1. Introduction

The Radio Frequency Identification (RFID) is a technology that allows the information to be transferred wirelessly between the interrogator (reader) and the transponder (tag) [1]. In recent years, the RFID in ultra-high frequency (UHF) band, which operates through the radiative coupling mechanism, is attractive to the users due to its longer read range comparing to the RFID in low frequency (LF) or high frequency (HF) band, which operate through the inductive coupling mechanism [2]. In the passive UHF RFID tag, the antenna plays a key role in the overall system performance. Several works have discussed about the antenna design and how to measure the performance [3], [4]. In the application such as conference registration and tracking system, the size of RFID tag can be as large, but limited to the size of the nametag, which is approximately the size of business card. Even though the nametag is commonly used in horizontal direction, we also can find some use in vertical direction. Most of the passive tag antenna is a printed dipole which is typically a linearly polarized antenna, where the read range is maximized when the orientation of the tag antenna is matched with that of the reader antenna and is minimized when it is 90° rotated. In order to eliminate the read-orientation sensitivity, various antennas have been proposed [5], [6]. However, a 2-port IC chip is required in [4] and the overall size is comparatively large in both [5] and [6].

In this paper, we proposed the UHF RFID tag antenna that can be fit within the size of business card. The read range of this tag antenna is maximized when the tag antenna is placed at 0° orientation. We also modify the antenna to rotate the angle of the maximum read range to -45° and 45° so that we can obtain the same level of read range when the tag antenna is placed at 0° and 90° orientation which is slightly lower than the maximum one. The read range of these antennas at different orientation is measured and compared with that obtained from the calculation.

2. Antenna Configurations

Figure 1 shows the configuration of the antenna S1 designed for passive UHF RFID tag. The antenna substrate is 0.8-mm FR4 ($\varepsilon_r = 4.3$, $\tan\delta = 0.02$) with 1-oz. copper ($\sigma = 5.8 \times 10^7$). The antenna is tuned to match with the conjugate impedance of the NXP UCODE G2XL chip in

![Figure 1: Configuration of the business-card sized antenna S1.](image-url)
Table 1: Parameters of the antennas.

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Figure 2: Configuration of the modified antennas.

TSSOP8 package that has input chip capacitance of 0.9 pF, quality factor of 9, and minimum operating power of -15 dBm [7], at the UHF band used in Thailand (920-925 MHz). This antenna is designed to achieve the maximum read range when using with vertically-polarized reader antenna. The dimensions of this antenna are listed in Table 1. The overall size of this antenna is 45 mm x 48 mm which can be fit within the business card (approximate size: 86 mm x 54 mm).

Furthermore, in order to achieve the tag that can be read even if it is rotated 90˚ clockwise or counter clockwise on XY plane, the antenna S1 is modified to rotate the axis of maximum read range from 0˚ to 45˚ and -45˚ and obtain the same level of read range when the tag is placed horizontally and vertically. The modified antennas, S2 and S3, are as shown in Fig. 2 and the dimensions are listed in Table 1. For the antenna S2, we extend the length $l₁$ and shorten the length $l₂$ to increase the horizontal field. For the antenna S3, we eliminate the length $l₂$ of antenna S1 and add large conductor area at both line ends. This part can increase the antenna gain and also can be used for inserting words or logos with less effect to the antenna properties. The overall size of the antennas S2 and S3 are 55.6 mm x 46 mm and 58 mm x 48 mm, respectively.

3. Results and Discussions

Figure 3 shows the results simulated using the Advanced Design system (ADS) momentum analysis software. The product of power transmission coefficient $τ = 4R_cR_a/Z_c + Z_a^2$, where $Z_c = R_c + jX_c$ is the impedance of the IC chip and $Z_a = R_a + jX_a$ is the impedance of the antenna, and maximum gain $G_{tag}$ of the antennas, are shown in Fig. 3 (a). According to [4], the bandwidth of the RFID tag antenna S1, S2, and S3, which is the frequency range that $τG_{tag} > 0.5$, is 8.20%, 10.58%, and 9.79%, respectively. The bandwidth of antenna S1 is narrower than the others due to its smaller size. Fig. 3 (b) shows the maximum read range ($r$) of these antennas in free space given by

$$r = \frac{\lambda}{4\pi} \sqrt{\frac{P_tG_tG_{tag}τ}{P_{th}}}$$

where $λ$ is the wavelength, $P_t$ is the power delivered to the transmitting reader antenna, $G_t$ is the gain of the transmitting reader antenna, and $P_{th}$ is the minimum threshold power required to power up the IC chip. These read range are calculated for the transmitted power ($P_tG_t$) of 4 W EIRP. We
can see that the maximum read range of the modified antenna S2 and S3 are slightly higher than that of the vertical-polarized antenna S1. The read-orientation sensitivity of the RFID tag antennas rotating on XY plane in free space are shown in Fig. 4. For the measurement results, the antennas are fabricated on 0.8-mm FR4 and the measurement setup and method are as described in [8]. The read range at each orientation angle is normalized to the maximum read range of each tag. We can see that the maximum read range of the antenna S1 is at 0° and 180°, while that of the antenna S2 is at 45° and 225°, and that of the antenna S3 is at 135° and 315°. The read range of the antenna S2 and S3 at 0° is -1.5 dB and -1.4 dB of the maximum one, respectively. Therefore, the read range of these tag antennas at 0° orientation
or the direction as shown in Fig. 1 and Fig. 2 are as shown in Fig. 5. We can see that the read range of the antenna S2 and S3 at 0˚ orientation decrease to approximately the same level of 7.7 m which is lower than that of the antenna S1 that has the maximum read range at 0˚ orientation. However, this read range of antenna S2 and S3 is comparatively higher than that of the antenna S1 at 90˚ orientation, which is -12 dB of the maximum one or approximately 0.7 m.

4. Conclusions

In this paper, we propose the UHF RFID tag antennas with the size smaller than that of the business card which can be used as name tag in the conference registration and tracking system. For the first tag antenna, we can achieve the maximum read range when the tag is placed at the orientation of 0˚ and the minimum one at 90˚. This antenna is modified to obtain the tag antennas with the maximum read range when they are placed at -45˚ or 45˚ orientation which we can obtain the same level of read range when the tag is placed at 0˚ and 90˚ orientation. The maximum read range of the first tag antenna is lower than that of the modified tag antennas. However, the read range of the modified tag antennas at 0˚ and 90˚ orientation are approximately -1.5 dB of the maximum one.

References