Solution for Collision Avoidance with chip-less RFID tags based on Fractional Fourier Transform

Chao Zhang

Student#: 200383834

Abstract:

For the chip-less RFID tags which are lower cost and more convenient than normal chip tags, I am going to give a solution for collision detection using chip-less RFID in this paper. Linear Frequency Modulated (LFM) is used as sent signal and the received signal is the summation of these LFM signal. Using a digital signal filtering system based on Fractional Fourier Transform(FrFT) to separate these overlapping signal and getting signal which is ready for decoding. At last, IDs of different chip-less tags are got and identified by users. It is a great solution to daily application because using chip-less tags in RFID both brings convenience to us and saves the cost compared to normal RFID system and it is easy to largely manufacture and can replace chip tags in the future.

Key words: *RFID, chip-less tags, LFM, FrFT.*

I Introduction

Components of normal RFID systems: A traditional RFID system includes three parts: RFID tags, a reader and an unit used to process the data. For the reason that the integrated circuits of RFID tags are too expensive, it prevents RFID to be a widely used method for application nowadays.

Introduction to chip-less RFID system: For better using RFID in wireless identification system to reduce the cost and both improve the efficiency, there we consider a chip-less RFID system and put this system into collision avoidance application.

The system I design includes two antennas. One is for receiving the signal and one is for transmitting the signal. The received signal should be the interrogation and the transmitted signal should be the signal after modulated. We will process the signal received from the chip-less tag in the reader and extract tag ID from the frequency spectrum and then decode it.

In application, for example many cars are on the road at the same time, multiple chip-less tags may be close to each other just like the graph shown below.

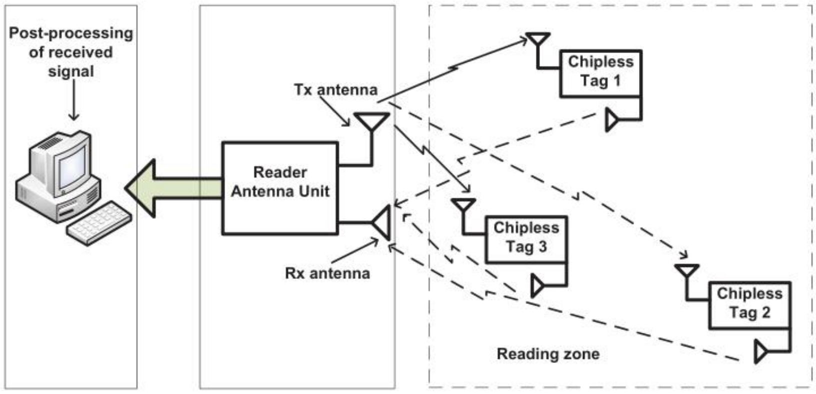


Fig. 1 Chipless RFID System, multiple tags in the reading zone [1]

RX(reader) interprets all interrogation signal tags. For chips including tags, they may have some components to turn off response but for the chip-less tags it is unfortunately that they will mess up because all chip-less tags respond simultaneously. Once collision happens, they all response their own ID by attenuating the interrogation signal. For the received signal, it may be all the collision signals from all tags.

The basic idea for solution to chip-less RFID is to detect the positions of multiple chip-less tags and decode their identifications in different situations. For chip-less RFID, it is very hard to match each other because it dose not have any controlling component. So our main task is to separate signal from multiple chip-less tags.

II Theoretical background of the solution:

(1) Linear Frequency Modulated(LFM) Signal

An LFM signal is defined as:

$$x(t) = e^{j2\pi((\frac{B}{2T})t^2 + (f_c - \frac{B}{2})t)} \quad (0 \le t \le T) \quad [2]$$

In other situations, x(t) is equal to 0.

B for total bandwidth, fc for center frequency and T for duration of the signal. For interrogation signal, the chirp rate is calculated by r=B/T.

C In chirp separation, we used to use Short Time Fourier Transform (STFT) or other techniques. Although it is efficient but not useful for overlapping signal. We think Fractional Fourier Transform (FrFT) is better for analyzing the connection between time domain and frequency domain. It does not just transmit signal from time domain to frequency domain just like common Fourier Transform does, FrFT transmits signal from time domain into an intermediate domain between time and frequency so it can get a minimum overlap between the chirps. The graph below shows the difference.

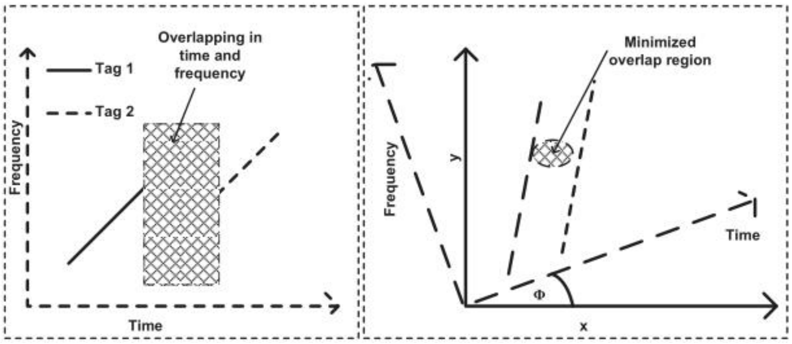
(2) Fractional Fourier Transform

For any real α, the α-angle fractional Fourier transform of a function *f* is denoted by $F_\alpha(u)$ and defined by:

$$Fa[f](u) = \sqrt{1 - i\cot(\alpha)}e^{i\pi\cot(\alpha)u^2}\int_{-\infty}^{\infty} e^{-i2\pi(\csc(\alpha)ux - \frac{\cot(\alpha)}{2}x^2)} f(x)dx \quad [3]$$

The most important part is that FrFT has a rotation angle. Then we can use this formula to calculate the angle α.

$\alpha = \tan^{-1}\left(\dfrac{f_s^{\,2} / N}{2r}\right)$. fs for sampling frequency, N for numbers of data points and r for chirp rate. We also can use rotation angle to calculate the order of transform α which is α=2*φ /π.



(a) (b)

Fig. 2 (a) Time-frequency representation of two overlapped LFM signals; (b) Same signals in fractional domain rotated by an angle φ [4]

III Proposed anti-collision solutions:

Generally, there are three steps in this processing system. First step is to calculate the order of α from fs and N and then transform the received signal to fractional domain of order α. Second step is to estimate the number of peaks which corresponds to number of tags and then build a signal filtering system to separate the signals to get the target signal. The target signal can be got through magnitude plot which are peak values. The last step is to restore separated signals in time domain by transforming of order -α then we can decode tag IDs according to these separated signals' frequency spectrum.

The most significant step is to separate the re-transmitted signal with other a great number of signal in multiple chip-less RFID tag system. The received signal consists of the total amount of multiple chirps which have same chirp rate as interrogation signal. Due to the reason that different tags are in different locations, it causes a delay from the antenna to the chirps.

There are some details about the solutions in three subsections:

(1) Transformation to fractional domain

We can use the equation above to calculate the order of transformation α. Then we use the Fractional Fourier Transform to transform the received signal to the the fractional domain of order α. This process compresses the signal in the fractional domain and shows spikes in magnitude graph. These spikes are corresponding to the LFM signals shown in the received signal. And also these LFM signals are connected with tags which re-transmit the signal. The spike is signal component without noise and any other overlapped elements from other sources.

(2) Separating the signals

Once we find these spikes shown in the transformed signal, we can use the number of these spikes to determine the number of tags present in the reading area. Then in the fractional domain, we build the filter to select non-overlapping tags. This part is also considered to be a significant part because how to design a good filter is important to efficiency in separating signals.

(3) Decoding the tag IDs

After separating the signals, we filter overlapping signals. For the remaining signal, we now can use FFT(Fourier Transform) to get the frequency spectrum and then decode these tags IDs.

IV Conclusion and future work:

In this proposed solution, we mainly solve the significant problem which is how to separate overlapping signals when using chip-less RFID. As we known, using RFID to detect collision is very popular and the technology is widely used in many luxury cars. For the low cost, we create this chip-less RFID algorithm to let even common cars have this technique to make better safety.

In future work, I have an adventure thinking which is creating a better system to transform the signal from time domain to frequency domain and transform from frequency domain back to time domain at the same time in FrFT. It should separate the signal into different parts and process the transformation synchronously. What I plan to do is to create a "buffer domain" separately from time domain, frequency domain and transformation domain. It is used as a springboard for transformation to increase the speed. The main problem for this adventure thinking is all of mentioned domains are changing all the time during transformation so what we should do is to find the best time to let the "buffer domain" work and then do the simultaneous transformation. It can save transformation time a lot especially in long distance communication and is a perfect solution for satellites communication.

References:

[1] S. Preradovic and N. C. Karmakar, "Chipless RFID: Bar Code of the Future," *Microwave Magazine, IEEE,* vol. 11, pp. 87-97, 2010.

[2] Z. Yin and W. Chen, "A new LFM-signal detector based on fractional Fourier transform," *EURASIP J. Adv. Signal Process,* vol. 2010, pp. 1-7, 2010

[3] Luís B. Almeida, "The fractional Fourier transform and time-frequency representations," *IEEE Trans. Sig. Processing* 42 (11), 3084–3091 (1994).

[4] D. M. J. Cowell and S. Freear, "Separation of overlapping linear frequency modulated (LFM) signals using the fractional fourier transform," *Ultrasonics, Ferroelectrics and Frequency Control, IEEE Transactions on,* vol. 57, pp. 2324-2333, 2010.

[5] D. M. J. Cowell and S. Freear, "Separation of overlapping linear frequency modulated (LFM) signals using the fractional fourier transform," *Ultrasonics, Ferroelectrics and Frequency Control, IEEE Transactions on,* vol. 57, pp. 2324-2333, 2010.

[6] A novel noise-insensitive chromatic dispersion estimation method based on fractional Fourier transform of LFM signals W Wang, Y Qiao, A Yang, P Guo - IEEE Photonics Journal, 2017