**Lab 3：Symbol Synchronization**

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| **Introduction**  In lab2, we ignore the propagation delay to do pulse shaping and matched filtering. However, there are propagation delay in the real channel when the signal transmits. So, we will talk about the basic principle of symbol synchronization and two methods of calculating time delay to get the optimal sampling times. Basic principle of symbol synchronization   In the real channel, there are propagation delay so the expression of the receive signal at the receiver can be expressed as following:  The diagram of symbol synchronization is shown below:    In the previous experience, we use square-root raised cosine function as the pulse function and matched filtering function, which makes the effect of inter symbol interference to reduce to the lowest level. And we do sampling at the maximum point. However, due to the time delay in communication system, the maximum point is shifted. For this, what is needed to do is symbol synchronization. In the next , two methods of symbol synchronization will be introduced, which are and Maximum Energy Algorithm The nature of is to find the most appropriate to make the energy of received signal maximum. The received signal can be expressed as follow:  So the detected signal can be expressed as follow:  The first term denotes the idea value, the second term denotes the effect of inter symbol interference and the third denotes the noise. So the expression of is :  The energy of sampled signal can be expressed as below:  Then let its value be maximum to find the most appropriate , which makes the energy maximum.  The flowchart of finding the most appropriate is showing below:      The train of thought to find the most appropriate fig: is to sample the received signal at the original point, which is the maximum point ignoring propagation delay with using square-root raised cosine function. Then do sample in the interval fig: and calculate energy of each. Then, the maximum point is the point whose calculated energy is highest. Early-Late Gate Algorithm Another important method for finding the maximum point in the real channel with propagation delay is fig: fig: fig:. From Maximum Energy Algorithm, the expression of sampled signal is known:  The changing rate for it can be expressed as follow:  When the changing rate equals to (), the energy is maximum, which means the point is the maximum point.  The flowchart of finding the point where the changing rate equals to is showing below:    **Lab results & Analysis**： Maximum Energy AlgorithmProgramming Diagram   In this part, the first thing is to set the initial time and do the down sampling. Then calculate the sum of square of the amplitude. After that, shift register is used to keep the maximum point. The value in the right shift register is always the maximum. The next structure will control the opening of symbol synchronization.  We can also use another method to implement this algorithm. And this method is much easier than the previous one, it is shown as below:    After decimating, we just need to calculate the sum of the power of the magnitude. And then, store then in an array, the index of the max value is the alignment offset. But we can clearly see the disadvantage of this method, if the oversample factor is quite large, it will store a lot of data in the array, which will consume much more space compared with shift register. Result The result of these two implement of the maximum energy algorithm is the same, so we will only show one set of the result.        From the above picture, what can be known is that the constellation result will diverge firstly and concentrate then with propagation delay increasing in the model where symbol synchronization closed. This phenomenon is caused by periods of samples.        The three pictures are totally different from the last three pictures. It is obvious that the constellation always concentrate with propagation delay increasing in the model where symbol synchronization is open, which means Maximum Energy Algorithm has a very good effect on symbol synchronization.    What's more, obviously, with $\alpha$ increasing, the proportion of total energy the energy of middle point occupies becomes larger and larger. Accuracy analysis In this part, the relationship between oversample factor, delay and the sample rate will be discussed.      What is easy to find is that the signal is just the same sample signal with propagation delay and , which is correct according to the theory.      The period of symbol synchronization is:  Next, trend of symbol synchronization accuracy with the change of oversample factor will be discussed when the period of sampled signal is fixed.    With the oversample factor increasing, the error statistic become smaller and smaller, which is correct according to the analysis. USRP Verification First, let we discuss the relation between delay and offset:      By looking at the upper data, we can draw the conclusion that:  We can test our equation:  $$delay\_1=\frac{4006-16}{4\times10^6}=9.975\times10^{-4}s \\ delay\_1=\frac{10017-40}{10\times10^6}=9.977\times10^{-4}s\qquad\text{(12)}$$  The reason is that the difference between the offsets is the difference of the index of the same point at Tx and Rx. Thus when it is divided by the sampling rate we get the delay time.  The results of USRP verification are shown as below:   * Transmitter:        * Receiver:         And the figures below show result of the error statistic under different oversampling factor in USRP experiment:   * Oversampling factor = 2M      * Oversampling factor = 4M      * Oversampling factor = 10M      * Oversampling factor = 20M      * Oversampling factor = 50M   Now we can draw the diagram of simulation and USRP verification in one chart:    As we can see, when the oversampling factor at Rx increasing, we have less mean square error, which means better result. | |
| **Experience**   1. Understanding of basic principle of symbol synchronization 2. Master of Maximum Energy Algorithm and understanding of Early-Late Gate Algorithm 3. Master of programming of Maximum Energy Algorithm  In class submission 汪海玉：   * Week6：     张旭东： | |
| **Score** | 99 |