RFID Microstrip Antenna for Supply Chain at Ultra High Frequency (UHF) Band

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Abstract

This paper describes the characteristics of microstrip antenna for transponder of Radio Frequency Identification (RFID) at Ultra High Frequency (UHF) band. The microstrip antenna is used to connect with the IC with standard ISO-18000-6A (Part ID: EM4223). The simulation tool based on Method of Moments (MoM) is used to analyze the transponder antenna. The antenna is designed to operate in UHF band from 860 to 950 MH with the advantage of simple structure and inexpensive cost. The antenna feeding structure is easily to integrate with a RFID microchip. This antenna has radiation pattern of omni-directional beam. In the analysis, the antenna characteristics such as radiation pattern, directivity, input impedance, standing wave ratio and bandwidth are investigated. The proposed antenna can be applied for data recording of supply chain.

1. Introduction

Auto Identification (Auto ID) is used for data tracking. Barcode is one type of the auto ID system. The demerits of the barcode are poor endurance and low memory although its large size is used. Therefore, barcode is improved to be new system for higher data transferring. Smart card can be read and written but it must be attached on the reader all time when it is on operating as reading or writing the data. After the smart card is detached then the contact surface will be scratched and deteriorated. To avoid these disadvantages, RFID is developed to have the benefits of both barcode and smart card such as higher data transfer rate, high endurance, long read range, low cost, small size and high data capacity. RFID is the wireless communication based on the principle of electromagnetic coupling. Nowadays, RFID is widely used in many functions such as data recording, access control, parcel and document tracking. Moreover it is applied in many industries such as in production, logistics and supply chain processes. It is well-known that the demand of RFID system have grown up and will be higher in future. The operations of RFID system are different depend on each environment. RFID with standard of ISO-18000-6A deals with the RFID air interface standards in UHF range from 860 to 960 MHz that uses pulse interval encoding, Aloha-based mechanism and bi-phase space FM0 return link encoding. RFID system uses radio frequency for data communication which follows the standard of the radiated power assignment [1]. RFID can be classified to be two parts; one is transponder and the other is reader. The transponder consists of antenna and chip. When the transponder passes into the read range of the reader antenna, the data inside tag will be read or written. Figure 1 shows the operation of RFID system. The reader will be interfaced to the control equipment such as a computer. Normally, the transponder should be small and easy to be attached on the interesting material so the research of this antenna is interesting. In this paper, the microstrip antenna [2] – [3] of RFID system in UHF range is presented. There are many applications of passive RFID [4]. The previous RFID tags have complicated structure to assembly and high cost although it is easily to integrate microchip to antenna [5]. Passive microchip [6] needs the power biasing to the microchip by electromagnetic coupling. RFID transponder for HF band (13.56 MHz) is employed in near field region based on inductive coupling but the UHF band (860–960 MHz) is employed in far field based on electromagnetic coupling.
This paper proposes the antenna of the passive tag in UHF range for supply chain. The necessary power for biasing the microchip on the transponder comes from the reader antenna by electromagnetic coupling. The antenna characteristics will be also presented in this paper such as radiation pattern, input impedance, standing wave ratio and directivity.

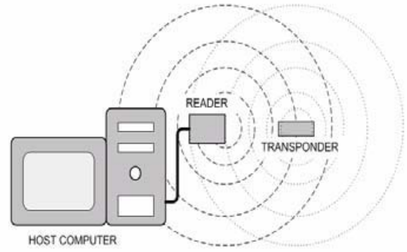

Fig. 1: RFID Operation System

2. Antenna Structure

The antenna structure is shown in Fig. 2. The antenna is designed to be planar for sticking on the outer box. The printed strip on the front side of the antenna is made of copper. The largest dimension of this antenna less than 5 cm is designed for having enough small area to place on the box.

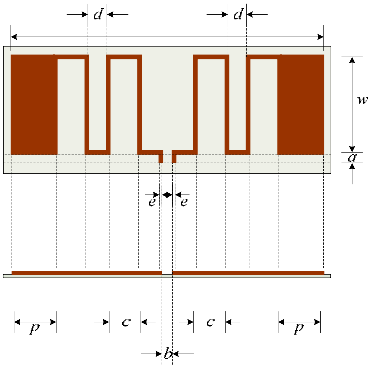

Fig. 2: Microstrip Antenna for RFID

The proposed microstrip antenna has thin metal strip printed on FR4 substrate with dielectric constant of 4.4 and the back side of the antenna is without ground plane. The concept of antenna design is developed from the structure of dipole antenna. The microchip with SOT-23 3 leads package will be placed on the antenna port. The microchip can excite the antenna based on the principle of back scattering. The antenna parameters are tabulated as shown in Table 1.

TABLE 1: ANTENNA PARAMETERS

Dimension	Parameter
Metal strip width	*a*
Port separated length	*b*
Upper line length	*c*
Lower line length	*d*
Substrate thickness	*g*
Metal strip thickness	*h*
Total metal strip length	*l*
Edge metal strip pad length	*p*
Feed port length	*u*
Edge metal strip pad width	*w*

3. ANTENNA DESIGN

Normally, the antenna has the input impedance around 50 Ω because the impedance of the transmission line is 50 Ω. For RFID system, antenna is not connected with the transmission line but it is connected with microchip instead. The microchip has low resistive and high capacitive impedance. Therefore, the transponder antenna must be designed in way of low resistance and high inductance for impedance matching. Therefore, the input impedance of the antenna is designed carefully to match the input impedance of chip 19 + j294 Ω for maximum power transfer by means of conjugate matching. The equations of the impedance matching that is necessary to investigate the antenna performance are described in next subsections.

Matching equation

The electrical circuit of matching between the chip and the RFID transponder antenna [7] is presented in Fig. 3. The impedances of the antenna and the microchip must be considered to meet the good matching. In this case, the return loss of the antenna must be less than 10 dB or SWR of the antenna must be less than 2:1 throughout 860 - 960 MHz.

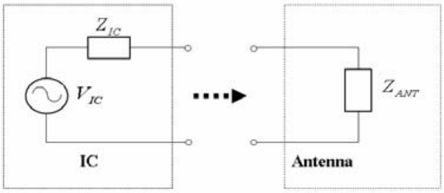

Fig. 3: Circuit Matching Between Antenna and Microchip

Knowing the impedances of both antenna and microchip, the reflection coefficient can be determined from

$$\Gamma = \frac{Z_{IC} - Z_{ANT}}{Z_{IC} + Z_{ANT}} \quad , \tag{1}$$

where, Z_{IC} is the input impedance of microchip and Z_{ANT} is the input impedance of antenna.

After the reflection coefficient was determined, the power reflection coefficient will be used to determine the maximum read range of RFID system.

$$|\Gamma|^2 = \left| \frac{Z_{IC} - Z_{ANT}}{Z_{IC} + Z_{ANT}} \right|^2 . \tag{2}$$

The maximum read range between RFID transponder and reader can be determined by using the equation as follows

$$r_{max} = \frac{\lambda}{4\pi} \sqrt{\frac{EIRP \times D_r \times (1 - |\Gamma|^2)}{P_{th}}} , \tag{3}$$

where

r_{max} is the maximum read range.

EIRP is the total power of reader antenna.

D_r is the directivity of transponder antenna.

P_{th} is the minimum power that transponder can in operation.

The RFID system has two main parts; the reader and transponder. Both of them have each antenna. As seen in Fig. 4, the supply chain system consists of three reader antennas attached on the gate-side to detect data of box that is passing into the detection zone. The reader antennas always radiate their power into space. When the transponder antenna is located within the detection zone, the power will be received and charged up the microchip and then the microchip will reradiate the power to the reader antenna by using back scattering method. In this case, at least one of reader antennas is able to detect the power that comes from the transponder. Following this mechanism, the data on the transponder will be tracked. This system is applied for the supply chain by using the transponder attached on the product box.

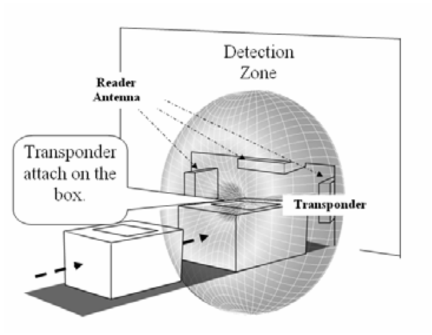

Fig. 4: RFID Transponder for Supply Chain

4. Simulation Results

The performances of the antenna were investigated and the simulated results are presented in this section.

A. Antenna Dimension

From the simulation, the suitable antenna dimensions are summarized as shown in Table 2.

TABLE 2: SUITABLE ANTENNA DIMENSIONS

Parameter	Size (mm)
a	1
b	2
c	3
d	2
g	1.6
h	0.02
l	49
p	9.5
u	3
w	22

B. Input Impedance

To obtain the good matching, the input impedance of the proposed antenna in UHF range was investigated in terms of resistance and reactance, as shown in Fig. 5.

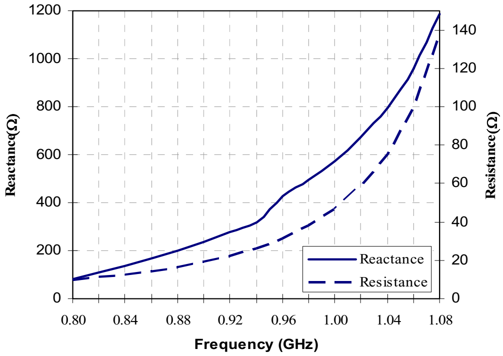

Fig. 5: Input Impedance as a Function of Frequency

C. Standing Wave Ratio

The difference between the antenna impedance and the microchip impedance causes the impedance mismatch. The higher SWR, the greater mismatch will occur. The advantage of being perfectly matching is that the transferred power loss is small. From the simulation result in Fig. 6, the frequency of 0.92 GHz is found to be the best SWR because it is nearly equal to 1:1 that means the antenna has the smallest reflected power. The SWR at the other frequencies of UHF range are acceptable with less than 2:1. The antenna bandwidth is from 0.84 to 1.02 GHz.

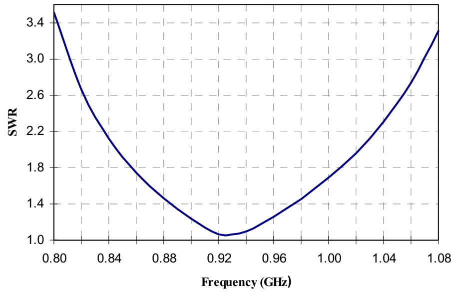

Fig. 6: Standing Wave Ratio as a Function of Frequency

D. Directivity

As shown in Fig. 7, the directivity of the antenna at UHF range is around 2 dBi. When the frequency increases, the directivity will also increase. It is found that the relationship between the frequency and the directivity is linear.

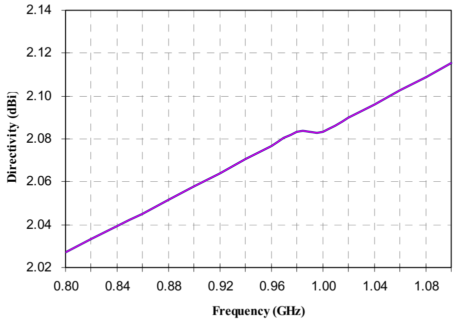

Fig. 7: Directivity as a Function of Frequency

E. Power and Distance

The radiated power of the RFID tag was dropped down while the distance is increasing, as shown in Fig. 8.

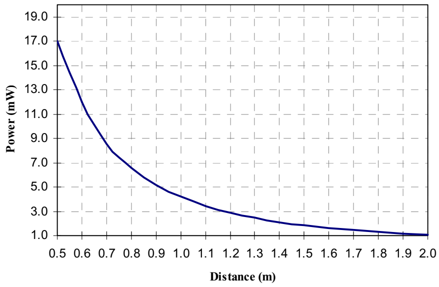

Fig. 8: Power as a Function of. Distance

F. Antenna Prototype

The prototype antenna is shown in Fig.9. The configuration of the antenna is symmetry. The microchip will be placed at the middle of the below edge of the antenna. This antenna do not have ground plane because this application needs omni-directional pattern.

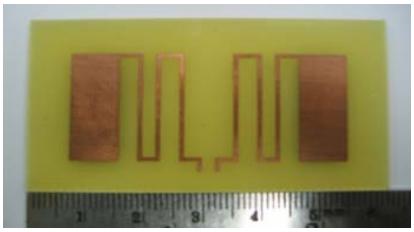

Fig. 9: Microstrip Antenna Prototype

5. ANTENNA MEASUREMENT

The radiation patterns of the antenna from the simulation and the measurement were compared both E-plane and H-plane, as shown in Fig. 10 and Fig. 11, respectively. It is found that the measured patterns have the similar trend to the simulated patterns. The pattern of the antenna is omnidirectional.

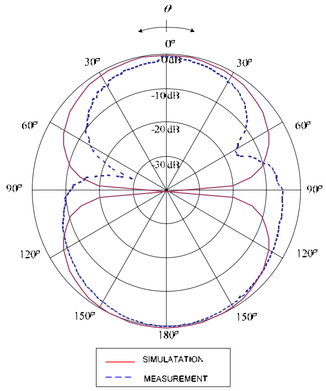

Fig. 10: Radiation Pattern in E-Plane

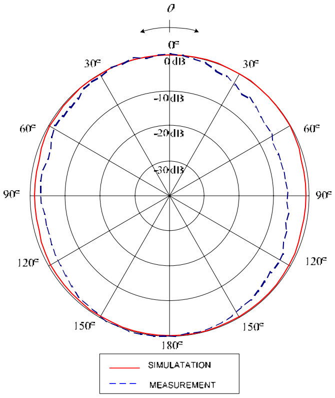

Fig. 11: Radiation Pattern in H-Plane

6. DISCUSSION AND CONCLUSION

This paper presents the microstrip antenna without using ground plane that has the input impedance 22.28 + j276.4 Ω at 0.92 GHz. This antenna has SWR of 1.065:1, band width from 0.85 to 1.02 GHz, directivity of 2.06 dBi and return loss of -30.09 dBi. The bandwidth of this antenna can cover UHF range for RFID system. The antenna is applicable for supply chain. The advantages of the antenna are simple structure, small size, easy to assemble and low cost. Moreover, the antenna feeding structure is easily to integrate with a RFID microchip. The output power will decrease when the distance increases.

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