Experiment Report

Accomplished time: 2015.1.6

Principles of Communications

Lab4: High sensitive capture mechanism

姓名：　王 玫　　　　　张哲慧

学号：5120309691　　5120309056

组 号：13

上海交通大学 电子信息与电气工程学院

Contents:

上海交通大学 电子信息与电气工程学院

地 址：东川路 800 号

邮 编：200240

1. Aim of the Project

Use LabVIEW and USRP digital experimental platform for the transmission of text messages. Use high sensitive packet capture mechanism for the complete digital transmission link design. Compare the difference of the packet capture sensitivity and transmission distance under the two kinds of capture mechanism of the receiver.

上海交通大学 电子信息与电气工程学院

地 址：东川路 800 号

邮 编：200240

2. Principles

The whole processes are all we have learnt from the theory class. In the lecture notes, the whole communication system is shown as the following figure.

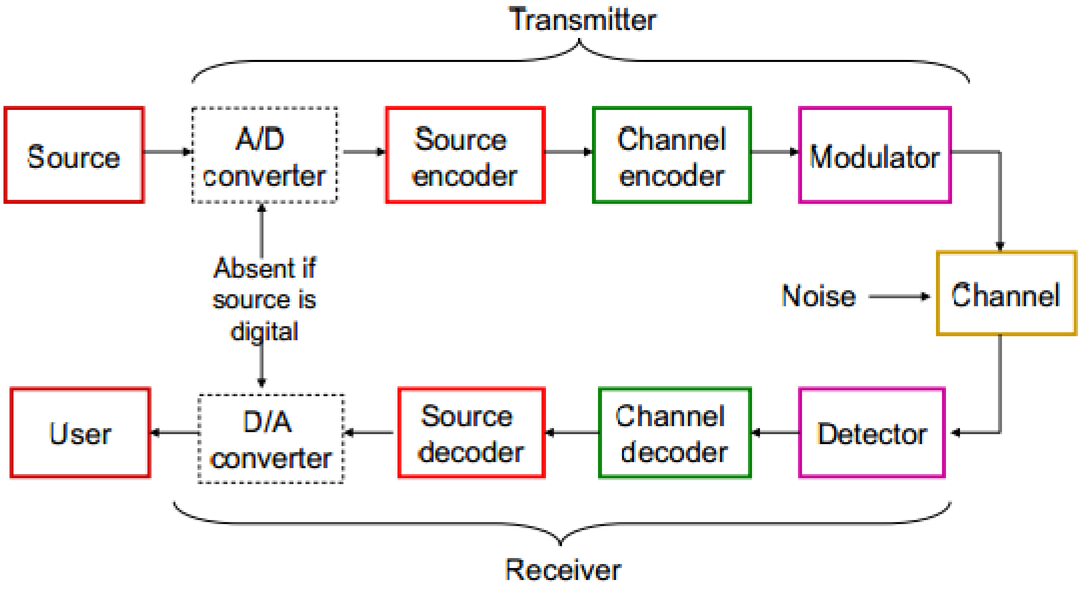


Figure 1. Block diagrom of the digitalcommunication system

In this experiment, we only take digital communication system into consideration. So the transmitter part starts from source coding and the receiver part ends with source decoder.

Transmitter:

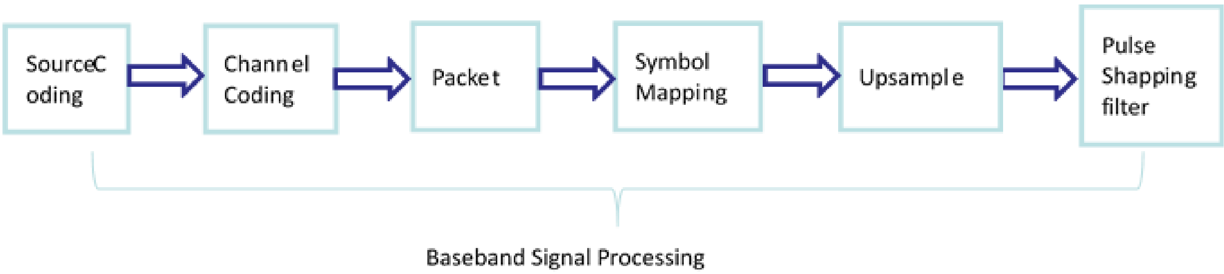


Figure 2. Digital baseband link of transmitter

上海交通大学 电子信息与电气工程学院

地 址：东川路 800 号

邮 编：200240

Receiver:

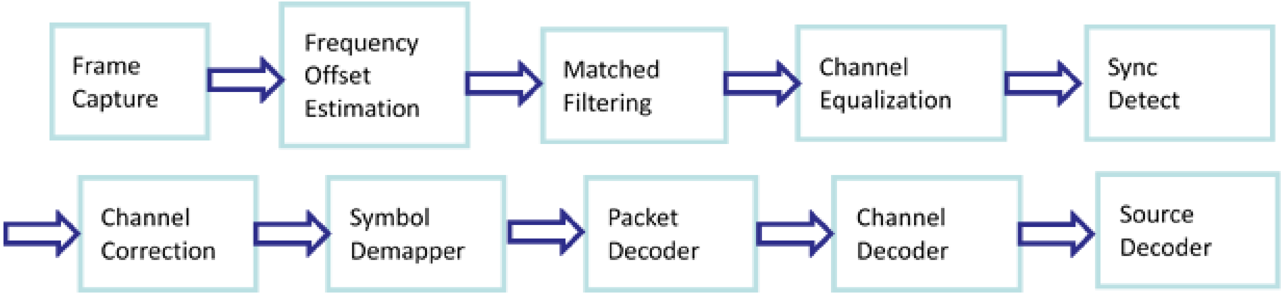


Figure 3. Digital baseband link of receiver

上海交通大学 电子信息与电气工程学院

地 址：东川路 800 号

邮 编：200240

3. Capture Mechanisms

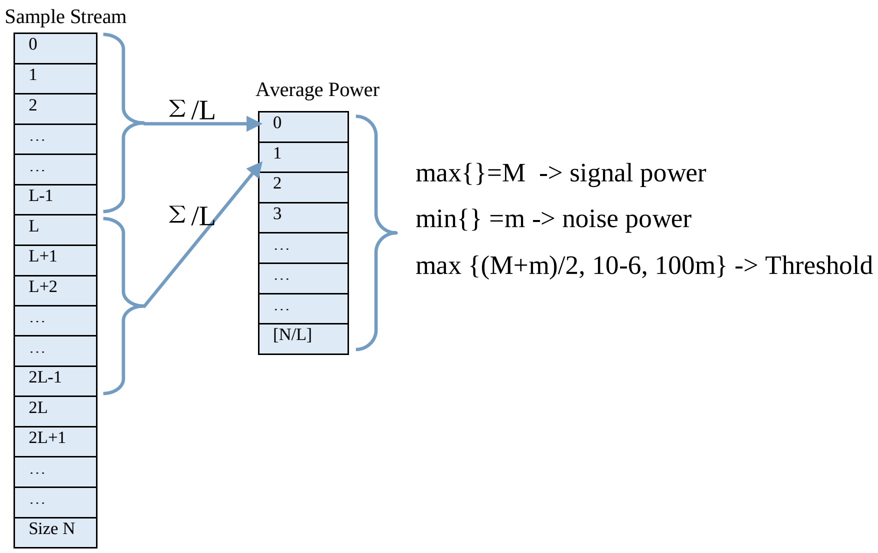
The receiver decide whether to revert ACK signal or not according to the verification result of the received packets. That is, revert ACK if the result is correct, otherwise the receiver continues to wait for packet retransmission. Transmitter resends a packet until it receives ACK message, then proceeds to the next packet sent.

Packet detection is to extract the header of the valid signal in the channel. We know that under normal circumstances, signal energy is greater than the noise energy.

The simplest algorithm for finding the start edge of the incoming packet is to measure the received signal energy. When there is no packet being received, the received signal consists only of noise. When the packet starts, the received energy is increased by the signal component, thus the packet can be detected as a change in the received energy level.

3. 1 Example Mechanism

The example only divide the samples into groups with size “Bin Size”, and then take the sum of each group, so that we can get the average power. In subVI “sub_est_noise_power” has the main program. The logic function can be interpreted as this:



上海交通大学 电子信息与电气工程学院

地 址：东川路 800 号

邮 编：200240

Thus the number of complex multiplications is reduced to one per received sample. The response of this algorithm is shown in Figure 3. The figure shows the value m_n for IEEE 802.11a packet with 10dB Signal to Noise Ratio (SNR) and sliding window length L = 32. The true start of the packet is at n = 500, thus in this case the threshold could be set between 10 and 25.

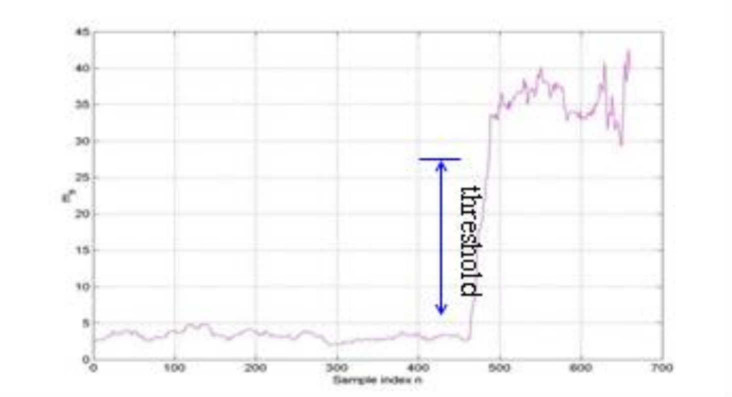


Figure 3. Received signal energy based packet detection algorithm [3]

Here follows the program diagram of example.

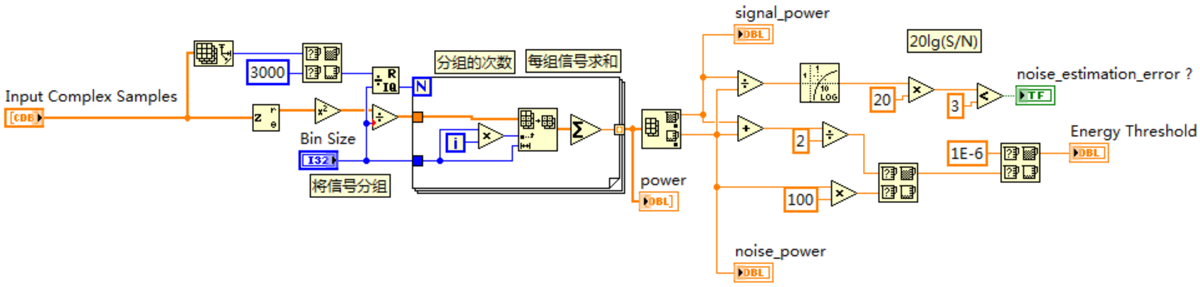


Figure 4. subVI “sub_est_noise_power” of example

上海交通大学 电子信息与电气工程学院

地 址：东川路 800 号

邮 编：200240

3. 2 Single Window Complementation

The decision variable m_n is then the received signal energy accumulated over some window of length L to reduce sensitivity to large individual noise samples.

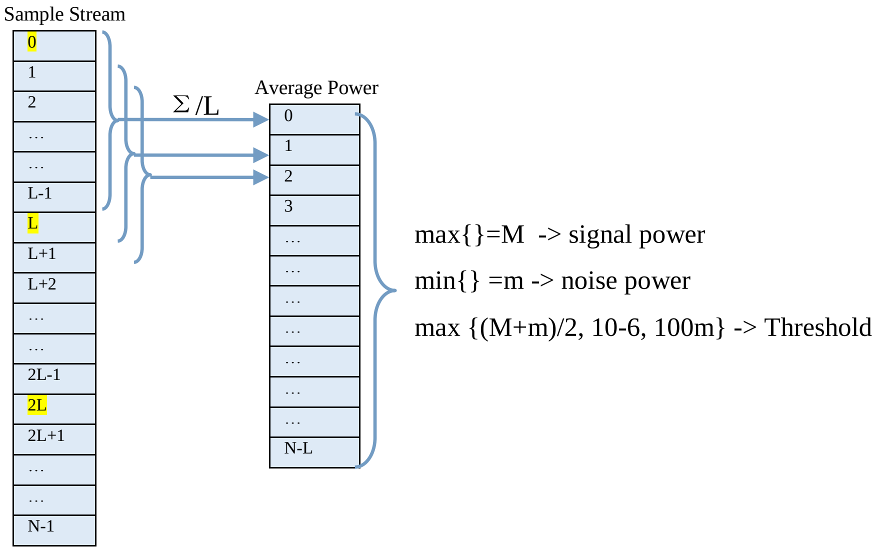
$$m_n = \sum_{k=0}^{L-1} r_{n-k} r_{n-k}^{*} = \sum_{k=0}^{L-1} |r_{n-k}|^2 \qquad (1)$$

Calculation of m_n can be simplified by noting that it is a moving sum of the received signal energy. This type of sum is also called a sliding window. The rationale for the name is that at every time instant *n*, one new value enters the sum and one old value is discarded. This structure can be used to simplify the computation of Equation (1). Equation (2) shows how to calculate the moving sum recursively.

$$m_{n+1} = m_n + |r_{n+1}|^2 - |r_{n-L+1}|^2 \qquad (2)$$

Thus the number of complex multiplications is reduced to one per received sample.

In subVI “sub_est_noise_power 1” has the main program. The logic function can be interpreted as this:



Here follows the program diagram of example.

上海交通大学 电子信息与电气工程学院
地 址：东川路 800 号
邮 编：200240

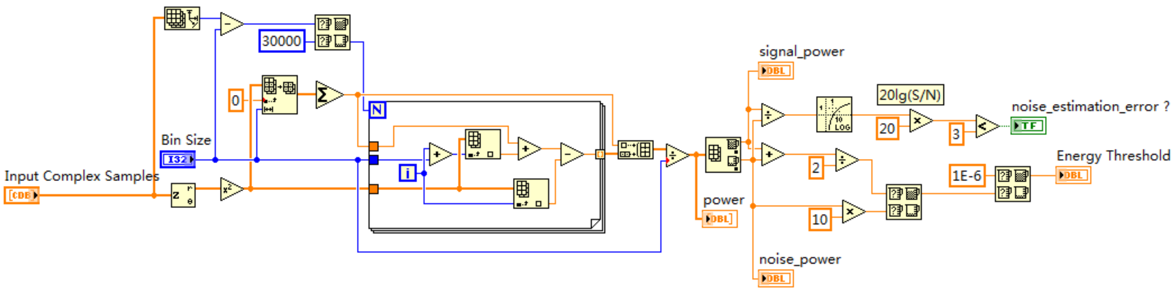


Figure 6. Block diagram

3. 3 Double Window Complementation

A high sensitive method of packet capture can refer to [3]. The double sliding window packet detection algorithm calculates two consecutive sliding windows of the received energy. The basic principle is to form the decision variable m_n as a ratio of the total energy contained inside the two windows. Figure 7 shows the windows A and B and the response of m_n to a received packet.A and B windows are considered stationary relative to the packet that slides over them to the right. It can be seen that when only noise is received the response is flat, since both windows contain ideally the same amount of noise energy. When the packet edge starts to cover the A window, the energy in the A window gets higher until the point where A is totally contained inside the start of the packet. This point is the peak of the triangle shaped m_n and the position of the packet in Figure 7 corresponds to this sample index n. After this point B window starts to also collect signal energy, and when it is also completely inside the received packet, the response of m_n is flat again. The packet detection is declared when m_n crosses over the threshold value Th.

Equation (3) shows the calculation of the A window value and Equation (4) the calculation for B window. Both a_n and b_n are again sliding windows, thus the computation can be simplified in the same recursive manner as for the energy detection window. Then the decision variable is formed by dividing the value of the a_n by b_n .

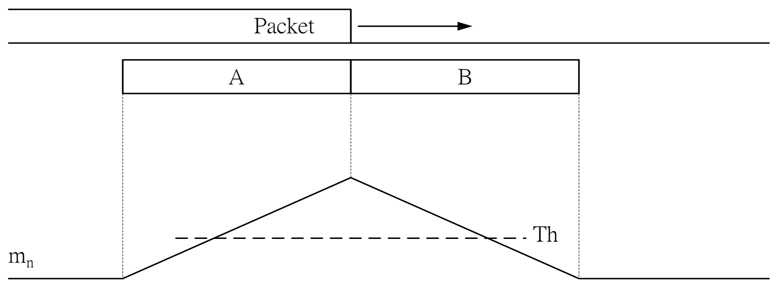


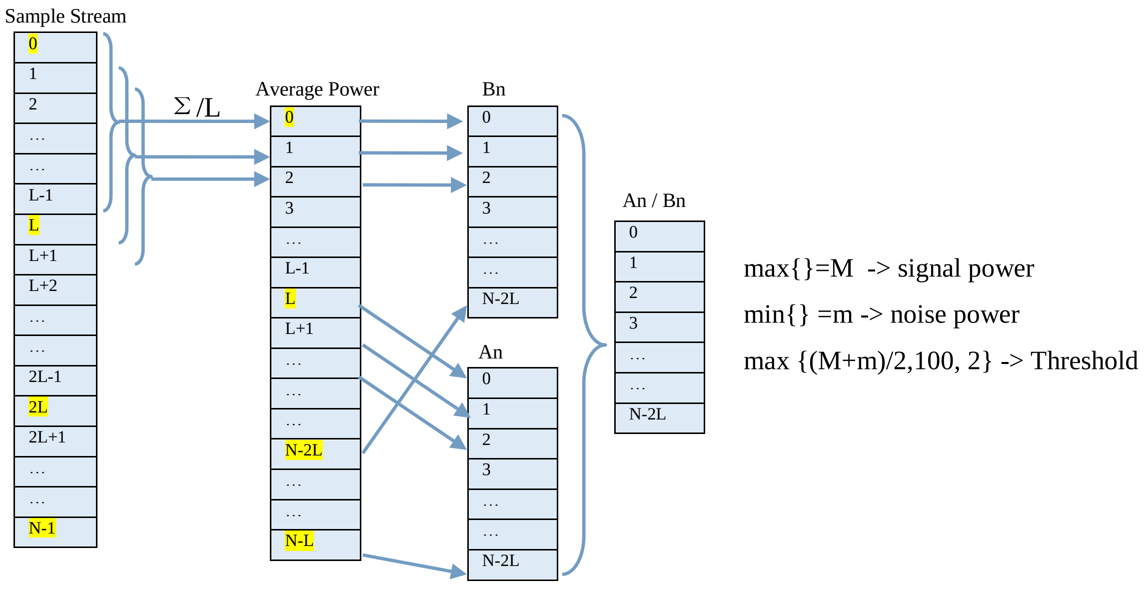
Figure 7. The response of the double sliding window packet detection algorithm [3]

$$a_n = \sum_{m=0}^{M-1} r_{n-m} r_{n-m}^{*} = \sum_{m=0}^{M-1} \left| r_{n-m} \right|^2 \quad (3)$$

$$b_n = \sum_{l=0}^{L-1} r_{n+l} r_{n+l}^{*} = \sum_{l=0}^{L-1} \left| r_{n+l} \right|^2 \quad (4)$$

$$m_n = \frac{a_n}{b_n} \quad (5)$$

In subVI “sub_est_noise_power 2” has the main program. The logic function can be interpreted as this:



上海交通大学 电子信息与电气工程学院

地 址：东川路 800 号

邮 编：200240

Here follows the program diagram of subVI “sub_est_noise_power 2”.

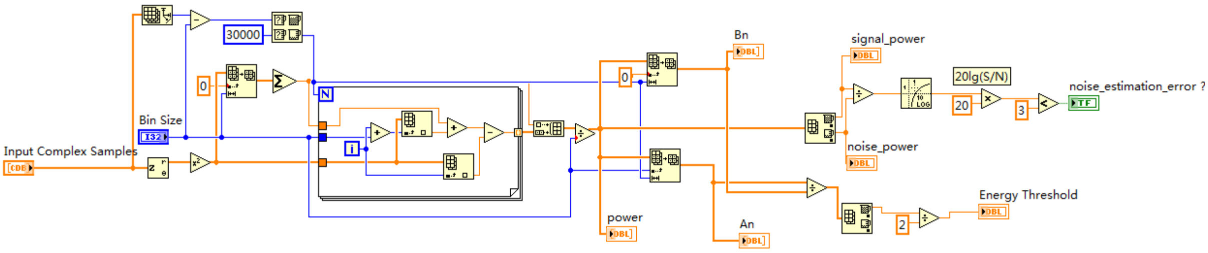


Figure 8. Block diagram

4. Contents related to USRP

4.1 Results

The receiver display is shown as below. The figure shows the successful reception and the figure shows a high error probability.

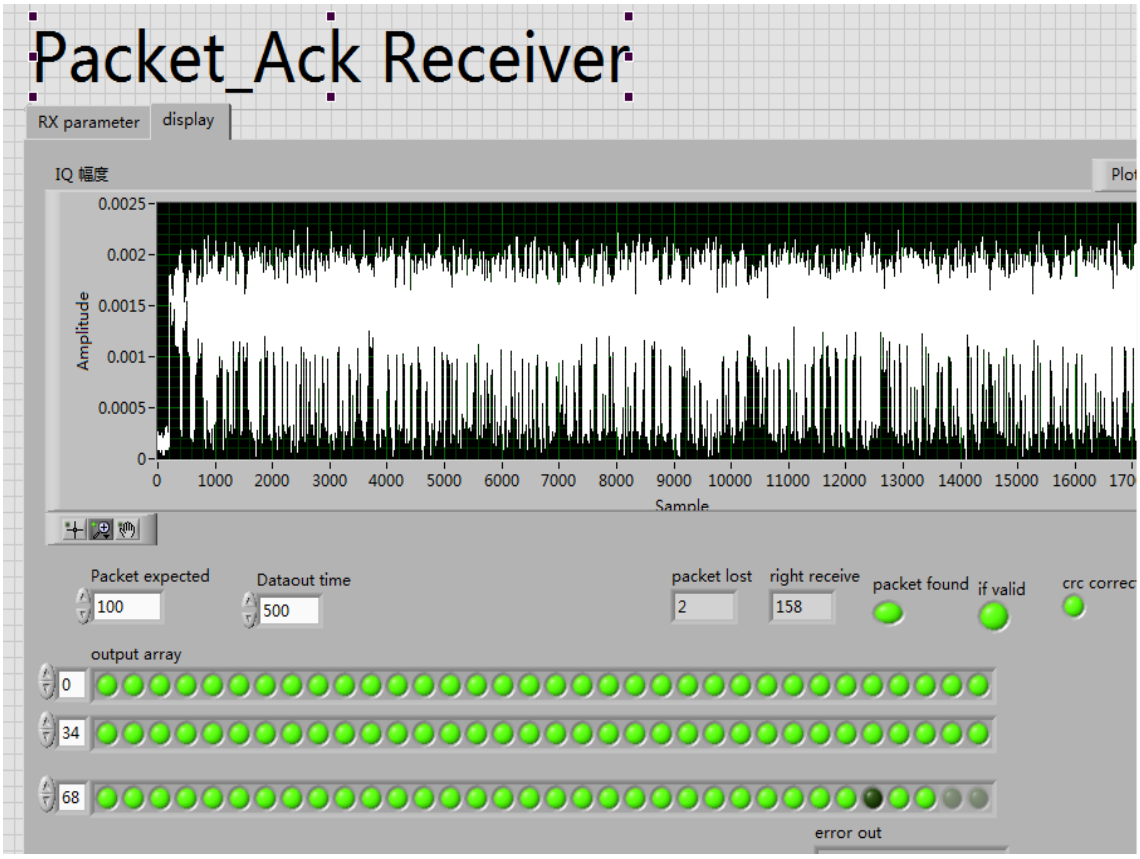


Figure 9. Receiver display when packet loss is small

上海交通大学 电子信息与电气工程学院
地 址：东川路 800 号
邮 编：200240

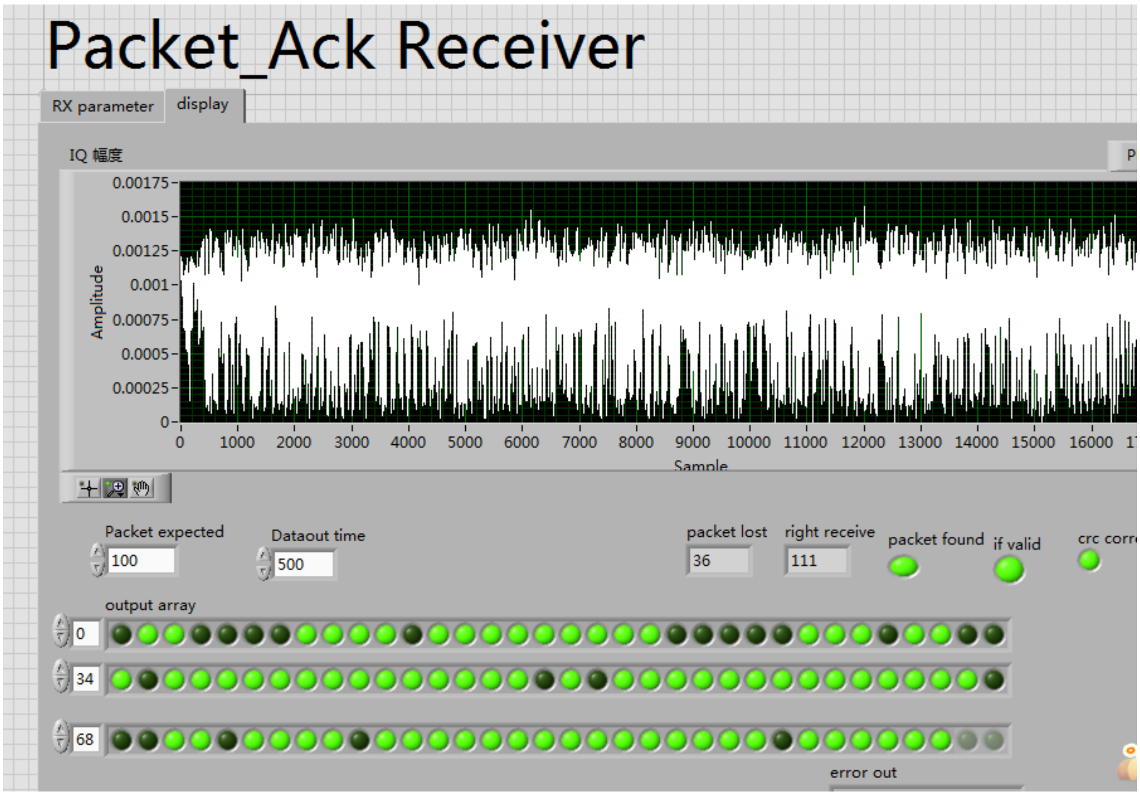


Figure 9. Receiver display when packet is large

As shown in the foregoing introduction, the high seneitivity capture system overwlems the other for its tolerance of long distance and low transimision power. In our experiment, its advantage is illustrated by experimental data. As you can see from table 1 and table 2 below. Recever gain is fixed at 0dB and the distance refers to the distance from two atennas.

Distance（cm）	Required gain for single window(dB)	Required gain for double window(dB)
24	14	6
32	17	14
38	20	10

Table 1. minimum gain under fixed distance

上海交通大学 电子信息与电气工程学院

地 址：东川路 800 号

邮 编：200240

Receiver gain （dB）	Max distance for single window(cm)	Max distance for double window(cm)
10	19	38
17	16	42
20	45	107

Table 2. maximum under fixed gain

From the table, the high sensitivity mechanism is superior to the single window one, since the required gain to ensure a secure transimission is lower and the maximum transimission distance under certain gain is longer. Results meets our expectation well, however, after careful scrutiny, we find that, the data vary dramaticly.

In table 1, to ensure a perfect capture accuracy, the minimum required gain for double window decrease as the distance increase. To illustrate that aberrance, these two group of data are colected in different time, as the envoronment factor may impact on the result. These factors are going to be discussed in the 4.2 section.

4. 2 Questions and answers

Q1：What is the impact of the threshold?

In [3], the author derived the following formula to show the optimal value of the peak value of m, the ratio of two sliding windows.

$$m_{peak} = \frac{a_{peak}}{b_{peak}} = \frac{S+N}{N} = \frac{S}{N} + 1$$

So when SNR equals to 10dB, S/N equals to 10, so the peak value is suposed to be 10. When the SNR increases, the peak value also changes with the reference to SNR. In our experiment, we tested different threshold values and the result corresponds with the estimation. When the distance becom longer, noise interference become larger and SNR decreases, so the small threshold overwhelms.

As discussed in [3], the double window scheme overwhelms the single window schme because its high tlerance to the varying SNR. In our experiment, the threshold between 1.1 to 1000 are all tested, and

上海交通大学 电子信息与电气工程学院

地　址：东川路 800 号

邮　编：200240

normally 2~100 all performs well, the coresponding SNR is between 1~200, if we regard half of the peak as the optimal threshold, and finally, we set the threshold as a dynamic value so as to get the optimal performance. This method is also utilized in the provided example.

Q2：Why the performance vary significantly in different conditions?

The aberrance conditions are shown in table 1 and 2. Even if we take experiment under same conditions, these aberrance also happen. So we are very curious about this circumstance. Although we didn't take scientific experiments to confirm our hypothesis, we think that some hypothesises can illustrate the results. Firstly, some externel factors influence the performance. These factors are shown in the next question. Secondly, some internel factors such as the computing capability of the computers will also change the performance.

Q3：Analysise possible environmental factors that may influence the performance.

In this question, we try to give an illustration about possible factors, which may impair the performance.

a) Relative positions of two USRPs.

In the experiment, we find that when the USRP are not align on the same line, i.e. atennas of one USRP are not direct opposite to atennas of the other one. The packet loss tend to be larger and when these two USRP are facing to the same direction, signal cannot transimitted to the receiver at all.

b) Reflection of the table top

We observe the infulence of this factor because when we put USRPs on the table intead of the chairs, the performance increases. As for the signal reflection increase the SNR rate, the performance increase is reasonable.

c) Interference of other signals

Interference of other signals will also impair the performance, such as the phone signal and voice signal. For example, when we put the calling phone between antennas, packets loss increase significantly.

d) Other environmental factors

Some other factors are not discussed specificly. However, the influence is very easy to see, such as the wind and air density

上海交通大学 电子信息与电气工程学院

地 址：东川路 800 号

邮 编：200240

These not be verified by specific data and the performance loss cannot be evaluated by certain degrees. .But the change are shown in our experiment, and its influence is rational. So the experiment should take these factors into consideration.

上海交通大学 电子信息与电气工程学院

地 址：东川路 800 号

邮 编：200240

Reference：

[1] EE dept. of SJTU. Lecture notes [EB/OL].ftp://202.120.39.248.

[2] Meixia Tao. Lecture notes [EB/OL]. http://iwct.sjtu.edu.cn/Personal/mxtao/teaching1.html

[3] Juha Heiskala, John Terry, Ph.D. OFDM Wireless LANs: A Theoretical and Practical Guide.

上海交通大学 电子信息与电气工程学院

地　址：东川路 800 号

邮　编：200240