# A Compact UHF RFID Tag Antenna for Soil Monitoring

Muhammad Zamani Ismail[1], Nabilah Ripin[1,2*], Mohamad Kamal A. Rahim[1,2], Nur Azliza Ahmad[3]
[1]Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTM), 81310 Skudai, Johor, Malaysia
[2]Advanced Radio Frequency Microwave Research Group (ARFMRG), Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTM), 81310 Skudai, Johor, Malaysia
[3]Electrical Engineering Department, Centre for Diploma Studies, Universiti Tun Hussein Onn (UTHM), 84600 Pagoh, Johor, Malaysia
*nabilah.ripin@utm.my



***Abstract*— UHF RFID technology is currently being chosen to replace the existing soil monitoring system for smart agriculture. However, when attached to backing objects, the current RFID tag typically has a large footprint and a short read distance. Therefore, this paper introduces a compact tag antenna design comprising a slotted radiating patch connected to a ground plane via an inductive stub. The tag antenna is mounted on loamy soil for soil monitoring purposes. The proposed tag has a small size of only 48.2 × 48.2 mm, a power transmission coefficient of 0.99, and a longer theoretical read range of 9m.**

***Keywords*— *UHF RFID, tag antenna, soil monitoring,***

## I. INTRODUCTION

According to the United Nations (UN), worldwide population growth will reach 9.7 billion in 2050 and 10.4 billion in 2100, necessitating a 60%-100% increase in food production [1]–[3]. In order to expand food production, the agricultural industry has transitioned from traditional approaches to smart agriculture. The smart agriculture system is developed to ensure a sustainable food supply, increase labor efficiency, and enhance agricultural quality [4]. This system includes a number of sensors that are designed for monitoring a variety of applications, such as soil, weather, crops, and livestock [5].

In the field of soil monitoring, small-scale farmers and environmental monitoring organizations face challenges with the existing devices due to their complexity and high installation costs. Therefore, an ultra-high frequency (UHF) radio frequency identification (RFID) system is chosen to replace the current soil monitoring system [2], [4], [6]. The RFID is employed due to its ability to improve operating efficiency and reduce expenses due to its faster data rates, a longer read range, and the capacity to read several tags at once [7]. However, the accuracy of the tag's read range is normally affected by the backing soil, as the tag's impedance matching is deviated when the tag is brought closer to the high dielectric constant material. Myriad studies have been conducted to improve the performance of the UHF RFID tag attached to the various backing objects. A folded dipole tag antenna for subsoil measurements has been reported in [8]. The reported tag can be buried in the soil for precision agriculture, but it can only be read from 0.5 m. Palazzi *et al*. developed an RFID temperature sensing system for precision agriculture [2]. The tag is attached to the leaf to monitor the water stress level of plants. The leaf-compatible wireless sensor is incorporated with a solar cell and can be detected from 2.8 m. However, the utilization of the solar cell would increase the cost of production. Another soil environment monitoring system has been proposed based on RFID and LoRa [9]. The reported tag not only has a large footprint, but it also provides a short read distance of only 1.3 m.

In this paper, a compact UHF RFID tag antenna incorporated with slots for soil monitoring is proposed. The proposed tag has a simple structure and a small size while producing a longer read range.

## II. DESIGN CONFIGURATION

The configuration of the proposed tag antenna attached to loamy soil is shown in Fig. 1. The proposed tag antenna has been designed, simulated, and optimised using Computer Simulation Technology (CST) software. The tag has a footprint of 48.2 × 48.2 mm and is designed on a flexible polyethylene terephthalate (PET) substrate with a dielectric constant, $\varepsilon_r$, of 3.4, a thickness of 0.05 mm, and a copper thickness of 0.009 mm. The loamy soil has a dimension of 200 × 200 × 10 mm$^3$ and a dielectric constant, $\varepsilon_r$, of 2.4. Referring to Fig. 1, a Monza 5 microchip with a read sensitivity of -17.8 dBm and an input impedance of 14.56 – j161.25 is bonded at the center of the patch. The radiating microchip connects two patches with a gap of $a$ = 1 mm and two thin slots with a width and a length of $w_s$ = 0.5 mm and $l_s$ = 7 mm, respectively. The radiating patch is connected to a ground plane via an inductive stub with a dimension of $s_1$ = 2 mm and $s_2$ = 1.71 mm.

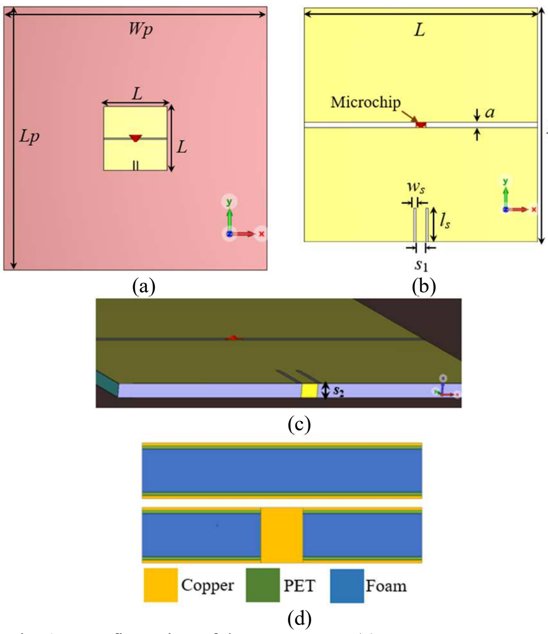


Fig. 1. Configuration of the tag antenna (a) Tag antenna mounted on loamy soil (b) Front view (c) Side view (d) Top and bottom views of the tag antenna.

## III. Result and Discussion

The proposed tag antenna has been designed to operate in the UHF RFID band with a small size and simple structure. In order to achieve this, thin slots on the radiating patch have been carved to enhance the surface current distribution, which brings down the resonant frequency. The slots also provide adequate resistance and inductive reactance, enabling conjugate impedance matching with the microchip. As shown in Figure 2(a), the proposed tag antenna resonates at 918.2 MHz with a reflection coefficient of -22.74 dB. The tag antenna achieves conjugate impedance matching with the chip as shown in Fig. 2(b), where the antenna's impedance, $Z_a$, is 17.82 + j160.35 Ω, while the chip's impedance, $Z_c$, is 14.56 – j161.25 Ω. A theoretical read distance of 9 m has been calculated based on the Friis transmission formula [10], where the tag's realized gain is -2.6 dB and the power transmission coefficient is 0.99, as shown in Figs. 2(c) and 2(d), respectively. The soil monitoring tag radiates omnidirectionally, which provides signals in all directions, as depicted in Fig. 2(e).

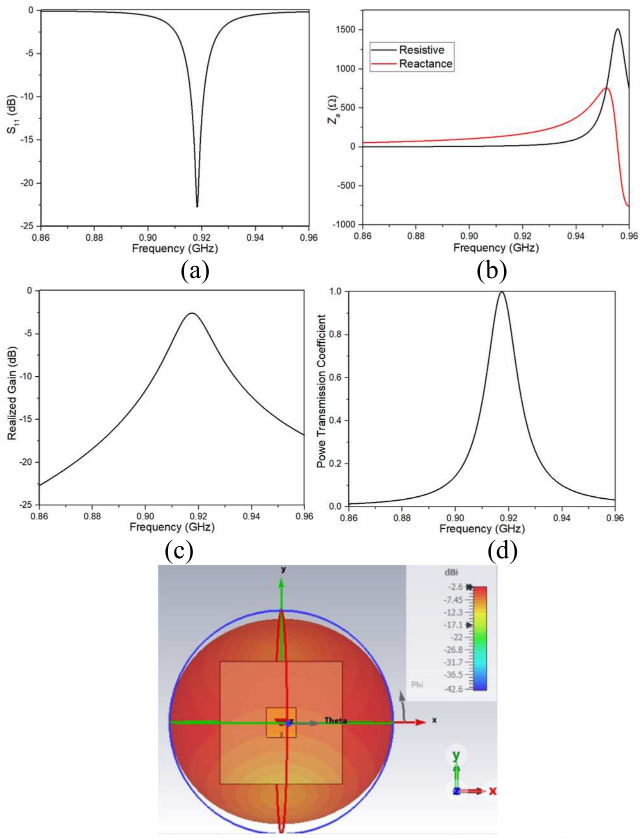


Fig. 2. Simulated results of the tag antenna (a) Reflection coefficient (b) Antenna impedance (c) Realized gain (d) Power transmission coefficient. (e) Radiation pattern.

## IV. Conclusion

A simple and compact UHF RFID tag antenna has been designed to be applied in smart agriculture for soil monitoring applications. The proposed tag consists of a small footprint of 48.2 × 48.2 mm yet manages to obtain an optimum theoretical read distance of 9 m when attached to loamy soil. Furthermore, the proposed tag achieves a power transmission coefficient of 0.9 with conjugate matching with the chip.

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