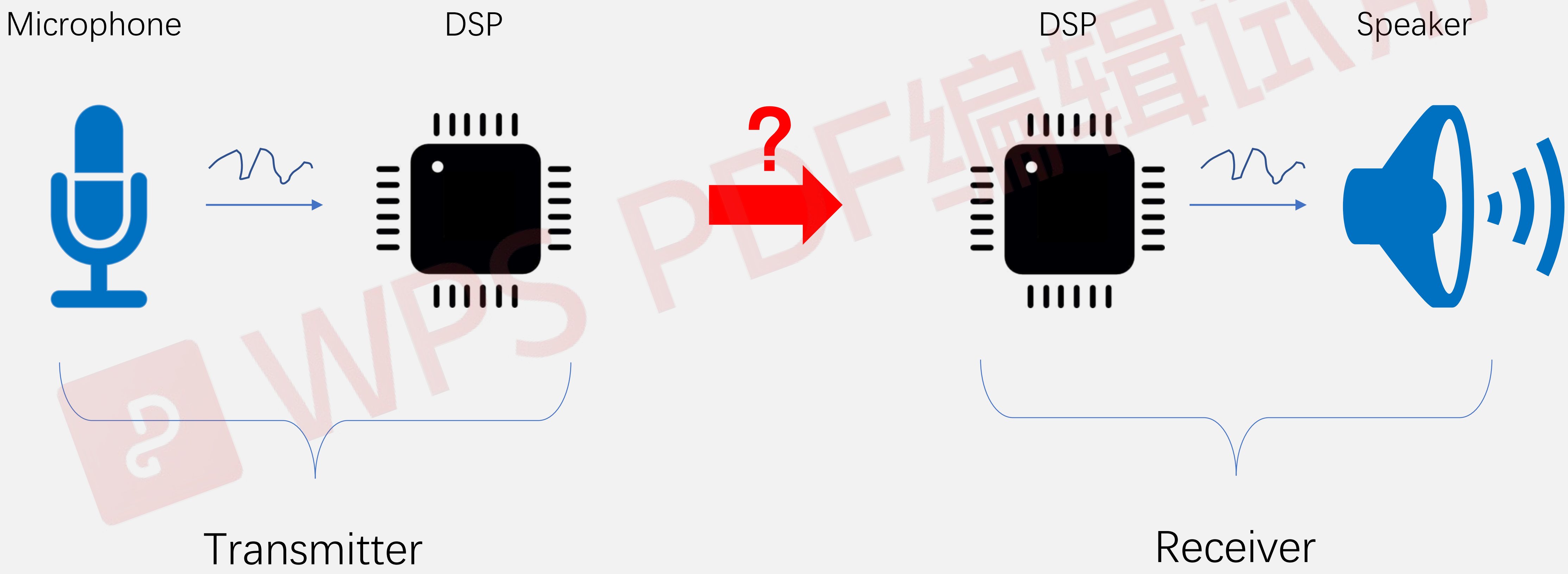
无线通信实验在线开放课程

主讲人：吴光 博士

广东省教学质量工程建设项目


Microphone
DSP
DSP
Speaker
Transmitter
Receiver

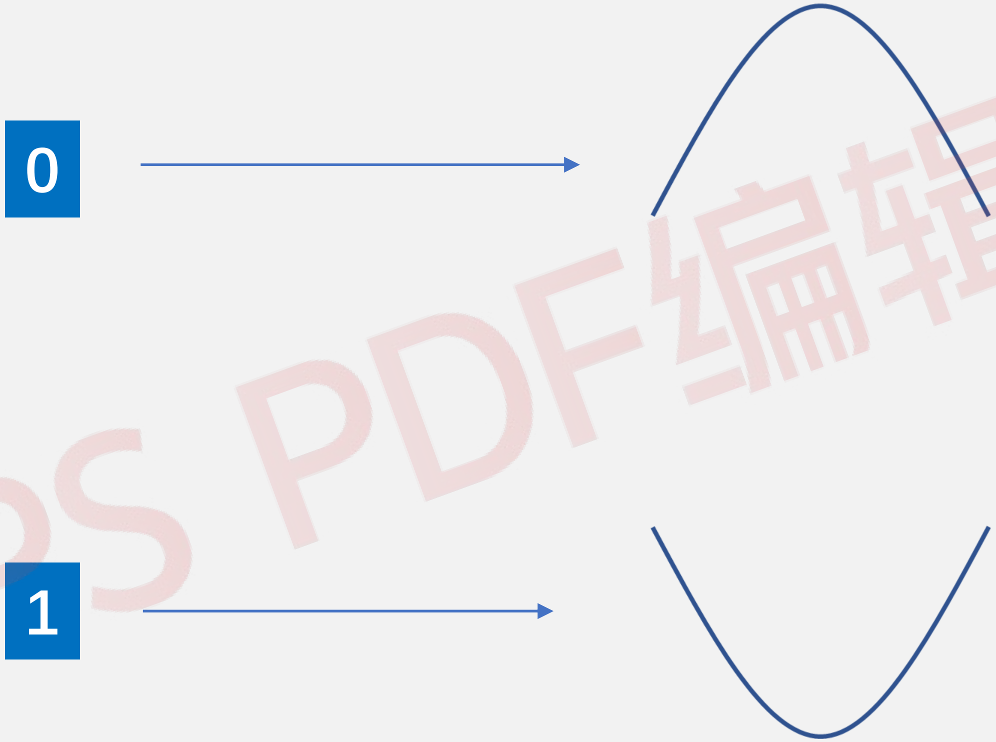
Lab 7 : Baseband Transmission

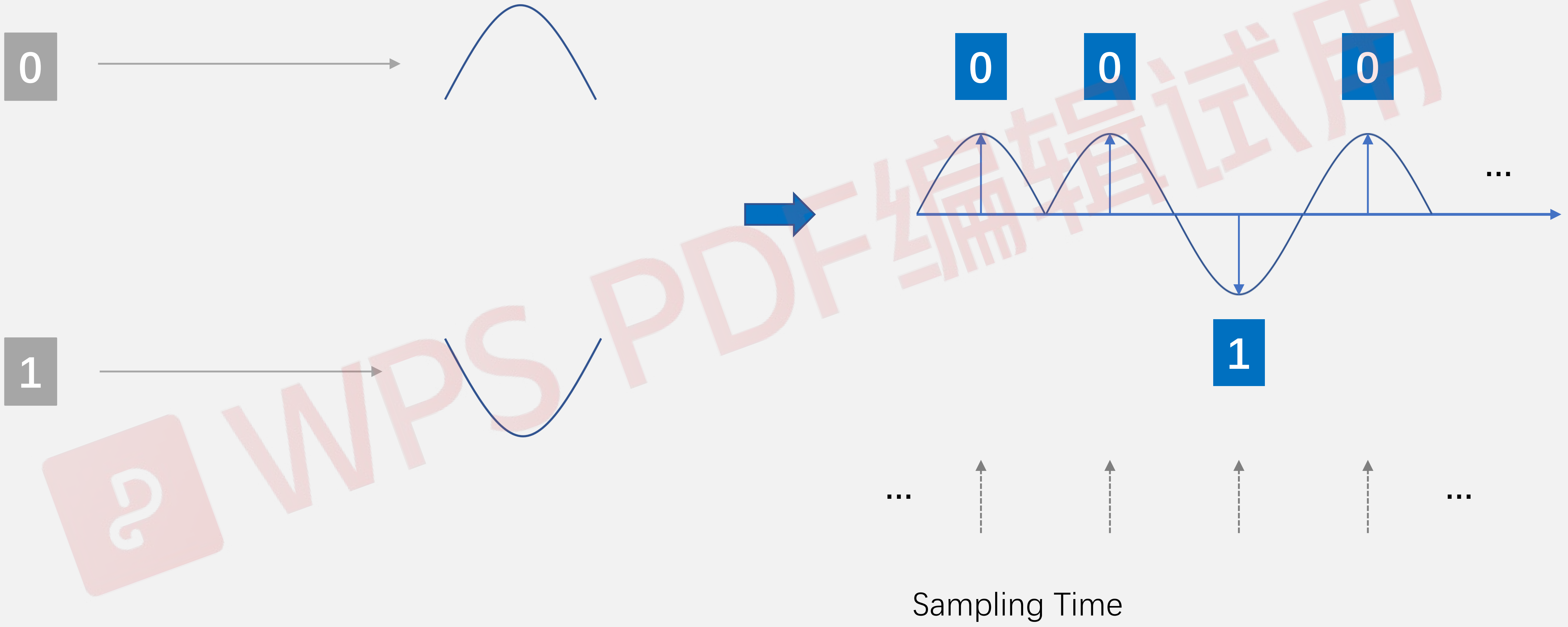
主讲人: 吴光 博士
Email: wug@sustech.edu.cn

Eye Diagram

1. Baseband transmission system
2. Inter-Symbol Interference (ISI)
3. Raised-cosine function
4. Eye Diagram and Experiment

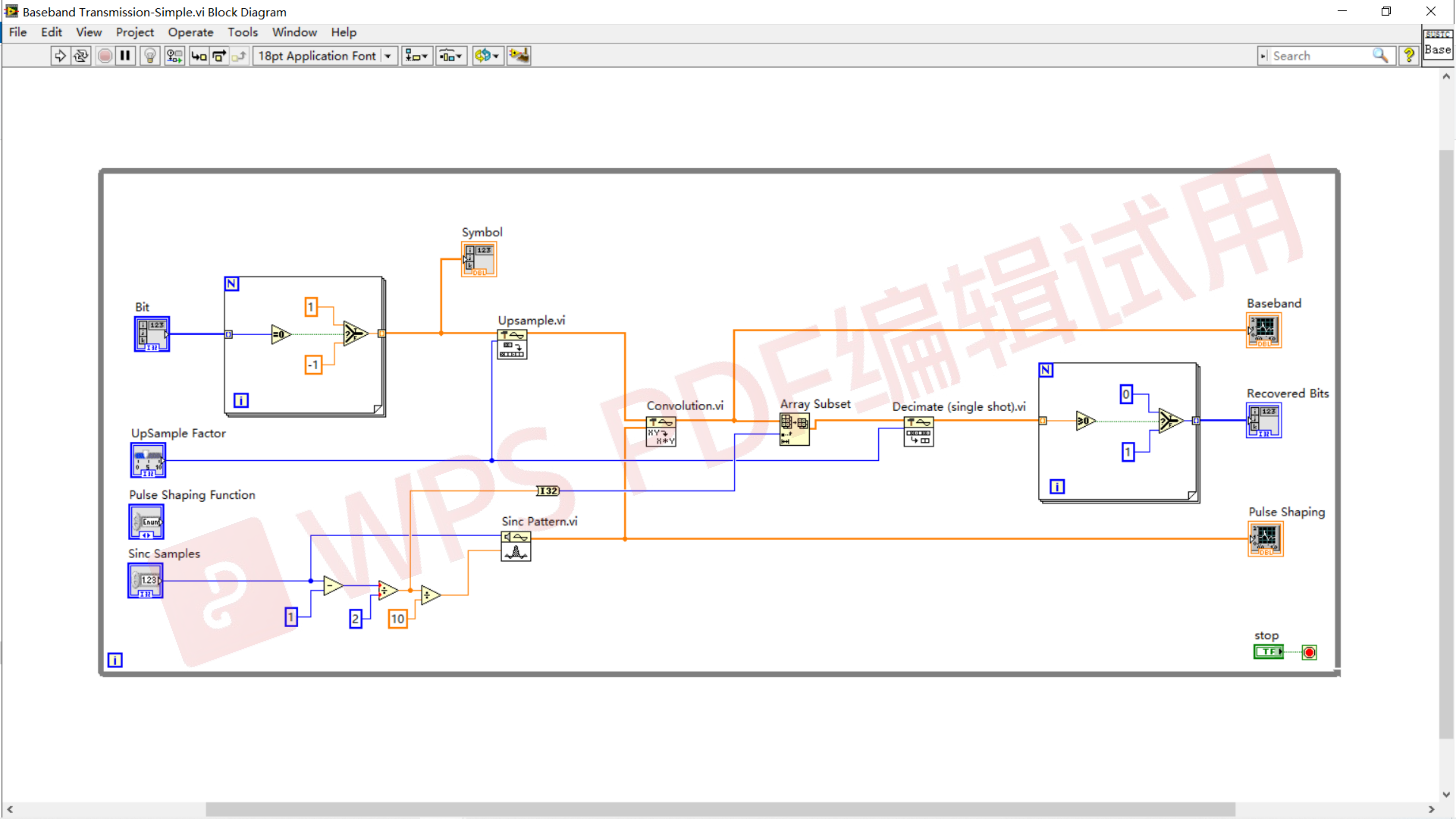
Demo: Baseband Signal Transmission

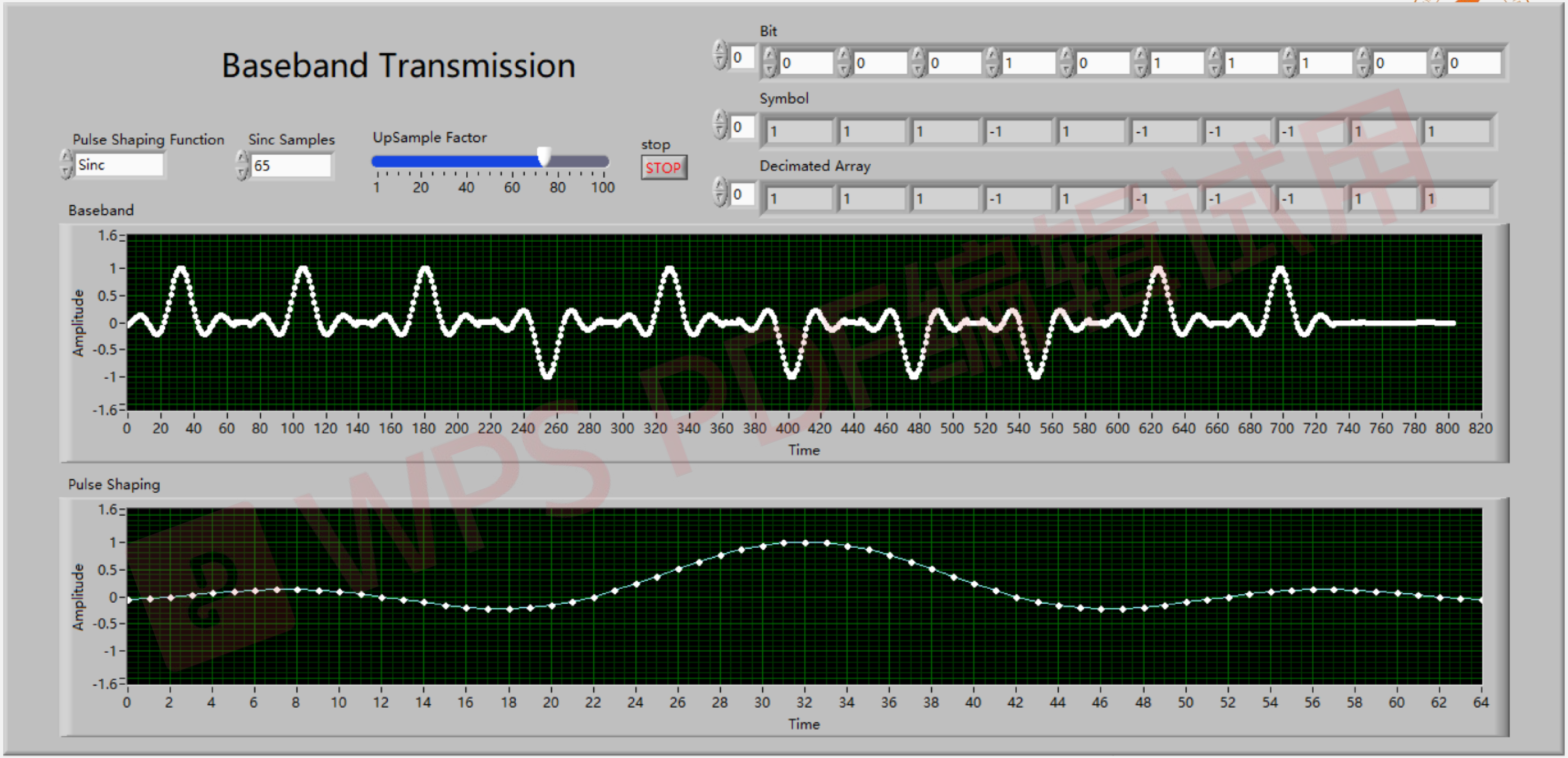

0
1

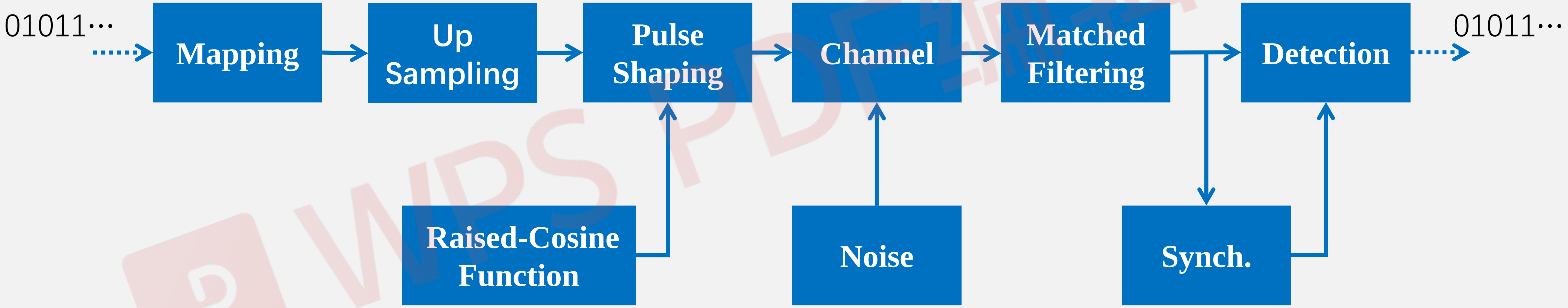

0
1
0
0
1
0
...
...
...
Sampling Time

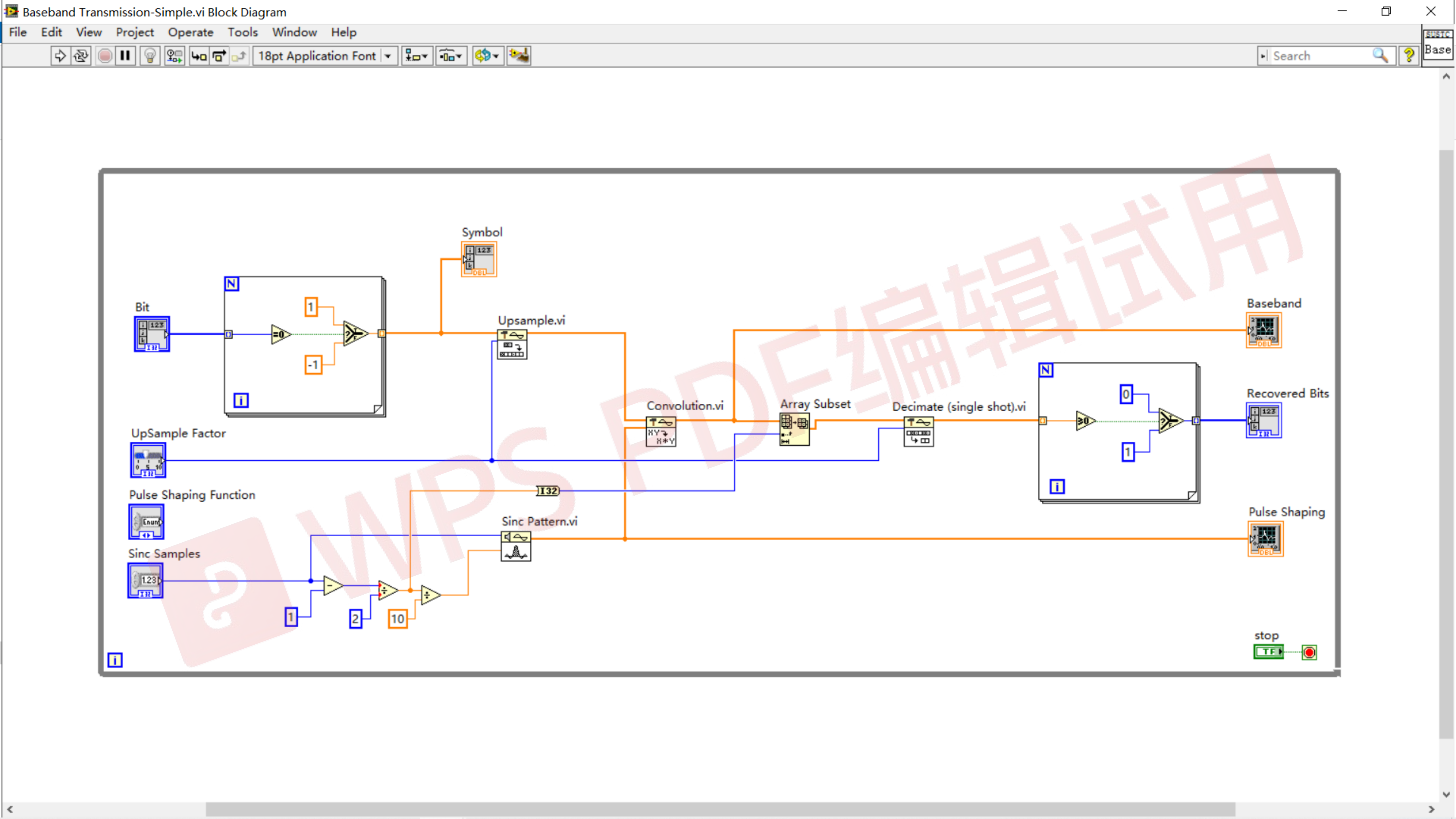
Exercise: Baseband Signal Transmission

本节的主要任务是练习程序，大概10分钟


Baseband Transmission-Simple.vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
Symbol
Bit
Upsample.vi
Baseband
Convolution.vi
Array Subset
Decimate (single shot).vi
Recovered Bits
UpSample Factor
Pulse Shaping Function
Sinc Pattern.vi
Pulse Shaping
Sinc Samples
stop


Baseband Transmission
Pulse Shaping Function
Sinc
Sinc Samples
65
UpSample Factor
1 20 40 60 80 100
stop
STOP
Bit
0
0 0 0 1 0 1 1 1 0 0
Symbol
0
1 1 1 -1 1 -1 -1 -1 1 1
Decimated Array
0
1 1 1 -1 1 -1 -1 -1 1 1
Baseband
Amplitude
1.6 1 0.5 0 -0.5 -1 -1.6
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820
Time
Pulse Shaping
Amplitude
1.6 1 0.5 0 -0.5 -1 -1.6
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64
Time


01011⋯
Mapping
Up Sampling
Pulse Shaping
Channel
Matched Filtering
Detection
01011⋯
Raised-Cosine Function
Noise
Synch.


Baseband Transmission-Simple.vi Block Diagram
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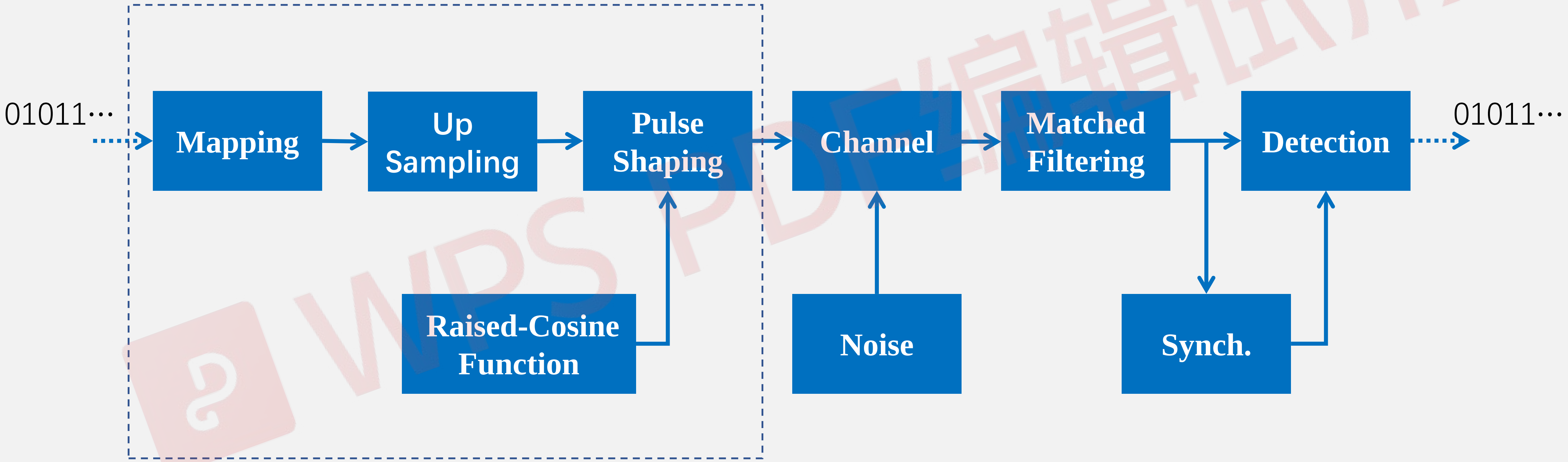
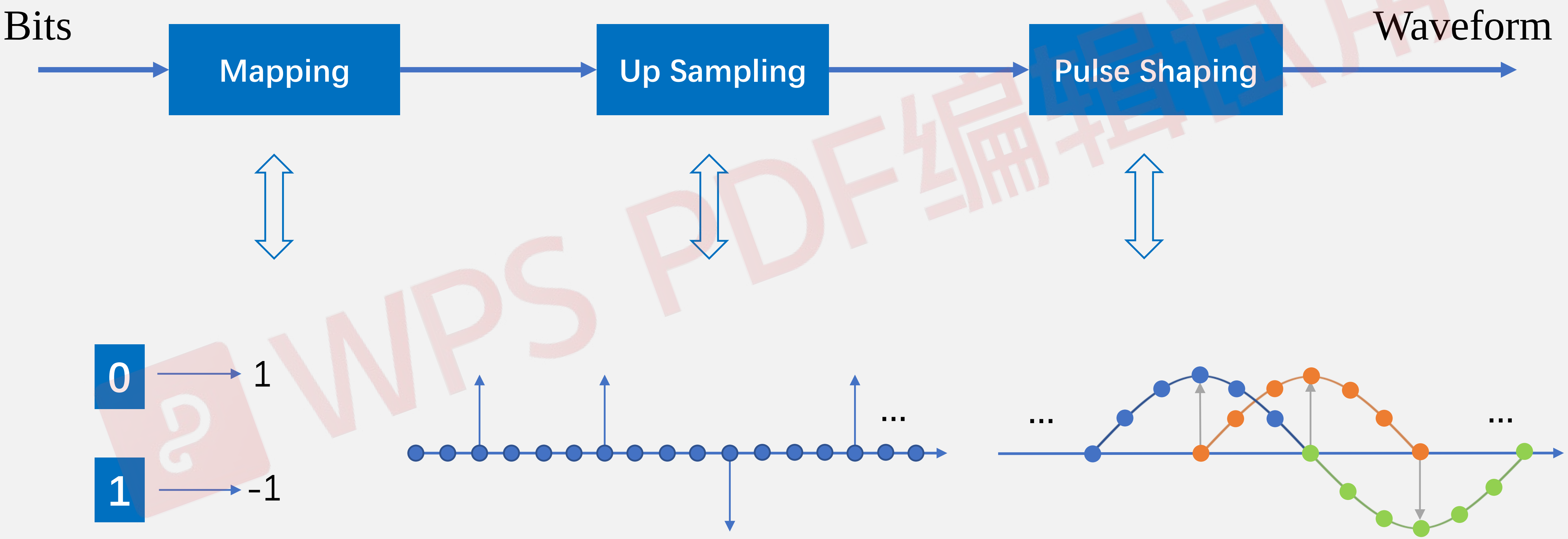
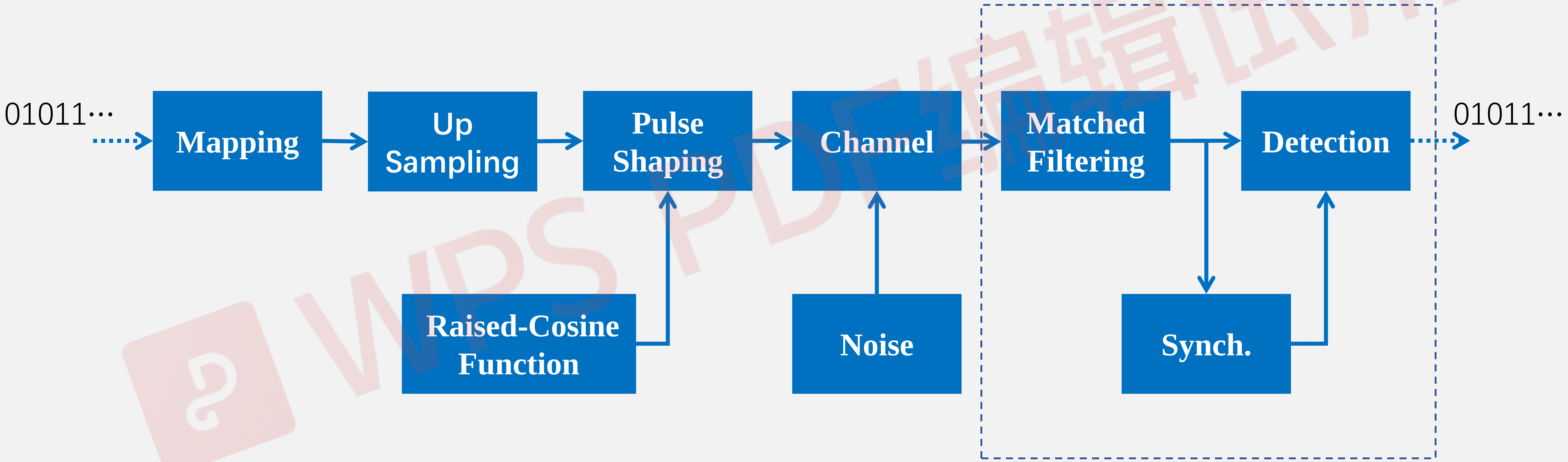
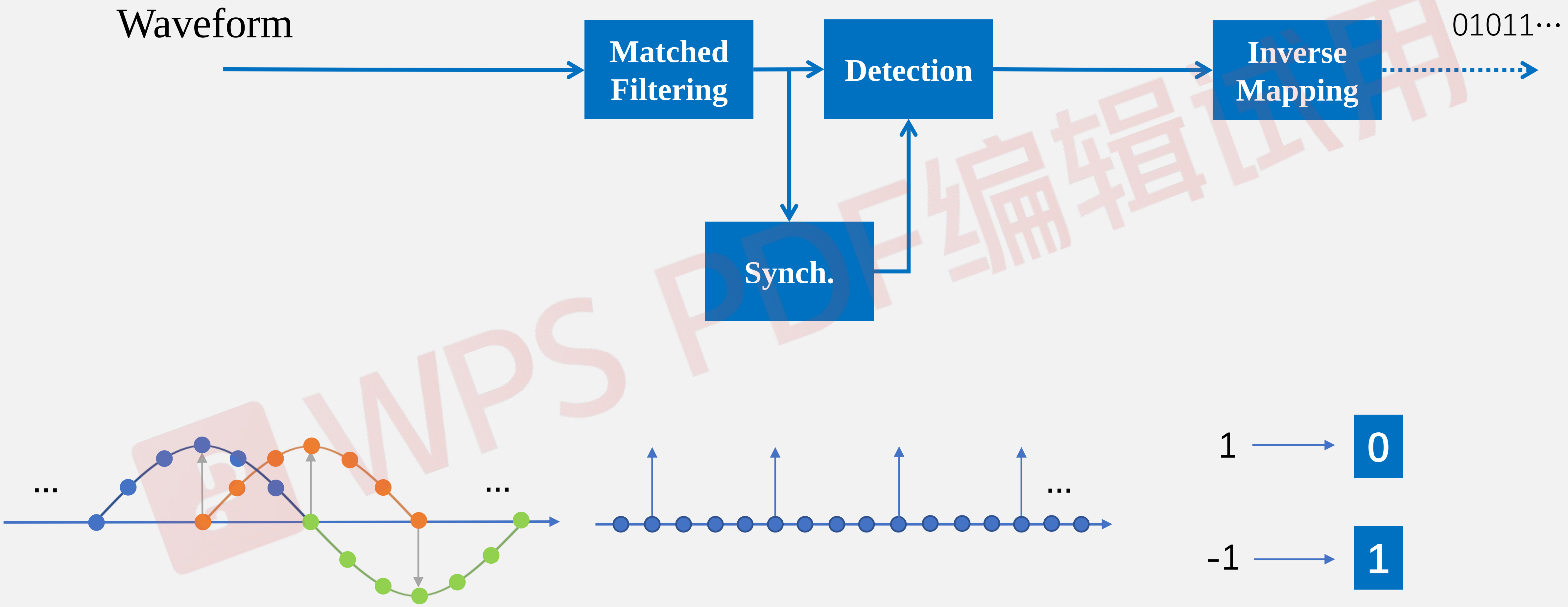
Symbol
Bit
Upsample.vi
Baseband
Convolution.vi
Array Subset
Decimate (single shot).vi
Recovered Bits
UpSample Factor
Pulse Shaping Function
Sinc Pattern.vi
Pulse Shaping
Sinc Samples
stop

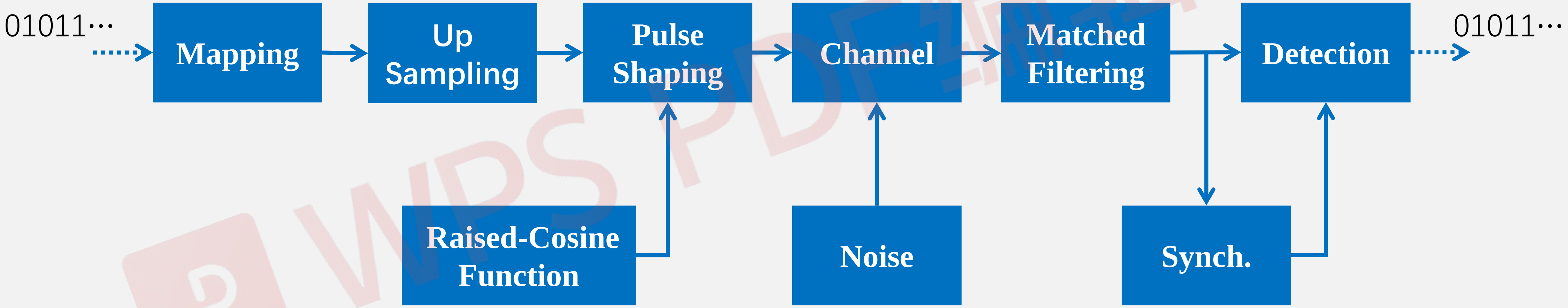

01011···
Mapping
Up Sampling
Pulse Shaping
Raised-Cosine Function
Channel
Noise
Matched Filtering
Synch.
Detection
01011···


Bits
Mapping
Up Sampling
Pulse Shaping
Waveform
0
1
1
-1
…
…
…


01011···
Mapping
Up Sampling
Pulse Shaping
Channel
Matched Filtering
Detection
01011···
Raised-Cosine Function
Noise
Synch.


Waveform
Matched Filtering
Detection
Inverse Mapping
01011···
Synch.
...
...
...
1
0
-1
1

Baseband Transmission-Simple.vi
File Edit View Project Operate Tools Window Help
Baseband Transmission
Bit
0 0 0 0 1 0 1 1 1 0 0
Symbol
0 1 1 1 -1 1 -1 -1 -1 1 1
Recovered Bits
0 0 0 0 1 0 1 1 1 0 0
Pulse Shaping Function
Sinc
Sinc Samples
65
UpSample Factor
1 20 40 60 80 100
stop
STOP
Baseband
Amplitude
Time
Pulse Shaping
Amplitude
Time

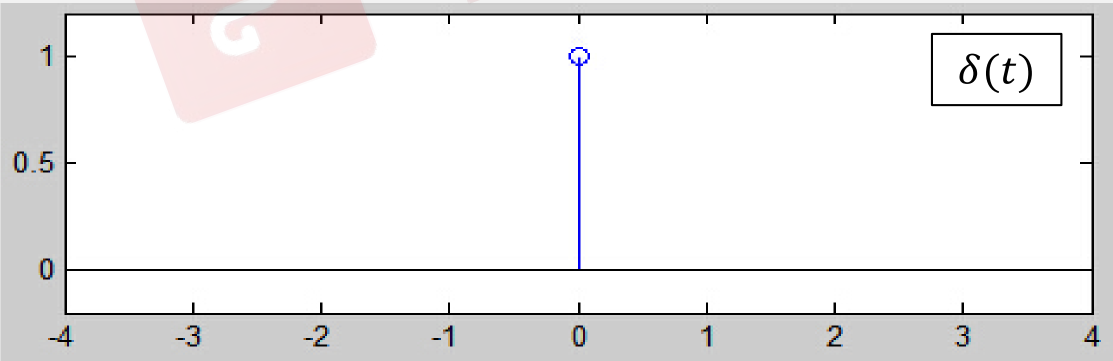

01011···
Mapping
Up Sampling
Pulse Shaping
Channel
Matched Filtering
Detection
01011···
Raised-Cosine Function
Noise
Synch.

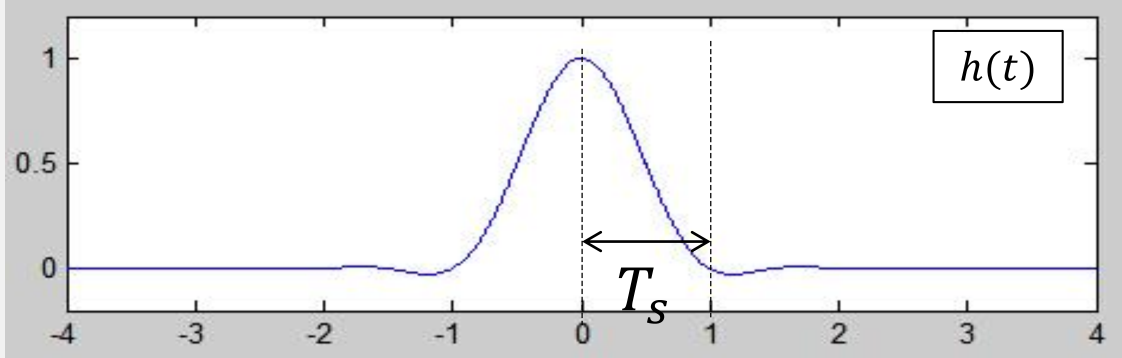
Linear Time Invariant System

Pre-Lab: Linear time invariant system

$$\delta(t) \longrightarrow \boxed{\mathbf{H}\{\cdot\}} \longrightarrow h(t)$$

$$H\{I_k\delta(t-kT_s)\} = I_k h(t-kT_s)$$





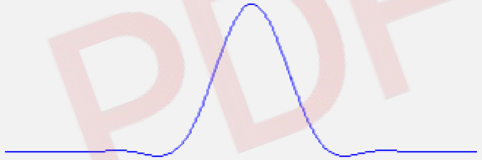
Pre-Lab: Linear time invariant system

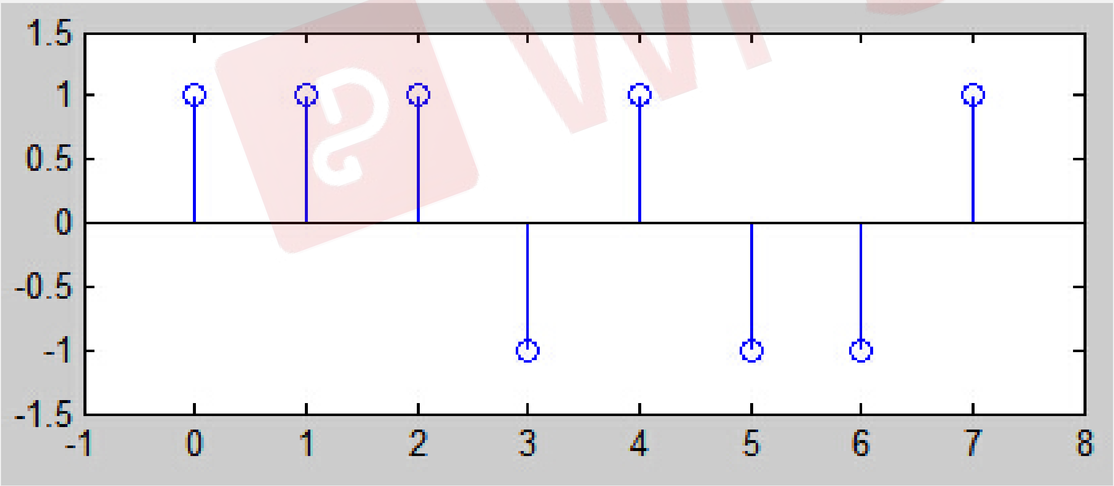
$$\sum_k I_k \delta(t - kT_s) \longrightarrow \boxed{\mathbf{H}\{\cdot\}} \longrightarrow \sum_k I_k h(t - kT_s)$$

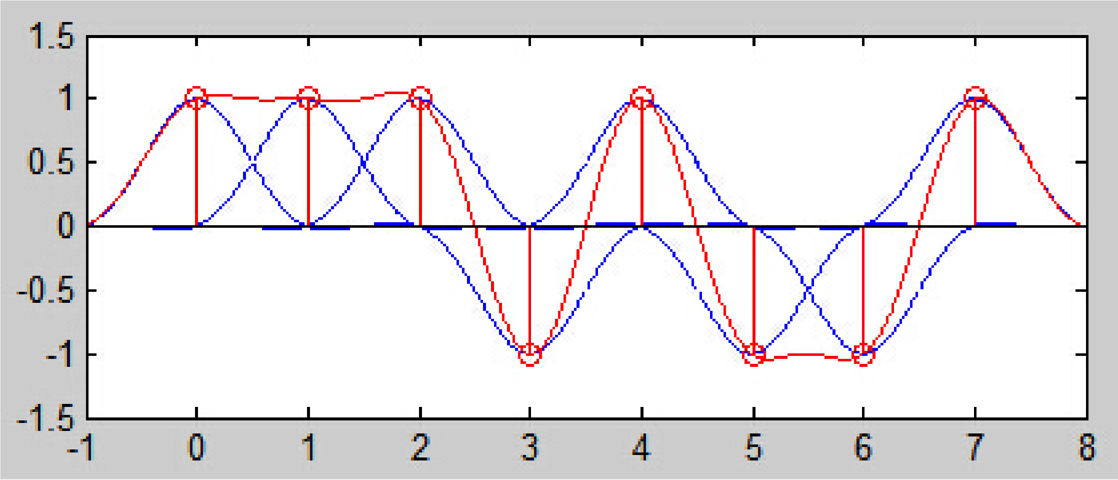
$$H\left\{\sum_k I_k \delta(t - kT_s)\right\} = \sum_k I_k h(t - kT_s)$$

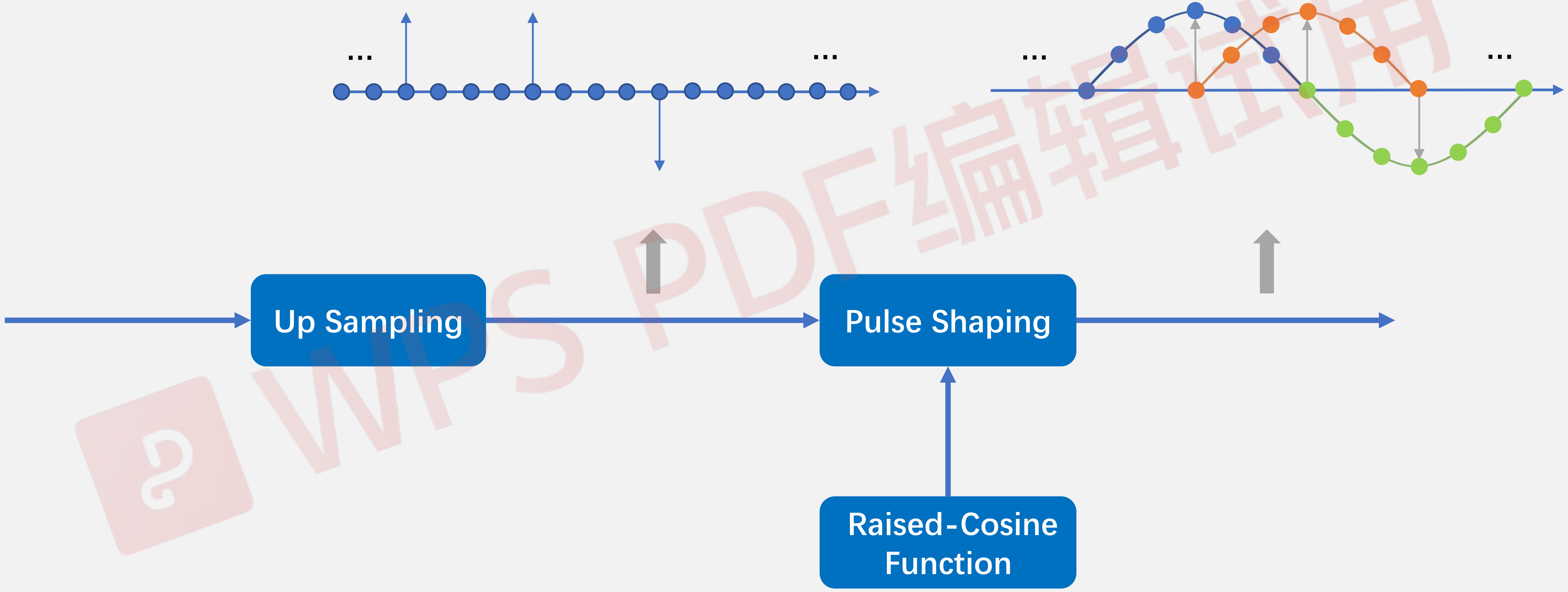
Pre-Lab: Linear time invariant system

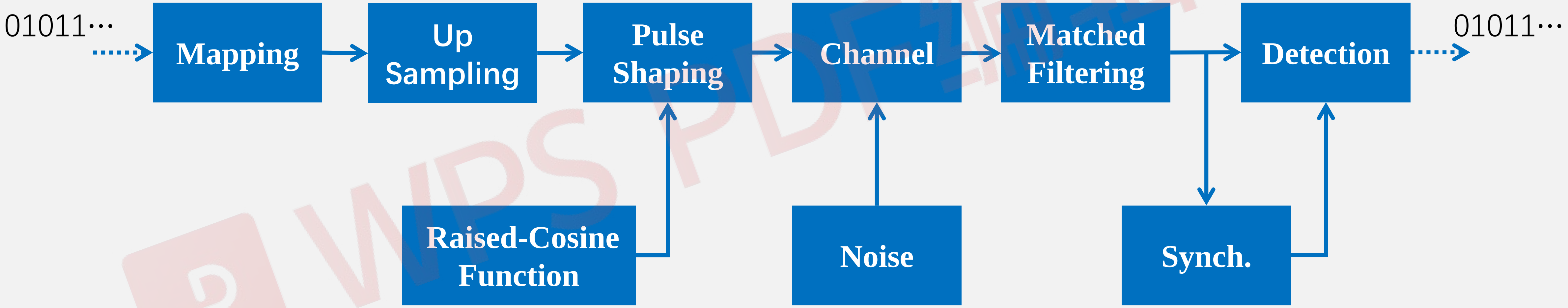
$$\sum_k I_k \delta(t - kT_s) \longrightarrow \boxed{\mathbf{H}\{\cdot\}} \longrightarrow \sum_k I_k h(t - kT_s)$$

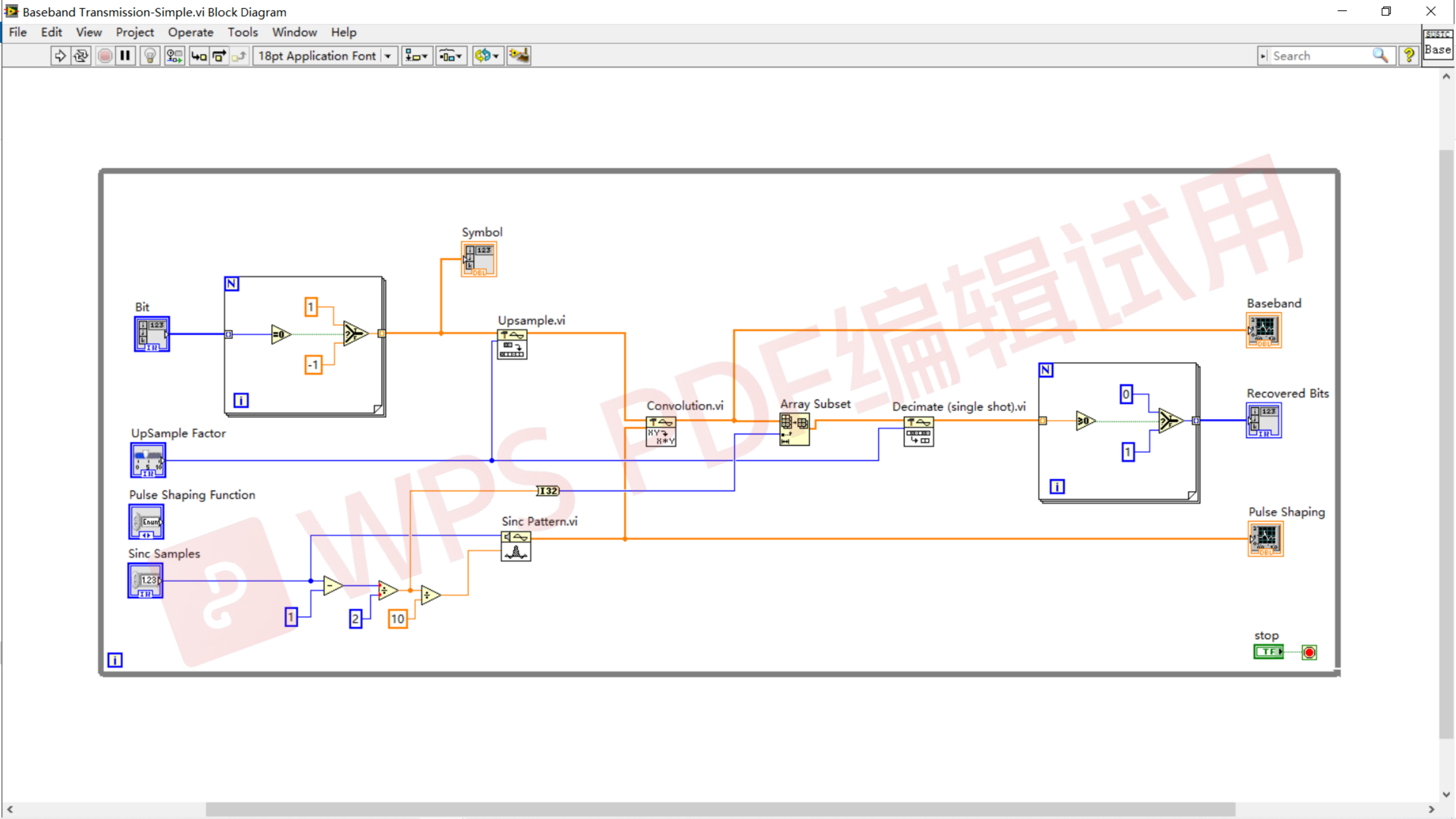




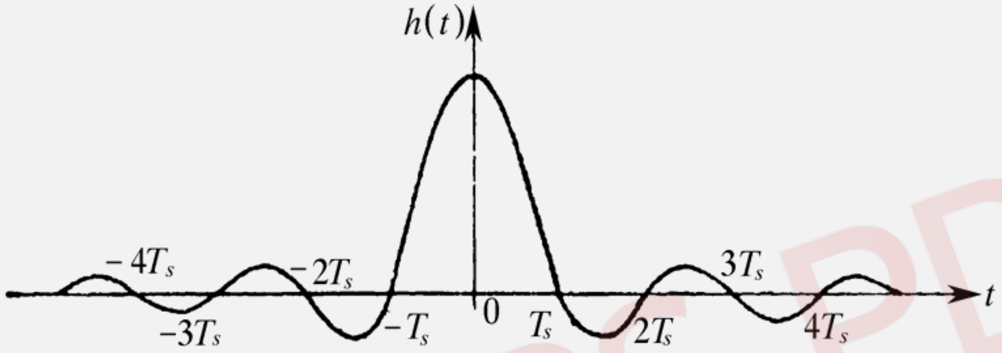



...
...
...
...
Up Sampling
Pulse Shaping
Raised-Cosine
Function

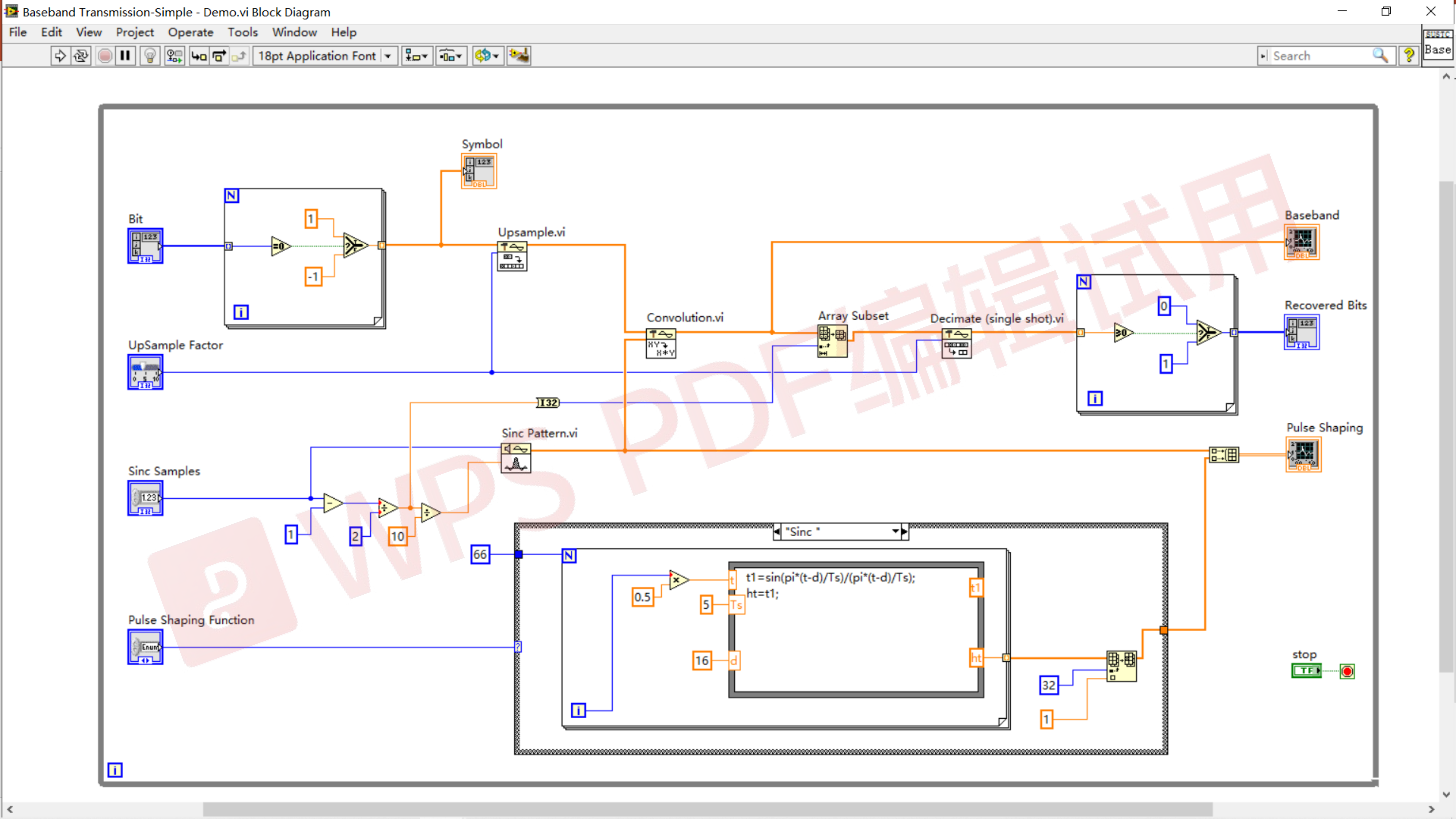

01011…
Mapping
Up Sampling
Pulse Shaping
Channel
Matched Filtering
Detection
01011…
Raised-Cosine Function
Noise
Synch.

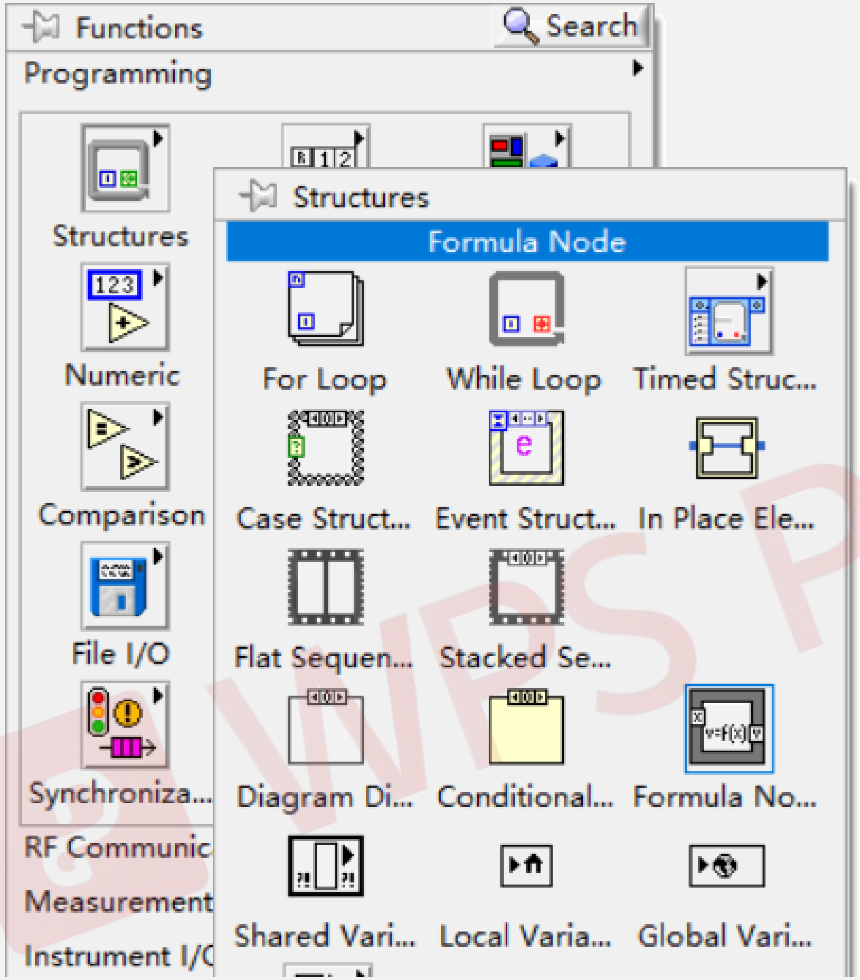

Baseband Transmission-Simple.vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
Symbol
Bit
Upsample.vi
UpSample Factor
Pulse Shaping Function
Sinc Samples
Sinc Pattern.vi
Convolution.vi
Array Subset
Decimate (single shot).vi
Baseband
Recovered Bits
Pulse Shaping
stop


Baseband Transmission-Simple.vi
File Edit View Project Operate Tools Window Help
Baseband Transmission
Pulse Shaping Function
Sinc
Sinc Samples
65
UpSample Factor
1 20 40 60 80 100
stop
STOP
Bit
0
0 0 0 1 0 1 1 1 0 0
Symbol
0
1 1 1 -1 1 -1 -1 -1 1 1
Recovered Bits
0
0 0 0 1 0 1 1 1 0 0
Baseband
Amplitude
1.6 1 0.5 0 -0.5 -1 -1.6
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100
Time
Pulse Shaping
Amplitude
1.6 1 0.5 0 -0.5 -1 -1.6
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64
Time

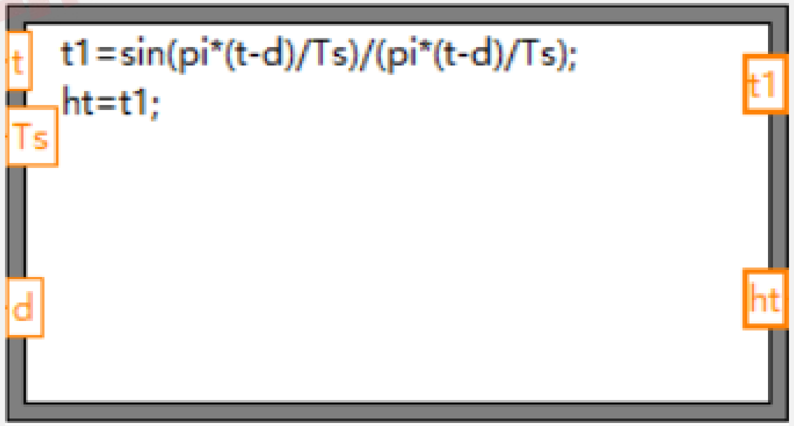


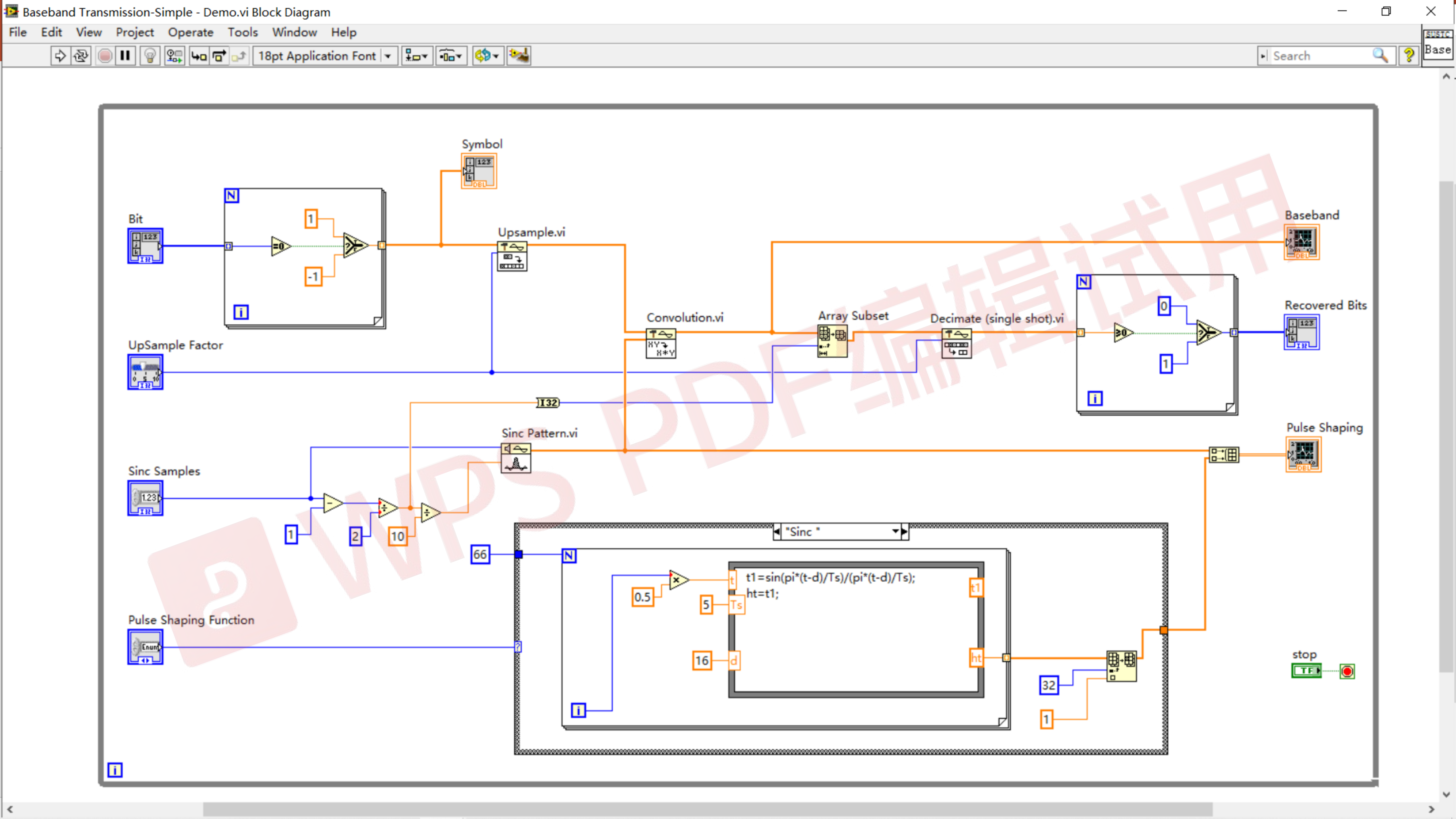
$$h(t) = \frac{\sin \frac{\pi}{T_s} t}{\frac{\pi}{T_s} t}$$


Baseband Transmission-Simple - Demo.vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
Symbol
Bit
Upsample.vi
Baseband
UpSample Factor
Convolution.vi
Array Subset
Decimate (single shot).vi
Recovered Bits
Sinc Pattern.vi
Pulse Shaping
Sinc Samples
"Sinc "
t1=sin(pi*(t-d)/Ts)/(pi*(t-d)/Ts);
ht=t1;
Pulse Shaping Function
stop

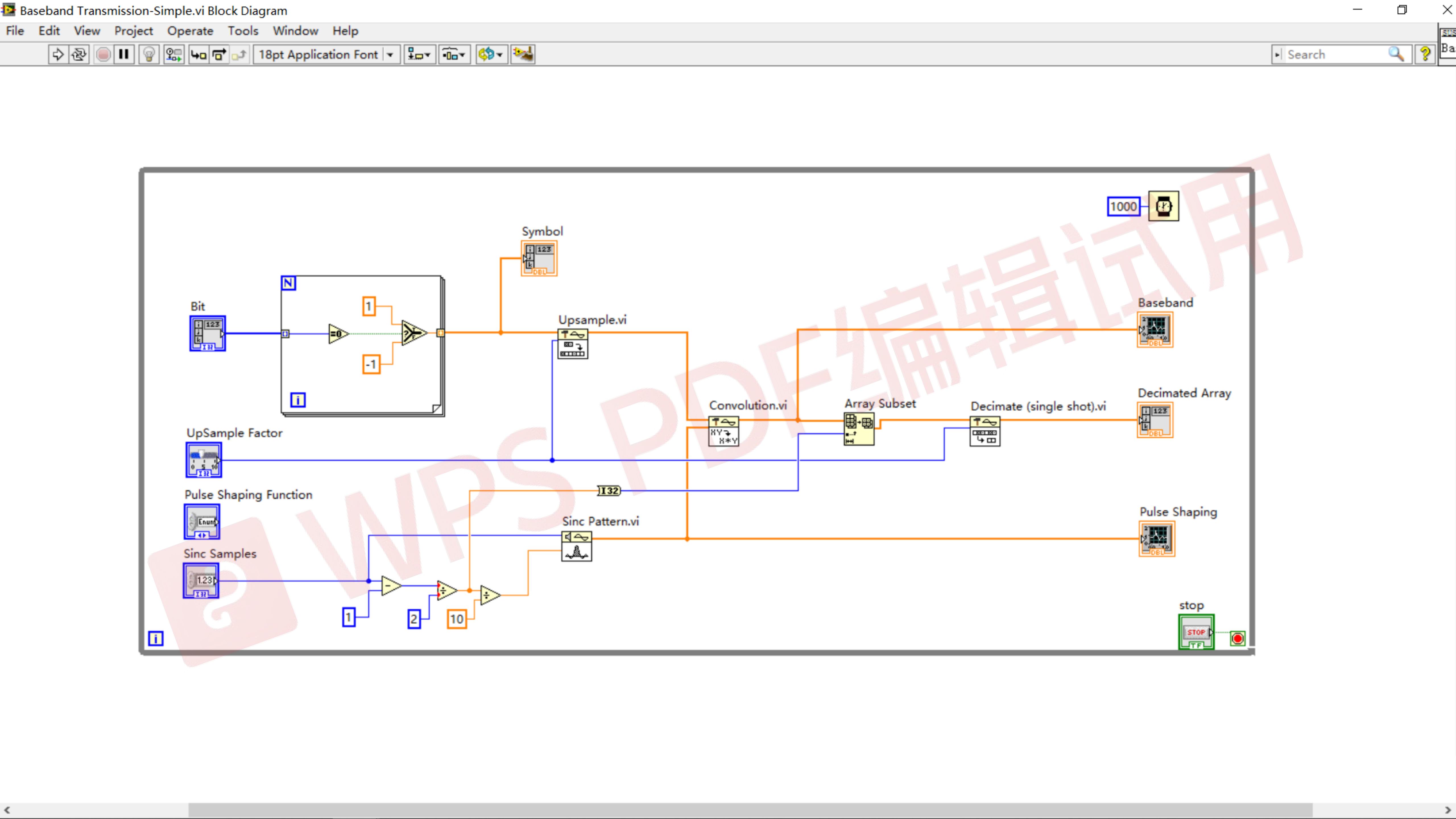


$$h(t)=\frac{\sin\frac{\pi}{T_s}t}{\frac{\pi}{T_s}t}$$

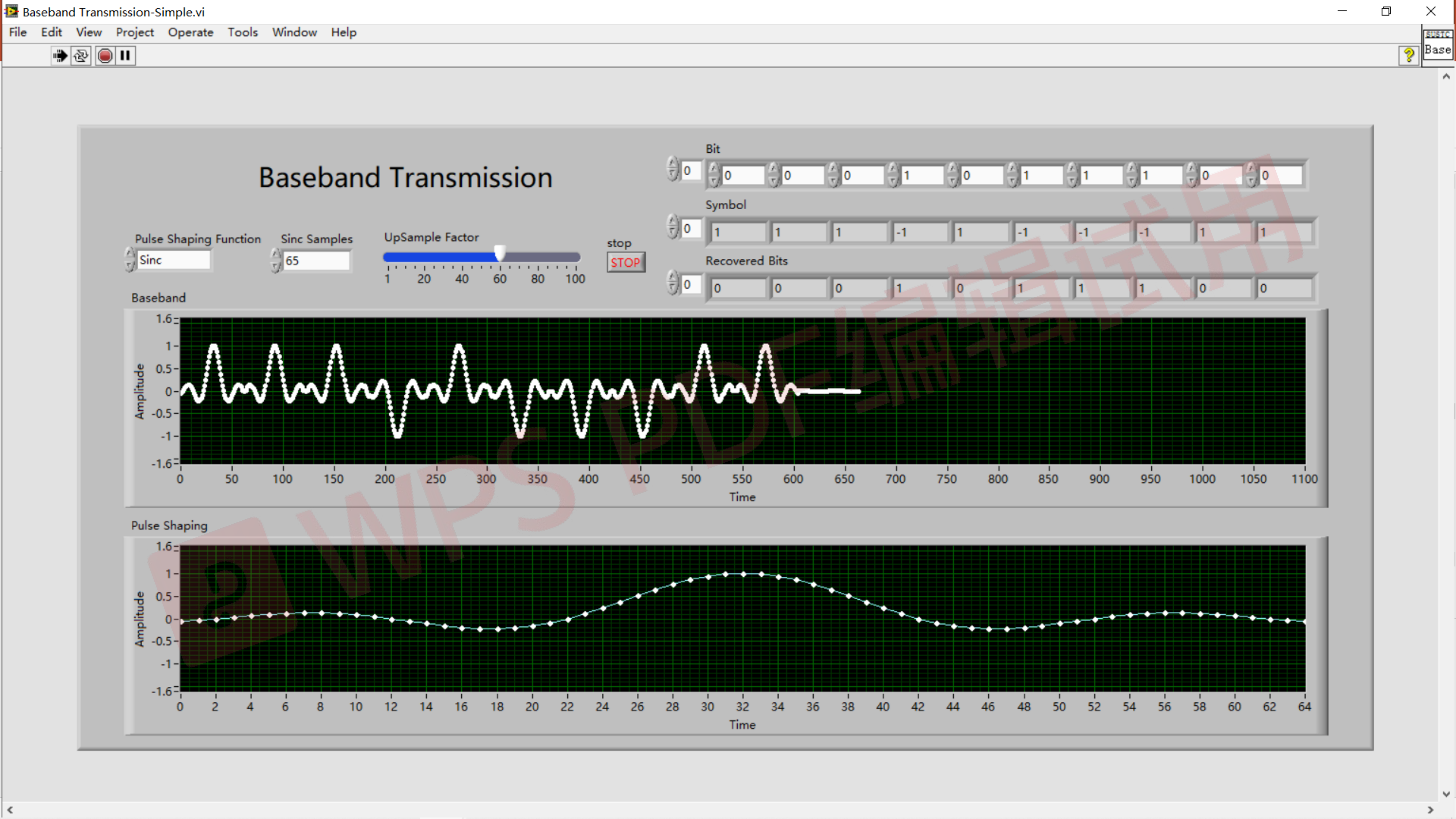


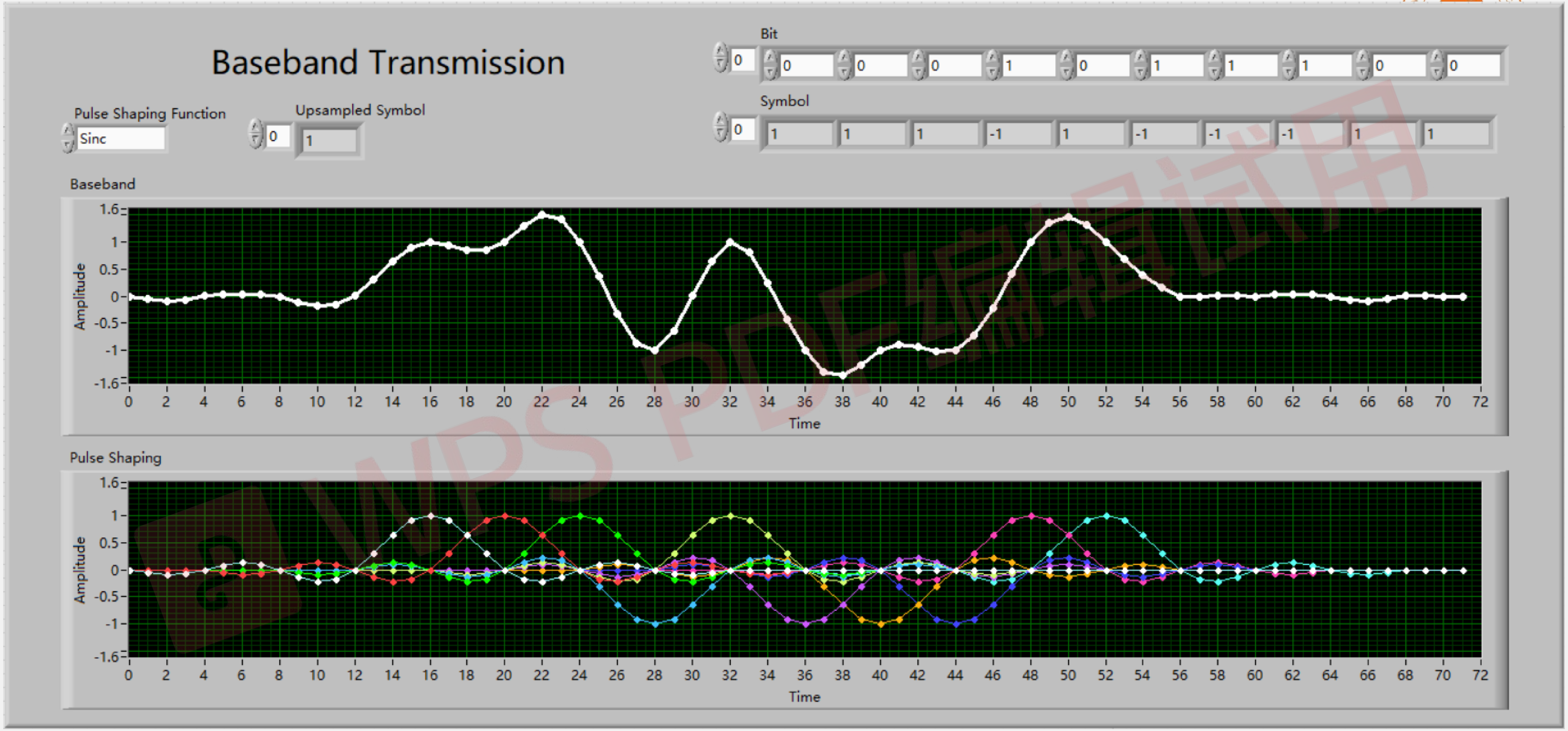

Baseband Transmission-Simple - Demo.vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
Symbol
Bit
Upsample.vi
Baseband
Convolution.vi
Array Subset
Decimate (single shot).vi
Recovered Bits
UpSample Factor
Sinc Pattern.vi
Pulse Shaping
Sinc Samples
"Sinc "
t1=sin(pi*(t-d)/Ts)/(pi*(t-d)/Ts);
ht=t1;
Pulse Shaping Function
stop

Demo: Baseband Signal Transmission

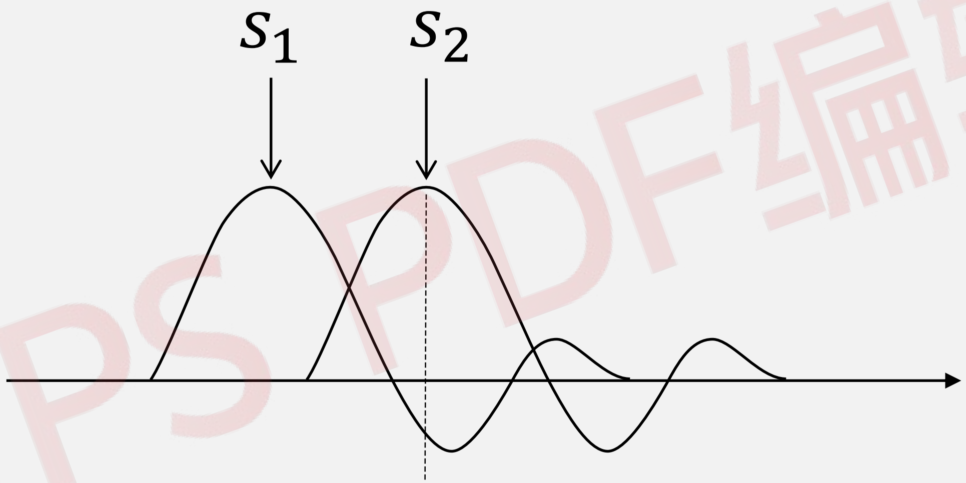

Baseband Transmission-Simple.vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
1000
Symbol
Bit
N
1
-1
i
Upsample.vi
Baseband
UpSample Factor
Convolution.vi
Array Subset
Decimate (single shot).vi
Decimated Array
I32
Pulse Shaping Function
Sinc Pattern.vi
Pulse Shaping
Sinc Samples
1
2
10
stop
i


Baseband Transmission-Simple.vi
File Edit View Project Operate Tools Window Help
Baseband Transmission
Bit
0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0
Symbol
0 | 1 | 1 | 1 | -1 | 1 | -1 | -1 | -1 | 1 | 1
Recovered Bits
0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0
Pulse Shaping Function
Sinc
Sinc Samples
65
UpSample Factor
1 20 40 60 80 100
stop
STOP
Baseband
Amplitude
Time
Pulse Shaping
Amplitude
Time

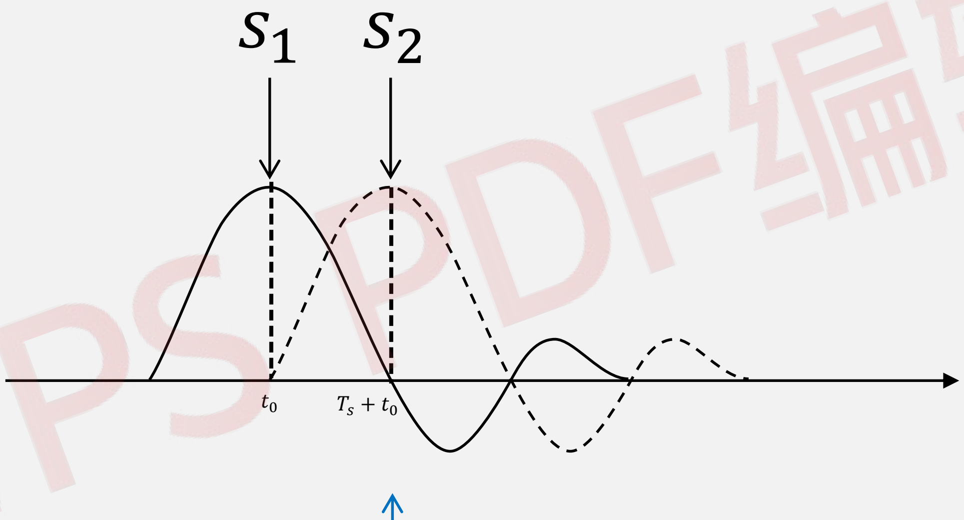

Baseband Transmission-Simple.vi
File Edit View Project Operate Tools Window Help
Baseband Transmission
Bit
0 0 0 1 0 1 1 1 0 0
Symbol
1 1 1 -1 1 -1 -1 -1 1 1
Recovered Bits
0 0 0 1 0 1 1 1 0 0
Pulse Shaping Function
Sinc
Sinc Samples
65
UpSample Factor
1 20 40 60 80 100
stop
STOP
Baseband
Amplitude
Time
Pulse Shaping
Amplitude
Time


Baseband Transmission
Bit
0
0 0 0 1 0 1 1 1 0 0
Symbol
0
1 1 1 -1 1 -1 -1 -1 1 1
Pulse Shaping Function
Sinc
Upsampled Symbol
0
1
Baseband
Amplitude
Time
Pulse Shaping
Amplitude
Time

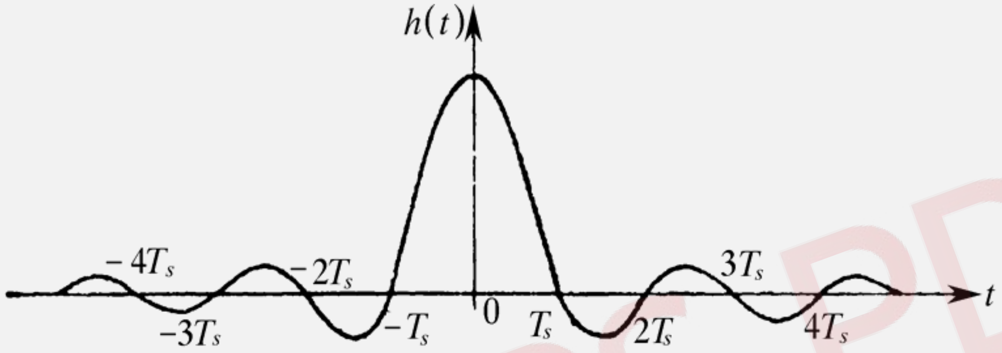
Inter-Symbol Interference (ISI)



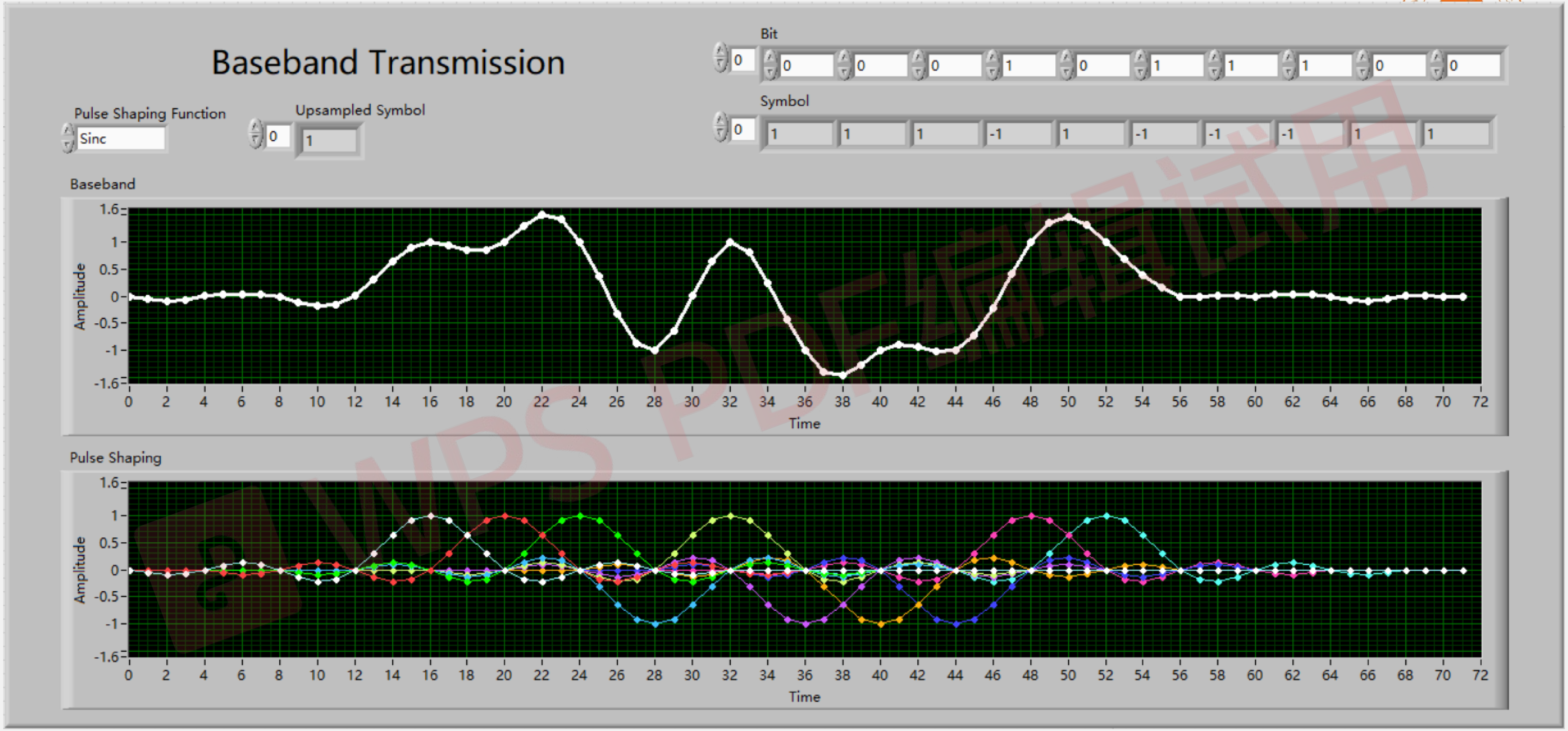
Inter-Symbol Interference (ISI)



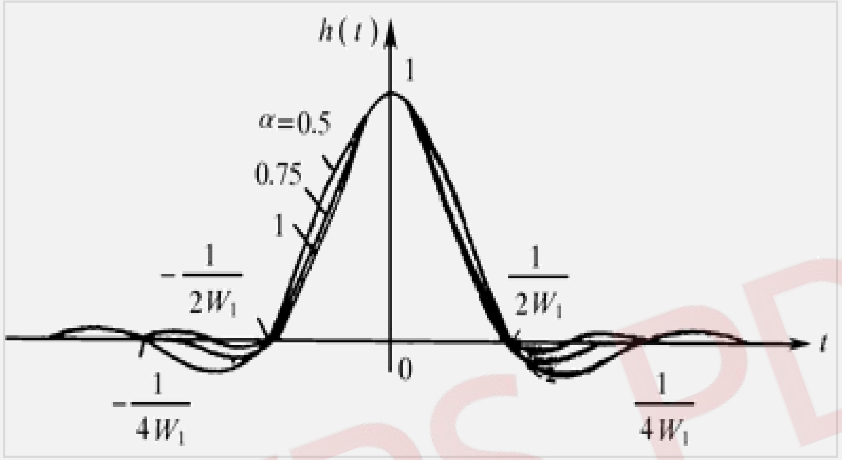
Send the S_2 waveform at $T_s + t_0$.

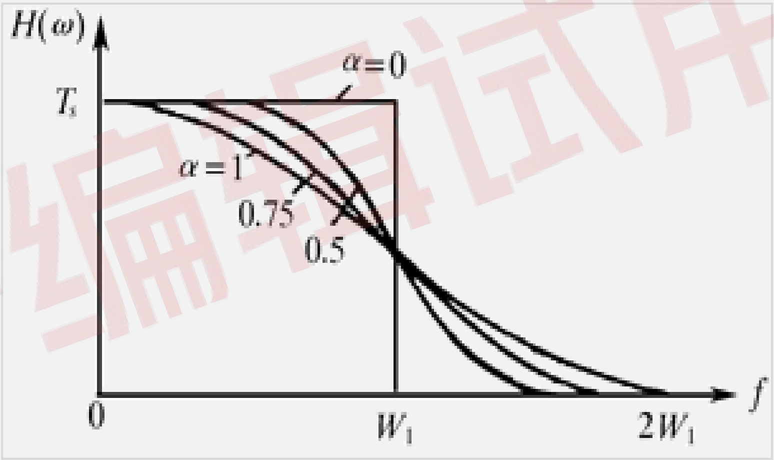


$$h(t)=\frac{\sin\frac{\pi}{T_S}t}{\frac{\pi}{T_S}t}$$


Baseband Transmission
Bit
0
0 0 0 1 0 1 1 1 0 0
Symbol
0
1 1 1 -1 1 -1 -1 -1 1 1
Pulse Shaping Function
Sinc
Upsampled Symbol
0
1
Baseband
Amplitude
Time
Pulse Shaping
Amplitude
Time

Raised-cosine function



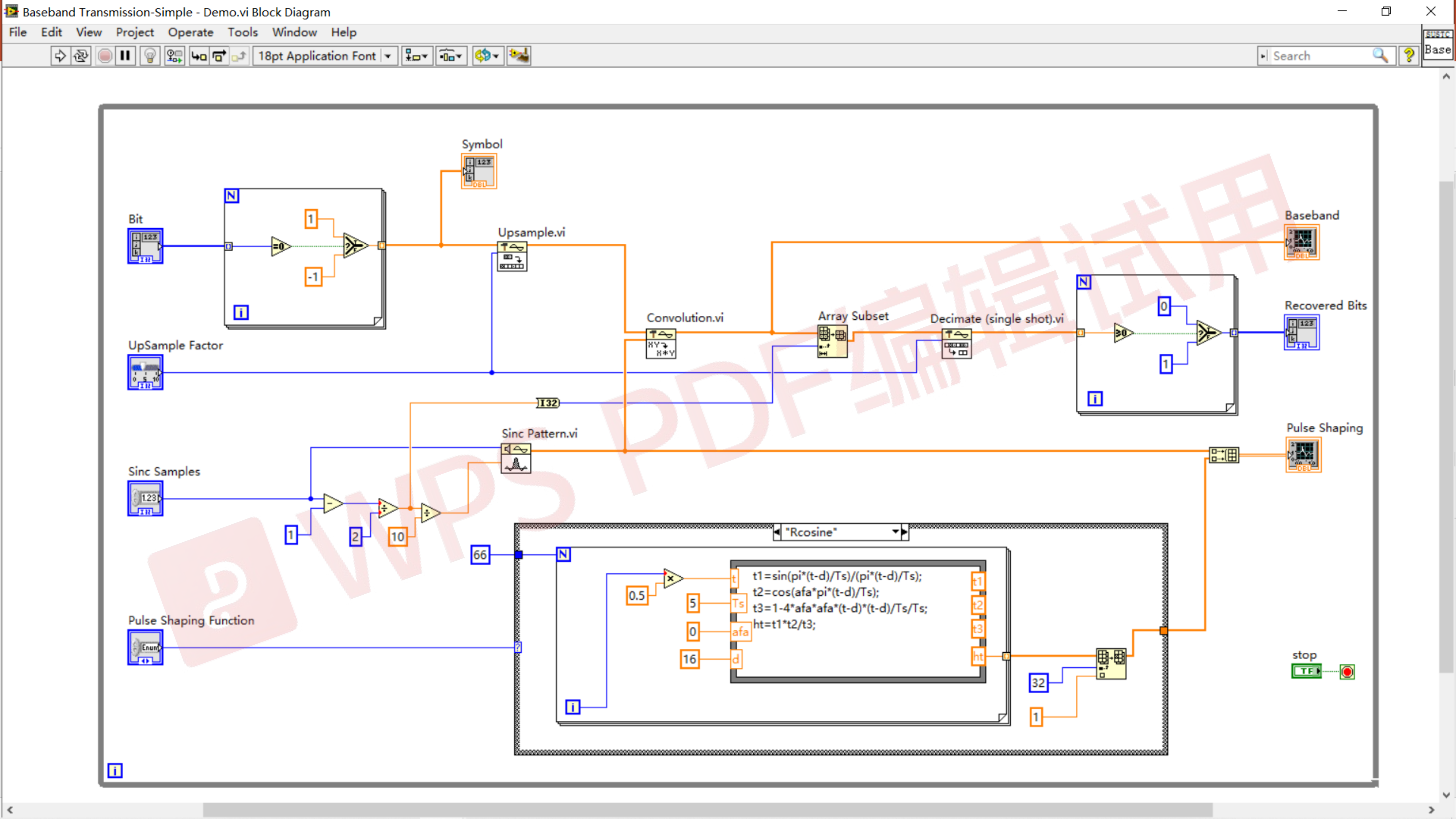


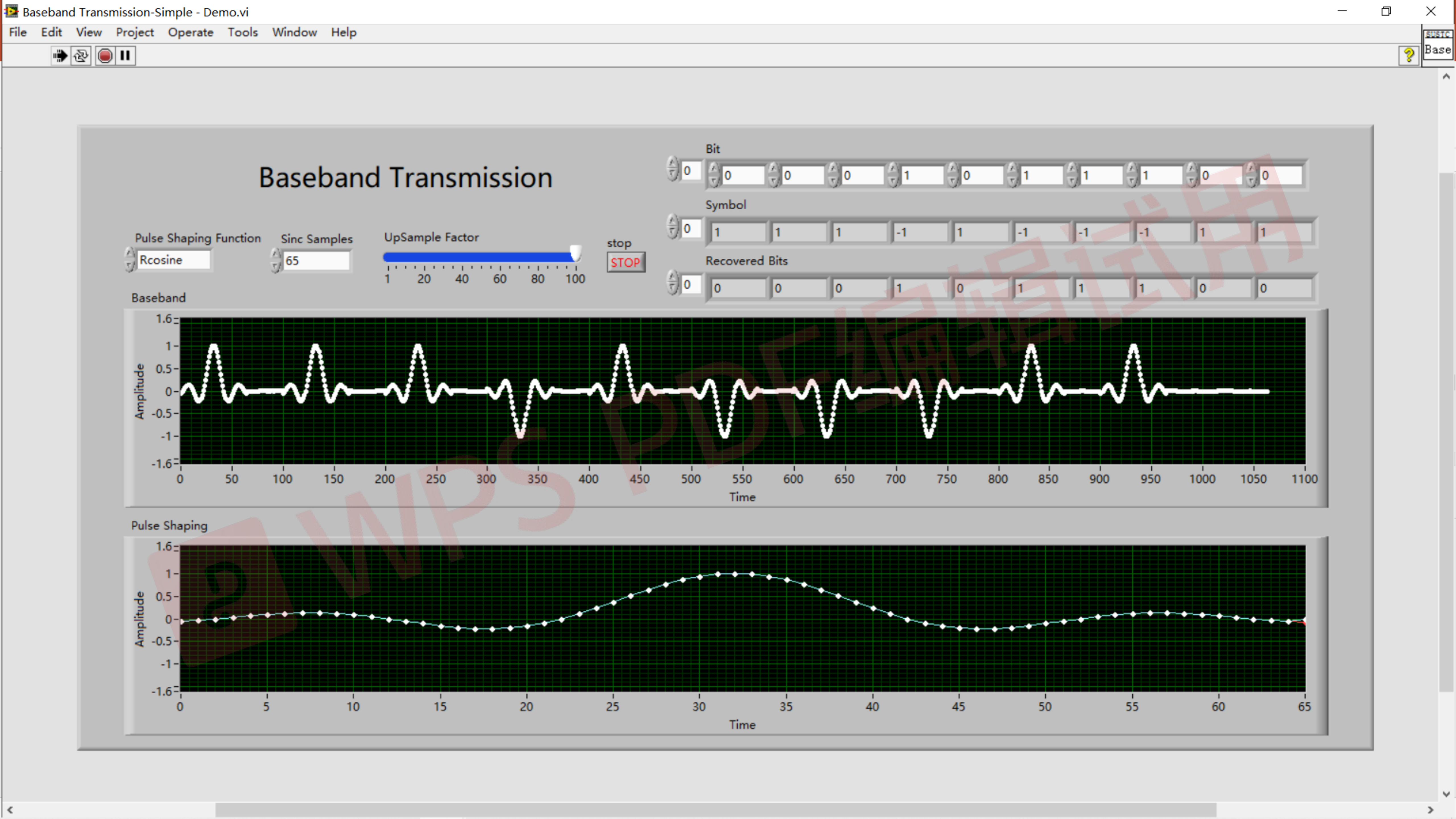
$$h(t)=\frac{\sin\frac{\pi}{T_S}t}{\frac{\pi}{T_S}t}$$

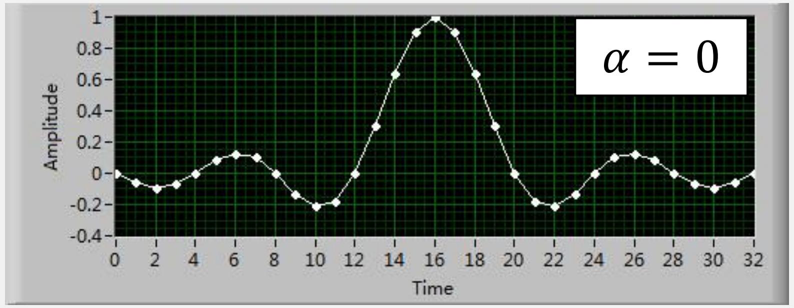
$$\boxed{h(t)=\frac{\sin \pi t/T_S}{\pi t/T_S}\cdot\frac{\cos\alpha\pi t/T_S}{1-4\alpha^2t^2/T_S^2}}$$

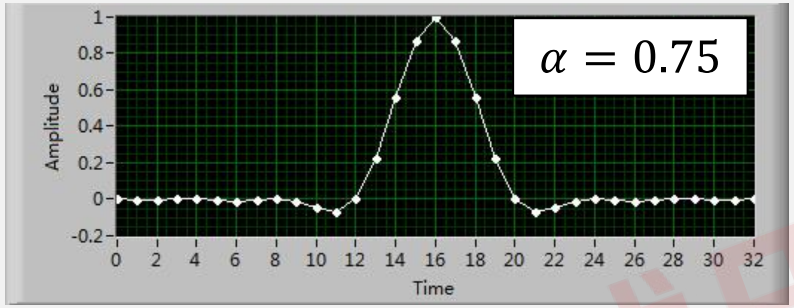
$$H(\omega)=\begin{cases} T_S, & 0\le|\omega|<\dfrac{(1-\alpha)\pi}{T_S} \\ \dfrac{T_S}{2}[1+\sin\dfrac{T_S}{2\alpha}(\dfrac{\pi}{T_S}-\omega)], & \dfrac{(1-\alpha)\pi}{T_S}\le|\omega|<\dfrac{(1+\alpha)\pi}{T_S} \\ 0, & |\omega|\ge\dfrac{(1+\alpha)\pi}{T_S} \end{cases}$$

Demo: Baseband Transmission


Baseband Transmission-Simple - Demo.vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
Symbol
Bit
Upsample.vi
Convolution.vi
Array Subset
Decimate (single shot).vi
Baseband
Recovered Bits
UpSample Factor
I32
Sinc Pattern.vi
Pulse Shaping
Sinc Samples
"Rcosine"
66
0.5
5
0
16
2
10
1
-1
32
t1=sin(pi*(t-d)/Ts)/(pi*(t-d)/Ts);
t2=cos(afa*pi*(t-d)/Ts);
t3=1-4*afa*afa*(t-d)*(t-d)/Ts/Ts;
ht=t1*t2/t3;
t
Ts
afa
d
t1
t2
t3
ht
Pulse Shaping Function
stop

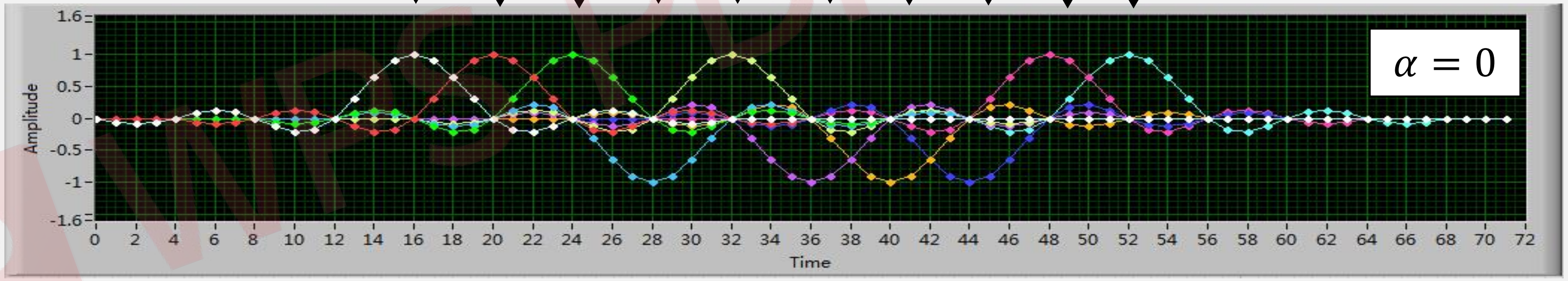

Baseband Transmission-Simple - Demo.vi
File Edit View Project Operate Tools Window Help
Baseband Transmission
Bit
0 0 0 0 1 0 1 1 1 0 0
Symbol
0 1 1 1 -1 1 -1 -1 -1 1 1
Recovered Bits
0 0 0 0 1 0 1 1 1 0 0
Pulse Shaping Function
Rcosine
Sinc Samples
65
UpSample Factor
1 20 40 60 80 100
stop
STOP
Baseband
Amplitude
Time
Pulse Shaping
Amplitude
Time

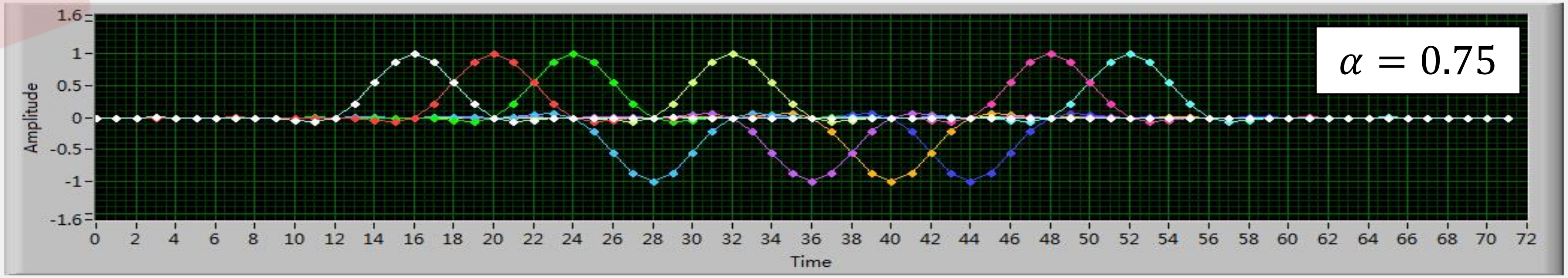


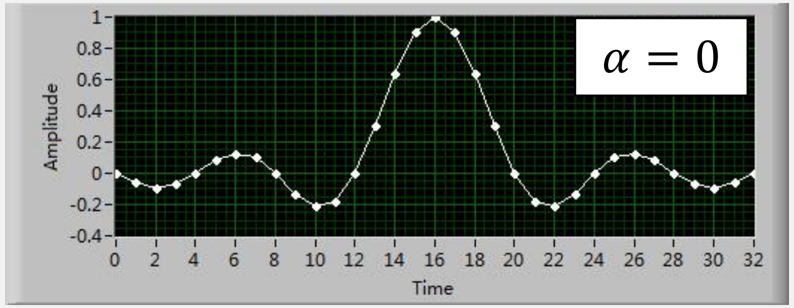


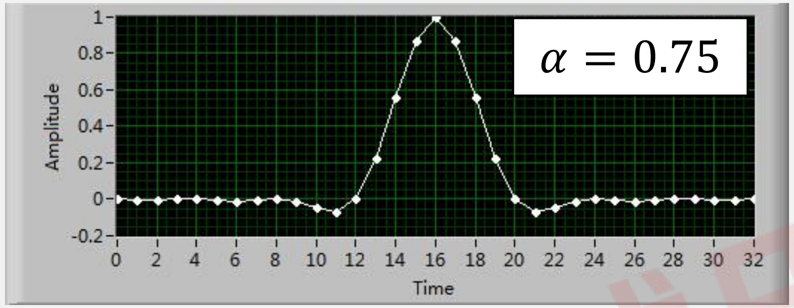
Bits Stream

0	0	0	1	0	1	1	1	0	0
1	1	1	−1	1	−1	−1	−1	1	1



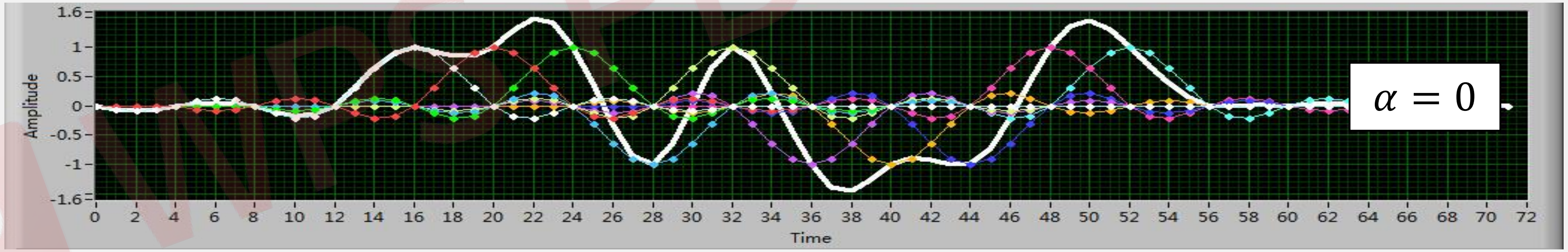


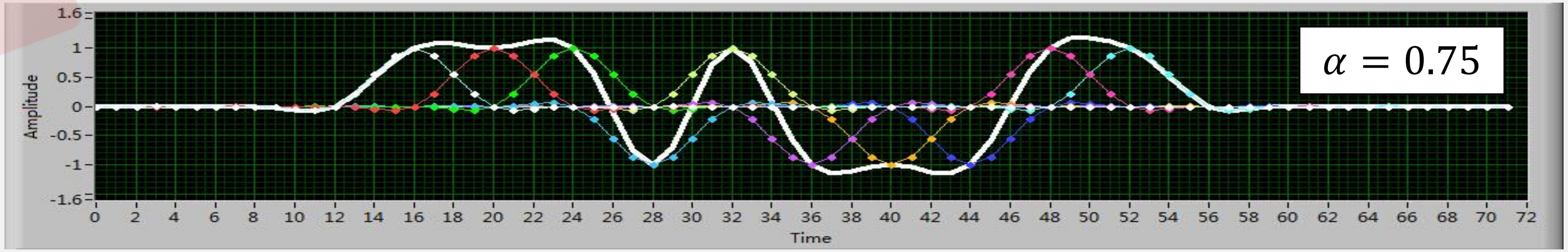




Bits Stream

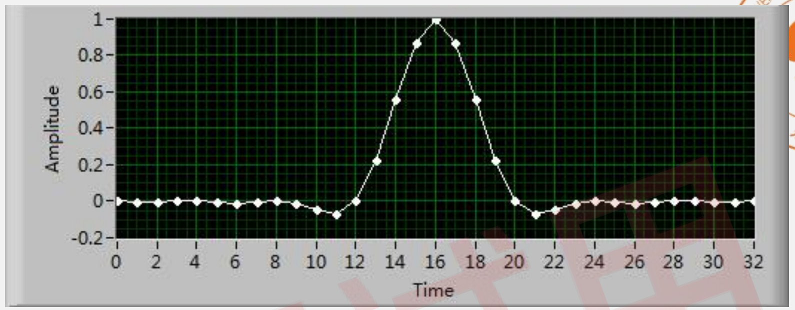
0	0	0	1	0	1	1	1	0	0
1	1	1	−1	1	−1	−1	−1	1	1

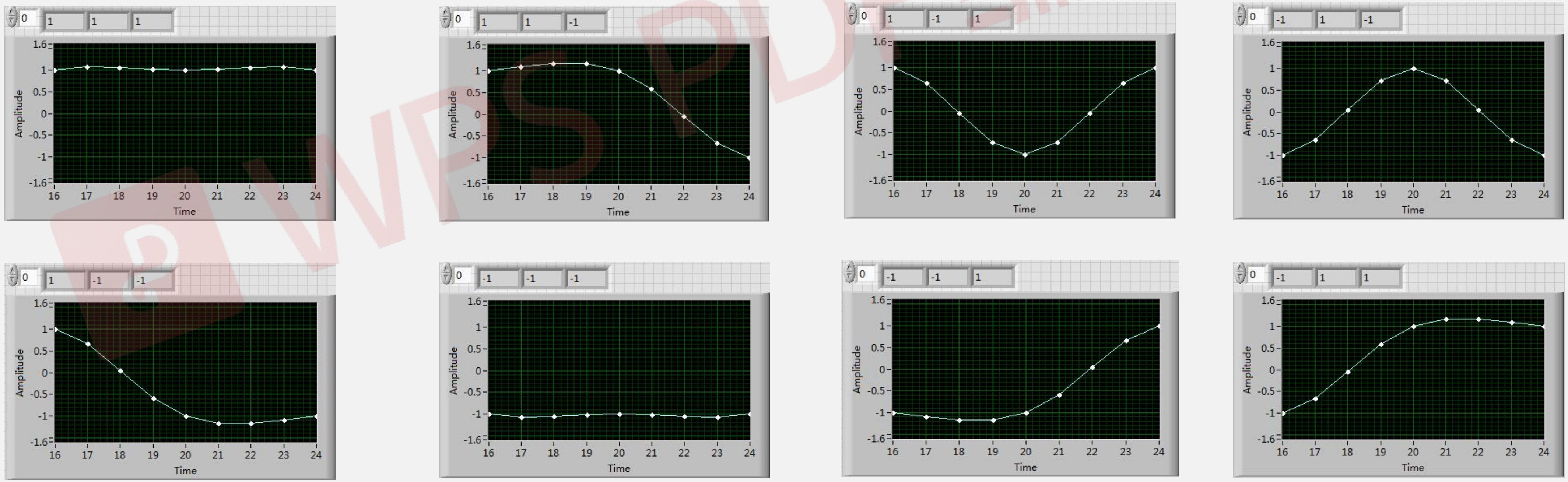


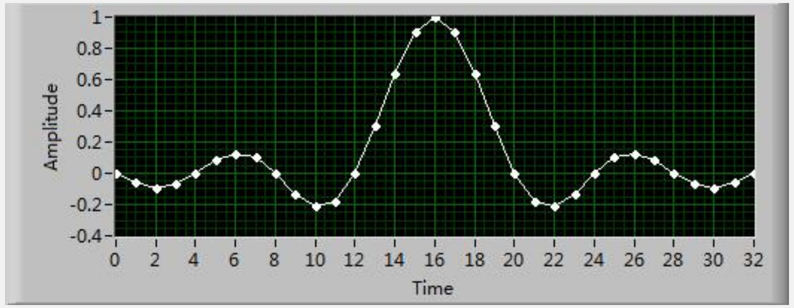


Demo: Eye Diagram

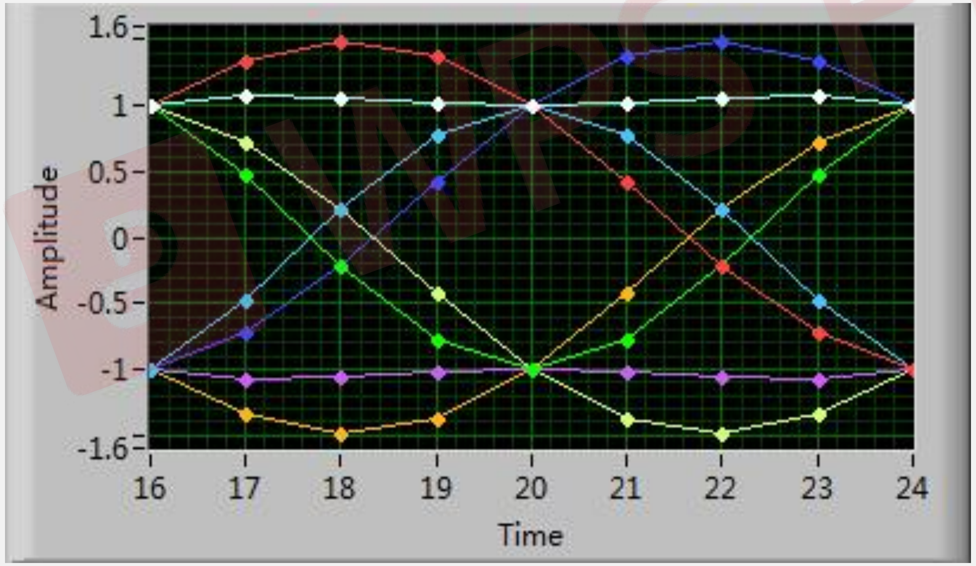
0	0	0	1	0	1	1	1	0	0
1	1	1	−1	1	−1	−1	−1	1	1

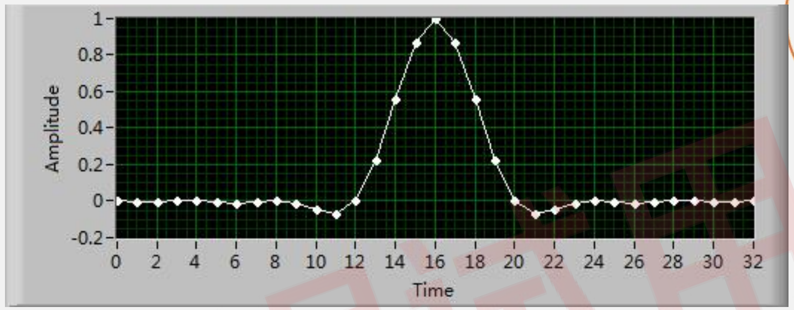




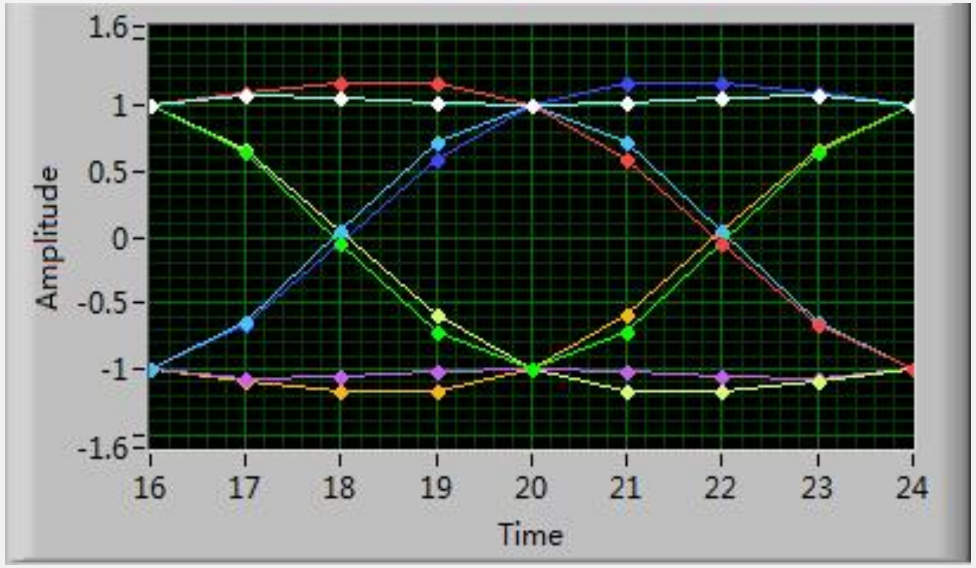


$\alpha = 0$

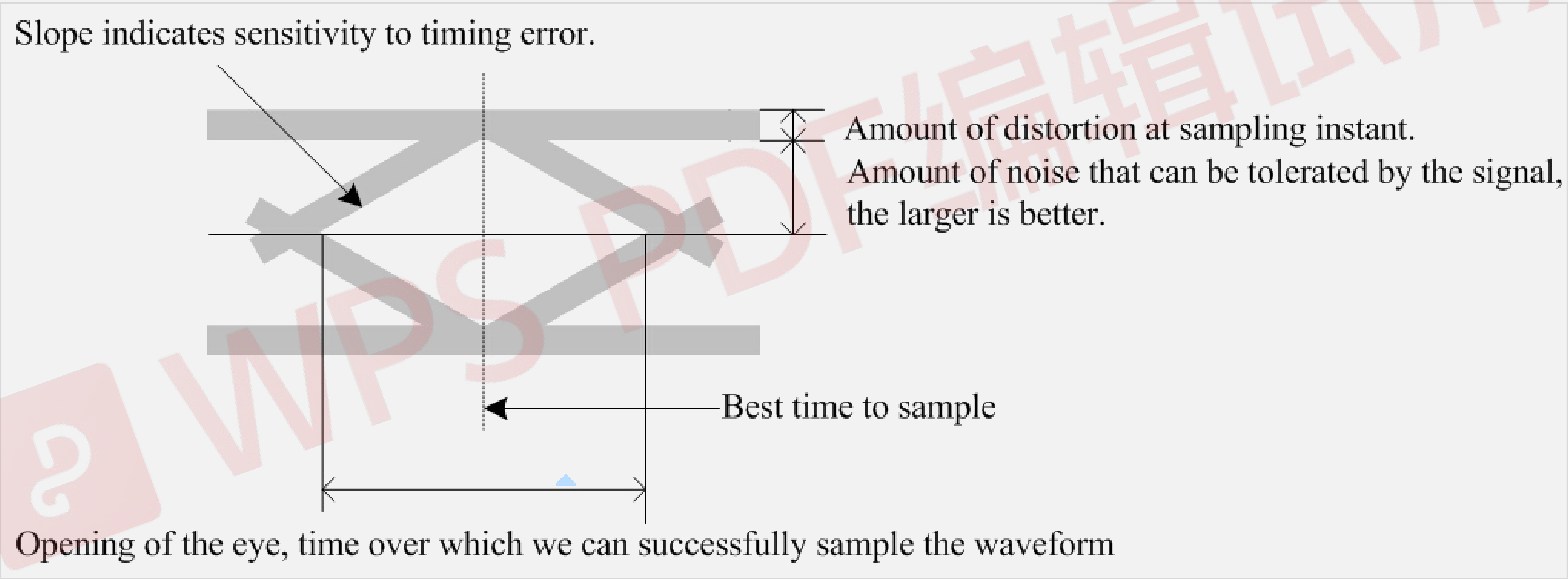




$\alpha = 0.75$



Eye Diagram


Slope indicates sensitivity to timing error.
Amount of distortion at sampling instant.
Amount of noise that can be tolerated by the signal, the larger is better.
Best time to sample
Opening of the eye, time over which we can successfully sample the waveform

- **Question ?**