Radio Frequency Identification for Commercial Purposes

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Table of Contains

Abstract

The RFID technology is evaluated for use in retail stores to replace barcodes system. The theme of the project is RFID Shopping Cart Scenario. At checkout lines, people can just walk through a checkout area where a reader is placed and get a bill for the merchandize purchased within seconds. Comparing to barcodes scanning, it makes shopping a less time-consuming experience, which is favored in today society. The system is based upon the Skyetek ISO 15693 reader, TI HF-I tags, and external metal plate antenna. There are four technical problems: orientation, multiple paths, multiple items, and identical items. The problems of multiple items and identical items have been solved through the project.

Introduction

Barcodes have been in existence for many years and have been used by department stores and supermarkets to manage purchases of merchandize by customers and keep track of inventory. However, the barcode system is no longer the best way to business operation. Customers are tired of waiting in a long, slowly moving checkout line in department stores, especially, in holiday seasons. With the decrease of prices through efficiencies of technology and large-scale production of semiconductor wireless components, there has been a search for new markets in which semiconductor chips can be used. This has led to the innovation of RFID also known as smart tags.

RFID stands for radio frequency identification. A basic RFID system has two main components: reader and transponder. The reader consists of an antenna, transceiver, and decoder. The transponder, also called tag, is electronically programmed with unique information. Figure 1 illustrates the basic operation of RFID system.

The RFID Shopping Cart Scenario has the Skyetek ISO 15693 reader, TI HF-I tags, and external metal plate antenna. Compatible with 13.56 MHz RFID tags, the reader, which has basic features of reading and writing, solely offers approximately 5cm of reading range. TI HF-I Transponder is selected due to its thin and flexible structure. An external antenna is added to the system for reading range improvement. Two kinds of antenna are proposed and built for better selection: plate antenna and loop antenna.

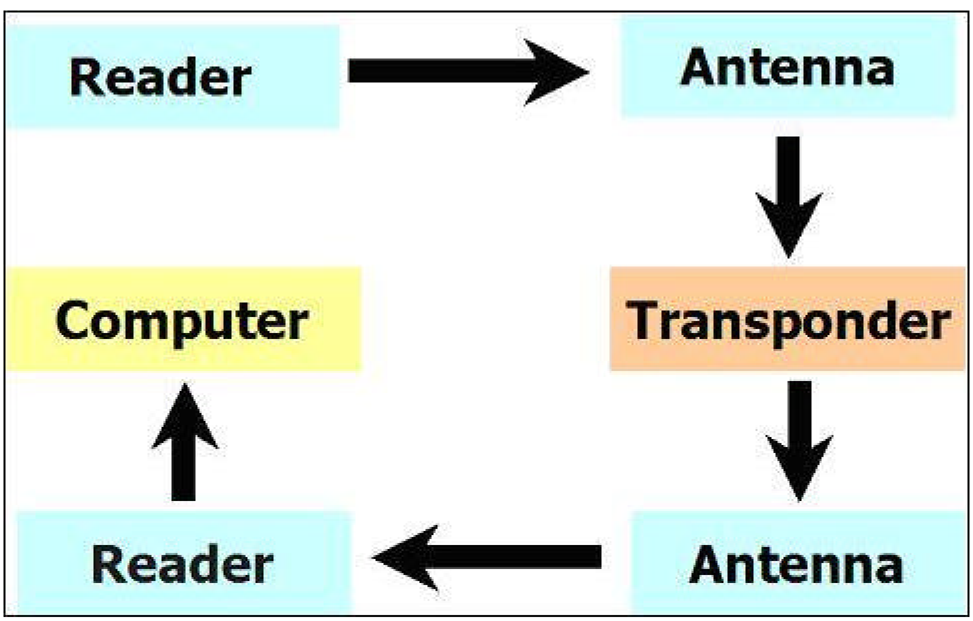


Figure 1 System Operation

Month	Task
June - July	Searched for the right reader & got the reader and tags
July - Aug	Decided for the right antenna & Built antenna
Sept - Oct	Waited for the lab code, measured, tested, and program
Oct - Nov	Built 2nd aluminium antenna, steel antenna and copper wire antenna
Dec	Prepared for the presentation

Antennas

Dimensions of Antennas

We built the 1000mm x 600mm antenna after we researched from the Texas Instrument website. This antenna works the best with the high power reader. It resonates at 13.56MHz and 50 Ohms impedance. The following are full of pictures and constructional details of the antenna:

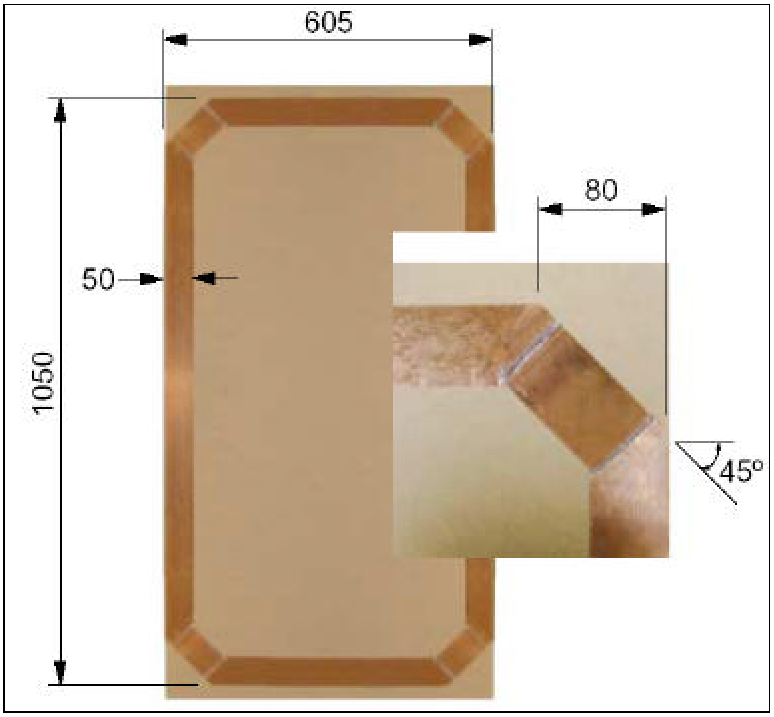


Figure 2 Soldered Copper Main Loop

Figure 3 Variable mica capacitor

Figure 4 Resonance capacitor and damping resistor

Matching the loop to 50 Ohms

The quarter (1/4) wavelength coaxial cable connects with the reader and the main loop antenna.

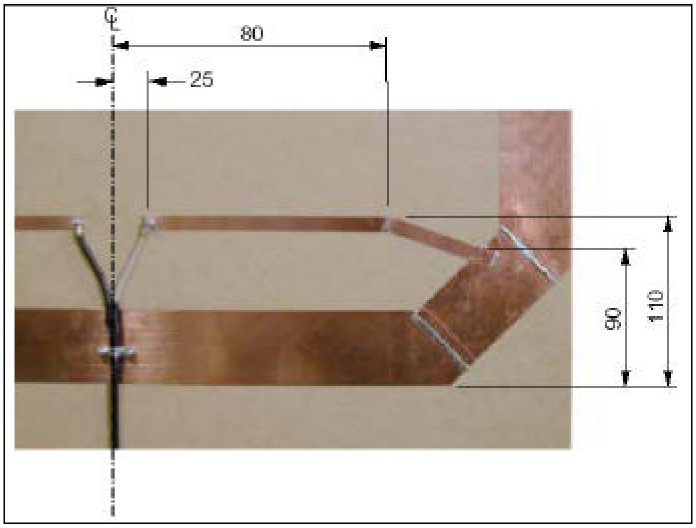


Figure 5 Matching T Network

Dimension of Matching Arms

The 'T' matching to tap the main loop gives the correct 50-Ohm matching. After we did some research, we figured out that the Texas Instrument's main loop antenna should have worked with our reader, and it is also easy to build. Therefore, we started with aluminum foil antenna instead of copper tape.

The following are the antennas we have done to expecting for improvement:

First antenna

This antenna is built with aluminum foil, 5-190 PF variable capacitor, 22K ohms resistor, and coaxial cable. We use the variable capacitor to allow for tuning the antenna and the 22K Ohms to adjust the antenna Q. It is a loop shape antenna; its resonance frequency is 13.56 MHz and supposedly, it can read long range. It is easy to make if we can get the right soldering. Soldering took us a lot of time building this antenna because the aluminum foil doesn't seem to stick with the zinc. Whenever we do the antenna testing, we need to do the soldering part even we finished building the antenna. This antenna is very unstable because it is depends on many parts, such as conducting and capacitance. Because of unstable, we had a hard time of tuning at the right frequency.

Figure 6 Second Antenna

Second antenna

This antenna is built based on the first antenna. Because of the soldering part made us very annoying, we got the idea of minimizing on soldering. Therefore, we cut the shape of the first aluminum foil antenna and stick it on the board. This idea not only saved us a lot of time on soldering, but it also gave us better ‘Q’.

Figure 7 Third Antenna

Third antenna

The first two antennas' reading range is about up to 2-3 cm and are not enough to apply our shopping cart scenario project. Thus, we were thinking that if we use the metal plate instead of the aluminum foil, then we might get the longer reading range. Therefore, we use the iron metal plate to replace the aluminum foil. It improves the reading range up to 5 cm, but not what we expected initially. However, the advantages of this antenna are salability, robust, and easy to do the testing, which means we do not need to solder again, whenever we do the testing. The disadvantage is very lossy as well as the first two.

Figure 8 Fourth Antenna

Fourth antenna

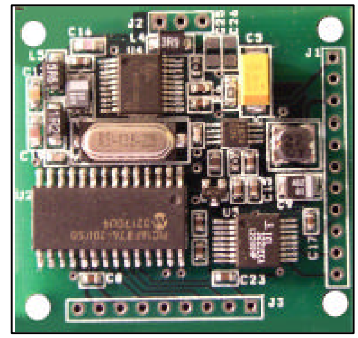
The reading range of this antenna still is not what we want, so we though of other shapes of antenna to achieve for the larger gain. Finally, we agreed to do the two-loop copper wire antenna for larger gain. One is the square shape copper wire antenna and another one is circular shape copper wire antenna. These antennas are easy to design, but they are very hard for tuning because they are very sensitive. The square shape antenna works at the right frequency, but the reading range of this antenna is worse than the first three because it can read only about 1cm. The circular shape of the antenna does not seem to work at the right frequency, which is 13.56 MHz; it works only at 14.99 MHz.

<u>Complications</u>

We face many complications while we are doing this project. Three of the most significant complications are reader selection, antenna selection and equipment lab.

Reader selection

Last semester, we planned to buy a RFID development kit from Texas Instrument, which includes a reader, an antenna, and some tags. We contacted the supplier during summer and the supplier informed us that the reader doesn't have enough power for long-range transmission, such as 50 cm. He suggested us to buy a high power, which cost about $2000 and we couldn't afford it. We researched on the Internet and contacted the other RFID group. We figured out that Skyetek reader is affordable, and it has a reading range of 7 cm on the data sheet. When we tested the reader, however, the reading range was only 2 cm.



Antenna Selection

After finding the reader, we needed to build our own antenna. We didn't look into this problem earlier because the development kit includes an antenna. We learned some basic knowledge of antenna from Dr. Kwok in EE172 class. Our group discussed about whether we should build a yagi antenna or helix antenna. We realized that we didn't have enough knowledge to design an antenna, so we researched on the web, and we found the design for our aluminum antenna. It works at the right frequency (13.56MHz), and it should cover a large area with more power.

Equipment Lab

After building the antenna, we needed network analyzer to test it; however, the school equipment was not available on that time because a professor took it home. We finally waited for one month to get the lab code. While we were waiting for the school lab, we also try to arrange a lab from the industry. We found a network analyzer lab, but we didn't use it because school lab was available at that time.

<u>Achievements</u>

Although we face many complications while doing our project, we also have three achievements solved multiple items and identical items problems, wrote a demo program and built, tuned, and tested five antennas.

We verify that our reader is capable of reading multiple tags at the same time. The reader is also capable of scanning identical items and distinguishes them because each tag has its unique ID number. We also try to put a tag on a can of soda, and the reader can't detect the tag. Since the tag is affixed directly on the can, we suspect that the aluminum can act as a big ground to the antenna on the tag. This grounding effect may interfere with tag data transmission. Another possible cause is the screening effect of the liquid. The liquid in the can may block the reader's RF wave.

We wrote a demo program to show our audience what we try to achieve with this project. On the senior project presentation, we plan to show an ideal demo before the real one. Sadly, we are a little nervous in the presentation and skip this part.

We built, tuned, and test five antennas with improvements to each new version. We spent numerous hours in the lab to tune our antennas. The longest reading range of our antenna is 5 cm, which performs better than the 2cm range of the reader internal antenna.

Things that We Learn

We learn many things while we are working on this project. The following list is some of the most important ones using network analyzer; interacting with supplier and people from the industry for material and laboratory; fabricating, tuning, and soldering antenna; learning the design cycle and cooperating as a group.

Our advisor taught us how to use the network analyzer. We know many of its functions, and we often measure the S11 of our antenna with the network analyzer. S11 is the refection coefficient, which indicates how much energy is transmitted through the antenna.

We have this wonderful experience of interacting and networking with people from the industry, which will help us in the future when looking for a laboratory outside and purchasing the antenna.

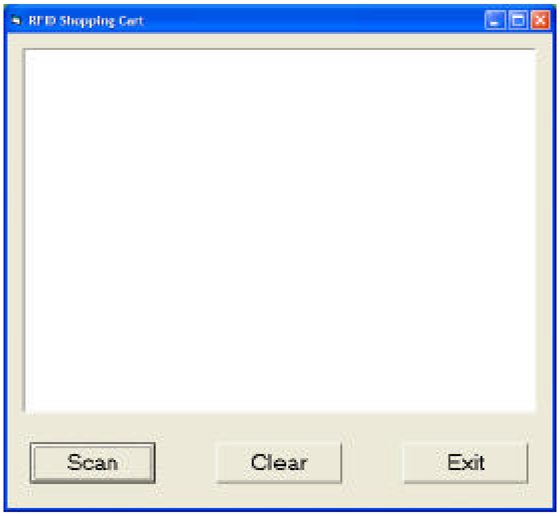
We learn to fabricate, tune, and solder antenna. The solder on our first antenna detached frequently, and we need to re-solder the parts repeatedly. We have mastered the soldering techniques through practice

We practice the design cycle in the project. A design cycle usually starts with an idea. After exploring the idea, we turned it into a workable concept. Then, we search for available parts to build a product. We then test the product, and try to fix any problem with it.

We are glad that we work together as a team. Teamwork experience is very important because engineers never work alone in the industry.

Ideal Demo

We wrote a program to show our idea about this project, and here is how it should work. Figure 9 shows the standby screen when a cashier is not helping customer. When a customer approaches the checkout line, the cashier will ask the customer to push his shopping cart to designated area. The cashier then clicks the “scan” bottom on screen. Figure 10 is a screen shot showing the scaning result and total. After clooecting the payment from the customer, the cahsier can clikcs the “clear” bottom to clear the screen and wait for the next customer.



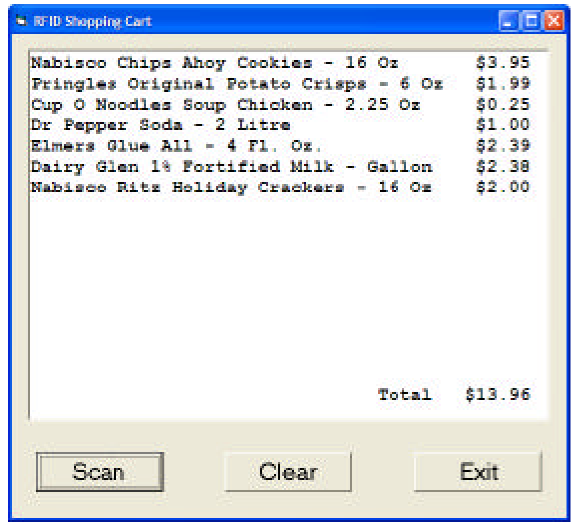


Figure 9 Standby

Figure 10 Scanning

<u>Future Developments</u>

Amplifier

There is a problem with the reading range because of the low power rating of the reader. Using an amplifier to send a stronger signal from the reader to the transponder can solve this problem. By sending a larger signal out of the antenna, the signal can travel further. The signal is inversely proportional with the square of the distance between the antenna and the transponder.

Since an amplifier can only amplify a signal in one direction, the amplifier needs switches on both sides and the system needs two amplifiers. In the Figure1, it shows the block diagram of the system that needs to be built to make this work.

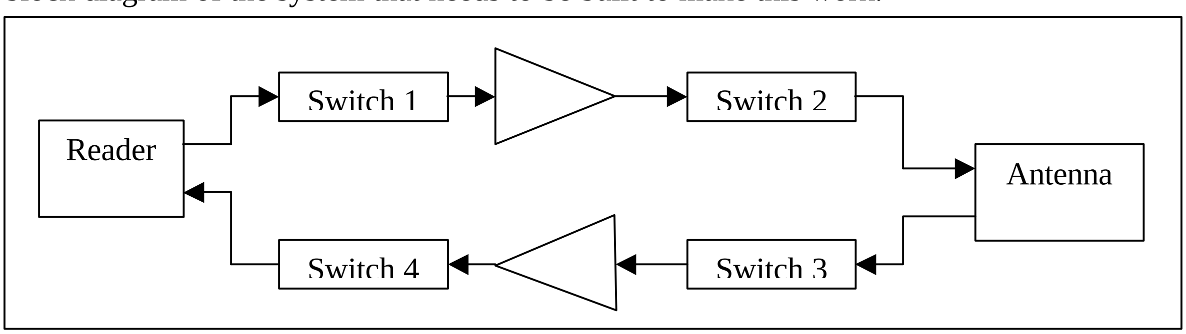


Figure 11 Block diagram of system

The four switches are to control the flow of the signal. Switches 1 and 2 are for the sending of the signal from the reader to the transponder(s) while switches 3 and 4 are for the receiving of the signal from the transponder(s) to the reader. The amplifier is to amplify both signals being sent and received by the antenna. This will help increase the power of the signal strength that attenuates with a factor of a inverse square of the distance of the antenna of the reader and the antenna of the transponder.

Antenna

There is still an orientation problem that needs to be solved using an array antenna. Since the size of the antenna needs to be half the wavelength on each side, the number of antennas in the array cannot be more the four. Using an array antenna to capture all of the orientation of the transponders might work. We need to cover a larger area using an array by setting up a vertical and horizontal magnetic fields so that it could be picked up by the transponder. Although using an array might help solve this orientation problem, we will have feeding of each antenna in the array.

A coupler should be used so that we have mixing of the signals from each antenna to form a greater or larger signal. The coupler needs to be built so that it could be used sum all the signals together.

Another solution to this problem is to use switches before each antenna. The switches will be used to control which antenna the reader will be using during scanning. The serial numbers that are read from the reader will be saved and compared between each antenna output.

Programming

With all the switches built with the amplifier and the antenna, the programming will be an essential part of this project to put the system together. The programming will be divided into four major parts that are identification and saving of the serial numbers of the transponders, controlling the switches, serial number database and the price display.

The reader will be used to identify the serial numbers of the transponder tags. The reader uses the serial port to get the information out. An interface between the program that is used to get the id tags and saving the serial numbers from the tags need to be established. Programming in C++ will be needed to remove the serial numbers from the tags. The serial numbers will then be stored in a location for comparison later.

Another program need to be written to control all the switches that are used in the amplifier and the array antenna. This control needs to be in-tune with the other identification of the transponder tags because when the reader is trying to identify the transponder(s), it needs to make sure that the correct switches need to be activated for the correct flow of signals. It must also take into account the time delay in which the reader needs to wait before the other switches are turned on for the receiving of signals from the transponder.

The other portion of this program is the serial number database. This database need to include a block of serial numbers be distributed for product in the market and the price for the product being sold. Another programming part of this database is to make sure that this program will remove all items sold and free those serial numbers from the database. It should have an option to reprogram serial numbers for the same items so that it could be a constant updating of data in the database for stocking purposes.

The last part of the programming will include several displays for stocking and pricing calculation for checkout. It should also include the serial numbers of the items for checking purposes. If not there is not way to verify if the serial numbers are incorrect.

Cost analysis

The cost of this project is divided equally by each member. The cost of this project lies in the reader and the transponder tags. The total cost of the project is $103.00 as shown in Table I.

The reader is the most expensive item of the project and is shown in Table I. The choice of the reader is to reduce the cost we have on this project. There were two options of choosing one reader was from Skyetek that was the reader that was used in this project and a more expensive reader from Texas Instruments that had a higher power rating. The conclusion that the cost difference between the two readers is not worth the small increase in power rating of the more expensive reader.

We used aluminum foil for the first prototype of the antenna because it is cheaper than buying copper sheets. Cost was the determinant of this first prototype because the antenna that was going to be built might not work and resources might be wasted. After the first prototype of the antenna worked, the group opted for metal sheet rather than copper sheet for the cost too. Finally, copper wire loop antenna was used rather than copper sheet because copper wire is cheaper than copper sheet.

Beside the reader and the antenna materials, there were other costs involved like variable capacitor, plywood boards for the antenna, coaxial cable, resister for power dissipation and lowering of Q of the antenna, and the transponder tags.

Table 1 Cost analysis

Reader	$117.00
Tag	$27.00
Male to female cable	$8.65
Variable capacitor	$5.00
Board	$12.70
Copper wire	$18.00
Coaxial cable	$5.00
Total	$193.35

Conclusion

There were some accomplishments such as solved multiple items and identical items problems, written a demo program and built, tuned, and tested five antennas. The members build and implemented a system that works partially. Scanning range was one main problem that other issues like orientation and multipath propagation of signal cannot be taken into account. Using the Skyetek reader and Texas Instruments identification tags, it is rather reliable although power rating for the reader might be a rather low.

Appendix

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

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