Exploring the Correlation Between Drug Formulation and Radio Frequency Performance in RFID-Enabled Pharmaceutical Product Packaging

The Axia Institute: Delivering Value Chain Solutions®
MICHIGAN STATE UNIVERSITY

Axia LAB

Ethan Claucherty, Danielle Cummins, & Bahar Aliakbarian

Introduction

Radio Frequency Identification (RFID) is a burgeoning technology pivotal for optimizing intricate supply chains. Although its potential benefits in healthcare and pharmaceuticals are substantial, RFID implementation in these sectors has been slow-moving. This study aims to explore the influence of diverse liquid drug formulations on RFID performance, utilizing a pre-optimized Ultra High Frequency (UHF) RFID tag. Five distinct drug formulations encompassing water, saline, and lipids, were studied alongside deionized (DI) water and empty vials as control subjects. The products were transferred to separate vials, each affixed with a pre-optimized UHF RFID tag. Performance evaluations, including Threshold Sweep, Orientation Sweep, and Population Analysis, were conducted to assess tag readability, focusing on Sensitivity, Backscatter, and Theoretical Read Range. The tests were performed in a C50 Anechoic Chamber equipped with Tagformance® Pro software both made by Voyantic. The results underscore how composition of different pharmaceutical drug formulations significantly impact RFID tag readability in a controlled, reflection-free environment. These findings provide valuable insights for designing intelligent packaging to enhance the readability of RFID-tagged pharmaceutical products.

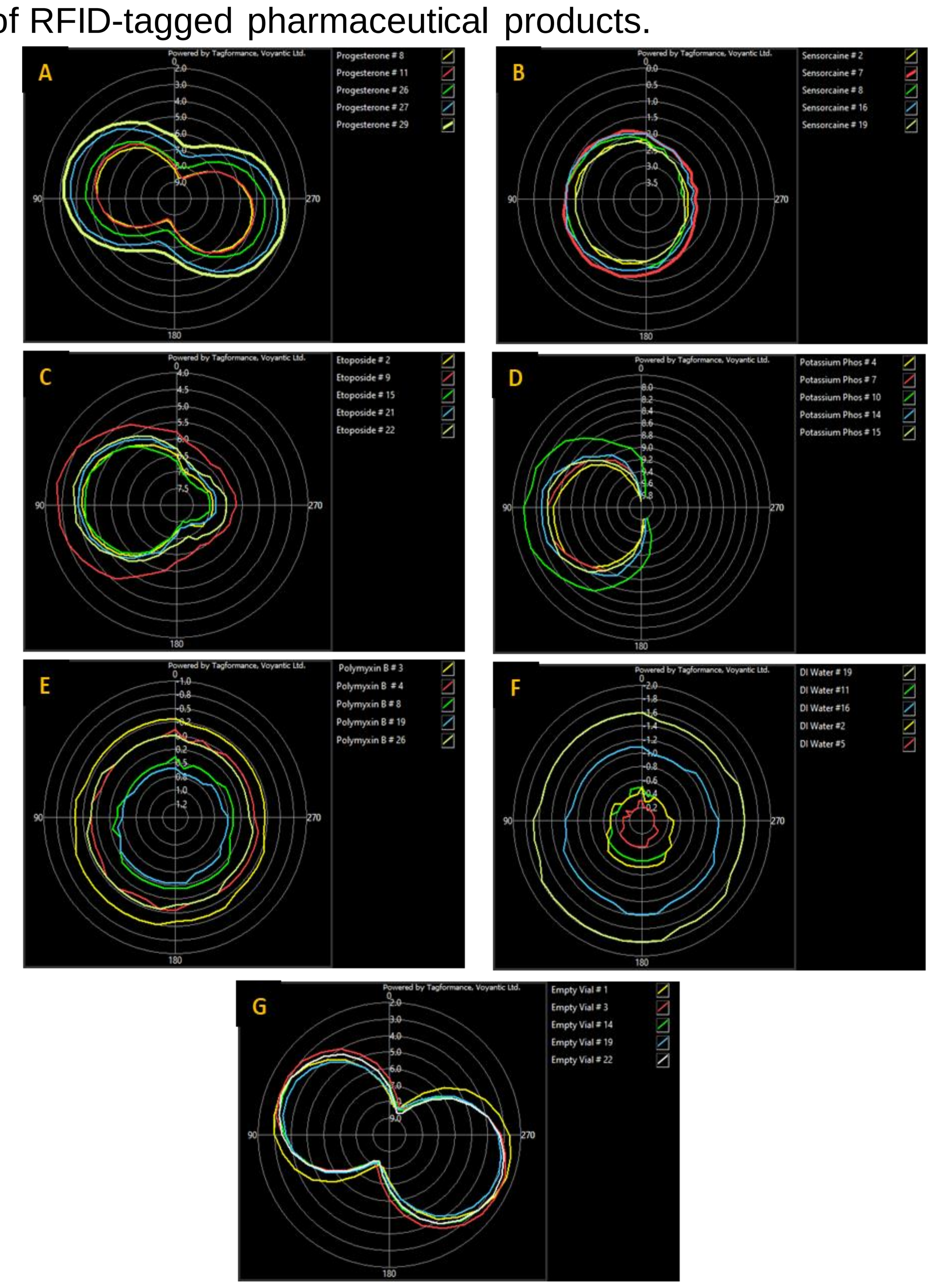


Figure 1: Orientation Sweep showing the Power on Tag Forward (PoTF) or tag Sensitivity of (a) Progesterone, (b) Sensorcaine, (c) Etoposide, (d) Potassium Phosphate, (e) Polymyxin B, (f) DI water, and (g) Empty vial. Five samples were tested for each product and angle.

Orientation Sweep

This test documents a tag's radiation pattern at different angles. Briefly, five vials of each solution were randomly selected to obtain the Power on Tag Forward (dBm). Figure 1 shows the results for each solution. The best performing solution was DI water that demonstrated an omnidirectional radiation pattern, emitting radiation equally in all directions. The worst performing were the vials filled with Potassium Phosphate, which failed to produce results for 15 angles. This substance exhibited a severely bidirectional pattern, strongly emitting radiation in only two directions.

Threshold Sweep

The threshold sweep analysis was performed between a range of 800 MHz and 960 MHz. The test was performed on a single vial of each drug and the results can be seen in Figure 2. It was found that regarding sensitivity, the best performing substance was DI Water, and the worst performing substance was Potassium Phosphate. Another Threshold Sweep was performed on 30 vials of each solution, results can be seen in Figure 3. These results confirmed the preliminary sweep, DI water performing best with Backscatter values ranging between -22.53 and -22.85 dBm, and Sensitivity values fluctuating between -0.67 and -0.97 dBm. The worst performing being Potassium Phosphate with Backscatter values ranging between -38.05 and -39.30 dBm, and sensitivity values changing between 8.31 and 9.67 dBm. Liquids are known to cause attenuations on RF waves as they absorb energy; however, the variations in the results is likely because of the raw materials used and differing ion concentrations in each solution.

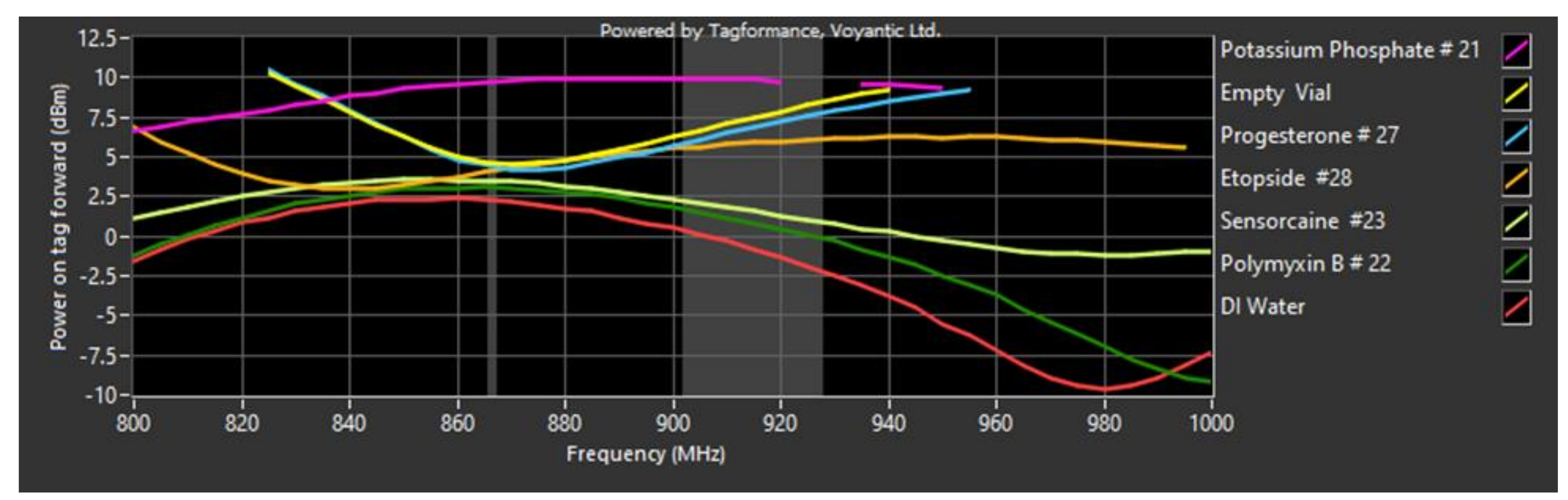


Figure 2: threshold sweep from 800-960 MHz showing tag sensitivity for each solution

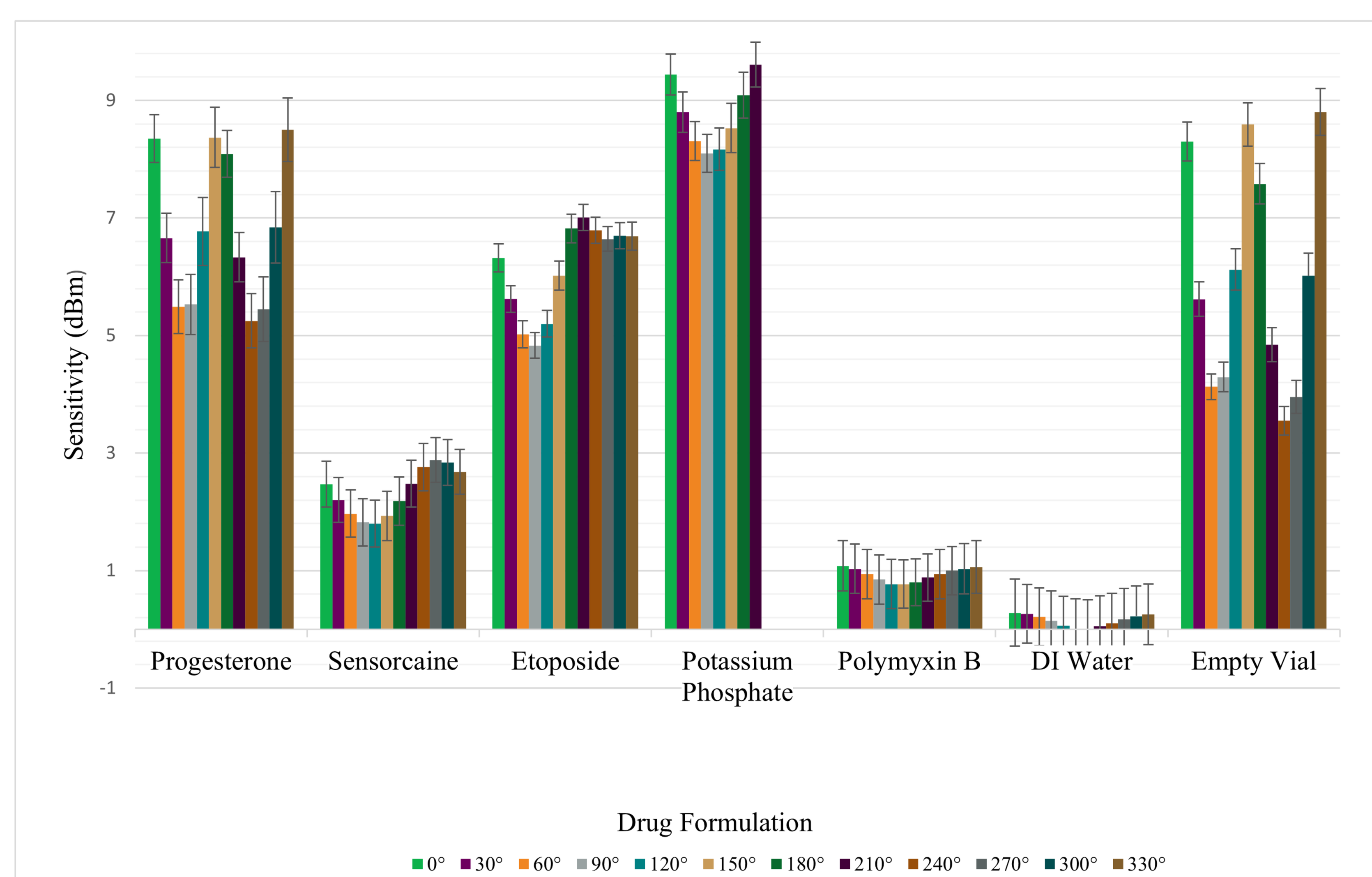


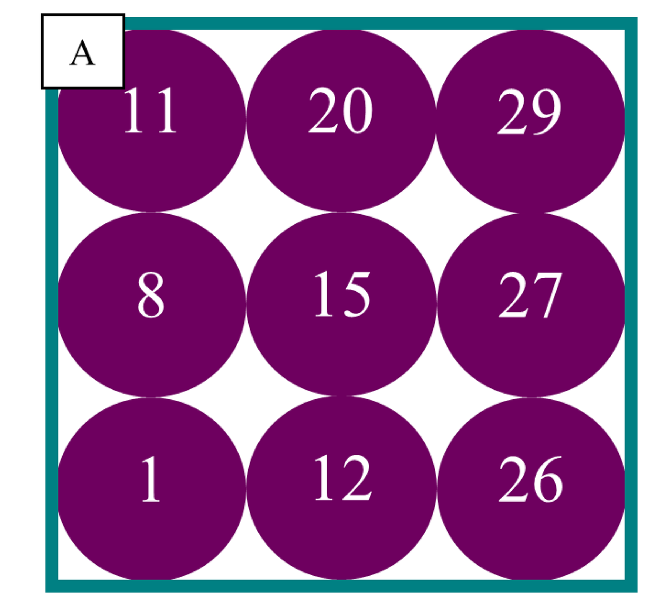
Figure 3: Tag sensitivity with standard deviations (dBm) for 30 vials of each solution

Theoretical Read Range

This value is the maximum interrogation distance between reader and tag. Five vials of each solution were randomly selected to test for the theoretical read range forward. The solutions performed similarly to the Threshold Sweep with DI Water performing the best with a read range of 1.71 m at 180°, and Potassium Phosphate performing the worst with four dead zone values for angles following 240° and a read range of 0.57 m at 90°.

Population Analysis

This test assess a tag's readability individually and, in a population. Nine vials of each solution were randomly selected and placed close to each other. An example of the setup and resulting values can be seen in Figure 4 and the overall results for each drug can be seen in Table 1. All Transmitted and Received Powers increased in a population for all solutions, likely due to ambient RF power reflecting off other tags. This would suggest that tags in larger populations would perform better; however, this behavior would have varied results depending on how many tags are in the population and how densely they are packaged together.



	Population A		
	Tag ID	Tx Power (Dbm)	Rx Power (Dbm)
Antenna 1	1	25	-62.1
	11	N/A	N/A
	12	22	-58.8
	15	22	-59.2
	20	N/A	N/A
	26	23	-61.5
	27	23	-63.2
	29	27	-68.8
	8	24	-64.4

Figure 4: An example of Population Analysis set up with Transmitted (Tx) and Received (Rx) Power (dBm) for Progesterone

Table 1: Transmitted (Tx) and Received or Backscattered (Rx) Power ± standard deviation (dBm,) of the vial closest to antenna 1 in a population of nine as well as alone for all solutions

Transmitted (Tx) & Received (Rx) Power				
Drug Formulation	Single Vial in Population of Nine (dBm)		Single Vial (dBm)	
	Tx Power	Rx Power	Tx Power	Rx Power
Progesterone	23 ± 0.00	-63.30 ± 0.10	27 ± 0.00	-68.7 ± 0.12
Sensorcaine	17 ± 0.00	-50.16 ± 0.05	22 ± 0.00	-52.42 ± 0.04
Etoposide	21 ± 0.00	-55.12 ± 0.04	26 ± 0.00	-62.36 ± 0.05
Potassium Phosphate	25 ± 0.00	-55.28 ± 0.04	30 ± 0.00	-60.96 ± 0.17
Polymyxin B	16 ± 0.00	-42.5 ± 0.00	21 ± 0.00	-44.2 ± 0.00
DI Water	14 ± 0.00	-45.7 ± 0.00	20 ± 0.00	-45.8 ± 0.00
Empty Vial	25 ± 0.00	-66.44 ± 0.11	28 ± 0.00	-69.3 ± 0.25

Conclusions

Five drug formulations were tested to assess their effects on RFID tag performance, the controls of this study being DI water and an empty vial. The performance tests executed were a Threshold Sweep, Orientation Sweep, Theoretical Read Range Analysis, and a Population Analysis. Overall, the solution that performed the best was the DI water and the worst performing solution was consistently Potassium Phosphate. This finding verified that the influence of material composition was a significant factor on RF performance. The results of the Population Analysis hint at the potential of increasing performance in large populations; however, further research is required to understand the extent of this finding.

Acknowledgements

This work was funded by Fresenius Kabi. The internship of the D.C. to work on this project was funded by the Axia Institute – Michigan State University. Special thanks eAgile for providing RFID tags for this project.