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The effectiveness of passive RFID Tags in the presence of charged particles

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ABSTRACT

Passive Radio Frequency Identification (RFID) Tags (also called Transponders) are being widely used in Item Level tracking. This includes shop floor of supermarkets, pallet/items in warehouses and also for luggage tracking at airports. Many of the mentioned operations make use of commercial tags with an operating frequency of 13.6 MHz. Data is transferred to the chip through the antenna from an RFID Reader/Writer which generates a strong EMF.

Published data has shown these Tags can be subject to ESD where the chip can be damaged or have a reduced operational life cycle.

Initial trials have taken place using commercial 13.56 MHz Tags to check the transfer of data during the read cycle. Tags are coated with electrostatically charged particles manually and also using tribo and corona systems. The objective of this study is to monitor if the stored information is either corrupted or attenuated by the presence of the charged particles of powder/dust. The initial results indicate the presence of charged particles attenuates the response with respect to the distance required between the Tag and the reader to allow the data to be read but the actual data is unaffected.

1. Introduction

Radio Frequency Identification (RFID) is an autonomous Identification technique which uses Radio Frequency (RF) to allow the remote reading and writing of data to and from transponders (also known as Tags). The terms transponder and Tag will be used to refer to the same device throughout this document. An RFID system consists of the transponder which is attached by various means to the object to be identified and the reader which may be able to read or read/write data to the transponder.

The reader consists typically of a transmitter and receiver, a control unit and a coupling element (antenna) to interact with the transponder. Readers may also have an additional interface such as RS232, USB etc. to communicate data with another system such as a PC.

The transponder contains at least an Integrated Circuit (IC) and also an antenna. The transponder is the part of the system which stores the data. The IC stores and processes the data and also handles modulation and demodulation of the Radio Frequency signal. The transponder may be passive, active or semi-passive. Passive Tags do not have their own power supply. They rely on the reader's RF signal to supply the required signal [1–3].

Typical commercial systems operate at:

- 125 KHz systems, known as Low Frequency (LF), they are normally inductively coupled and have a range of a few centimetres. Typically used for Animal Identification.
- 13.56 MHz systems, known as High Frequency (HF) are also inductively coupled and can have a range of tens of centimetres. Used for Passports, Payment Cards, in Libraries, Access Control, Inventory systems and Product tracking [4,5].
- Ultra High Frequency (UHF) systems, typically 868 MHz (Europe) and 915 MHz (USA) use backscatter coupling and can achieve a range greater than one metre. Used for Product tracking, Inventory systems, Payment systems, etc.

The commercial Tag and Reader used in these trials were rectangular with average dimensions of 40 mm × 70 mm. Because they were rectangular it was essential to test the alignment and in the trials the orientation was varied and readings taken when they were parallel and crossed.

2. Experimental method

To simulate charged particles/dust, the triboelectric effect is used to charge powder. Firstly talcum powder is used to simulate the particles/dust. Talcum powder is hydrated magnesium silicate. The powder bottle which is made from high density polyethylene is shaken vigorously. From field mill observations the bottle is charged negative with the powder positive. The powder was then liberally sprinkled onto the Tag which is primarily an insulator. It

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Table 1
Summary of Test Methods.

Method	Method description	Tests description	Alignments	Charged particles
1	Talcum powder, shaken in bottle (tribo)	Induced voltages at set distances with note of first read.	Crossed and Parallel	Positively charged particles
2	Epoxy/polyester powder and Triboelectric spray gun	Induced voltages at set distances with note of first read.	Crossed and Parallel	Positively charged particles
3	Epoxy/polyester powder and Corona spray gun	Induced voltages at set distances with note of first read for coating on Antenna side and Substrate side.	Crossed and Parallel	Negatively charged particles

was observed that the powder did not adhere to the surface. The Tag surface was then modified by applying a thin layer of detergent which was allowed to dry before powder was applied (Method 1 as shown in Table 1). This technique is to partially improve the electrical properties of the Tag surface which improved the deposition.

The reader software was limited and we were unable to write data to the transponder (Tag) beforehand to test for data corruption. However the transponder's identification number is already stored in an allocated memory block on the IC. Data corruption could be ruled out if the reader could identify the transponder's unique id.

Read distance tests were achieved by decreasing the distance between the Tag and the Reader and recording the separation 'first read' i.e. the distance when the reader is able to read the Tag identification number. The RF induced voltage (V_I) was measured using an oscilloscope to in the transponder's antenna. The alignment of the Tag and the Reader was also adjusted between Crossed and Parallel as indicated in Table 1.

Powder coatings were also made using conventional tribo and corona guns with epoxy/polyester powder. As the Tag surface was insulating the surface again was initially prepared by applying a similar coating of detergent and allowing the surface to dry. With tribo systems the powder is positively charged where as for the corona system the powder is negatively charged.

Crossed Aligned: The Tag and Reader antennas are at 90° with each other. Less of the antenna cross sections are aligned.

Parallel Aligned: The Tag and Reader antennas are at 0° with each other. Most of the antenna cross sections are aligned.

3. Experimental results

The range for the Tags had a theoretical maximum of 75 mm. Figs. 1 and 2 show the induced voltages measured using the oscilloscope method with and without a coating of talcum powder. The alignment of the Tag and Reader was varied for the two orientations Crossed and Parallel.

Talcum powder was applied to the surface of the Tag after vigorously shaking the powder in the container producing a thin layer of powder. Measurements of the induced voltage show there is a significant reduction with a powder layer for both orientations. In comparing the results for no powder it is observed that for a crossed orientation of 90° the induced voltages are approximately 5 mV higher than for the parallel orientation (0°). This shows that while the effect of the particles can be measured in terms of the induced voltage, the Tag receives its required induced voltage at shorter distances to power the Tag IC which in turn affects the 1st read distance which is shown by the "1st read" arrows in the figures. An error margin of ±5 mV should be taken into

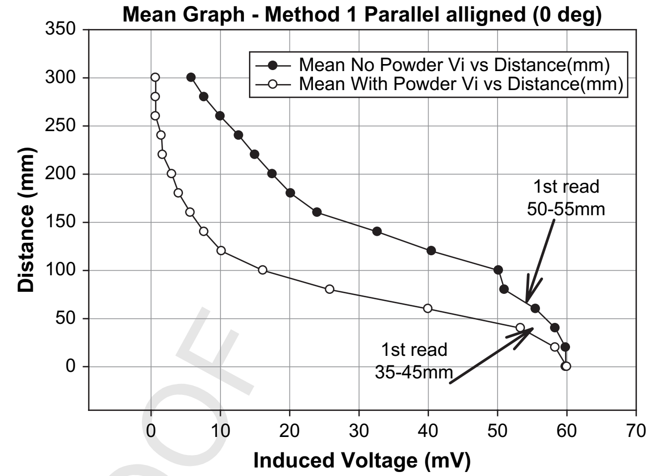

Fig. 1. Effect of a coating of Talcum Powder on Induced Voltages, Method 1, Parallel.

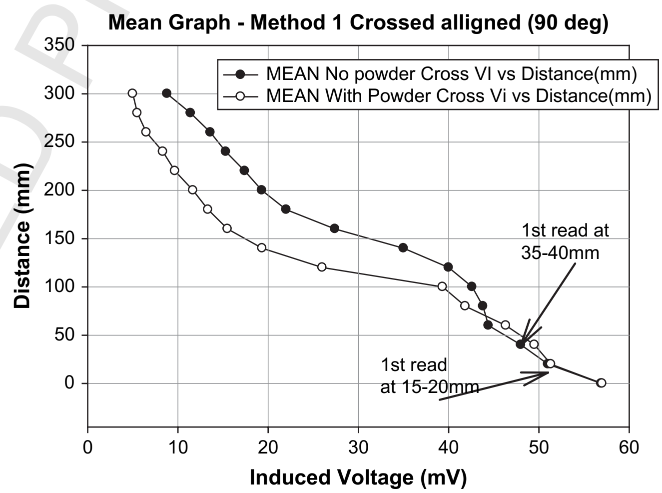

Fig. 2. Effect of a coating of Talcum Powder on Induced Voltages, Method 1, Crossed.

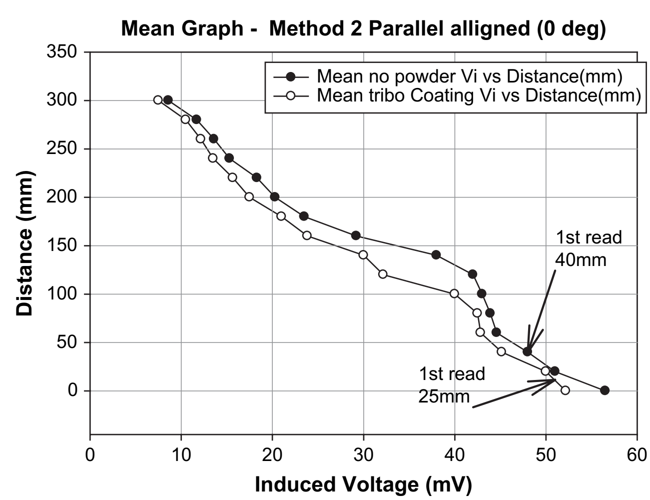

Fig. 3. Induced Voltage Measurements with a positive Powder Coating from a Tribo Gun Method 2, Parallel (0°). Q4

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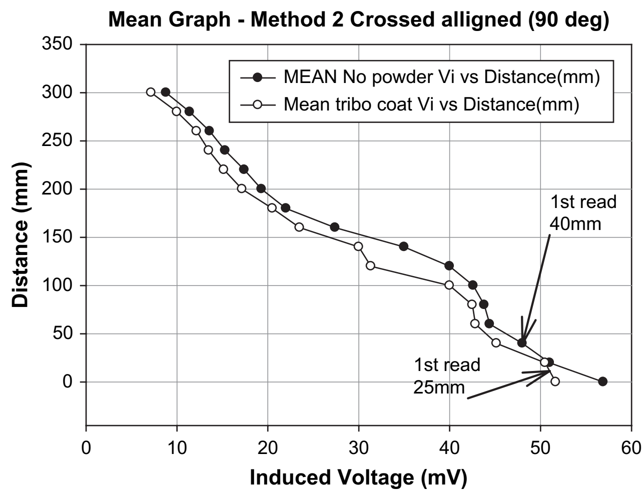

Fig. 4. Induced Voltage Measurements with a positive Powder Coating from a Tribo Gun Method 2, Crossed (90°).

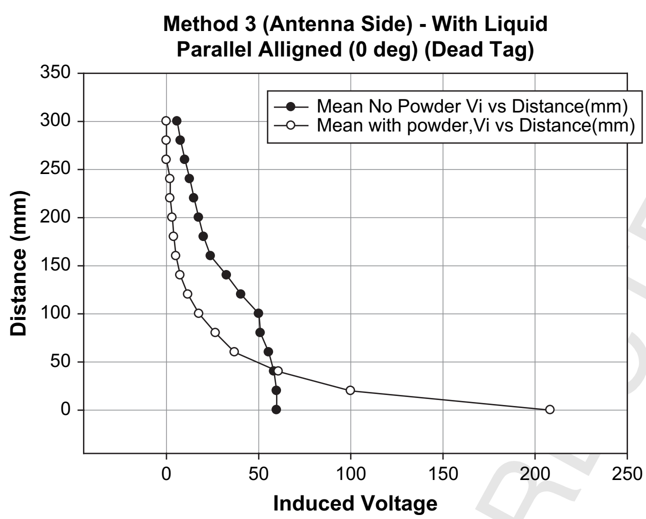

Fig. 5. Induced Voltage Measurements with a negative Powder Coating from a corona gun at −60 kV Method 3, Parallel (0°). (Dead Tag).

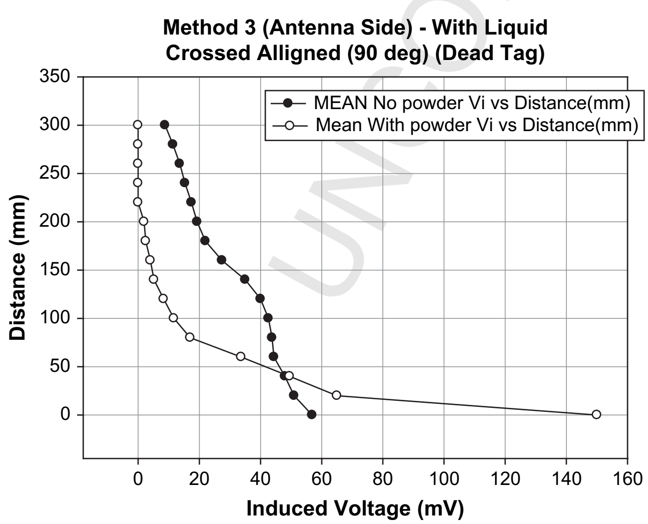

Fig. 6. Induced Voltage Measurements with a negative Powder Coating from a corona gun at −60 kV Method 3, Crossed (90°). (Dead Tag).

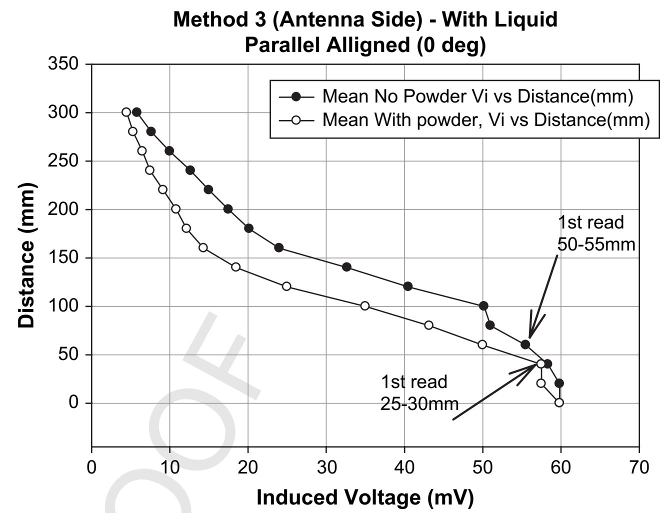

Fig. 7. Induced Voltage Measurements with a negative Powder Coating from a corona gun at −60 kV Method 3, Parallel (0°). Coating on the Antenna Side.

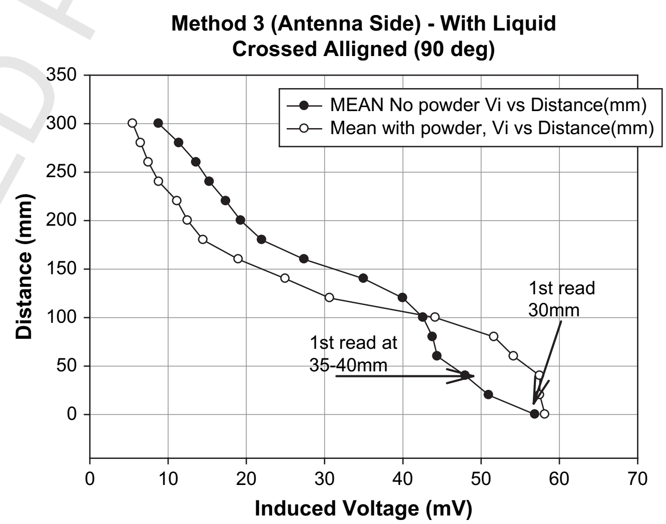

Fig. 8. Induced Voltage Measurements with a negative Powder Coating from a corona gun at −60 kV Method 3, Crossed (90°). Coating on the Antenna Side.

consideration due to the range of the oscilloscope used to measure the induced voltages. This applies to all the induced voltage measurements.

The results from a powder layer using a tribo spray gun are illustrated in Figs. 3 and 4. We can see that these are virtually identical for both parallel and crossed aligned Tags, the marginal differences are mainly at the higher set distances. The difference in the Induced Voltage between a coated and non coated Tag is between 0 mV and 10 mV. By visual analysis of the figures we can deduce that the actual difference is around 2 mV. We can still see the difference in the read distances. This was not as expected as it was assumed the tribo gun would induce a greater charge in the particles than the talcum bottle method.

To test the effect of negatively charged particles the Tag was similarly coated with a thin layer of water/detergent and allowed to dry producing a conducting surface. An industrial powder coating gun was used to deposit a layer or epoxy/polyester powder at an operating voltage of −60 kV. Figs. 5 and 6 illustrate the

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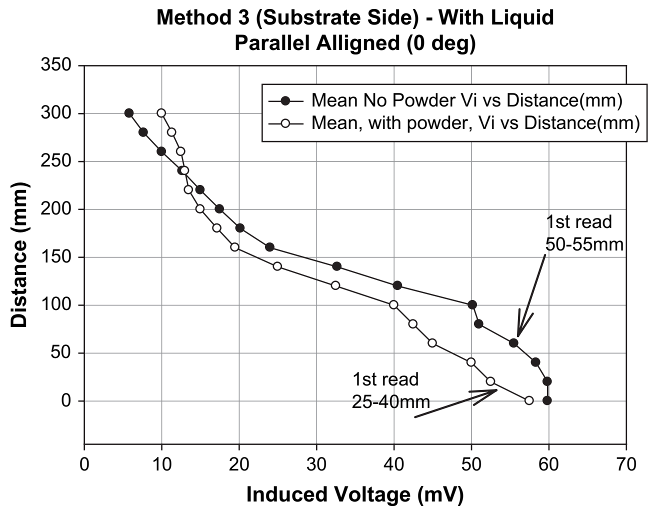

Fig. 9. Induced Voltage Measurements with a negative Powder Coating from a corona gun at −60 kV Method 3, Parallel (0°). Coating on the Substrate Side.

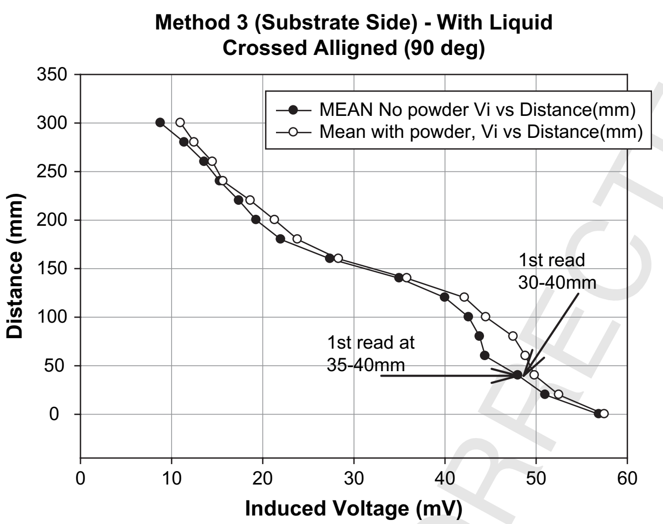

Fig. 10. Induced Voltage Measurements with a negative Powder Coating from a corona gun at -60 kV Method 3, Crossed (90°). Coating on the Substrate Side.

measurement of the induced voltage for both alignments of the Tag and Reader.

Published data has shown RFID Tags can be subject to electrostatic discharge. The results shown in Fig. 5 indicate the Tag is dead. It was not possible to deduce if this was due to the negative charged powder or if the Tag was dead before the experiment was carried out. A repeat experiment with a crossed alignment also indicated the Tag was dead. It was decided to coat a known working tag to confirm if failure was due to the corona coating. The results are illustrated in Figs. 7 and 8.

From Figs. 7 and 8 we can see that the Tag does indeed function after a corona coating. This does not rule out the failure of the previous Tag to be due to the corona coating as we cannot be sure it was a dead Tag before the coat was applied. To confirm the failure of the Tag due to the static discharge, the experiment would have to be repeated several times, which has not been undertaken as yet.

Figs. 9 and 10 illustrate results from corona coatings on the substrate side of the Tag. All previous results have been of antenna side coatings. The difference in induced voltages from the crossed aligned Tag is very small compared to the parallel aligned Tag. The induced voltage results give a clear indication of the differences in performance with and without the different powder coating together with the effect of alignment. The real performance of an RFID system date is not influenced by the shape of the curves at high separations (say >50 mm) as this represents the maximum operating range for the device under test. The transmission of digital data indicated as the 1st read observation in all the figures is the most significant information. A compilation of this data is presented in Table 2.

4. Conclusion and discussion of results

The method of application of the Talcum powder did not produce a continuous layer as was experienced with both of the regular spray systems. Excess Talcum powder was removed prior to any measurement. The electrostatic performance from both spray systems is well documented where the specific charge is typical 2×10^{-3} C k[illegible]r epoxy/polyester powder with resistivity of 10^{12}–10^{13} Ωm [6]. The quality of the coating onto the Tag demonstrated a satisfactory layer after the surface was modified by the inclusion of a conducting film. Q2

Measurement of the induced voltage is an indication of the performance of Tags. The results obtained show the effect of charged particles on the 1st reading of the RFID system. From Table 2 the parallel configuration is more effective than the crossed alignment. We can see a the percentage reduction in the 1st reading for both spray guns is 38% while for Talcum the reduction is variable. The Tag under investigation had a maximum reading range of up to 55 mm. The data shown in Table 2 also indicates the range of the system is significantly reduced for all the tests when charged powder was deposited on the Tag either on the antenna side or the substrate side.

The objective of this study was to investigate if there was any significant effect in the performance of Tags in the presence of charged particles. The results clearly demonstrate a significant reduction in the operational range to receive the digital transmission of the identification code. As both commercial spray systems reliably produce electrostatically charged particles it can

Table 2
The 1st read of Data Transmission.

Alignments	Talcum powder (+ve)		Triboelectric spray gun (+ve)		Corona spray Gun (−ve)	
	No Powder (x_0)	With Powder (x_p)	No Powder (x_0)	With Powder (x_p)	No Powder (x_0)	With Powder (x_p)
Crossed	35–40 mm	15–20 mm	40 mm	25	35–40 mm	30 mm
Percentage reduction $100(x_0-x_p)/x_0$	53%		38%		21%	
Parallel	50–55 mm	34–45 mm	40 mm	25	50–55 mm	30–35 mm
Percentage reduction $100(x_0-x_p)/x_0$	25%		38%		38%	

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be concluded there is qualitative confirmation of reduced performance of RFID Tags in the presence of charged particles.

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