**Lab 4：Frame Detection and Frequency Correction**

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| **Introduction**  In previous lab, we have discussed about some algorithms used in symbol synchronization, after finishing symbol synchronization, we get a sequence symbols, but we still don't know how to split different frames from the symbol stream. And that's is what we are going to discuss in this lab.    We can first look at the graph above. We first need to do Frame Synch to get the right information bit stream, and then we need to do Frequency Synch to handle the frequency shift caused by the Doppler shift. Frame detection To discuss about the frame detection we need to look at the structure of frame first.   | Packet Head | Training sequences | Key bits sequences | Guard band | | --- | --- | --- | --- |     Packet head can mark the number of this frame, to help build a ordered information. And the guard band is to help split different frames. And the Training sequences is the key role to help detect the start bit of the key bits sequences. training sequence Training sequences is a strong autocorrelation sequences. Normally, Barker Sequence is commonly used. And the barker sequency of different length is shown as below:    This kind of sequences has very strong autocorrelation, and this property is of vital importance in detect the start bit of information. Take the barker sequence with 11 bits for example: When it is perfectly matched, the value is quite high, it will drop sharply with a slight offset, and that is the key of sliding correlator algorithm.   Sliding correlator algorithm To find the start point of the key bits sequences, we can calculate the cross correlation of received symbols and training sequences, which is also similar to "sliding", the formula is shown as below:  Due to the autocorrelation property of the training set, this function will get its maximum value when two training sequences matched perfectly. And the length of training set is known by both transmitter and receiver so we can find the correct position of the start bit. Frame detection In the process of transmission in reality, there will be frequency offset in the channel.    The frequency offset can be expressed as follow:  The received signal can be expressed as follow:    An important algorithm called ***Moose Algorithm*** can be used to do the frequency correction. There are three steps.  **Step1:** to estimate the with the training sequences  **Step2:** solve this problem using **LLSE**  **Step3:** get the frequency offset correction  Let y(t) denotes the demodulated signal, if the x(t)=x(t+N) is periodical, we finally get:  **Lab results & Analysis**： Programming diagramSliding correlator algorithm The programming diagram of sliding correlator algorithm is shown as below:    This program follows the step below:   1. Add a set of zero as Zero Pad to the waveform. 2. Do the convolution to get R[n]. 3. Find the maximum value in R[n]. 4. Separate the training set according to the index of maximum we find.  Moose algorithm The programming diagram of Moose algorithm is shown as below:    This program follows the step below:   1. Get subarray and . 2. Get conjugate . 3. Add every element of to get the sum . 4. Convert it to a polar representation and obtain phase expression. 5. Divide phase expression by .  Separate the training set according to the index of maximum we findProgramming ResultSliding correlator algorithm Because the whole system can't show any meaning result without the implement of Moose algorithm to handle the doppler frequency shift, so We will only show the result of R[n]. And further discussion will be covered in the following section.    We can see that, R[n] get its maximum value around 300, which indicates the position of the training sequences, and it won't change with the increase of frequency offset at the beginning.  But if continuous increase the frequency offset to around 15KHz, R[n] is shown as below:    The shift of maximum value indicates the algorithm can no longer function. Moose algorithm The following three pictures are with closing ***Correct Frequency Offset.***   The following three pictures are with opening Correct Frequency Offset.       From the first three pictures, what is obvious is that the constellation result will show a big frequency offset if the frequency correction isn’t done. Besides, with the frequency offset increasing, the constellation result will be more like a circle. The constellation result will be accureate again for QPSK with the frequency correction is done, which means ***Moose Alogrithm*** has a good effect. Performance Analysis Another imprtant issue in the frequency correction is that the performance analysis should be considered. According to the periodicity to the discrete-time exponential, the estimate of will be only accurate for , thus the maximum range for frequency correction can be expressed:  Where T is the symbol period, which is the oversample factor divide the sample rate. is the length of the training sequences.      The above two pictures show the simulation frequency maximum range in Labview.In frequency offset 10942, the constellation result are still accurate. However, in frequency offset 10943, the constellation isn’t correct. Through theory analysis:  Which is close to simulation result, which prove analysis is correct.      The above two pictures show the simulation frequency maximum range in Labview.In frequency offset 2188, constellation result are still accurate. However, in frequency offset 2189, the constellation isn’t correct. Through theory analysis:  Which is close to simulation result, which prove analysis is correct.  In a conclusion, with increasing, the range of the frequency offset is getting smaller and the performance of the system will decrease. USRP Verification In USRP experiment, we set carrier frequency to 915MHz, and we going to discuss the influence of frequency offset.  The TX is shown as below, we first set frequency offset to 100Hz:    The result of RX:      We can find that the performance is much better with Correct Frequency Offset.  And then, we set the frequency offset to 150Hz:    The result of Rx is shown as below:      We can see that, the shift of received symbol is much more significant than that with 100Hz frequency offset.  We can conclude that, the real channel much more complicated than AWGN channel as we simulate. BER is much lower than the simulated one. And we can also notice that the results in AWGN channel and ISI channel have a little difference. ISI channel has larger distortion thus here it is not obvious. | |
| **Experience**  In this experiment:   1. We learnt how to detect the start point of a frame. 2. We understood the function of training sequence. 3. We understood and designed sliding correlator. 4. We understood and designed moose alpgrithm. 5. We understood how to get the maximum range for frequency correction.   汪海玉：        张旭东： | |
| **Score** | 99 |