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IMPLEMENTATION OF RFID AND BLUETOOTH TECHNOLOGY FOR DATA TAGGING AND TRANSMISSION TO POINT OF SALE

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Abstract—The design of wireless technology which involves radio frequency identification (RFID) and Bluetooth technology for tagging and transmission of data that will be applied to point of sale (POS) is presented. A complete POS circuitry system has been designed to allow certain item to be a tag easily identified and localized. This is implemented by using RFID technology which will communicate with personal computer (PC) either through Ethernet or Wifi connection. An Impinj RFID reader and Bluetooth mobile phone are selected in the proposed POS system. Matlab simulation has been performed for RFID transceiver part and Bluetooth data transmission. A prototype software is developed to interface the Impinj RFID reader through the Ethernet connection. Additionally, a data encryption from Bluetooth is paired with PC to achieve a secure and simple pairing feature when customer transaction is performed. It involves hardware and software implementation. Moreover, in simulation result, a double side band modulation is used to design the RFID reader for better item tagging. The results show the feasibility of using this design for POS and achieving very good read ranges. Finally, Bluetooth system enables fast transaction and makes purchase securely by using the proposed asymmetric algorithm.

1. OVERVIEW

Point of sale (POS) system is referred to a location where the transaction is performed at mall, library, etc. Nowadays, many country businesses are growing, that leads to a lot of transaction required at POS system. The common technology uses a barcode system

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at POS [1–3]. Unfortunately, as we observed from shopping malls, the POS terminal becomes crowded easily [4–6], especially when the "Special Offers" is launched. Thus, it was motivated to overcome this problem by using RFID and Bluetooth technology for item tagging and data transmission purpose.

Unlike barcode system, both new technologies stated do not require any line of sight. RFID technology can be used for item tagging and identify each individual item. It also allows a unique serial number product authentication to be implemented. For Bluetooth technology, it is used for data transaction purpose. The RFID technology will involve reader, antenna, and tag. The reader will acts like a transmitter and receiver which will communicate with the tag and personal computer. Each tag will carry a unique tracking identifier coding. Thus, with the item tagged with RFID tag and passing through the RFID reader, the specific item will be easily recognized and their location identified. Besides this, Bluetooth technology becomes very common on our mobile phone. Many mobile phones will acquire Bluetooth communication link [7–9]. With this kind of technology, we can perform the authorization of transaction at POS system.

In this work, using both of the technologies can make the POS system faster and convenient. There are researches on RFID reader communicates with tag by using 'Low Level Reader protocol (LLRP)', type of tag used, type of modulation applied to the reader and stack of Bluetooth system through protocol [10–12].

In this implementation, Impinj RFID reader and Bluetooth mobile phone are selected for POS system, and Matlab simulation has been performed for RFID transceiver part and Bluetooth data transmission. As a result, an amplitude-shift keying (ASK) signal is obtained when the reader and tag communicate with each other. The Bluetooth mobile phone for frequency hopping on Matlab simulation has been studied. The RFID reader and tag are obtained from Impinj for analysis purpose. Besides, a connection between PC and Bluetooth mobile phone also has been performed and investigated.

2. IMPLEMENTATION OF RFID AND BLUETOOTH TECHNOLOGY

As we enter the new decade of technology, business is growing rapidly, which results in a busy POS system, and bar codes system cannot keep up the pace [13–15]. In this work, a RFID and Bluetooth are proposed as a solution. The RFID system involves reader, tag, and antenna able to keep track the item. First, the tag will be placed on each item inside the inventory. In order to communicate with the tag, a RFID reader is required. The RFID reader transmits the signal and waits until the reflected signal from the tag back to the RFID reader via the antenna. This technique of tag communication uses backscatter modulation. The proposed POS system by using Bluetooth technology can involve mobile phone and computer laptop as a transaction purpose. The proposed design of the overall POS

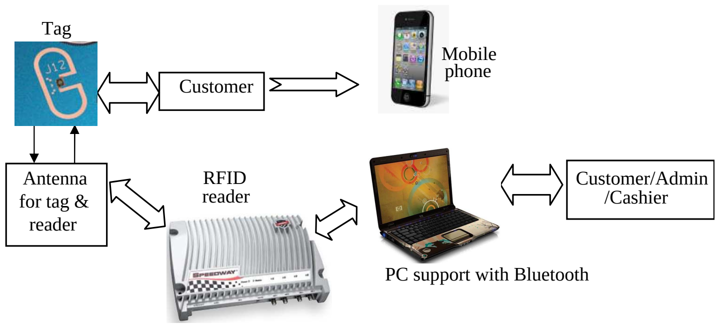

Figure 1. POS system using RFID and Bluetooth technology.

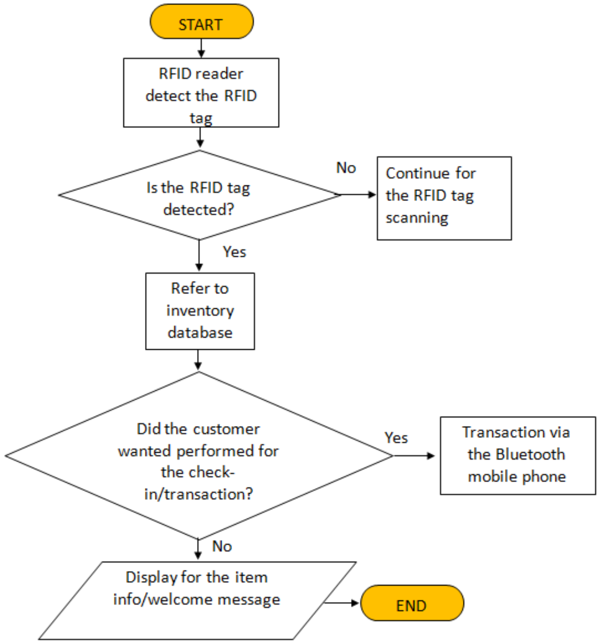

Figure 2. Flow chart of overall implementation.

system is shown in Figure 1. Figure 2 shows the flow chart of overall implementation of this POS system.

2.1. Circuit Design: RFID Tag with Reader Communication

This circuit design consists of two parts, Impinj RFID reader and tag. The passive tags are produced by Impinj which encodes the backscattered data as FM0 baseband at the data rate on the passive tag. The reader then commands the encoding choice result of the ASK modulation. As shown in Figure 3 of the Matlab simulink, the reader communicates with the tag using FM0 baseband data modulation. It can be observed from the figure that there are two pulse generators (positive and negative) which will act as a bi-phase space encoding. These pulses then will invert the baseband phase at every symbol

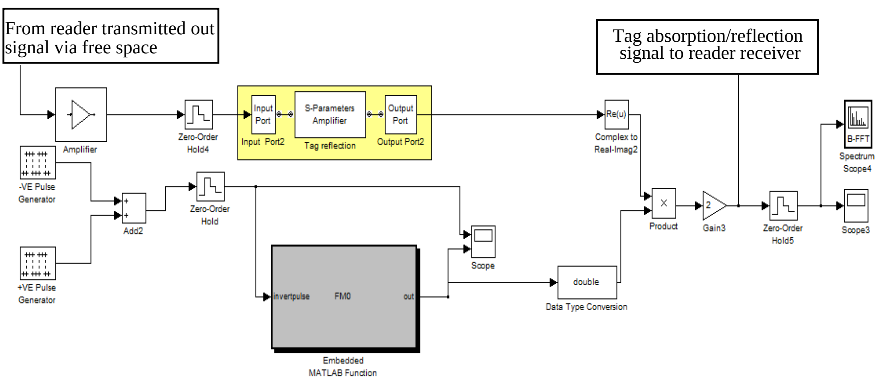

Figure 3. RFID tag to reader communication using baseband FM0 data modulation.

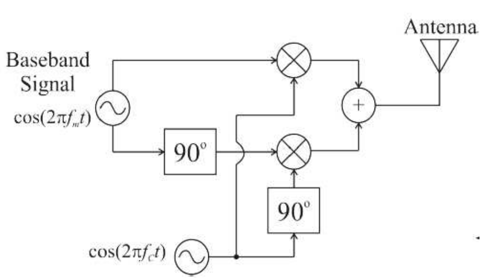

Figure 4. Single side band — Amplitude shift keying modulation (SSB-ASK).

boundary. The data-0 has an additional mid-symbol phase inversion which results in the FM0 baseband generated. The FM baseband plays an important role in the ASK modulation between the tag and the reader. Since RFID tag is a passive type which does not require any power source, with implementation of ASK modulation, it can obtain the energy or power by converting the electromagnetic energy emitted by the reader into the DC power level. This is required to activate the tag. ASK modulation can also be easily detected with a simple envelope detector. The reader modulation uses a Single side band — amplitude shift keying modulation (SSB-ASK) as shown in Figure 4. This means that the I/Q modulator consists of two frequencies which are carrier frequency, f_c, and modulating frequency, f_m, thus this will improve the signal spectrum efficiently.

However, in order to track the item, the tag requires a code to identify the product. RFID systems use the standards developed by EPCglobal Inc. The electronic product code (EPC) is the naming convention used in programming of the tag. EPC allows each tag to have a unique code so that each tag can be recognized individually. The following Figure 5 is the breakdown of the code convention. Through this EPC number, the item can be easily associated with RFID passive tag.

When the reader and tag are able to communicate with each other, it is important to take the consideration on timing. Figure 6 shows the link timing between the reader and a single tag. The period of T_2 indicates the timing/period of the tag in the reply or acknowledges (ACK) states. If the two systems communicate with each other, a response of acknowledgement will be definitely needed when the problem or error is found.

If the tag facing an invalid command, an invalid EPC number or collision will occur, then it will enter the ACK states or enter the reply states. The reader must transmit a continuous wave, CW within the duration to change the data symbol parameters for a subsequent inventory round. Within this CW period, this link will become reset.

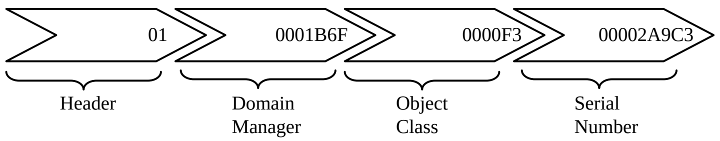

Figure 5. Example of EPC number program inside the RFID tag.

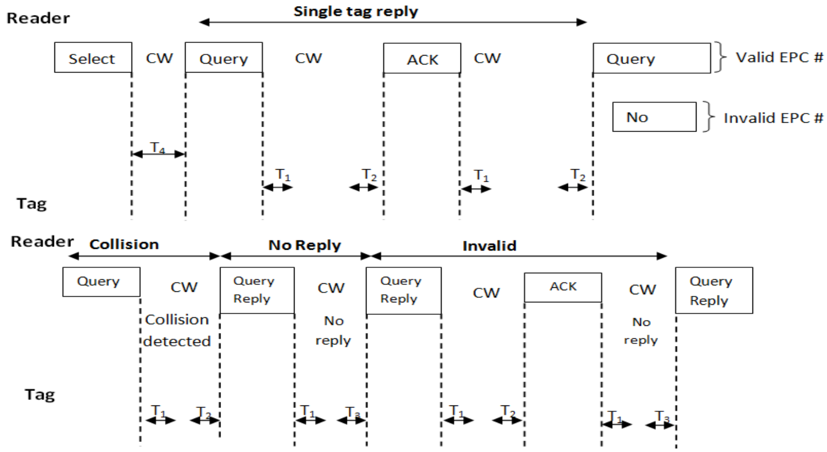

Figure 6. Reader and tag link timing.

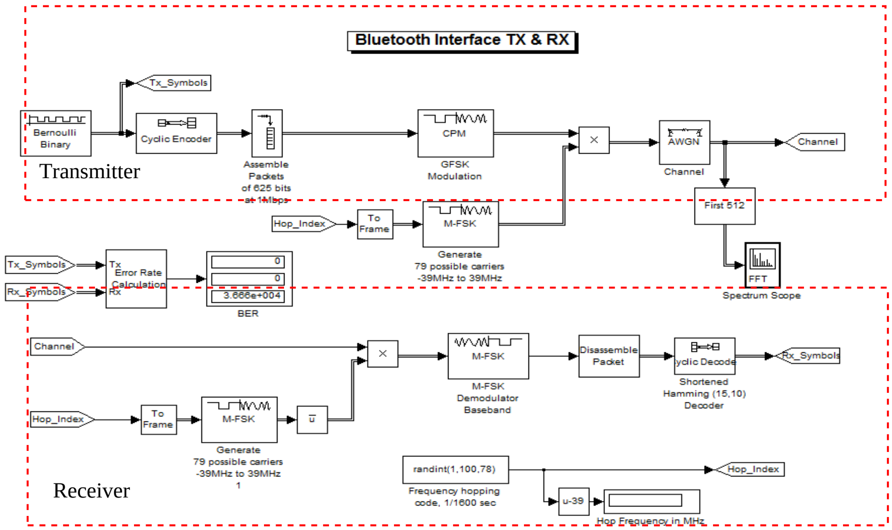

Figure 7. Gaussian frequency shift keying (GFSK) and multiple frequency shift keying (M-FSK) for Bluetooth interface.

2.2. Circuit Design: Bluetooth Transceiver

Figure 7 shows a circuit design for Bluetooth wireless data link between transmitter and receiver. Bluetooth is a short-range radio link technology that operates in the 2.4 GHz Industrial, Scientific, and

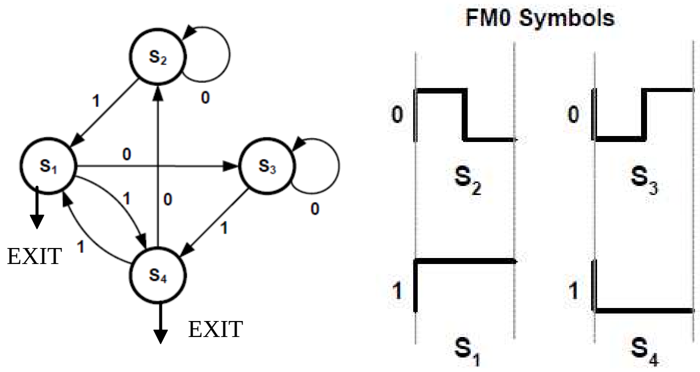

Figure 8. FM0 generator state diagram with symbols.

Medical (ISM) band. It uses modulation signals for Gaussian frequency shift keying (GFSK) over a radio channel with maximum capacity of 1 Mbps. The purpose of the frequency hopping over a 79 MHz frequency range is to avoid interference with other devices transmitting in the band. In addition, the sender divides the transmission time into 625-microsecond slots and uses a new hop frequency for each slot. Although the data rate is only 1 Mbps, a much larger bandwidth of 79 MHz is required to simulate the frequency hopping effects. A Binary Cyclic Encoder block is used for the error correction encoder. The frequency hopping GFSK modulation is constructed with a continuous phase modulation (CPM) modulator block together with the MFSK Modulator block. An MFSK demodulator block is used to construct the frequency hopping demodulator.

3. SIMULATION RESULT

3.1. RFID Reader Communicate with Tag

Based on Figure 3, when the tag receives a signal from the reader, the tag feeds back a signal via backscatter or reflects the incident RF waveform by switching reflection coefficient of its antenna pair between reflective and absorption states. Backscatter data are then encoded as FM0. The detail of how FM0 is encoded based on the state diagram is shown in Figure 8. The output result is shown in Figure 9.

As shown in Figure 8, a state diagram maps a logical data sequence to the FM0 basic function that is transmitted. The state labels also represent the FM0 waveform transmitted upon entering the state. The labels on the state transitions indicate the logical values of the data

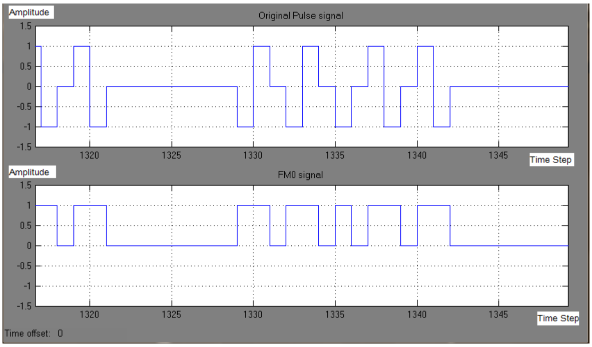

Figure 9. Matlab simulation result for FM0 coding.

sequence to be encoded. States S_1–S_4 indicate four possible FM0-encoded symbols shown in Figure 8, represented by the two phases of each of the FM0 basic function. A transition from states S_2–S_3 is disallowed because the resulting transmission would not have a phase inversion on a symbol boundary.

Theoretically, in order to generate a FM0 coding state diagram, the simulation is performed by using Matlab software as shown in Figure 9. From the figure, the first pulse waveform shows the origin pulse (+ve & −ve) from the scope as discussed in Figure 3. The phase invertion is shown at the beginning of each new symbol. Bit 1 is constant over symbol period, and bit 0 has a single phase change during the symbol period.

Basically, the tag communicates with the reader by using a backscatter modulation, in which the tag switches the reflection coefficient of its antenna between the two states which are absorptive and reflective. The tag backscatters are implemented by using a fixed modulation format, data encoding and data rate within the duration of an inventory round.

The tag backscatters using ASK modulation are produced by changing the magnitude component of the input reflection coefficient. It is to prove that the magnitude component of the input reflection coefficient will be most likely used for powering up the passive tag as shown in following derivation.

First, the amplitude shift keying (ASK) can be defined as in the equation below:

$$s(t) = A\,m(t)\cos 2\pi fct, \quad 0 < t < T \tag{1}$$

where A is a constant, $m(t) = 1$ or 0, fc the carrier frequency, and T the bit duration. The ASK modulation has a power $P = A2/2$, so that $A = 2P$. Thus Equation (1) can be written as:

$$\begin{aligned} s(t) &= \text{sqrt}(2P)\cos 2\pi fct, \quad 0 < t < T \\ &= \text{sqrt}(PT)\text{sqrt}(2/T)\cos 2\pi fct, \quad 0 < t < T \\ &= \text{sqrt}(E)\text{sqrt}(2/T)\cos 2\pi fct, 0 < t < T \end{aligned} \tag{2}$$

From the above derived equation, amplitude of the ASK modulation can be determined. The amplitude which is two times larger than power can be used to power up the passive tag. The result of this equation can be simulated by using the MATLAB application that shown in Figure 10.

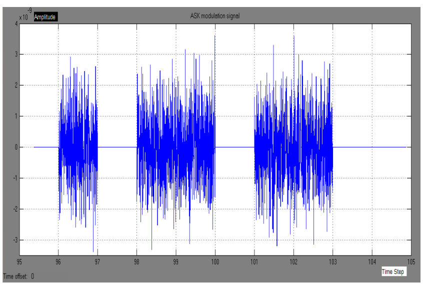

Figure 10. Result of amplitude shift keying (ASK) generated after tag communicates with reader.

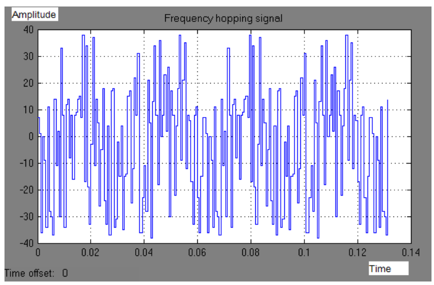

Figure 11. Scope show the hop frequency over the time.

3.2. Bluetooth Transceiver

The purpose of this simulation is to simulate the avoidance frequency interference in the ISM band. In this scheme, the sender divides the transmission time into 625-microsecond slots and uses a new hopping frequency for each slot. Although the data rate is only 1 Mbps, a much larger bandwidth of 79 MHz is required to simulate the frequency hopping effects as shown in Figure 11. The simulation of the frequency hopping effects is important for analyzing the spectral interference. This received spectrum is shown in Figure 12. Besides, observing the bit error rate (BER) is important for determining the bit transfer accuracy. The data BER is calculated as plot on the scope as shown in Figure 13. The BER is analyzed to check the accuracy of transmitter (TX) and receiver (RX) communication and achieves very good read ranges.

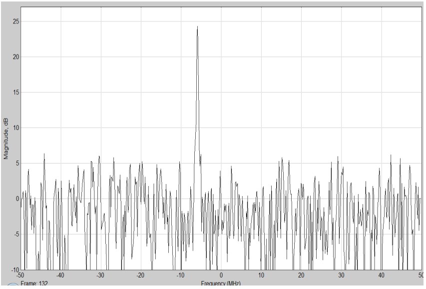

Figure 12. Received signal spectrum.

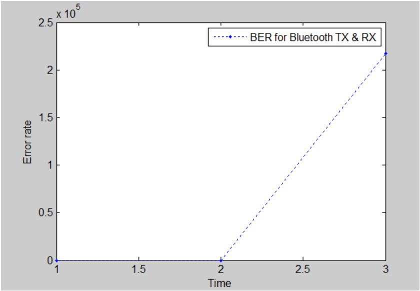

Figure 13. Bit error rate data to compare for transmitter (TX) and receiver (RX).

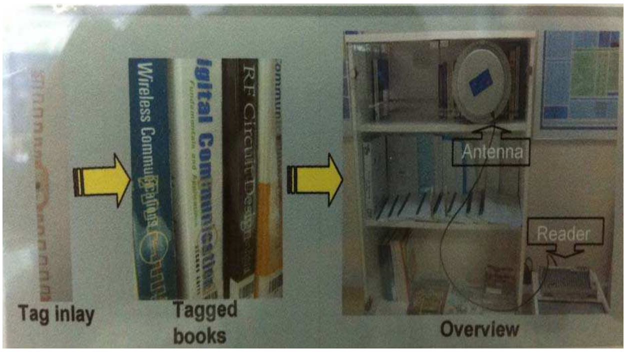

Figure 14. Experimental for RFID system.

4. EXPERIMENTAL RESULT AND DISCUSSION

In system verification, the experiment is carried out in order to test the communication between the RFID reader and the passive tags as shown in Figure 14. It shows that the book is attached with the RFID tag based on UHF Gen 2 to test the tagging system. This experiment shows how the system can identify the items by using the RFID reader. In fact, it can be observed that the reader is connected with the antenna in order to optimize the performance of the reader. There are different types of tags are used, based on the frequency band, which require different kinds of antennas in order to read the tag information. Besides, the result of ASK signal will be produced when the reader and tag communicate as shown in Figure 15.

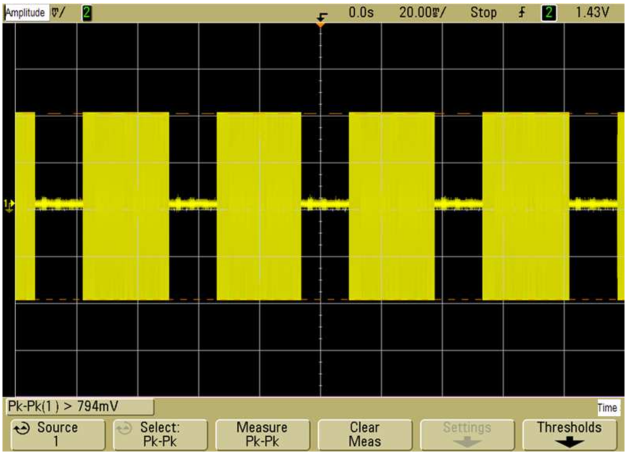

Figure 15. Communication between reader and passive tag result of the ASK signal.

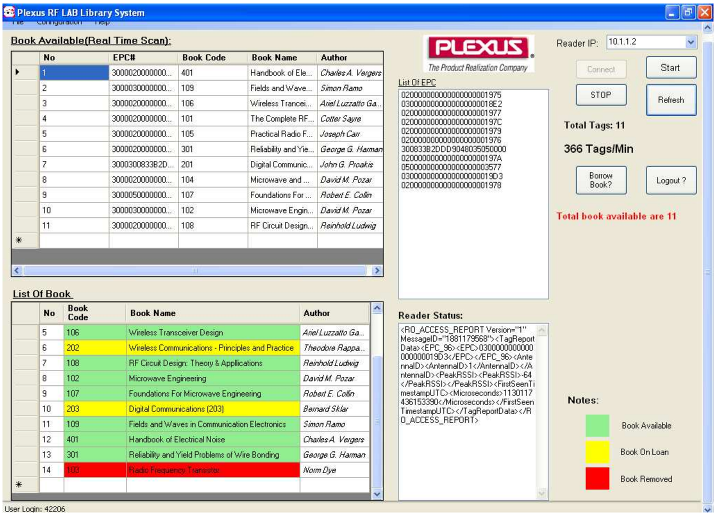

Figure 16. Prototype software design for RFID tagging system.

4.1. Prototype Software Design

Moreover, a prototype software is developed in order to interface with Impinj RFID reader through the ethernet connection as shown in Figure 16. This prototype software is able to fast identify the item simultaneously based on the EPC number read from the tag. The EPC

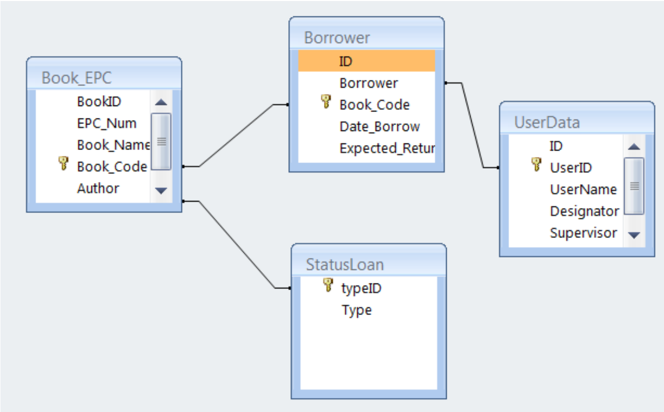

Figure 17. Prototype software design for RFID tagging database system.

number from each tag will be automatically recorded in the database corresponding to the specific items. All information such as an ID, name, and date and so on can be found in the database system as shown in Figure 17.

Moreover, this software can be implemented to check the quantity of the product available in the stock. It also can be observed in the list of books that a different color is used to classify whether a book is removed or borrowed. This system identical to the current developed RFID library system can be implemented at the POS system for product tracking purpose. Apart from this, by using the LLRP protocol identified as asymmetric protocol, the Client-PC is able to speak with the reader where it can initiate the connections. Based on the Reader Operation Specification of Antenna Inventory Specification (AISpec), it will instructs the reader from the antenna settings and particulars about the inventory operation, such as an inventory stop time and type of antenna. In some cases, even though the client PC has lost connection with the reader, it is still able to obtain the reports back from the reader. Besides, the software also allows the tag selection criteria to be configured and is implemented by using a tag data pattern, antenna, or a specific Reader Operation Specification.

Meanwhile, another prototype software is developed as shown in Figure 18. The purpose is to make a pairing with the PC in order for them to communicate through the virtual COM port. The interface with the Bluetooth mobile phone is important for transaction purpose. The transmitted and received data are needed to perform the encryption and decryption process in order to ensure the security.

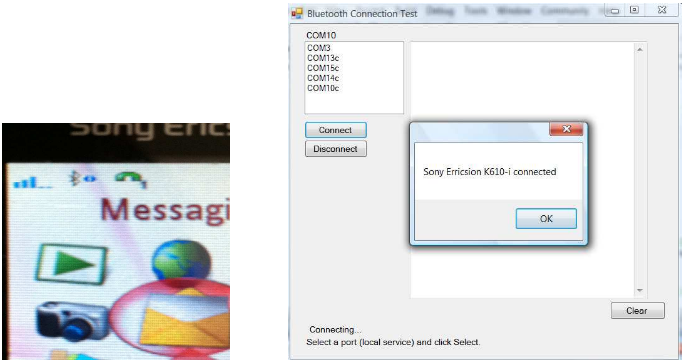

Figure 18. Prototype software design for Bluetooth device link with PC.

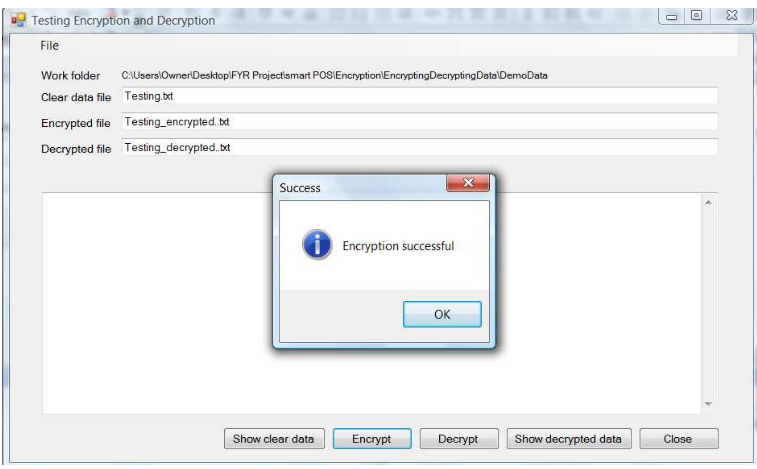

Figure 19. Prototype software for data encryption and decryption toward the security level of transactions.

As a verification result, the data encryption and decryption toward the security level of transactions has been successfully implemented as shown in Figure 19.

Finally, the whole complete prototype POS software as an integrated system is developed as shown in Figure 20. This POS software is designed as user friendly, such as auto-summing up the prices of the items purchased by the user, which makes the operator work easier. It does not need a traditional scanning method where the

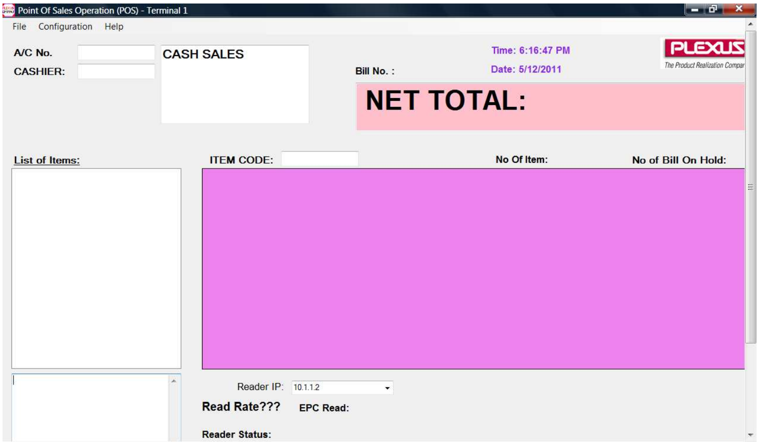

Figure 20. Prototype software design for POS integrated system.

customers just send their authorization signal for customer approval via Bluetooth and will show the items taken in the trolley to the customer. The customer is able to make a fast transaction because without waiting there will be less crowded at the counter. Besides, this integrated system allows controling the inventory system such as tracking, restoring, or refilling the items found in the stock. The development of this integrated POS software shows that the RFID and Bluetooth technologies are successfully implemented and useful for everyone and make sales business grow rapidly.

5. PROJECT CONTRIBUTION

Based on the result and discussion, the design of wireless technology which involves radio frequency identification (RFID) and Bluetooth technology for tagging and transmission of data is successfully implemented. By using the RFID and Bluetooth technologies implemented in the POS system, consumers no longer waste time to queue up at the cashier terminal and can select their preferred items and easily purchase through the Bluetooth mobile phone. Besides, consumers are able to search the availability of their preferred items from the stock database through the Bluetooth mobile phone. With both the technologies implemented in POS system, sales business will grow rapidly.

6. CONCLUSIONS

In conclusion, in this paper, wireless communication, such as RFID system and Bluetooth system, is investigated for POS system improvement. RFID tagging enables items tracking and identifying easily compared with barcode system. Meanwhile, Bluetooth system enables fast transaction to make purchase secure by using the proposed asymmetric algorithm. Finally, the design for such a wireless communication system is useful for future POS system improvement.

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