Characterization of Double Directional RFID in an Indoor Environment with Human Body

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Abstract

Radio frequency identification (RFID) system has the significant advantage that is capability in reading data correctly and readily without contacting the object surface. Moreover, it can communicate in several mediums and can detect data in unsuitable environment such as more humidity and more vibrating. From these advantages, RFID is bring to apply on daily activities in present moment [1]. The interesting issue is implementation of RFID technology on human body to locate the position and to identify the person. Because the population has grown rapidly, it necessary to separate the detail from each person. To make usage comfortable in communication, RFID system is the best suitable choice to be suitable in identifying and locating human body.

This paper introduces the concept of measuring double directional channels in RFID systems. Antennas independent channel data were derived by doing the measurements. The data was useful for investigating the impact of RFID antennas and analyzing signal distortion.

I. Introduction

RFID technology is capable of storing electronic data, developed to replace the barcode system, to be tracing system, and to find object by using transfer function data with the radio frequency system. RFID technology is not new because it has around since World War II (in aircraft Identification Friend or Foe systems) and in limited use in inventory management since the 1970s. This technology relies on the packet transferring of information through radio waves or electromagnetic waves. However, it has been the exponential growth in information and communication technologies coupled with the expansion of global production and trade. Therefore, RFID technology becomes useful for managing and tracking large shipments and product sales with a means of identification for security purposes and supply chain management [2].

The communication process between the Transceiver and Transponder is managed and controlled by one of several protocols, such as the ISO 15693 and ISO 18000-3 for HF or the ISO 18000-6, and EPC for UHF. Basically what happens when the transceiver is switched on, which is it starts emitting a signal at the selected frequency band (typically 860 - 915MHz for UHF or 13.56MHz for HF). Any corresponding transponder in the vicinity of the transceiver will detect the signal and use the energy from it to wake up and supply operating power to its internal circuits. When the transponder has decoded the signal as valid, it replies to the transceiver, and indicates its presence by modulating the transceiver field [3].

This paper, we discuss the characterization of double direction in RFID system with human body. We will know the efficiency of RFID system by measuring and analyzing transmission power signals. The both of the transmitter and the receiver antennas are microstrip patch antennas at 2.45 GHz [8]. It was developed by King Mongkut's Institute of Technology Ladkrabang (KMITL), Thailand that was suitable for the operation with this signals. The Friis's transmission formula has been widely used to analyze transfer function and evaluate the transmission in line of sight (LOS) channel. The reception consider the maximum signal to noise ratio at the receiver in this double directional modeling.

The results in this paper are shown in path loss that is the maximum amplitude of the output signal, in correlation coefficient that is the efficiency receiver side, in delay characteristic and bit error rate are the probability of error receive signals on the double direction of RFID system in indoor environment. We can apply to use with human for design and evaluation

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of wireless body area network (WBAN) in RFID systems.

II. TRANSMISSION SIGNAL ANALYSIS

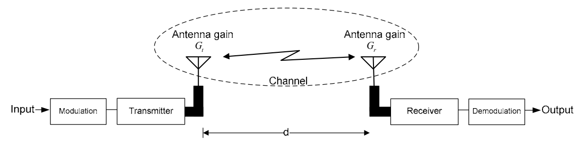

Figure 1. **RFID transmission in free space.**

In this study, we focus on transmission channel in free space by using Friis's transmission formula [4] to evaluate signal between transmitter and receiver in narrow band as shown in equation (1). Transmission gain in free space was written in that equation.

$$G_{friis}\frac{\mathrm{P_r}}{\mathrm{P_t}}=G_{\mathrm{t}}G_{\mathrm{r}}\left(\frac{\lambda}{4\pi d}\right)^n \quad (1)$$

where G_{t} and G_{r} are the antenna gain of the transmitting and receiving antennas, respectively. The free space propagation gain (less than unity in practice), $\lambda = c/f$ is the wavelength, c is the velocity of the light, f is the operating frequency and d is the separation between transmitter and receiver antennas.

The transmit signal we use sine wave in microwave band and modulate signal by amplitude shift keying (ASK). The transmit signal can be written as

$$v(t)=A\sin(2\pi ft) \quad (2)$$

$$f_{ask}(t)=m(t)\cos(\omega_c t) \quad (3)$$

Path loss (P_L), is the maximum amplitude of the output signal. Therefore, chosen for the purpose of simulation is given in (4), and is explained by [5]

$$P_L(dB)=P_L(d_0)+10n\log\left(\frac{d}{d_0}\right) \quad (4)$$

where d_0 is arbitrary reference distance, n is a value that depends on the surroundings and building types, and d is distance between two antennas (Tx1 and Rx, Tx2 and Rx).

TABLE 1. PATH LOSS EXPONENT

Propagation Environment	n
Free Space	2
Urban Area	2.7 - 3.5
Shadowed Urban Area	3 - 5
In-Building Line-of-Sight	1.6 - 1.8
Obstructed In Building	4 - 6
Obstructed In Factory	2 - 3

Path of signal propagation between transmitter and receiver in multi direction and each signal is transferred in the different distance. Some signals will be transfer between transmitter and receiver in directional. This signal will be transfer to the receiver faster than other paths while multi direction has path loss from the reflection. This multi direction signal propagation spent more time and more delay than other signals called Delay spread. That means each signal has different transferring time so the delay time of receiver signal must be considered. The time dispersion was analyze from Mean Excess delay parameter and Root Mean Square (RMS) delay spread parameter are shown in equation (5) and (6) [6].

$$\bar{\tau}=\frac{\sum_{k=1}^{n}a_k^2\tau_k}{\sum_{k=1}^{n}a_k^2}=\frac{\sum_{k=1}^{n}\mathrm{P}(\tau_k)\tau_k}{\sum_{k=1}^{n}\mathrm{P}(\tau_k)} \quad (5)$$

where a_k is the amplitude of signal at k path. τ_k is the delay spread of signal at k path. $\mathrm{P}(\tau_k)$ is the power of signal at k path. In equation (7), we will use it including with equation (5) and (6) to find the power delay profile (PDP).

$$\sigma_\tau=\sqrt{\overline{\tau^2}-\left(\bar{\tau}\right)^2} \quad (6)$$

$$\overline{\tau^2}=\frac{\sum_{k=1}^{n}a_k^2\tau^2{}_k}{\sum_{k=1}^{n}a_k^2}=\frac{\sum_{k=1}^{n}\mathrm{P}(\tau_k)\tau^2{}_k}{\sum_{k=1}^{n}\mathrm{P}(\tau_k)} \quad (7)$$

The correlation coefficient is ratio between receive correlation and transmit correlation, given in (8). And explain by [7].

$$C_c=\frac{\int_0^\infty\left|V_c(f,d)\right|df}{\int_0^\infty\left|V_c(f,d)\right|^2df\cdot\left|H_c(f,d)\right|^2df} \quad (8)$$

Bit error ratio (BER) is the number of error bits divided by the total number of bits transmitted, received, or processed over some assumed period.

$$BER = Q\left[\sqrt{\frac{(E_b/N_0) f_b C_c}{b_r}}\right] \quad (9)$$

$$Q = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-t^2/2} dt \quad (10)$$

Q is cumulative distribution function (Gaussian distribution), $x \geq 0$. E_b is the energy in one bit and N_0 is the noise power spectral density, so E_b/N_0 is a form of signal to noise ratio. b_r is rate of transfer (bps) and C_c is correlation coefficient, as following [7].

III. EXPERIMENTAL

A. Measurement Setup

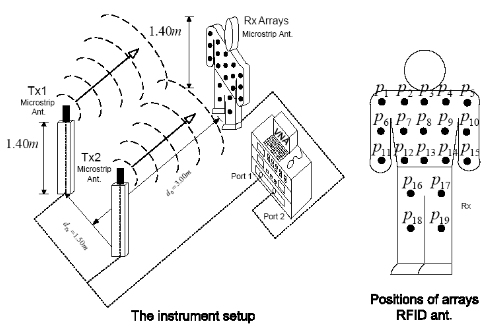

Figure 2. **Measurement setup.**

The RFID channel transfer function is measured in frequency domain by using the vector network analyzer (VNA) in the indoor environment at the room of Department of information engineering (KMITL). The VNA was operated in the response measurement mode, where port-1 was used as the transmitter port (Tx) and port-2 was used as the receiver port (Rx). Fig. 1 shows the configuration of the measurement setup. Distance between Tx1 and Tx2 as 1.5 m and fixed at height of 1.40m. Rx antennas were fixed at point of position p_1 - p_{19} on human body. The transmitters and receiver were separated by d_1 and d_2, respectively. Figure 2 shows top view antenna setting.

B. Antenna Under Test

We used a microstip antenna which has a frequency at 2.45 GHz. It was developed by KMITL's Lab that was suitable for the operation with signal. The structure of the RFID antennas and the reflection coefficient S_{11} of the antenna feed point are shows in Figure 3 Tx and Rx antennas are microstip antenna with width of 10 cm and length of 10 cm used as the antenna under test (AUT).

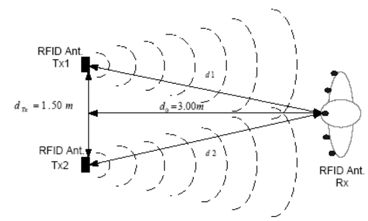

Figure 3. **Top view antenna setting.**

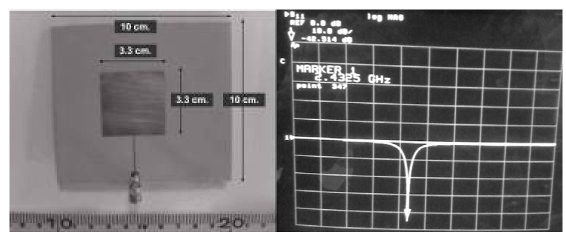

Figure 4. **Antenna under test and characteristic of antenna.**

C. Parameters of Measurements

The measurement parameters are listed in Table II. It is note that the calibration of VNA is done at the connectors of the cables to be connected to the antennas. Therefore, all impairments of the antenna characteristics are included in the measurement results.

TABLE 2. EXPERIMENTAL SETUP PARAMETERS

Parameter	Value
Frequency range	2-3 GHz
Number of frequency points	801
Tx1 and Tx2 antennas height	1.40 m
Rx antenna fixed point	p_1 - p_{19}
Distance between Tx1 antenna and Tx2	1.50 m
Distance between Tx1 antenna and Rx	d_1
Distance between Tx2 antenna and Rx	d_2

IV. EXPERIMENTAL RESULTS

Path loss of signal was shown in figure 5. At p_{16} to p_{19}, which receiver antenna is adhere on the lags is the maximum path loss. At p_1 to p_5, which receiver antenna is adhere on the chest is the minimum path loss. The result in each position was close to each other. In case of without human body, path loss of signal in each position is less than the case of human body.

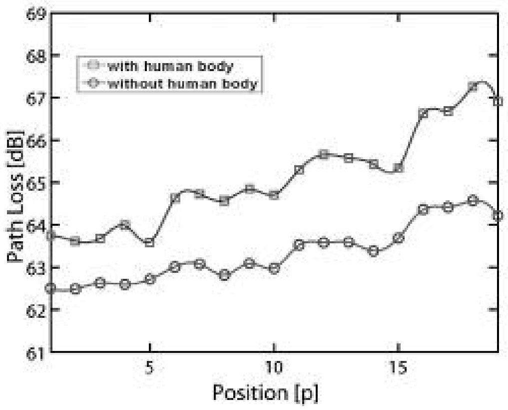

Figure 5. **Path loss of receiver signal.**

Power delay spread in case of comparison between without human body model and with human body model as shown in figure 6 and figure 7 The result are shown that human body affects RFID propagation with wireless body area network. Received power decreases in all positions. In figure 7 is shown that received power decreases from p_1 to p_{19}. Experiment of double directional using two transmitter antennas, value of power delay profile higher than using one transmitter antenna and in same way the value is close to each other.

For the value of correlation coefficient with human body are shown in figure 8. We can see that a value of correlation coefficient of position p_1 to p_{19} have about 0.35 - 0.39.

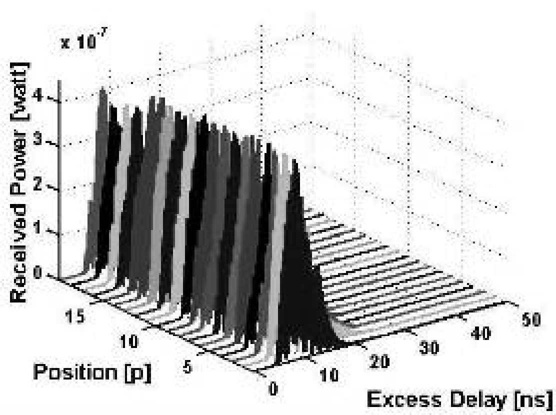

Figure 6. **Power delay profile without human body.**

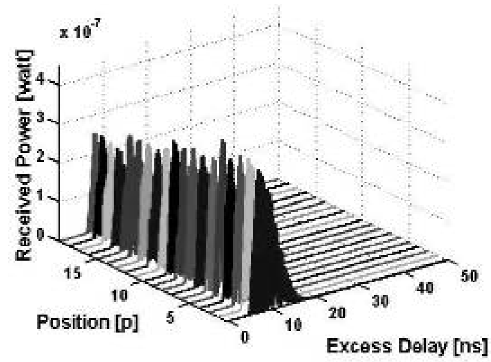

Figure 7. **Power delay profile with human body.**

Finally, we can find performance this model from bit error rate. Figure 9 shown bit error rate with human body, which point of positions p_{16}, p_{17}, p_{18} and p_{19} (top lines in figure 9) are error more than other positions (bottom lines in figure 9). From result, we can use best of these positions for applying in other equipments.

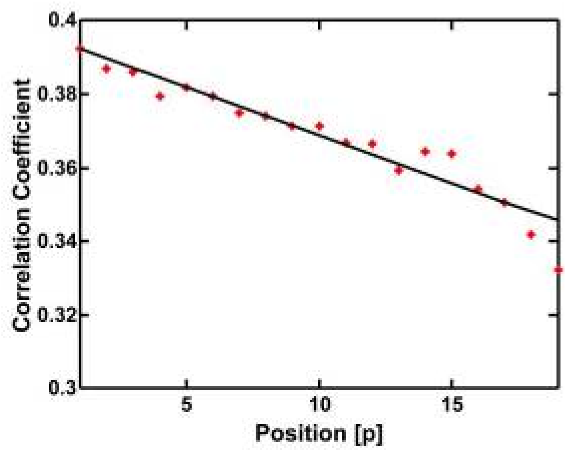

Figure 8. **Correlation coefficient of receiver signal with human body.**

V. CONCLUSIONS

This paper is studied on experimental evaluation scheme of RFID propagation channel with wireless body area network. By creating the model to find the effect from human body that impacts on communication system of RFID propagation channel with wireless body area network. It was shown fading and distortion of received signal. From analyzing, using of two transmitter antennas find the received signal on human body that is better than using of one transmitter antenna [8]. Therefore, this research is shown the using of two transmitter antennas to reduce signal distortion in case of the receiver antenna stick on human body. In the future, this experiment will be benefit for researching and developing communication system of RFID propagation channel with wireless body area network.

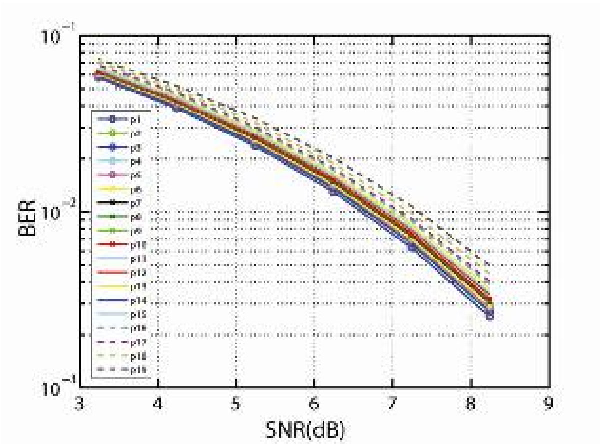

Figure 9. **Bit error rate of receiver signal with human body.**

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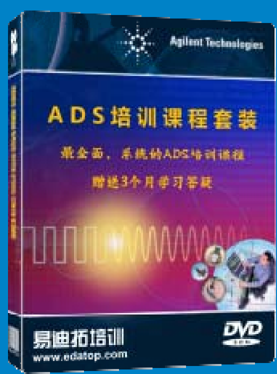

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