

An algorithm to calculate phase and amplitude of tag on RFID protocol conformance test system

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Abstract-- Either tag amplitude or tag phase is important factor in RFID indoor location system, so it is vital to get the correct amplitude and phase of tags. This paper propose an algorithm solving carrier frequency offset (CFO) caused by that signal generator and receiving is different and carrier frequency drift based on Radio Frequency Identification (RFID) protocol conformance test system and RFID signal analysis system. We find the change of signal with statistical idea and use piecewise linear fitting to solve how to correct every signal. The difficulty is how to pinpoint the location where rate of change changes and how to locate the start and the end of signal. We use rate of change of tag phase and I-tag signal and Q-tag signal and tag amplitude to separate tag signal to correct it and get correct signal, and then we can use cluster to get the points of IQ-signal to calculate tag phase and amplitude. This algorithm has been used in our RFID protocol conformance test system and RFID signal analysis system.

Keywords- RFID system, tag phase, tag amplitude, CFO, piecewise linear fitting, segmentation

I. Introduction

RFID is one of the main research of application of Internet of Thing (IOT), it is a research hotspot in the field of information technology, and RFID has been widely used in many fields, such as healthcare [1,2], assisted living [3] and retail[4], fitness monitoring[5], security[6], tracking and indoor localization [7,8]. In the field of subject location and tracking, tag phase and tag amplitude are important factor to realize location or tracking, for example PinIt [9], Tagoram [10].

Based on the current situation of the development and requirements of RFID test system, relying on the high

performance microwave spectrum analyzer developed by national major scientific instrument special project, we designed and completed hardware and software of RFID Signal Analysis System and RFID Protocol Conformance Test System and we has tested our system and achieve good performance. In this system, we complete a lot of work and realized the fundamental function of RFID signal analyzer.

In our system, our spectrum analyzer demodulate the receiving signal. But as we know, it is inevitable to have carrier frequency offset of devices between carrier of signal source and receiver [11]. And the temperature may also influence the frequency. If the frequency of carrier is different, the phase of signal is change with the point number increment [11]. We know that CFO and carrier shift have obvious impacts on tag phase and tag amplitude, so we will focus on how to lower the impact and to get the correct tag phase and tag amplitude.

Our system contains system overall design, system hardware design and software design. Here we give a brief description of system overall design and system hardware and software. In this system, we will to test protocol conformance and analysis signal. And we will calculate the T1 and T2 and link frequency and so on. Almost most of those items, tag signal and reader signal should be separated. Here we adopt a segmentation algorithm to separate tag and reader signal according protocol. Then we can to get parameters from tag signal or reader signal.

The problem of CFO estimation in OFDM direct-conversion receivers has been extensively studied in recent years and several solutions are available. In [12] and [13], the authors propose simple CFO recovery schemes that operate on a training sequence composed of three repeated segments. In [15], a low-complexity non-data aided CFO estimation scheme for OFDM is developed based on the kurtosis criterion. But there are few ways to CFO in RFID system and the modulation type of this system does not include OFDM. So we will propose a method for RFID

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system and apply it in our system.

II. Signal Preprocessing

1) Signal Filter

To separate the tag signal and reader signal more accurately, we need to filter our signal firstly. Here, in our system, we adopt three-order median filter to process our signal. In Fig1, the red one represent filter signal and the blue one represent original signal. From figure above, we can get that filtered signal is smoother than the original signal.

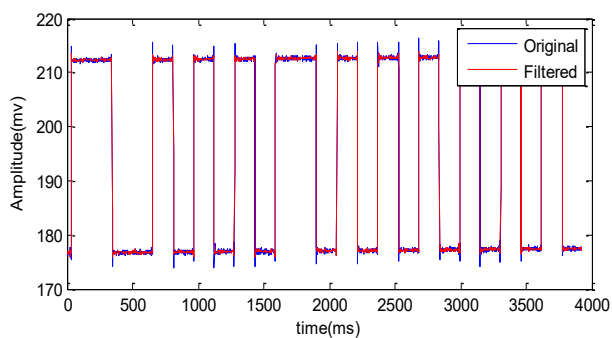


Fig1. Filter before and after signal

2) Signal segmentation

In our system, we get the signal which is the whole entire communication by listening with spectrum analyzer. And we do not deal with reader signal and tag signal together for that their paras are different such as coding, modulation method and so on[15][16]. If we want to get better result, we need to deal with them separately. Next we will introduce the segmentation process, and we use state transition to realize segmentation.

According to RFID protocol, we can get that either signal of 6b or signal of 6c has seven status which are no signal, carrier, start of reader signal, end of reader signal, start of tag signal, and end of tag signal. Even if the signal we get is not whole, the status it contains is a set of all status.

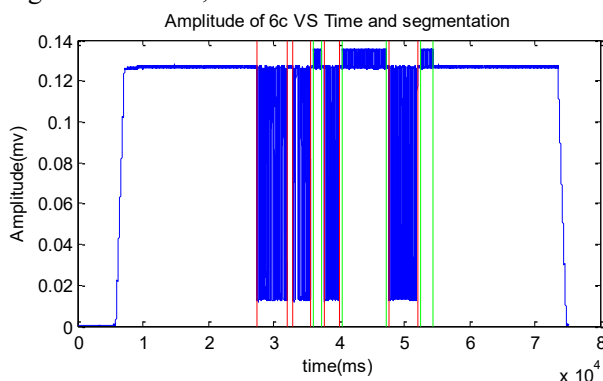


Fig2. Amp and segmentation of 18000-6C signal

Before we start to segment signal, we calculate the

value of carrier roughly with simple cluster. We get the maximum and minimum of the whole signal and take half of the sum of the two as the threshold. Then we use simple cluster algorithm to complete the signal classification roughly. We choose this value whose number is larger and that is greater than others as value of carrier amplitude.

Then we will start our work with the amplitude of carrier wave. We will start our work at the state of no signal whether the signal start at any state. We give the conditions of state transfer according to the protocol.

Finally we can get the right location of reader signal and tag signal and the result is shown in Fig2. The signal between the two red lines is the reader signal and between the two green lines is the tag signal.

III. Technology and Implementation

In this section, we will introduce how to get the phase and amplitude of 18000-6C tag signal and 18000-6B tag signal in our system. In our system, we generate signal with reader but we receive signal with spectrum analyzer. Their carrier frequency is inconsistent and the initial phase is different. Here we will introduce an algorithm to reduce impact which carrier frequency offset (CFO) have.

We will analysis the influence of 18000-6c signal and 18000-6B that CFO and frequency drift generate, and then propose algorithms for different protocol.

A. The Influence

In our system, we generate signal in one device but we collect signal with another device. There will be carrier frequency offset between two devices. And we cannot always use RFID in theoretical environment, and there is noise. If the frequency of carrier is different, we can know that the signal is the base-band signal not zero frequency. And either the phase of signal or IQ signal is unstable. According to RFID protocol, we need to calculate tag phase and tag amplitude from constellation diagram.

Comparing Fig4, Fig5 and Fig6 with Fig11, Fig12 and Fig13, we get that the CFO of 18000-6B signal is greater than 18000-6C signal. So if we want to get the correct value, we need to reduce the influence that CFO has. We will take different approaches to deal with signal. Next, we will show how to calculate tag phase and tag amplitude correctly with our proposed method.

B. Method and Approach

As we know, we have get tag signal from the whole signal in a communication. So we can plot its IQ-graph, its

As Fig3 show, we can get tag phase and tag amplitude by tag signal. Tag amplitude is the distance between point A and point B and tag phase is θ



$$\theta = \pi - \arccos(x) \quad (2)$$

We can get that signal of 18000-6b is approximately periodic from both figure of IQ VS Time and figure of tag-Phase. But there are not only CFO but also carrier frequency shift, period is a little fluctuate. We use statistical idea to find the period accurately and we will to use fitting curve to fit the change of phase. And we will modify the phase according rate of tag phase change to get the accurate value.

Above all, we get that there are frequency difference between transmitting terminal and receiving terminal and the value of CFO is big.



Fig6. Tag Phase Vs Points

Considering the problems above, we will take action on those problems.

When we calculate tag phase we lock range of tag-phase in $[0, 2\pi]$. But we will adjust the tag-phase with an increment whose value is 2π where the tag-phase comes down with a run to get the similar linear variation.

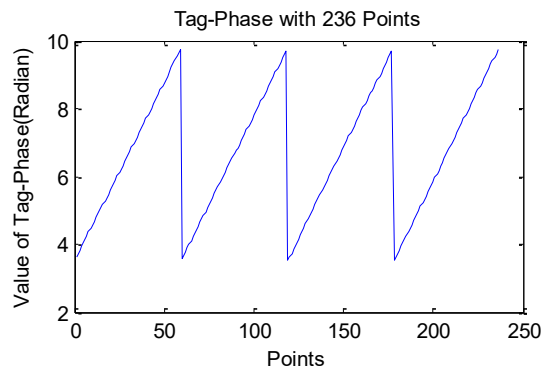


Fig7. Adjusted in a line over a period

Above all, we think that tag-phase increased linearly. We can get the correct tag phase according the fitting line. Furthermore, in the light of this conclusion, we choose to use linear regression to build a model. From the tag-Phase graph, we can get that tag-phase change linearly in every period.

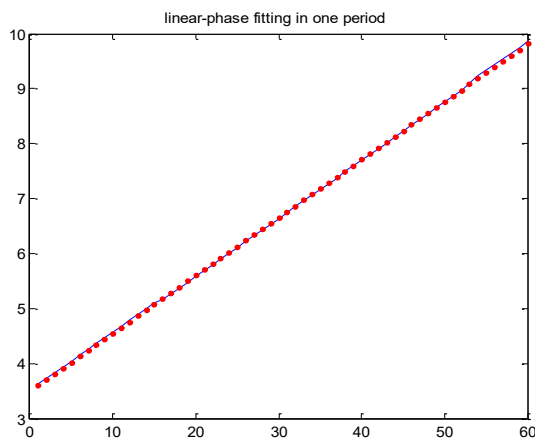


Fig8. Linear regression over a period

So we deal with this with a linear fit over a period. And the result shown on Fig7. Formula(3) represent the relationship between points number and tag phase where $F(x)$ represent tag phase and x represent points number..

$$F(x) = p_1 x + p_2 \quad (3)$$

According to the formula(3), we will make adjustments to the phase over every period. And then we get the final result shown in Fig8.

Comparing Fig9 with Fig7, we can get that tag-phase become much stabler. And we get I-signal and Q-signal use formula (4) and formula (5) where TagAmp represent the amplitude of tag and tag phase represents the modified tag phase shown in Fig9.

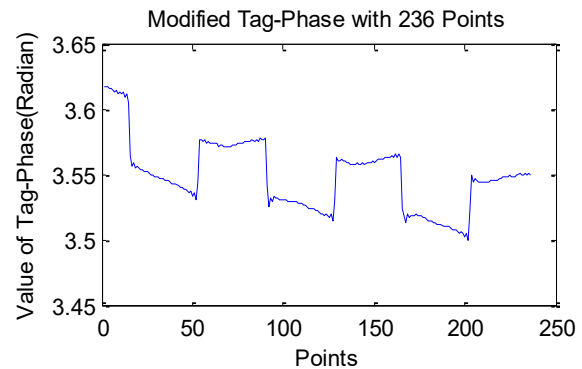


Fig9. Modified Tag-Phase

$$ISignal = TagAmp * \cos(tagPhase) \quad (4)$$

$$QSignal = TagAmp * \sin(tagPhase) \quad (5)$$

We get I-signal and Q-signal by formula (4) and formula (5) and we scatter it. Comparing Fig10 with Fig5, we get that we can get tag amplitude and tag phase with it. Blue point in Fig10 is the center of tag signal.

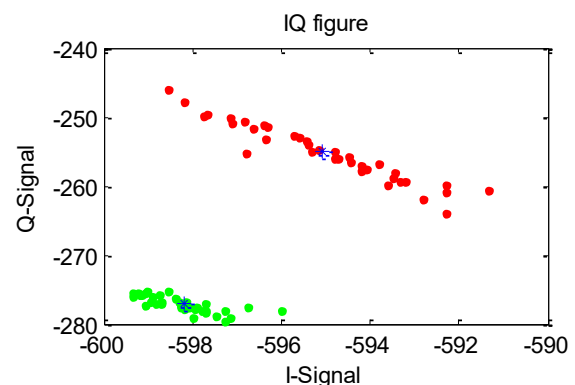


Fig10. Modified IQ-Signal

2). 18000-6C Signal Analysis

We can get that signal of 18000-6C is time-dependent from both figure of IQ VS Time and figure of tag-Phase and tag-phase of 18000-6C signal increased linearly in a symbol. So with 18000-6c signal, we adopt piecewise linear fitting not linear regression in a whole of tag signal.

1. IQ Signal

In the IQ-Graph, we can see that both the I-value and Q-value changes, especially Q-value. Either I-Signal or Q-signal should be smooth square wave. Here they all change obviously. And rate of change is not constant.

From Fig12 and Fig11, we can get that either I-Signal or Q-Signal have no significant changes not like 18000-6B signal. We need to use a different approach to deal with 18000-6C signal.

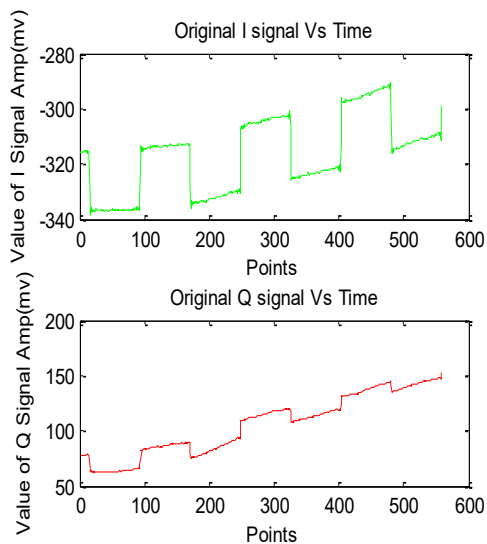


Fig11. IQ-signal Vs time

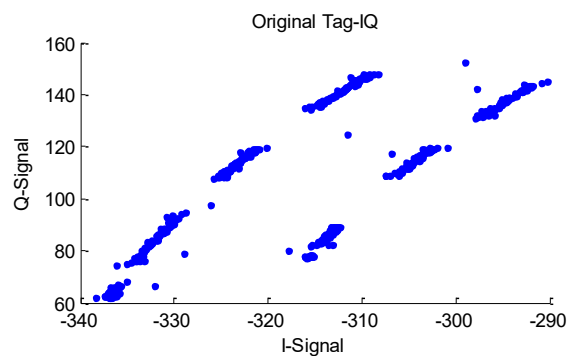


Fig12. Constellation diagram (IQ)

2. Phase

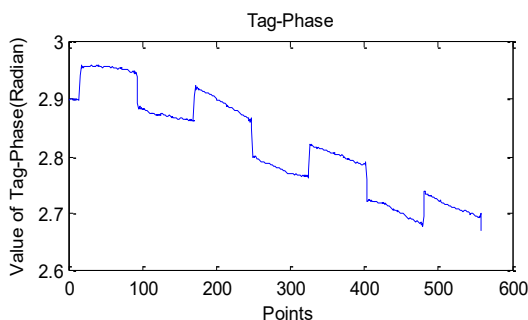


Fig13. Tag Phase

From Fig13, we can get that tag phase have the obvious linear variation tendency in a section. So we will to use piecewise linear approximation idea.

3. Solution

Above all, we think that tag-phase increased linearly in a symbol. And in a symbol, we can get that the phase is little changed. So with 18000-6c signal, we should adopt piecewise linear fitting not linear regression in a whole of tag signal. Here we try to different method to adjust the tag

phase with piecewise linear fitting.

3.1 Signal Segments

Here we use linear fitting in seven or more segments. In other words, we first adopt segmenting the tag phase, and then use linear approximation in every segmentation.

According to protocol, we know that the high is high reflectivity signal and the low is low reflectivity signal in this figure of tag amplitude. And from Fig14, we can get that the beginning and end of each tag phase segment is same as tag amplitude. So we will segment the tag-phase according tag-amplitude.

We will get the mid-value of tag amplitude firstly. And then we find the start and end of every piece of tag amplitude signal with mid-value. Accordingly, we finish the segmentation of tag phase.

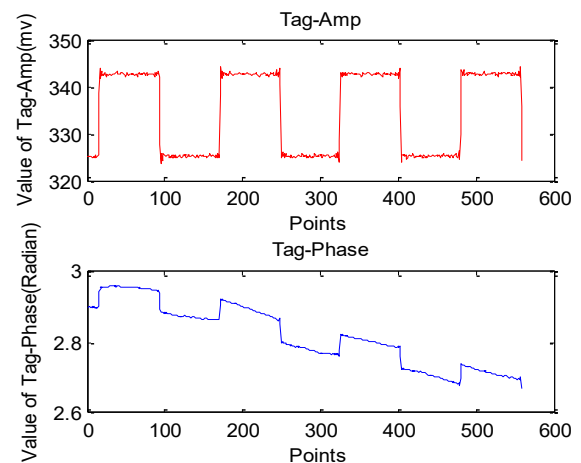


Fig14. Tag Phase & Tag Amplitude

3.2 Piecewise linear fitting

From graph of tag phase in Fig14, we can see that rate of phase vary on each piece. So we will use linear approximation idea in each piece as shown in Fig15. And we will adjust tag phase next.

In formula (6), we define tag phase of 18000-6C signal as $f(x)$, and x is the number of each piece signal. And in this formula, we get the relationship between tag phase and number of points in each piece.

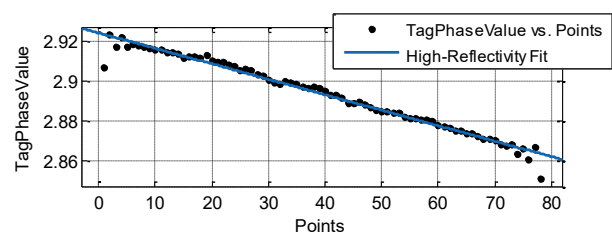


Fig15. Linear Fitting

$$f(x) = p_3x + p_4 \quad (6)$$

3.3 Phase Adjustment

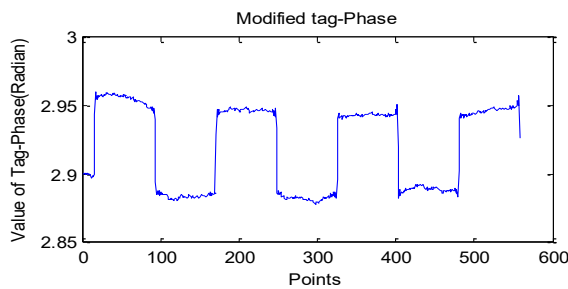


Fig16. Adjusted tag phase

We will firstly adjust tag phase according Fig15 and formula (6) on each piece, and then we will adjust each piece with a cumulant to reduce the affect that CFO carry. Finally, we get the result as shown in Fig16.

We can get that either tag phase of low reflectivity or tag phase of reflectivity shown in Fig16 is much stabler than that in Fig13. And change of tag phase is in line with ISO-18000-6C protocol.

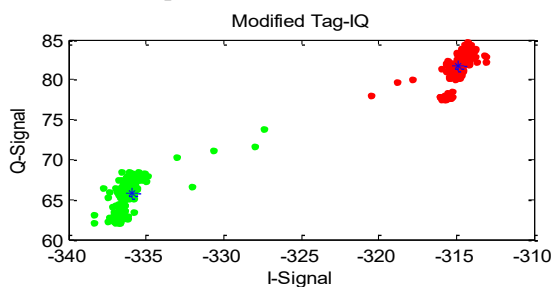


Fig17. Adjusted tag IQ

After we get the correct tag phase, we get I-signal and Q-signal by formula (4) and formula (5) and we scatter it. Comparing Fig12 with Fig5, we see that we can get tag amplitude and tag phase with it. Blue point in Fig17 is the center of tag signal.

Finally we will calculate tag phase and tag amplitude according formula (1) and formula (2).

IV. Conclusion

A novel algorithm method to reduce the influence CFO have in calculating the tag phase in RFID protocol conformance test system. We use piecewise linear fitting to adjust tag phase and then get the IQ signal and finally get the tag phase and tag amplitude. Compared other methods, our method is easy to understand and simple. The system used this method can calculate tag phase and tag amplitude correctly.

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