designing chipless RFID tag based on slot resonators mechanism. The size of the ring slot indicate difference resonate frequency which can define as different ID. The larger the ring slot the lower resonate frequency.
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