ACSE Labs14

Lab Report

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Lab 14 －Fixed Point Implementation

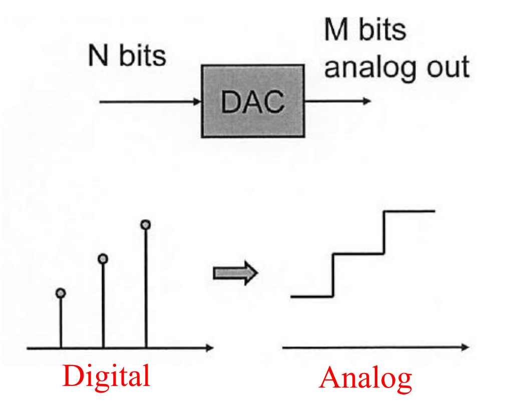
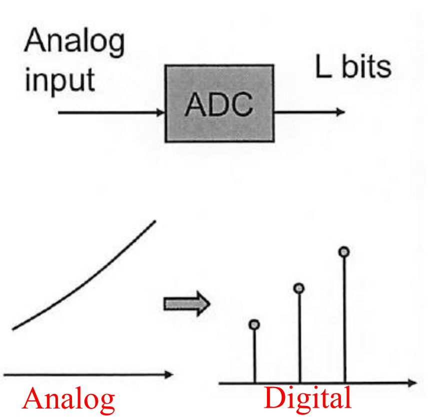
A. Goal of Experiment :

- To Realize the Property of Communication System, including of realistic ADC and DAC simulationm techniques, physical meaning of SQNR, Dnamic range and Number of bits for utilization .
- Use realistic ADC technique to quantize signal to tranmit .
- Realize the how effect of various calculation impact the number of bits to use.

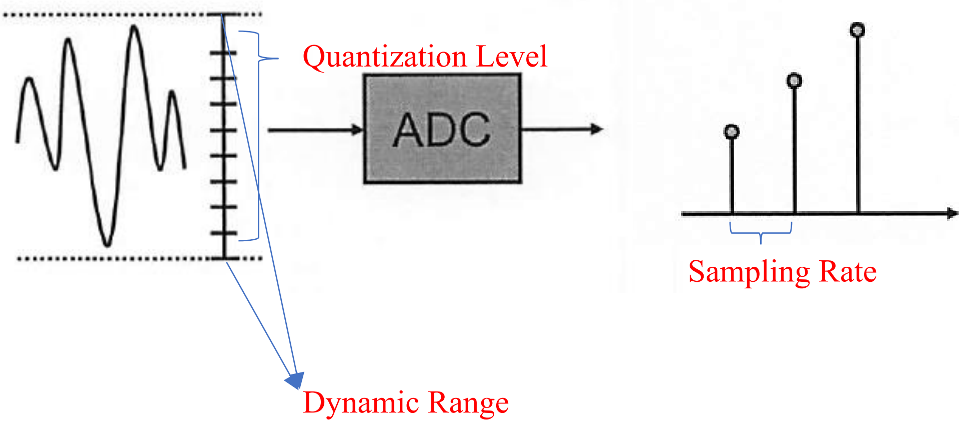
B. Background of experiment :

■ Realistic ADC :

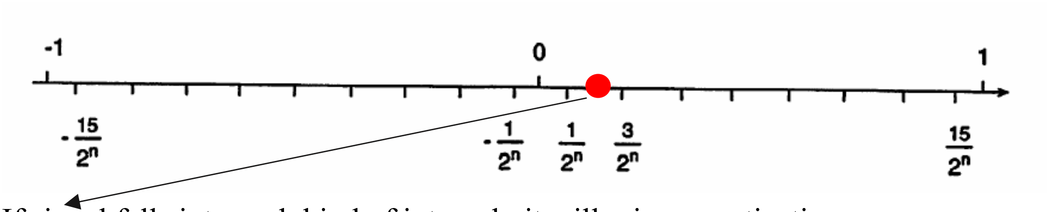
◆ Block Diagram of the realistic DAC/ADC :

<table>
<tr><th>DAC</th><th>ADC</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>DAC is resposible for transform digital siganl to ananlog signal</td><td>ADC is resposible for transform analog siganl to digital signal</td></tr>
</table>

◆ Quatization error for the realistic ADC and SQNR :



Signal after quantized will fall into below range :



If signal falls into such kind of interval , it will arise a quatization erro.
Based on this conception, we can formulate the average quantization power , and the quntization error is uniformly distribution between Dynamic Range.

$$\sigma_q^2 = \frac{1}{\frac{1}{2^N} - \left(-\frac{1}{2^N}\right)} \int_{-\frac{1}{2^N}}^{\frac{1}{2^N}} X^2\, Fdx = \frac{1}{3}\left(\frac{1}{2^N}\right)^2$$

Then we can tag 10*log10 in the both side of the above form to get the energy in dB :

$$10log10\frac{1}{3}\left(\frac{1}{2^N}\right)^2 = -4.77 - 6.02N\; dB$$

N is number of bits utized in the quantization. We can conclude that we will will get $6.02N\, dB$ loss by every increase 1-bit for utilized.

- SQNR :

SQNR is assemble to the SNR, measure the quantization error of a reaistic ADC. It is defined as below :

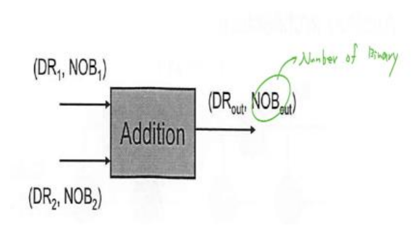
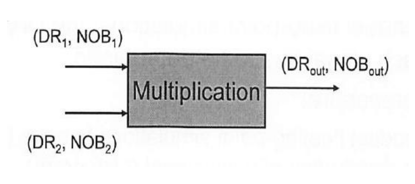
$$\text{SQNR} = 10\log_{10}\frac{E\{x^2(n)\}}{E\{x(n) - x_Q(n)\}^2}$$

Where :

$E\{x^2(n)\}$: signal power

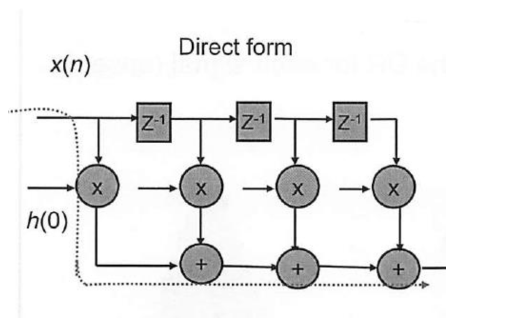
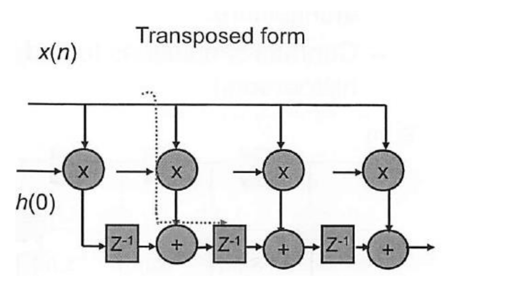
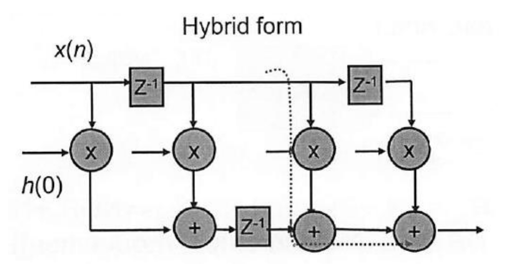
$E\{x(n) - x_Q(n)\}^2$: quantization noise power

- Dynamic Range (DR) and number of bits (NOB):
  - Some definition :
    - Dynamic Range (DR) : the position of decimal point
    - Number of quantization level (NQL) : the to store the signal.
  - Comparison between some calculation :

Addition		$NOB_{out} \ll NOB_1 + NOB_2$	$01_2 + 01_2 = 10_2$ 2-bits < 4-bits
Multiplication		$NOB_{out} < NOB_1 + NOB_2$	$01_2 + 01_2 = 01_2$ 2-bits = 2-bits

  - For example : for the 4-coeficient filtering operation :

$$y(n) = \sum_{i=0}^{3} h(i)x(n-i)$$

	1 multiplier + 3 adders	NOB utilization is the most
	1 multiplier + 1 adders	NOB utilization is the lowest
	1 multiplier + 2 adders	NOB utilization is medium

- Following the below procedure to determine the DR and NOB for each blocz
  - Use floating-point simulations to determine the performance of the system (MSE, SNR. or BER)
  - Quantize the input of the first system and compare the performance with that of the unquantized case. This will determine the NQB for the ADC.
  - Quantize the output of the first system and determine the requirement for SQNR (output NOB).
  - Continue this process until the NOBs of all inputs and outputs are obtained.
  - For each system, we can determine the NOBs of its subsystems to meet the required SQNR.

- Practice Experiment Result :
  - Practice 1 :
    - Notation of Practice 1 :

      From background of this experiment, we can utilize the below formula to relize how the rule of 6dB of thumb while increasing 1bits for quantization .

      ✓ Quantization error when utilizing N bits for quantizing:

$$10log_{10}\sigma_q^2 = -4.77 - 6.02N\ (dB) \quad (1)$$

      ✓ Overal SQNR :

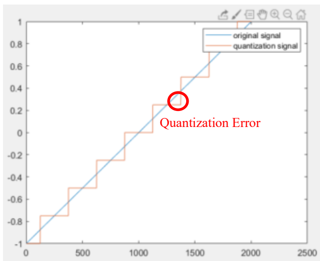
$$10log_{10}\frac{\sigma_s^2}{\sigma_q^2} = 10log_{10}\sigma_s^2 - 10log_{10}\sigma_q^2$$
$$= 10log_{10}\sigma_s^2 + 4.77 + 6.02N\ (dB) \quad (2)$$

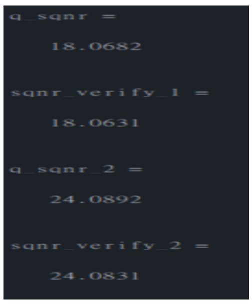
      ✓ SQNR:

$$10\log_{10}\frac{E\{x^2(n)\}}{E\{x(n)-x_Q(n)\}^2} \qquad (3)$$

We can quantize the signal first then calculate it SQNR for the quantized signal and original signal by the (3) above. After the quantization procedure, we can use the theritical SQNR (2) to verufy the result.

    - List of parameter and result :

<table>
<tr><td></td><td>Real ADC</td><td rowspan="3">
</td></tr>
<tr><td>NOB</td><td>3/4</td></tr>
<tr><td>signal</td><td>[-1:0.001:1]</td></tr>
<tr><td colspan="2">From theoritical (2) we will get :
$10log_{10}\sigma_s^2 + 4.77 + 6.02N\ (dB)$

Therefore compare with 4 and 3 bits :
$10log_{10}\sigma_s^2 + 4.77 + 6.02*4 - 10log_{10}\sigma_s^2 + 4.77 + 6.02*3$ =6.02dB
We can verify this result by the experimnet result .</td><td>
</td></tr>
</table>

■ Practice 2 & 3 :

◆ Notation :

From background of this experiment, we can utilize the below formula to make some analysis.

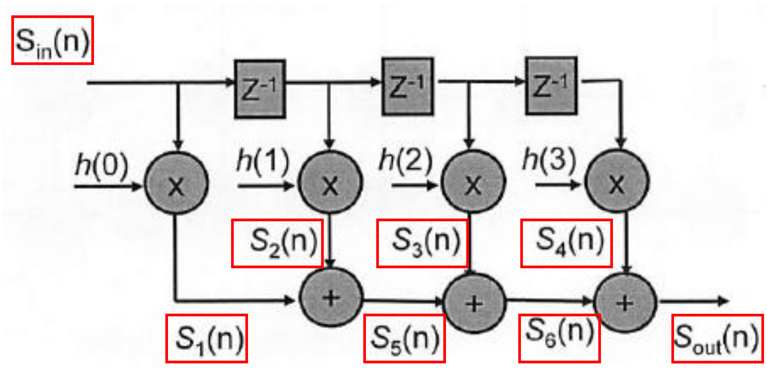
✓ SQNR:

$$10\log_{10}\frac{E\{x^2(n)\}}{E\{x(n)-x_Q(n)\}^2} \qquad (1)$$

◆ List of parameter utilize in the experiment :

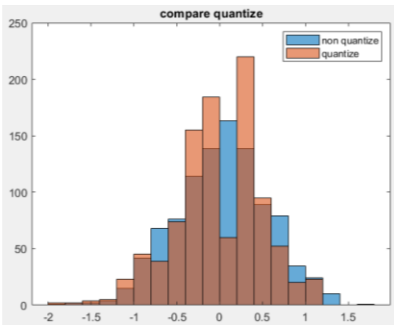
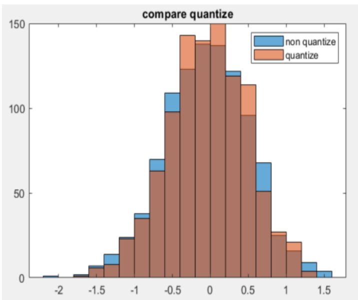
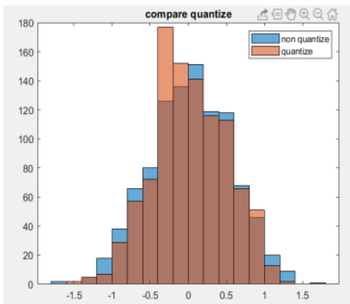
Signal	AWGN-variance = 1
NOB	2、5、10

◆ Block diagram and some notation in the experiment :

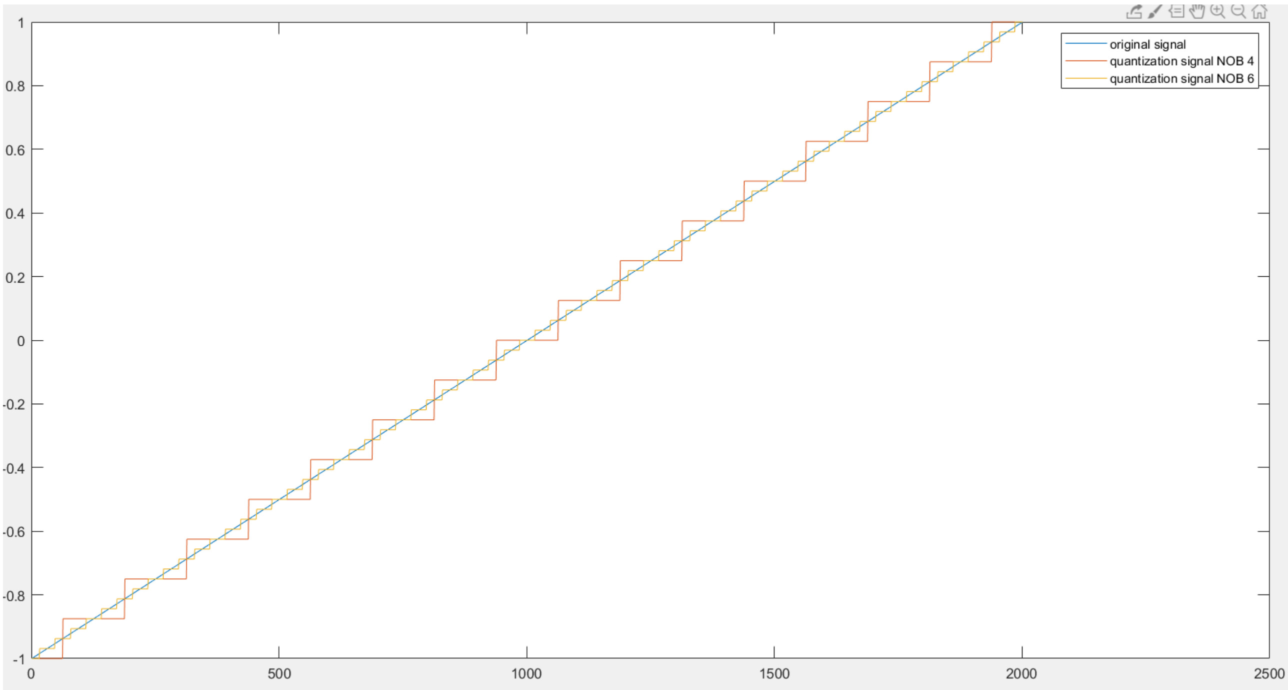


Quantized Signal

We should quantize each signal in every stage. Then observe their Dyanmic Range to determine the number of bits for quantization operation. We can also compare it with a non-quantized version :

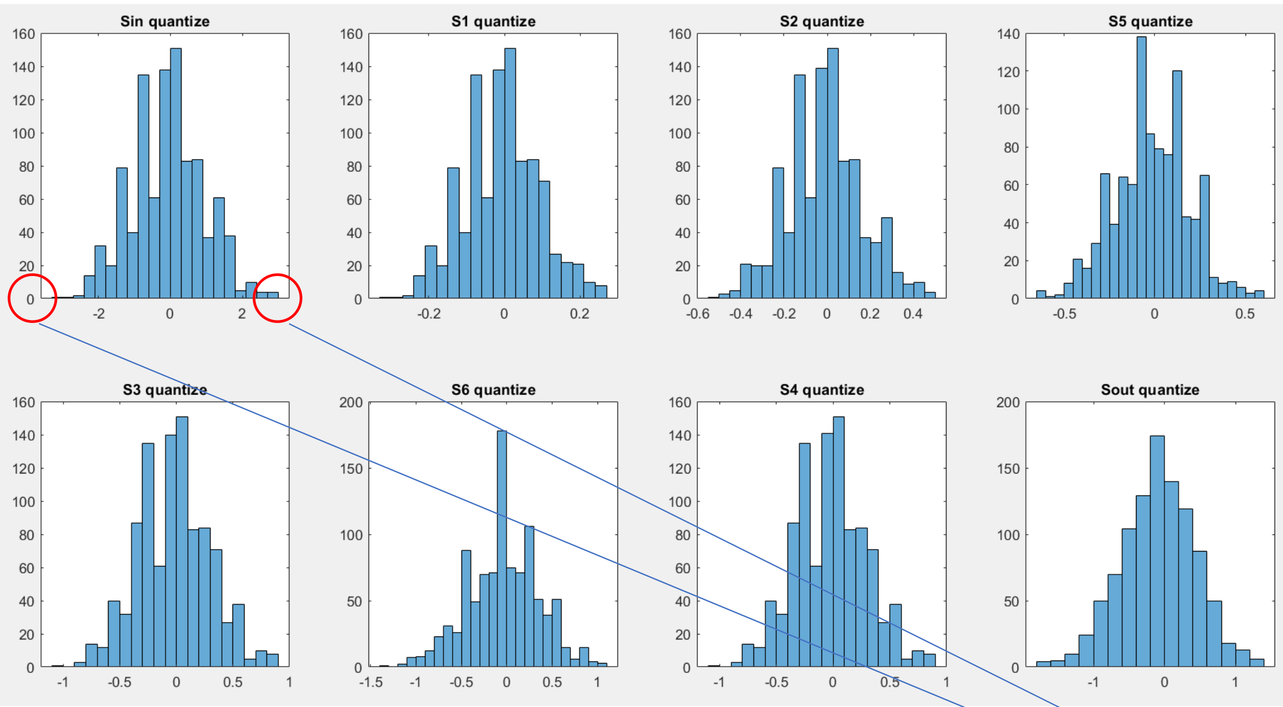
NOB	2	5	10
			
SQNR	6.0010	14.9906	15.5388

Incresing the NOB will make signal be analog alike that will increase the SQNR of the siganl. We can verify by the practice 1 result.



We can observe that the signal will be more analog-like when it utilze increasing NOB.

- Experiment result :



For instance , the Sin quantization dyanamic range is fall into -3 ~ 3. We can represent it as -4 ~ 3.75. Then the number of bits is utized as

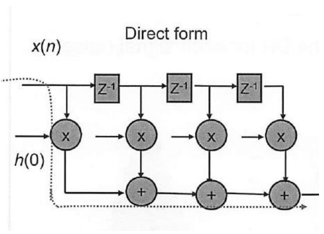
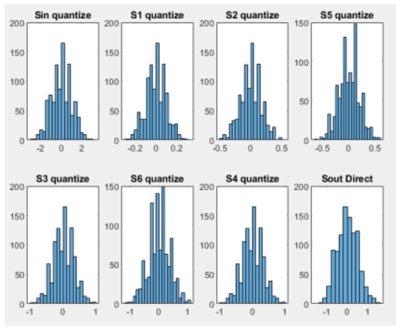
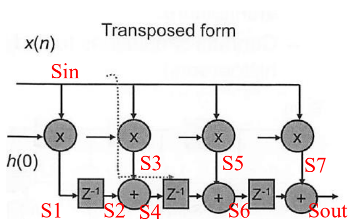
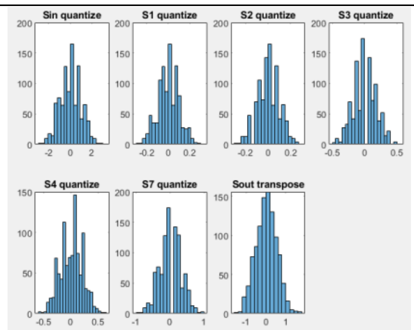
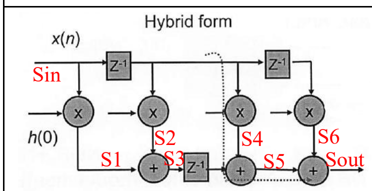
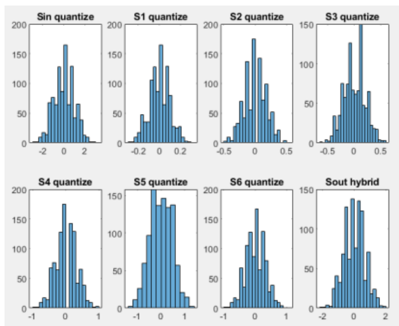
-4	100.0_2
3.75	011.11_2

To meet the 3.75 bits utilization state, we should deploy 5 bits quantization.

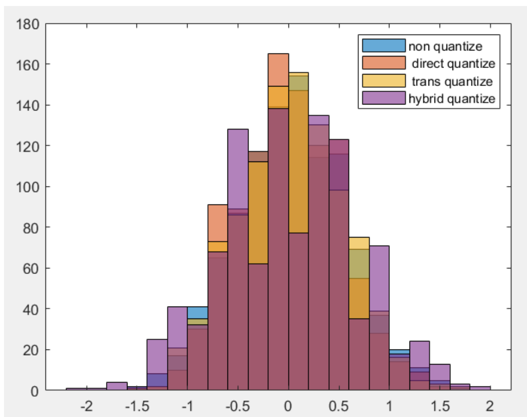
We can get almost the same dynamic range of the transmitted and received signal in the followning test . We will explore more property of some combination of parametors in the Homework experiment.

● Home work Experiment Result :

■ Experiment result :

	1 mul+3 add -> NOB utilization is the most SQNR = 15.1049	
	1 mul+1 add ->NOB utilization is the lowes SQNR = 2.5636	
	1 mul+2 add -> NOB utilization is medium SQNR = 0.6309	

Their Sout stage intergration is as below :

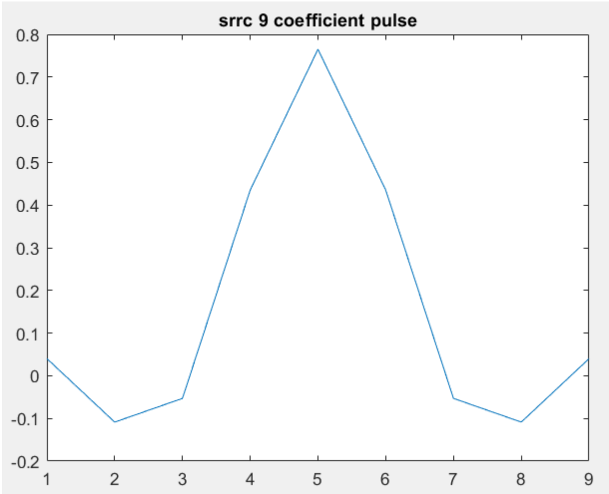


We can obesrve that direct has the highest SQNR which indicate that we favor a precise calculation if hardware cost is not a consideration.

SRRC filter can be obtained from the below formula :

$$\frac{4\alpha}{\pi}\frac{\frac{cos(1+\alpha)\,\pi t}{T}+Tsin((1-\alpha)\pi t/T)/(4\alpha t)}{1-\left(\frac{4\alpha t}{T}\right)^{2}}$$

When we choose a span as 2 and the srrc periodd T as 2 , we will get a 9 coefficient as result. Then we use these nine parametors to simulate as srrc just ploted as below :



Then we adopt this nine points in the FIR filter, we will get :

$$srrc \otimes awgn\ signal$$

The same calculation by the FIR filter, we can verify it by the diagram below: