Modulation Technology in RFID

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1 Motivation

Radio Frequency Identification (RFID) systems use radio frequency to identify, locate and track people, assets, and animals. It has drawn more and more sight in item identification and indoor localization. Compared with barcode, RFID does not require human intervention, thus it reduces employment costs and eliminates human errors from data collection. What's more, as no line-of-sight is required, tag placement is less constrained. In indoor localization area, compared with BLE, the tag component of RFID does not need energy source thus it can save more energy. What's more important is that RFID is more accurate than BLE thus it can be used in item-level localization.
Our group wants to use RFID for book localization in library but before we can use RFID, we must know the modulation technology used in RFID to start the experiment.Based on this motivation, I am responsible for investigating the modulation technology used in RFID in the past literature and these are the reference [1], [2], [3], [4] and [5]. The total report is the result of the investigation.

2 Introduction

RFID is short for radio frequency identification devices. The system is usually used for Item Identification and Indoor Localization. Usually a RFID system consists of these major components: Reader, antenna and RFID tag(Figure 1).

Figure 1: RFID reader, antenna and tag

Reader and antenna are used to transmit energy to tag and demodulate the signal it received from the tag. Tag is attached to the item to be localized like book or box. In our project the RFID tag is passive tag, which means it does not need source energy. It can use the energy from the reader to demodulate the command from reader and modulate the data in its memory and backscatter the signal to reader after modulation.
The overall structure of a RFID system is like this(Figure 2)

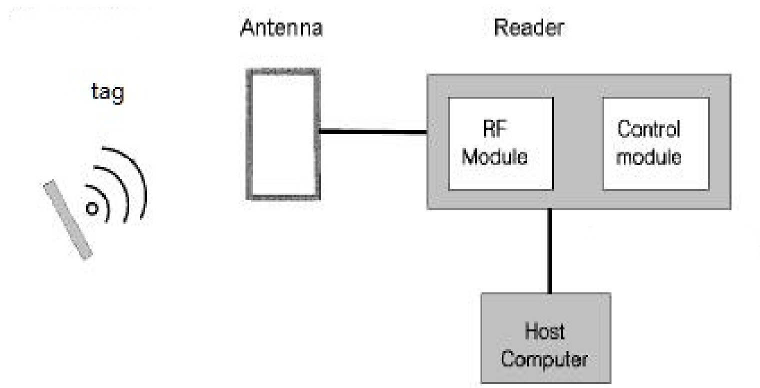

Figure 2: overall structure of a RFID system

A host computer or just a microprocessor with corresponding program controls the reader to send specified commands to the tag to read information from tag or write information into it. Receiving the signal from reader, tag will get energy from the signal, demodulate the command and backscatter a signal with information modulated in it.

3 Modulation Technology

The modulation technology used in RFID includes two parts: physical mechanism i.e. backscattering modulation and digital modulation technology.

3.1 Backscattering Modulation

The definition of backscattering modulation is a process where tag receives energy from reader and backscatter the signal modulated with information in it.According to the different mechanism used, Two fundamentally different RFID design approaches exist for transferring power from the reader to the tag. They are near-field coupling and far-field coupling.

3.1.1 Near-field Coupling

The EM field in the near-field region is reactive in nature-the electric and the magnetic fields are orthogonal and quasi-static. Depending upon the type of antenna, one field (such as the electric field for a dipole or magnetic field for a coil) dominates the other. Most near-field tags rely on the magnetic field through inductive coupling to the coil in the tag. This mechanism is based upon Faraday's principle of magnetic induction. A current flowing through the coil of a reader produces a magnetic field around it. This field causes a tag's coil in the vicinity to generate a small current.(Figure 3)

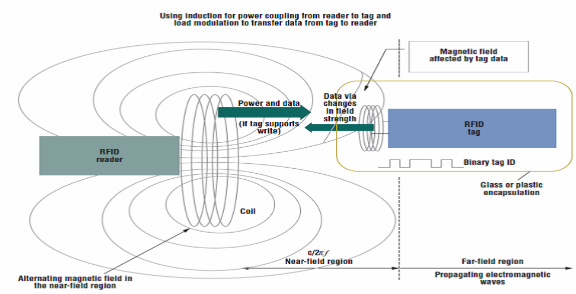

Figure 3: Near-field coupling

Though the design is easy to implement, it has limitation. Firstly, The range for which we can use magnetic induction approximates to λ, that is one wavelength. Secondly, Energy available for induction as a function of distance from the reader coil. Attenuation of power is proportional to r^{-6}.

3.1.2 Far-field Coupling

RFID tags based on far-field coupling capture electromagnetic waves propagating from a dipole antenna attached to the reader. A smaller dipole antenna in the tag receives this energy as an alternating potential difference that appears across the arms of the dipole.(Figure 4)

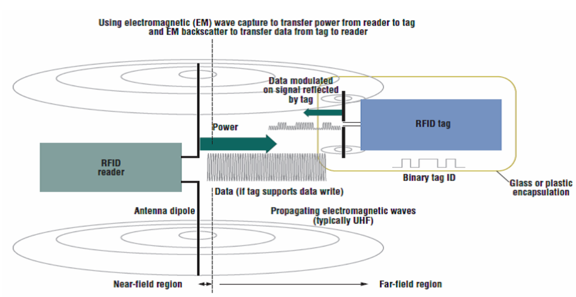

Figure 4: Far-field coupling

Compared with near-field coupling, far-field coupling has two superiorities. The first one is that because EM field can only be used in one wavlength, in order to make the range larger, the frequency of near-field is usually low, causing

a narrow bandwidth. While the far-field doesn't have such a limitation so its bandwidth is broader. The second one is that the attenuation of far-field is less than near-field, which is proportional to r^{-4}.
We use far-field coupling in our system.

3.2 Digital Modulation

We can use backscattering modulation to calculate energy and to transport the information in the tag, we need digital modulation. Briefly the circuit in the tag is like this(Figure 5).

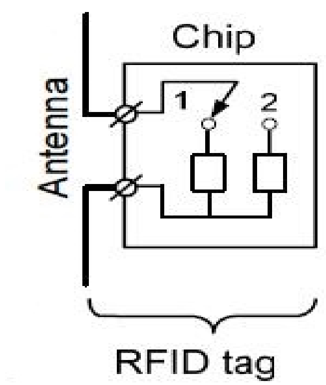

Figure 5: Far-field coupling

We can see that there are two loads in the chip and their impedance are different. Thus different impedance makes different current intensity to distinguish one from zero. Thus we can modulate the information on the signal.

3.2.1 ASK

ASK is short for amplitude shift keying. The different amplitude of the signal forms a bit stream which consists of the information. A high in the amplitude is a '1' and a low is a '0'.Reader just needs to see whether the amplitude of one cycle is greater than or smaller than a threshold value to tell one from zero(Figure 6).

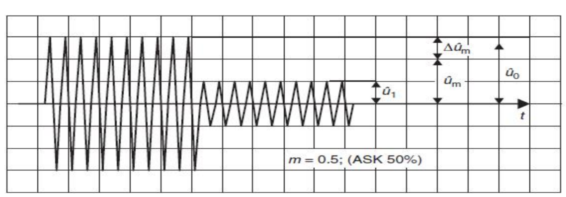

Figure 6: ASK

Our system uses ASK as it can provide a high data rate and it's easy to get phase of the wave which can be used for localization. But it also has limitaion, that is low noise immunity.

3.2.2 FSK

FSK is short for frequency shift keying. This form of modulation uses two different frequencies for data transfer(Figure 7).

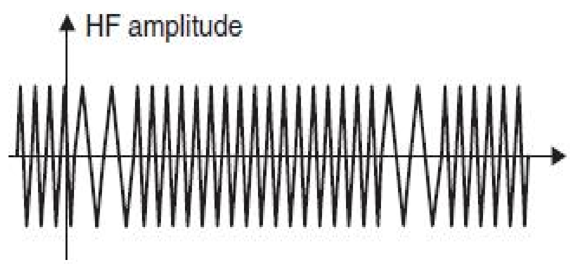

Figure 7: FSK

FSK allows for a simple reader design, provides very strong noise immunity, but suffers from a lower data rate than some other forms of data modulation.

3.2.3 PSK

PSK is short for phase shift keying. In PSK, the binary states 0 and 1 of a code signal are converted into corresponding phase states of the carrier oscillation, in relation to a reference phase(Figure 8).

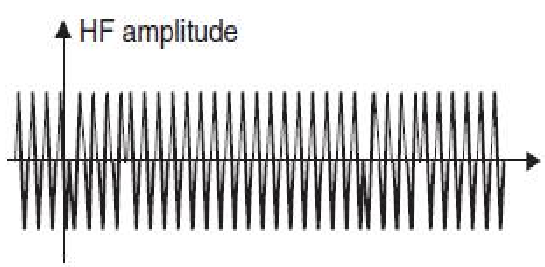

Figure 8: PSK

PSK provides fairly good noise immunity, a moderately simple reader design, and a faster data rate than FSK. But the design and implementation of the circuit in the tag is complex.

4 Localization Algorithm

In fact I'm not responsible for designing algorithm and here I will only briefly introduce the algorithm. The algorithms here are just some prototypes which only calculate the distance between antenna and tag.
All the algorithms need to know the phase difference between the received signal and transmitted signal. The phase difference can be calculate as follows(Figure 9)

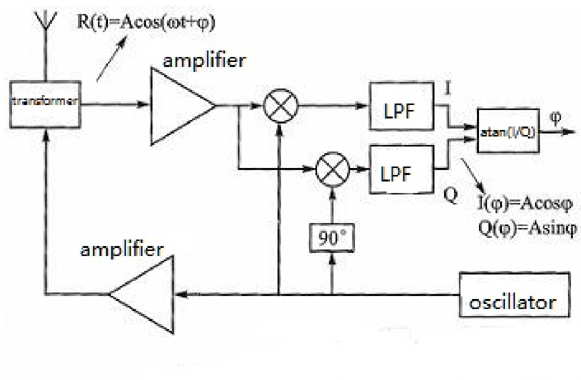

Figure 9: Demodulation

4.1 Single-Frequency

RFID reader can get the phase difference between the received signal and transmitted signal. According to the formula:

$$d = \frac{1}{2} \cdot c \cdot \frac{\varphi}{2\pi f} \tag{1}$$

where d is the distance between antenna and tag, c is the velocity of light, φ is the phase difference between the received signal and transmitted signal and f is the frequency of the carrier signal.
However this algorithm can only measure the distance in half a wavelength because the value of φ is in $[0, 2\pi)$ because of the range of $arctan(I/Q)$. For example if the real phase difference is 3π, we can only know the value of φ is π.

4.2 Double-Frequency

To measure the distance beyond half a wavelength we choose two carrier signals with different frequencies. From the last measurement method we can know if the frequency is smaller, the wavelength is larger, meaning a larger range of measurement. But low frequency means narrow bandwidth so here we use two carriers with small frequency difference. We know that

$$\varphi_1 = 2\pi f_1 \cdot t \tag{2}$$

$$\varphi_2 = 2\pi f_2 \cdot t \tag{3}$$

where the φ_1 and φ_2 is the phase difference of two carrier and f_1 and f_2 are the frequencies of two carrier. Thus we have

$$t = \frac{\varphi_1 - \varphi_2}{2\pi(f_1 - f_2)} \tag{4}$$

$$d = \frac{1}{2} \cdot c \cdot \frac{\varphi_1 - \varphi_2}{2\pi(f_1 - f_2)} \tag{5}$$

Here the system can be seen as one carrier whose frequency is $f_1 - f_2$. But this method demand an extremely accurate phase difference measurement which can hardly be realized in our experiment environment.

4.3 Single-Frequency with RSSI

As BLE uses RSSI to perform indoor localization, we try to combine RSSI and phase difference to localize items. RSSI can roughly indicate a distance range and in this range, phase difference can give a more precise answer.

5 Experiment and Result

Our group wants to design a RFID system to localize books in library. For a start we need to know the phase we receive at the reader and its stability. As introduced before, the accuracy and stability of the phase directly influence the accuracy of localization result. We used the RFID reader and antenna produced by Impinj Inc. (Figure 1) and chose 921.625Hz as the carrier frequency. And the overall system is just like Figure 2. The reader will transport the phase it received from the tag and the result is show as follows(Figure 10).

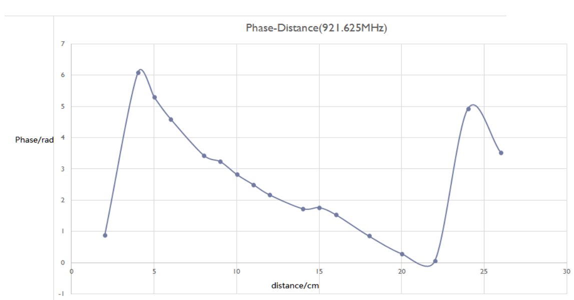

Figure 10: Phase versus distance between reade and tag

From the result we can see that the phase is continuous and it changes smoothly with the change of distance unless it is larger than 2π or less than 0. So we can say that the change of the phase is stable.

6 Future Work

From the result we know that the phase is stable preliminarily but we have not tried to implement an algorithm to meansure the distance out of half a wavelength. In the future we will try to implement the double-frequecy method and single-frequency with RSSI method and measure their accuracy and stability.

References

[1] P Sorrells. *"Passive RFID Basics"*. Microchip Technology Inc. 1998

[2] Vipul Chawla and Dong Sam Ha, Virginia Polytechnic Institute and State University. *"AN OVERVIEW OF PASSIVE RFID"*. IEEE Applications and Practice. September 2007

[3] Mandeep Kaur, Manjeet Sandhu, Neeraj Mohan and Parvinder S. Sandhu. *RFID Technology Principles, Advantages,Limitations and Its Applications*. International Journal of Computer and Electrical Engineering. 2011

[4] Klaus Finkenzeller, Translated by Dörte Müller. *"RFID Handbook, 3rd Edition"*, 2010

[5] K Shoarinejad, M Soltan, M Moshfeghi. *"Method and system for determining the distance between an RFID reader and an RFID tag using phase"*. US Patent. 2006