Comparison of Conductive Ink Optimization Techniques for Body-Mounted RFID Tags

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Abstract- This work aims to evaluate the performance of different approaches, which have been employed in achieving conductive ink usage reduction, or optimization for inkjet printed Radio Frequency Identification (RFID) tags and other electromagnetic and electronic devices. Two factors; read range and volume of ink used are then used to formulate a figure of merit, which would be used to determine the best ink usage optimization technique. Three general ink reduction or optimization techniques were considered viz: selective ink deposition, conductive area trimming and use of gridded designs. Figure of merit assessment suggested that even though the longest read range was obtained from the tag that had 48% of its conductive area trimmed off, the best figure of merit was obtained from the tag that had 65% of its conductive area trimmed off.

Keywords: *RFID, Epidermal Tags, Inkjet Printing, Body Mounted Antenna*

1. Introduction

Inkjet printing of body mounted (Epidermal) tags has become more attractive for use in body-mounted devices including RFID tags (Taylor & Batchelor, 2019), sensors, smart devices as well as antennas for application in 5^{th} generation technologies (Gupta & Gupta, 2020). This popularity is due to some inherent benefits of inkjet printing and inkjet printed devices, which include flexibility, ease of fabrication and conformance with surfaces (substrates).

It is however noteworthy that these benefits of inkjet printing of devices can be maximized if production costs are kept at a minimum since there is increasing cost per inkjet printed tag fabricated due to increasing conductive ink volume (Pongpaibool, 2012) and (GEM Ltd, 2020). Some popular methods used to reduce ink usage per tag, which are considered in this work, include selective deposition of ink in high current density area of the RFID tag, trimming off of low current density areas of the tag and use of gridded designs.

This work aims to evaluate the performance of these different approaches while considering the volume of ink used.

2. Methodology

The tag used for this study, which is designed to have peak performance at the EU UHF RFID Frequency band of 865 – 868 MHz, had earlier been presented in (Oyeka et al., 2014). Further design and fabrication details of the tag are as discussed in (Oyeka et al., 2019). The conductive ink used was (Sun Chemicals, 2014) while CST^{TM} Microwave Studio (CST Microwave Studio, 2015) was the electromagnetic simulator utilized. Measurements were obtained with the Tagformance kit (Voyantic, 2021).

For the selective deposition of ink on the tag design, this was informed by simulation which showed high current density around the tag feedline and port area. Consequently, these areas were deemed critical to the operation of the tag. This is shown in Figure 1.

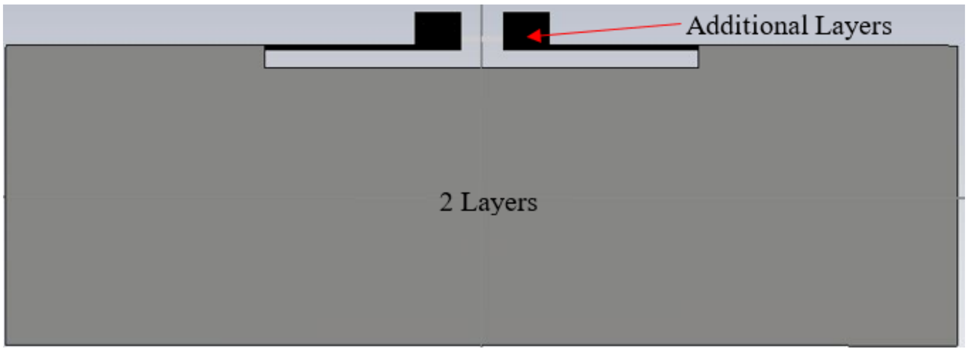
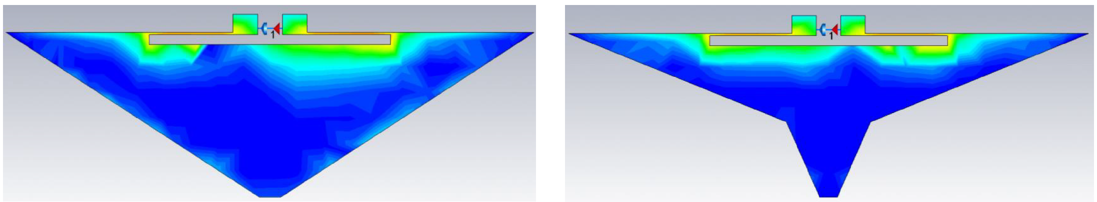


Figure 1: Additional Ink Deposition Regions

This ink optimization technique had three variations: 2 full layers with one additional later on the feedline and ports (2F + 1), 2 full layers with two additional later on the feedline and ports (2F + 2) and 2 full layers with three additional later on the feedline and ports (2F + 3).

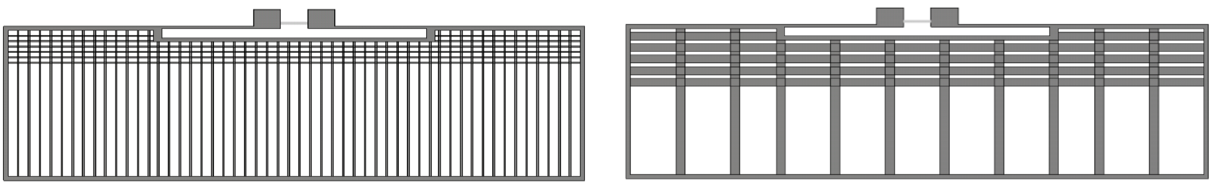
Alternative to selective deposition of ink on high current density areas is to trim off the low current density areas. By doing this, only the high current density areas of the designed tag would be printed. Two samples of this were examined; 'Trim 1' with 48% of the surface area removed and 'Trim 2' with 65% of its surface area removed. Figure 2 show these.



(a) (b)

Figure 2: Trimmed Tags (a) Trim 1 – 48% Trimmed (b) Trim 2 – 65% Trimmed

Two gridded designs were examined for this work; Grid 1 which is a mesh with 0.2mm wide grids and 5mm spacing with 4 horizontal grids in the high surface current area located around the slot and feedline area and Grid 2 which is a meshed design comprising of 1mm wide grids with 5mm spacing and 4 horizontal grids in the area around the slot and feedline area. The gridded tags are shown in Figure 3.



(a) (b)

Figure 3: Gridded Designs (a) Grid 1 (b) Grid 2

3. Results and Discussion

A summary of the obtainable read range and utilized silver nanoparticles by each tag with reference to the full tag is presented in Table 1. The figure of merit was defined as the ratio of the achieved percentage read range with respect to the percentage of conductive ink used for the fabrication of the sample with reference to a full 3-layer tag. Using this approach, a high figure of merit is desirable. 2F + x is used to illustrate the tags fabricated by selective ink deposition with x denoting the number of additional layers on the feed line ($1 < x \leq 3$) and 2F represents 2 full layers of conductive ink.

TABLE 1: COMPARISON OF INK USAGE MINIMIZATION TECHNIQUES

TAG DESIGN	Ink mass (%)	Ag Nanoparticle Mass (%)	Read Range (%)	Fig of Merit
TRIM 1	51	51	88	1.72
TRIM 2	35	34	75	2.14
GRID 1	27	28	52	1.92
GRID 2	44	44	71	1.61
2F + 1	71	71	109	1.54
2F + 2	72	72	117	1.63
2F + 3	73	73	126	1.73

Results from Table 1 show that the tags with selectively deposited ink on the feedline and port provide the best-read range. This however comes at a cost of higher conductive ink quantity use. This accounts for the low figure of merit for these tags with the best being the tag with 3 additional layers on the ports and feedline with FoM of 1.73. The highest read range of 88% was obtained from the Trim 1 tag. However, the trimmed conductive area tag with 65% of its conductive area removed (Trim 2) provided the best conductive ink use and achieved read range balance with the highest figure of merit of 2.14. The least ink utilization was realized with Grid 1 although this also resulted in the most reduced read range measured from any of the tags. Grid 2 was able to achieve 71% of the read range of the original tag with 44% of the conductive ink used for the full 3-layer transfer tattoo tag.

4. Conclusion

Methods to reduce the volume of ink used for the fabrication of the tags were also examined in this paper. These include the selective deposition of ink where simulation showed high current density existed, or trimming off parts of the tag with low current density, and application of meshed designs. These results showed that reasonable read range results can be achieved with a reduction in the amount of ink used. The best read range was achieved when the surface area of the tag was reduced by 48%.

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