Impedance Matching of RFID Tags to Maximize Read Range & Optimization of Antenna Design

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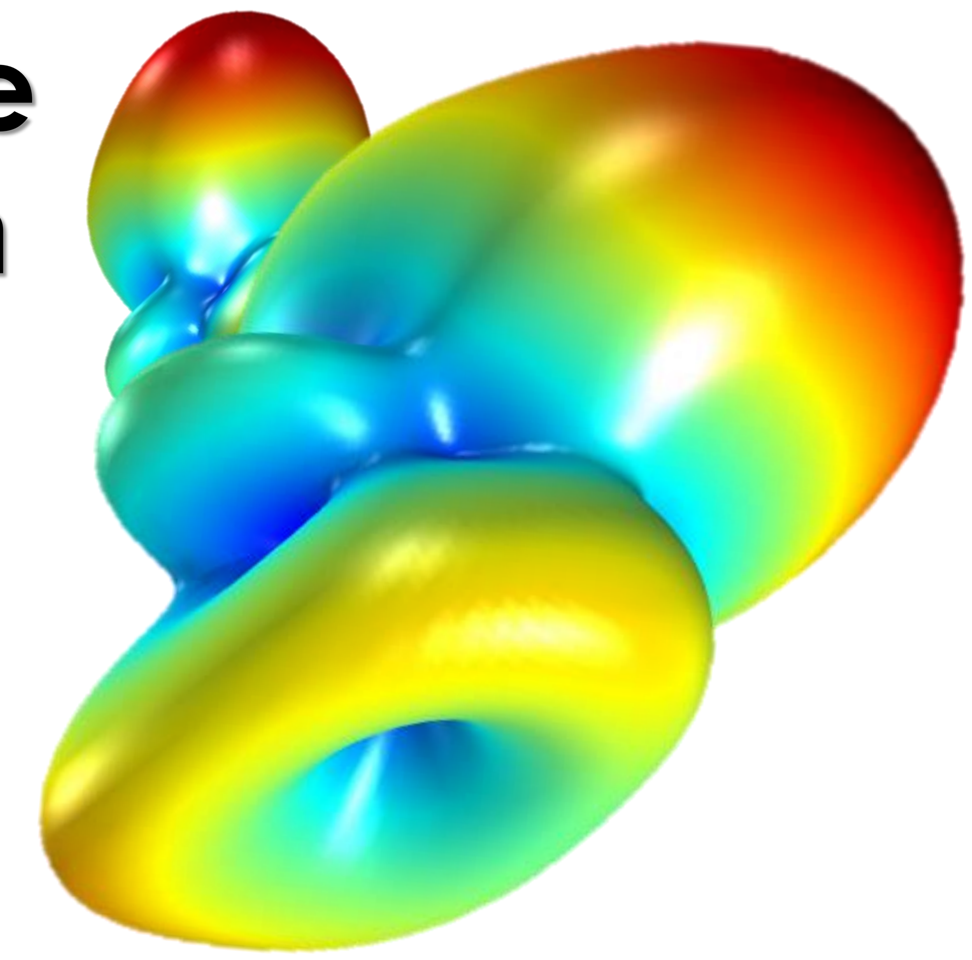

INTRODUCTION

RFID tags are ever increasing in their use, from the tracking of products, to touch-less technologies, seen in today's payment cards. With this there has been an increasing need to reduce their size, & the power required to activate the tag, while maximizing their operating range, or read range. In order to maximize a tag's read range, it is important to ideally match the impedance of the tag's antenna with the chip (Figure 1) [1-3].

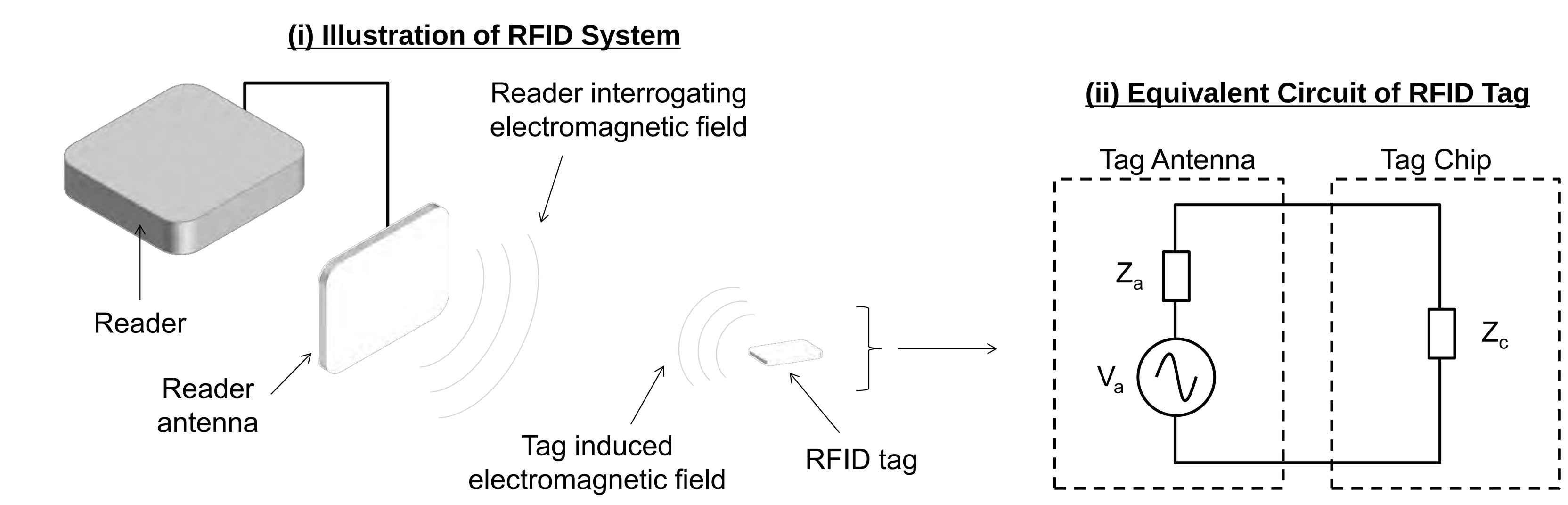

Figure 1. (i) Illustration of RFID System & (ii) Equivalent Circuit of RFID Tag

AIM

To developed a numerical model to quantify a RFID tags read range, validate the model against physical test data & use it to optimize a tag's antenna design to maximize the read range for an example store card.

METHOD (1)

A numerical model of an RFID tag's antenna & chip was developed in COMSOL (Figure 2), using the RF Module's Electromagnetic Waves, Frequency Domain node to describe the physics of the RFID tag's circuit (Figure 1ii). In order to maximize the read range of an RFID system, it is important to ideally match the impedance of the tag's antenna with the chip. The power transmission coefficient (τ), which relates the power absorbed by the chip (P_c) to the maximum power from the antenna (P_a), describes the impedance match between chip and antenna, where as $\tau \rightarrow 1$ the better the match. The power received by the tag's antenna can be calculated using Friis' free-space transmission equation, from which one is able to formulate the read range (r) for a particular RFID tag design & reader. The model developed was then validated against physical test data from literature[3].

Equations. Power Transmission Coefficient (τ), Friis Free-Space Transmission & Read Range (r)

$$P_c = P_a \tau \qquad P_a = P_r G_r G_a \left(\frac{\lambda}{4\pi d}\right)^2$$

$$\tau = \frac{4R_c R_a}{|Z_c + Z_a|^2} \qquad r = \frac{\lambda}{4\pi}\sqrt{\frac{P_r G_r G_a \tau}{P_{th}}}$$

- P_c : Power absorbed by chip
- P_a : Maximum power from antenna
- R_c : Chip resistance
- R_a : Antenna resistance
- Z_c : Chip impedance
- Z_a : Antenna impedance
- λ : Wavelength
- P_r : Reader transmitted power
- G_r : Reader antenna gain
- G_a : Tag antenna gain
- P_{th} : Chip minimum threshold power

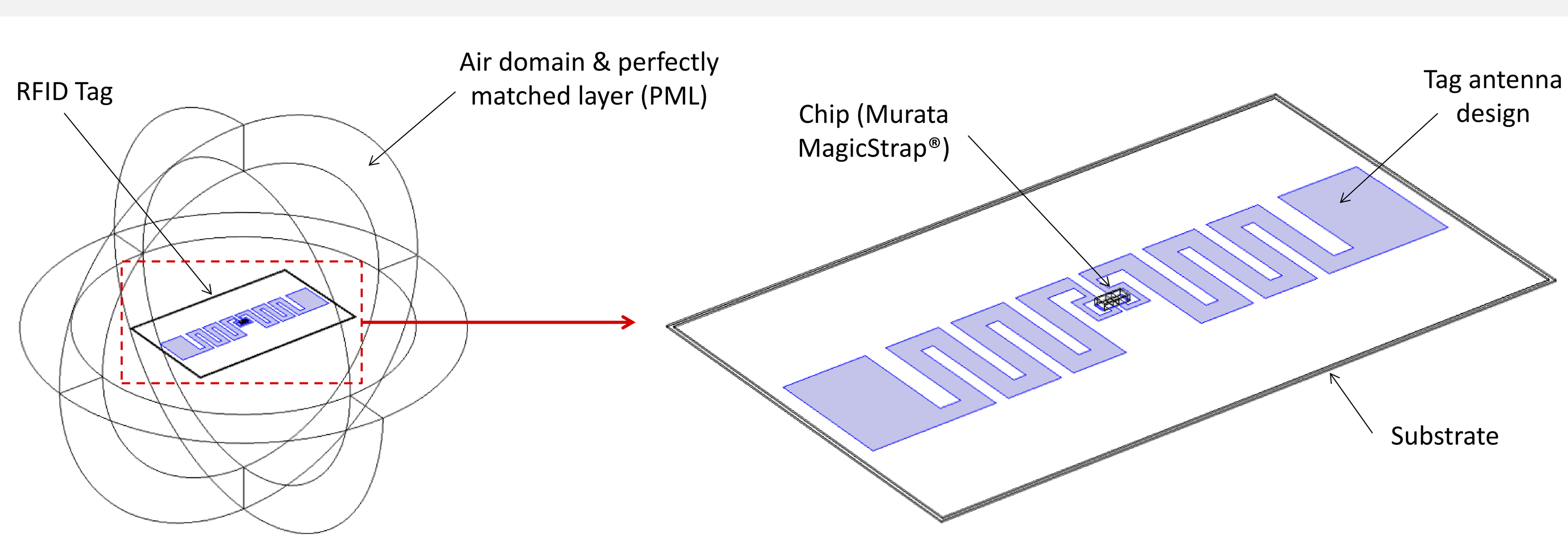

Figure 2. COMSOL model of RFID tag, including substrate, antenna & chip

METHOD (2)

An optimisation node was added to the model to optimize the geometric parameters of a store card antenna (Figure 3), to maximise the read range for a specific chip and reader system. The geometric parameters of the antenna were constrained to a specified design region. Additionally, manufacturing constraints were added to ensure that the chip mounting & antenna manufacture were possible.

METHOD (3)

The optimization objective function was set to maximize the power transmission coefficient (τ), for the following chip & reader system:

- Chip frequency / impedance [4]: 866.5 MHz /15-45j Ω
- Reader Power [5] / Antenna Gain [6]: 1W / 9dBi

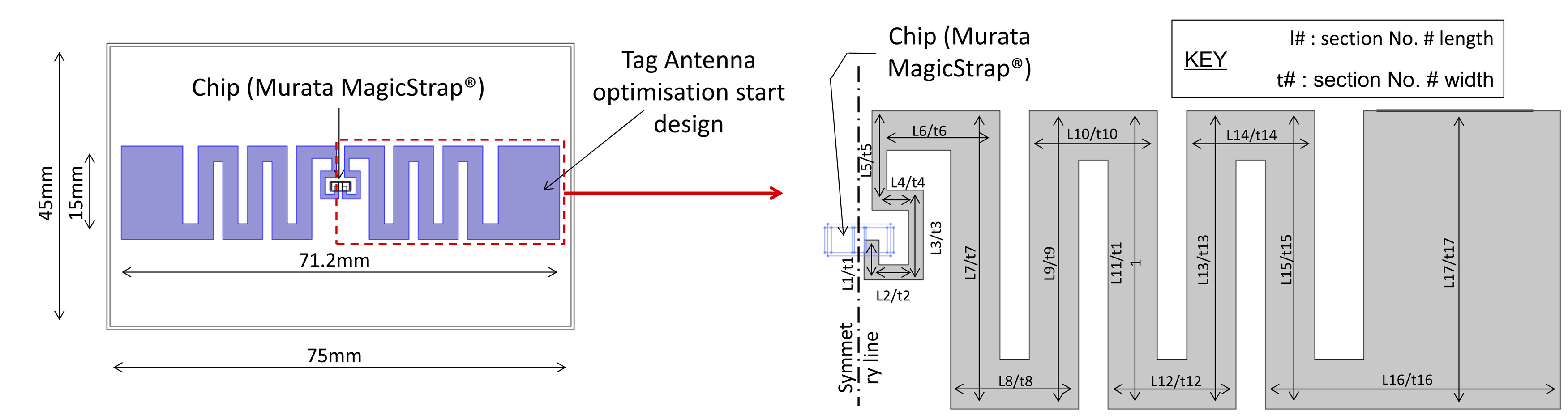

Figure 3. Tag antenna start design & geometric variables for optimization

RESULTS

Validation: From Figure 4, it can be seen the model trends gave reasonable & realistic results, and followed the physical test results, for both read range & power transmission coefficient. However, the model predicted marginally higher values for the tag's resonance frequency, the read range & the power transmission coefficient at resonance. Where, the percentage increase in the tag's resonance frequency, read range & power transmission coefficient were found to be 1.34%, 2.43% & 4.77% above the physical test data, respectively. These small variations were deemed minor & the results from the model acceptable.

Optimization: Overall it took a total 42h 23m of simulation time to find the an optimized antenna design as illustrated in Figure 5, using both the BOBYQA & Monte Carlo methods [7]. The optimized solution's objective value (τ) was found to be 0.676, & gave a read range of 2.38m. Variations in read range for different reader settings are presented in Table 1.

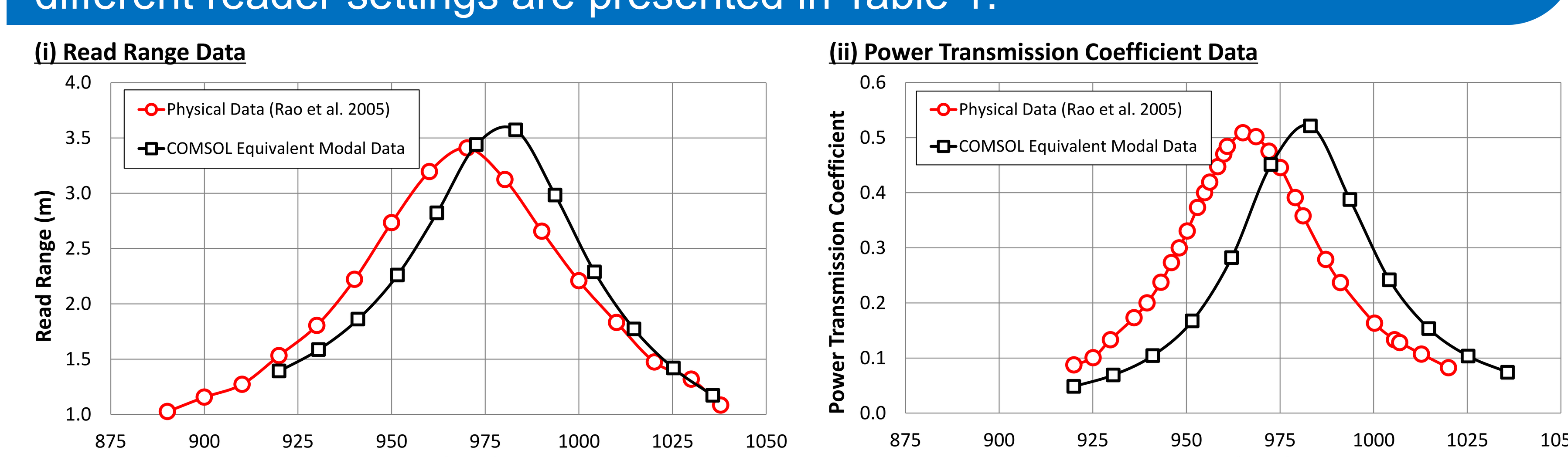

Figure 4. Comparisons of (i) read range & (ii) power transmission coefficient obtained from COMSOL model vs. physical test data from Rao *et al.* [3]

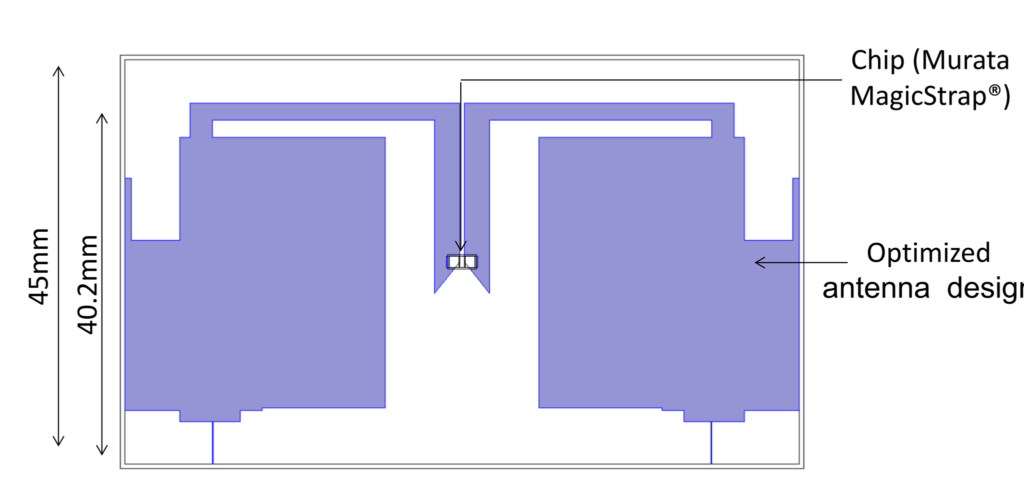

Figure 5. Optimized tag antenna design

Description	Units	Reader System			
Reader Power	W	1	2	1	2
Reader Antenna Gain	dBi	9	9	11	11
Read Range	m	2.38	3.36	2.99	4.23

Table 1. Read ranges for different reader settings

DISCUSSION & CONCLUSION

An RFID tag model was developed & validated. The model was found to marginally over-estimate the tag's response. This is possibly due to variations in geometric & material properties compared to the physical samples used in [3]. The model was used to find an optimal tag antenna design, where geometric & manufacturing constraints were implemented. These designs are to be manufactured & tested for further model validation.

References:
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