无线通信实验在线开放课程

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广东省教学质量工程建设项目

Lab 4: Frequency Modulation

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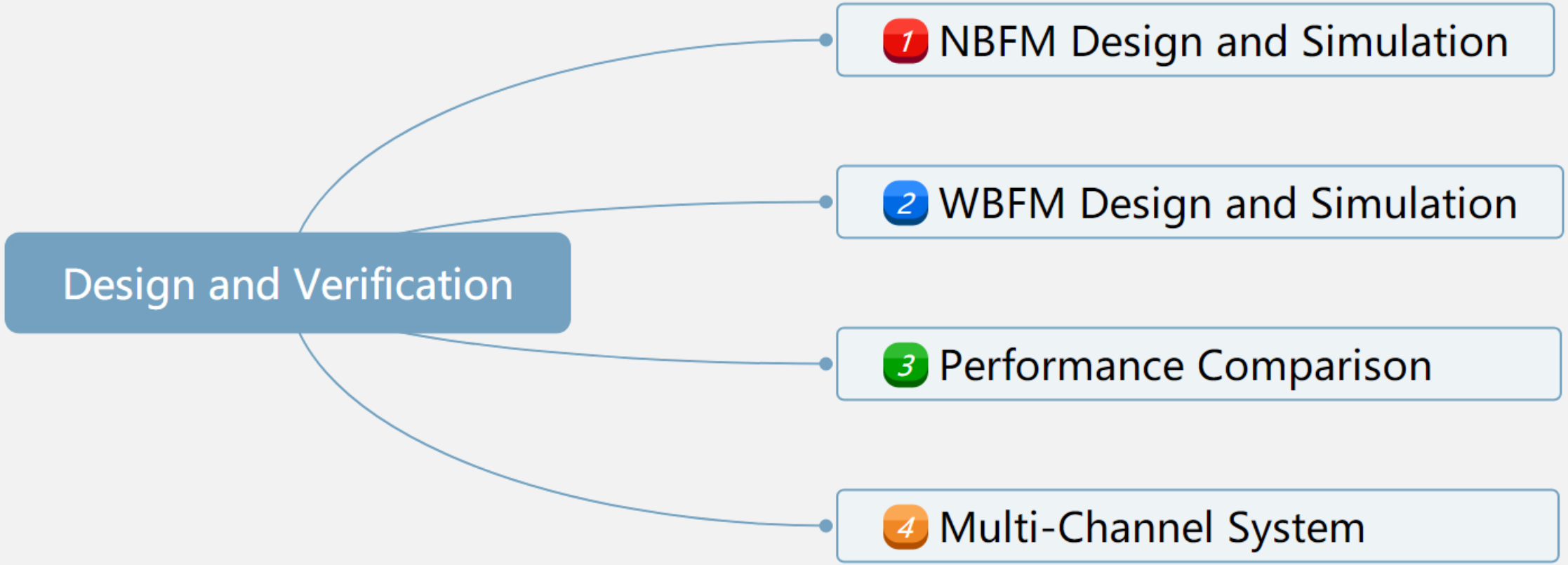
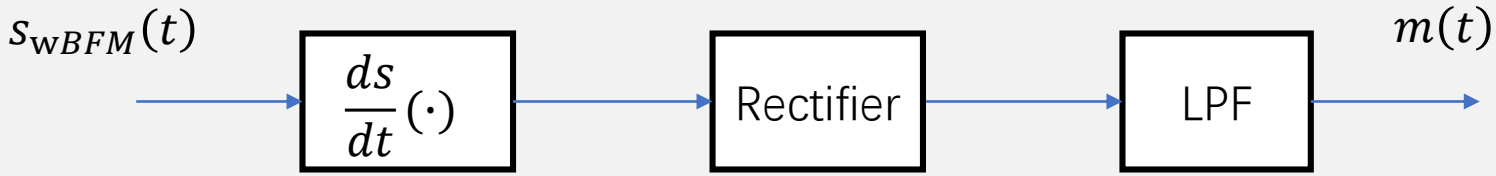
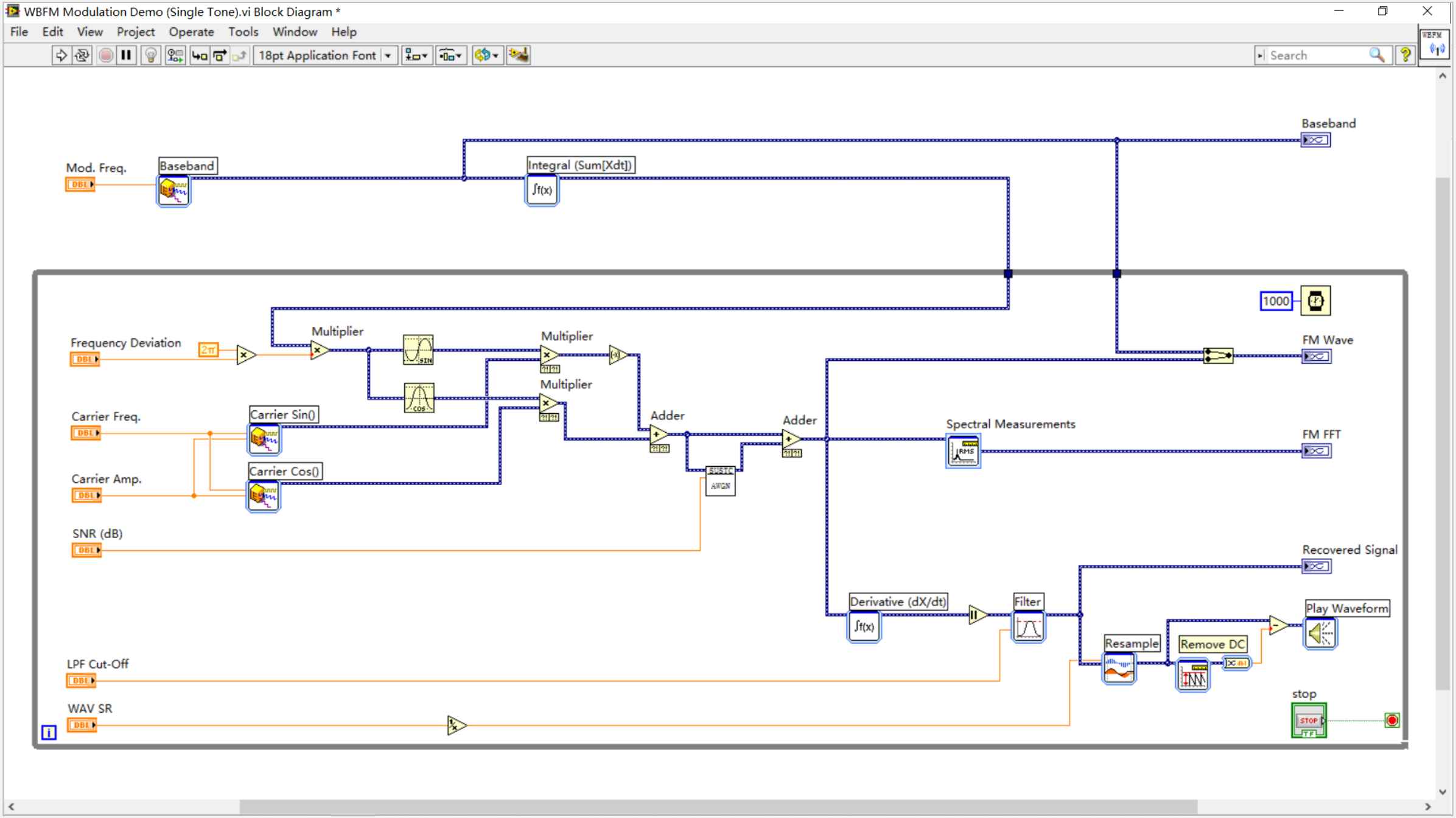

Design and Verification
1 NBFM Design and Simulation
2 WBFM Design and Simulation
3 Performance Comparison
4 Multi-Channel System

Demo: WBFM Simulation

Pre-Lab: WBFM Mathematical Model

Demodulator




WBFM Modulation Demo (Single Tone).vi Block Diagram *
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
Mod. Freq.
Baseband
Integral (Sum[Xdt])
Baseband
1000
Frequency Deviation
2π
Multiplier
Multiplier
Multiplier
FM Wave
Carrier Freq.
Carrier Sin()
Adder
Adder
Spectral Measurements
FM FFT
Carrier Amp.
Carrier Cos()
SNR (dB)
Recovered Signal
Derivative (dX/dt)
Filter
Play Waveform
Resample
Remove DC
LPF Cut-Off
WAV SR
stop

Frequency Modulation

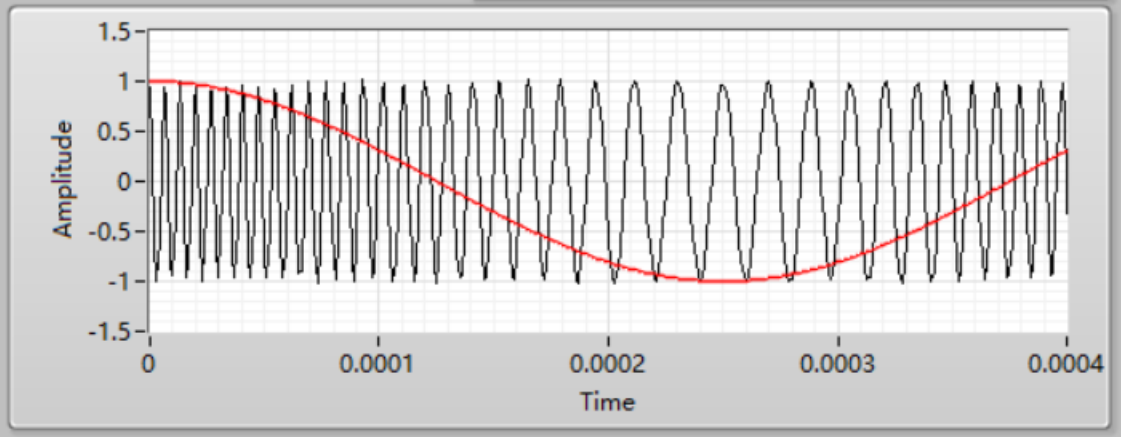
Carrier Amp. 1
Carrier Freq. 100000
WAV SR 44100
Mod. Freq. 2000
LPF Cut-Off 3000

AWGN (dB) 30
-20 -10 0 10 20 30 40 50 60 70 80 90 100

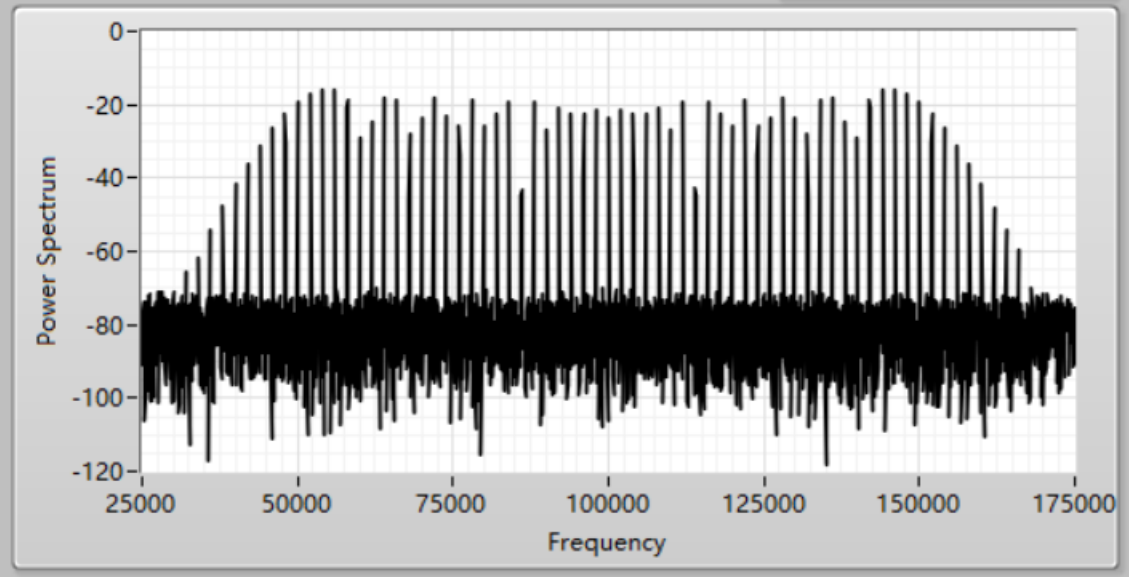
Frequency Deviation 50000
4000 20000 30000 40000 50000 60000 75000

stop
STOP

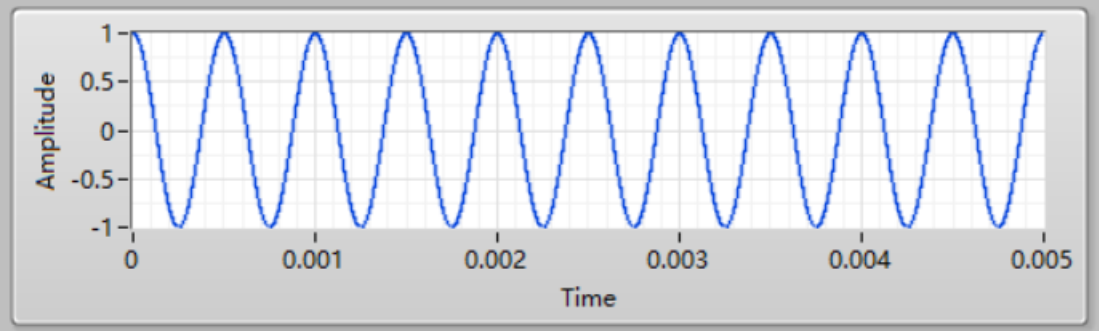
FM Wave
Baseband Signal
Modulated Signal



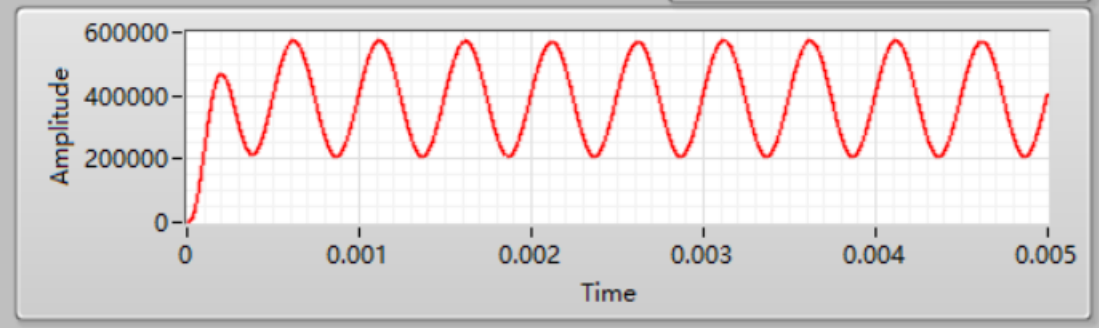
FM FFT
Sine (FFT - (RMS))

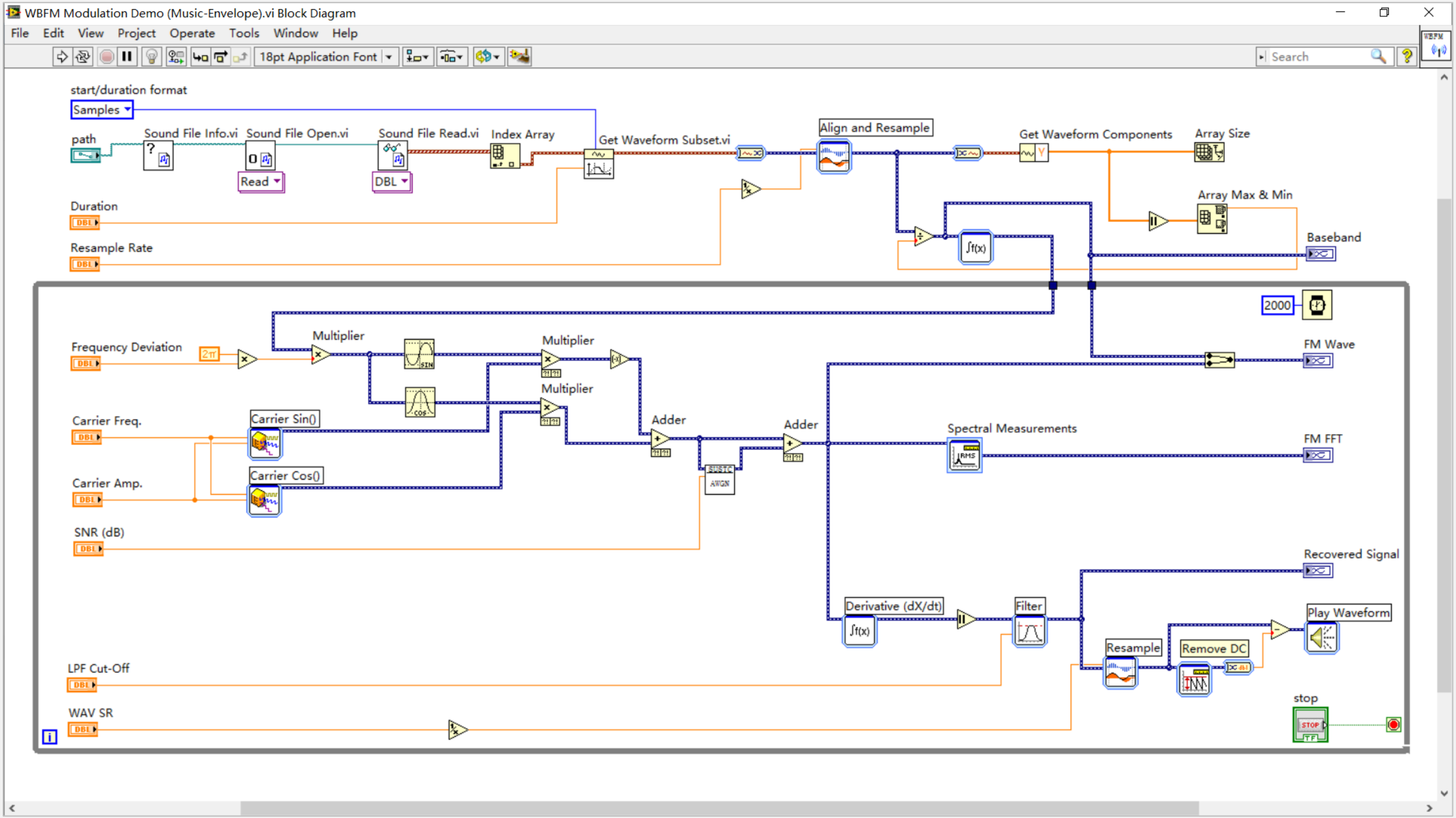


Baseband



Recovered Signal
Sine (Filtered)




WBFM Modulation Demo (Music-Envelope).vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
start/duration format
Samples
path
Sound File Info.vi
Sound File Open.vi
Read
Sound File Read.vi
DBL
Index Array
Get Waveform Subset.vi
Align and Resample
Get Waveform Components
Array Size
Array Max & Min
Baseband
Duration
Resample Rate
2000
Frequency Deviation
2π
Multiplier
Multiplier
Multiplier
SIN
COS
FM Wave
Carrier Freq.
Carrier Sin()
Carrier Cos()
Carrier Amp.
Adder
Adder
SNR (dB)
MUSIC
AWGN
Spectral Measurements
RMS
FM FFT
Recovered Signal
Derivative (dX/dt)
∫f(x)
Filter
Play Waveform
Resample
Remove DC
LPF Cut-Off
WAV SR
stop
STOP
TF

Frequency Modulation

path

D:\File\mozart.wav

Duration

44101

LPF Cut-Off

5000

Carrier Amp.

1

Carrier Freq.

100000

WAV SR

44100

Resample Rate

1000000

SNR (dB)

30

Frequency Deviation

75000

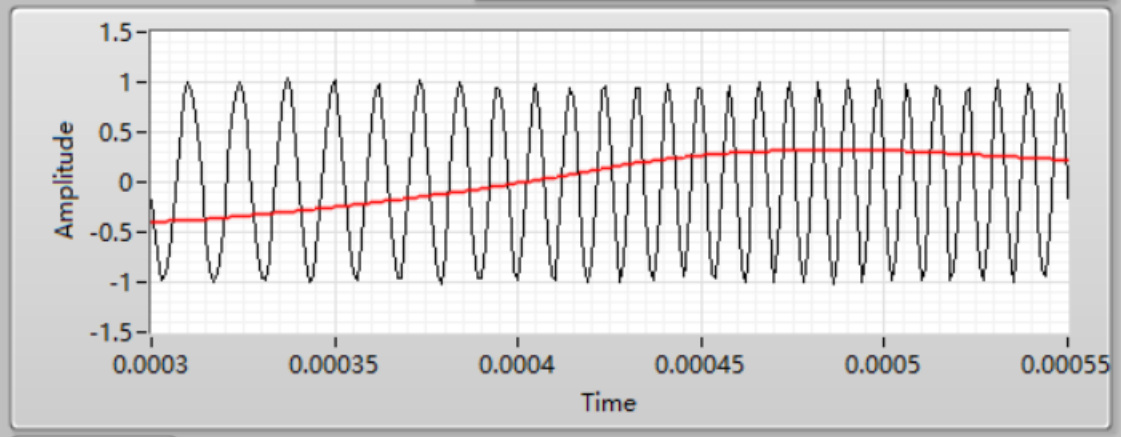
stop

STOP

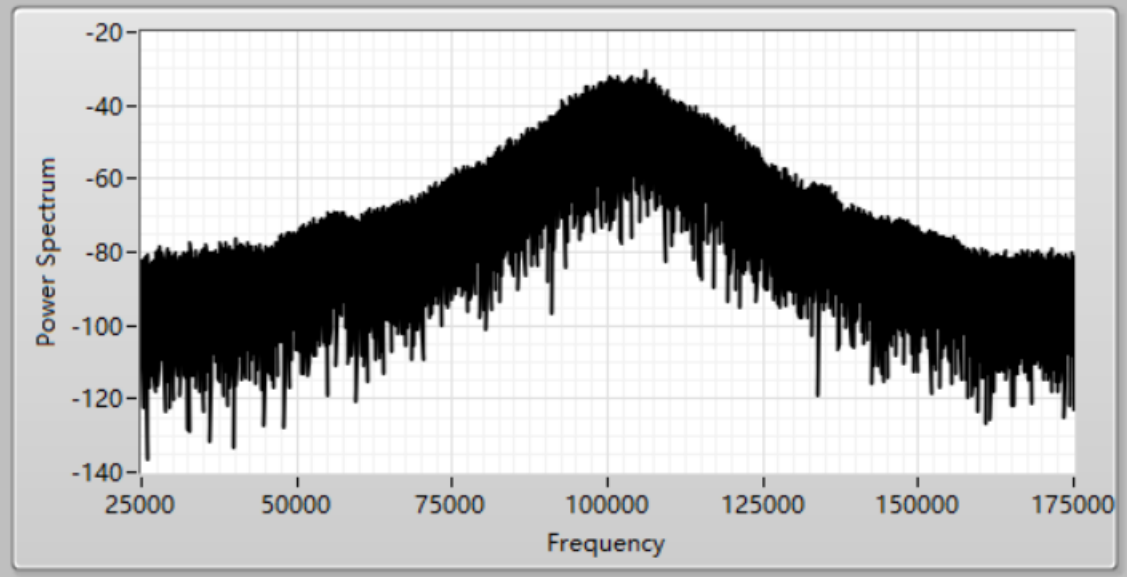
FM Wave

Baseband Siganl

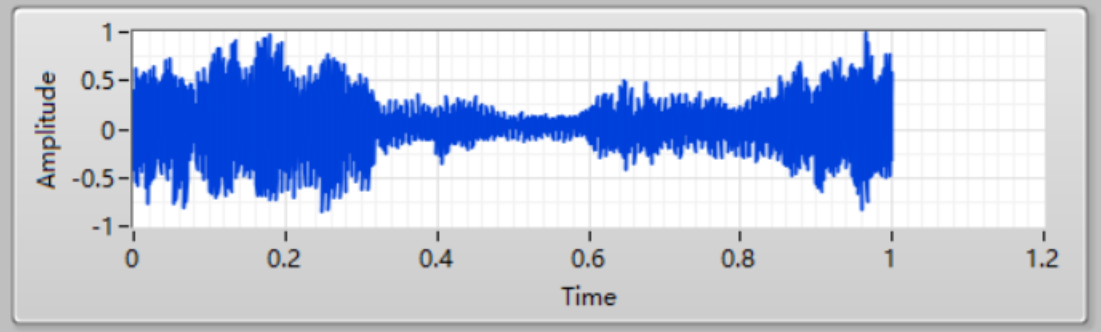
Modulated Signal



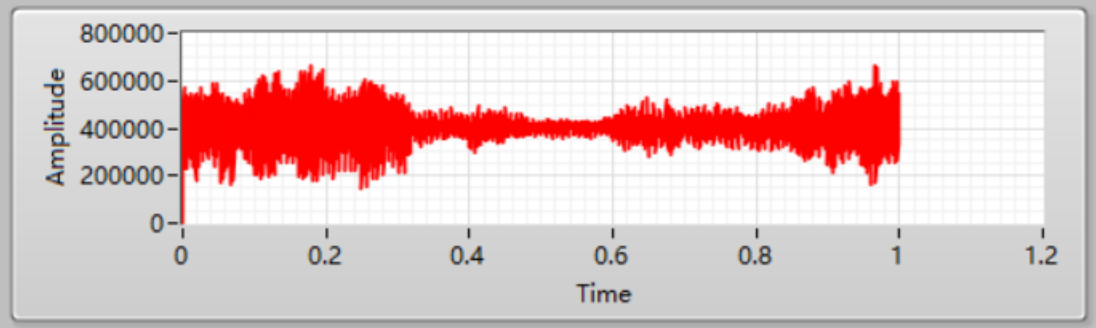
FM FFT



Baseband



Recovered Signal



Analysis: The Bandwidth of WBFM

$$B_{\mathrm{FM}} \simeq 2\Delta f + 2f_m = 2\Delta f\left(1 + \frac{1}{\beta}\right)$$

Carson's rule

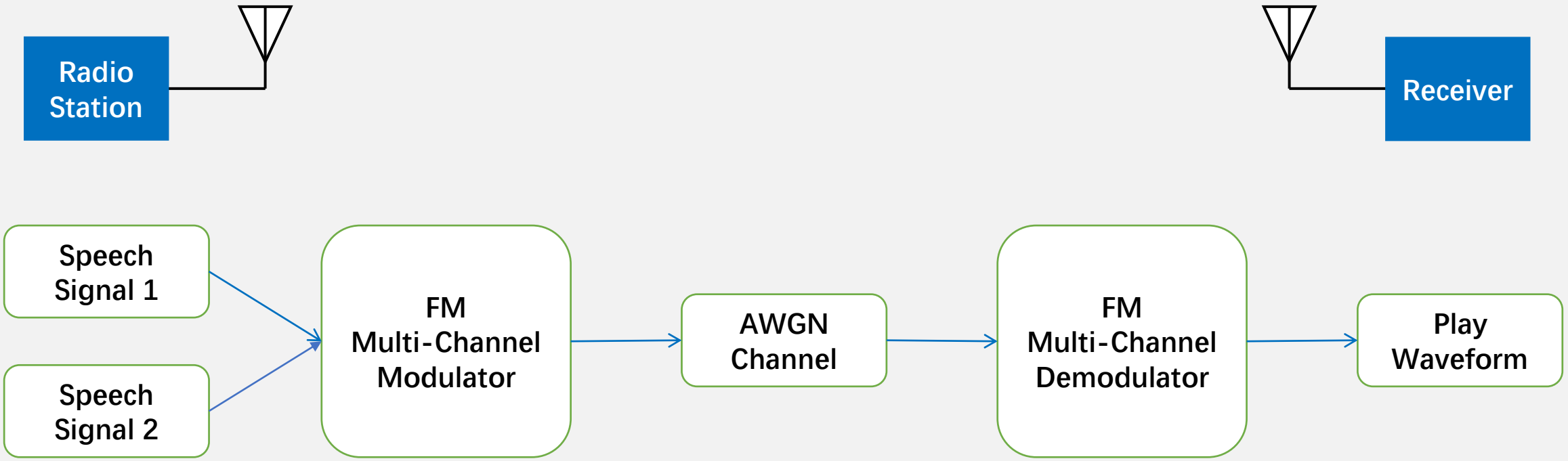
$$S_{\mathrm{FM}}(f) = \frac{A_c}{2}\sum_{n=-\infty}^{\infty} J_n(\beta)\left[\delta(f - f_c - nf_m) + \delta(f + f_c + nf_m)\right]$$

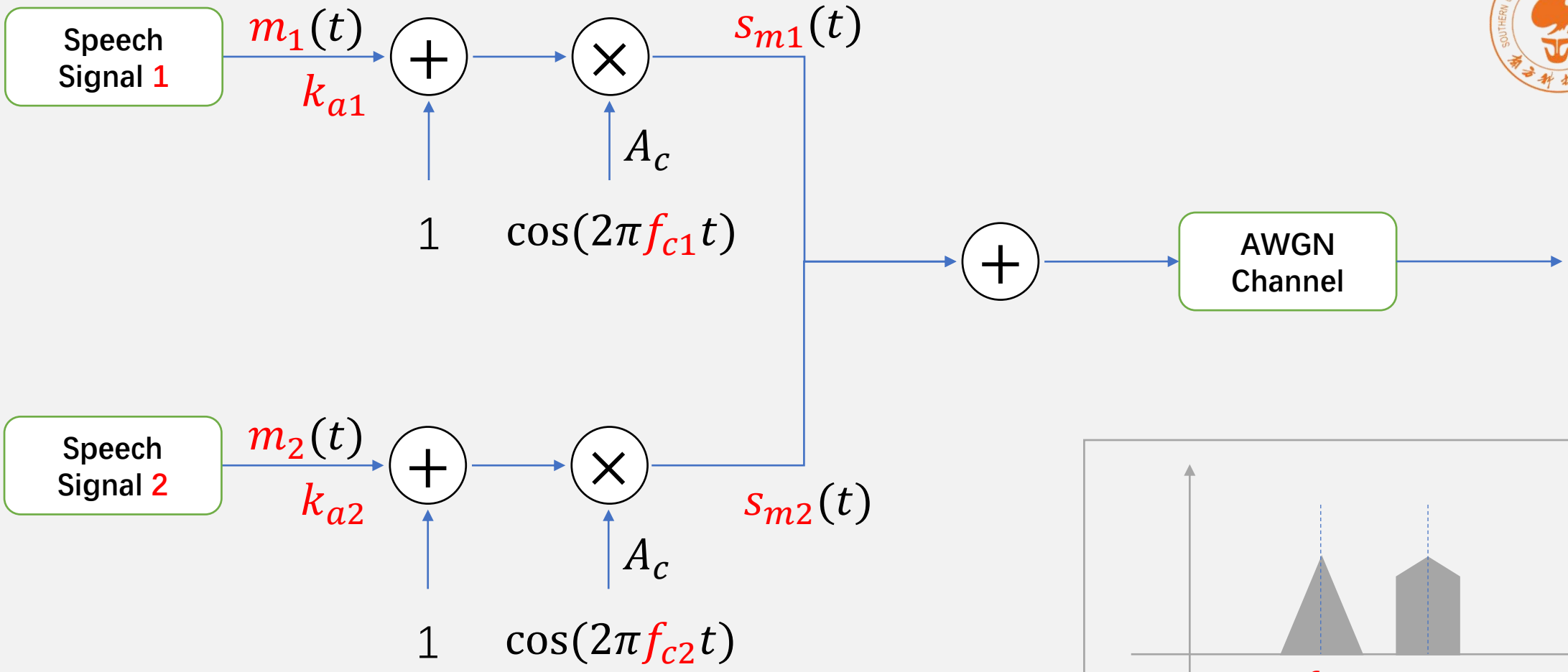
Demo: Comparison and Analysis

Modulation Type	SNR
WBFM	
NBFM	
AM	
DSB	

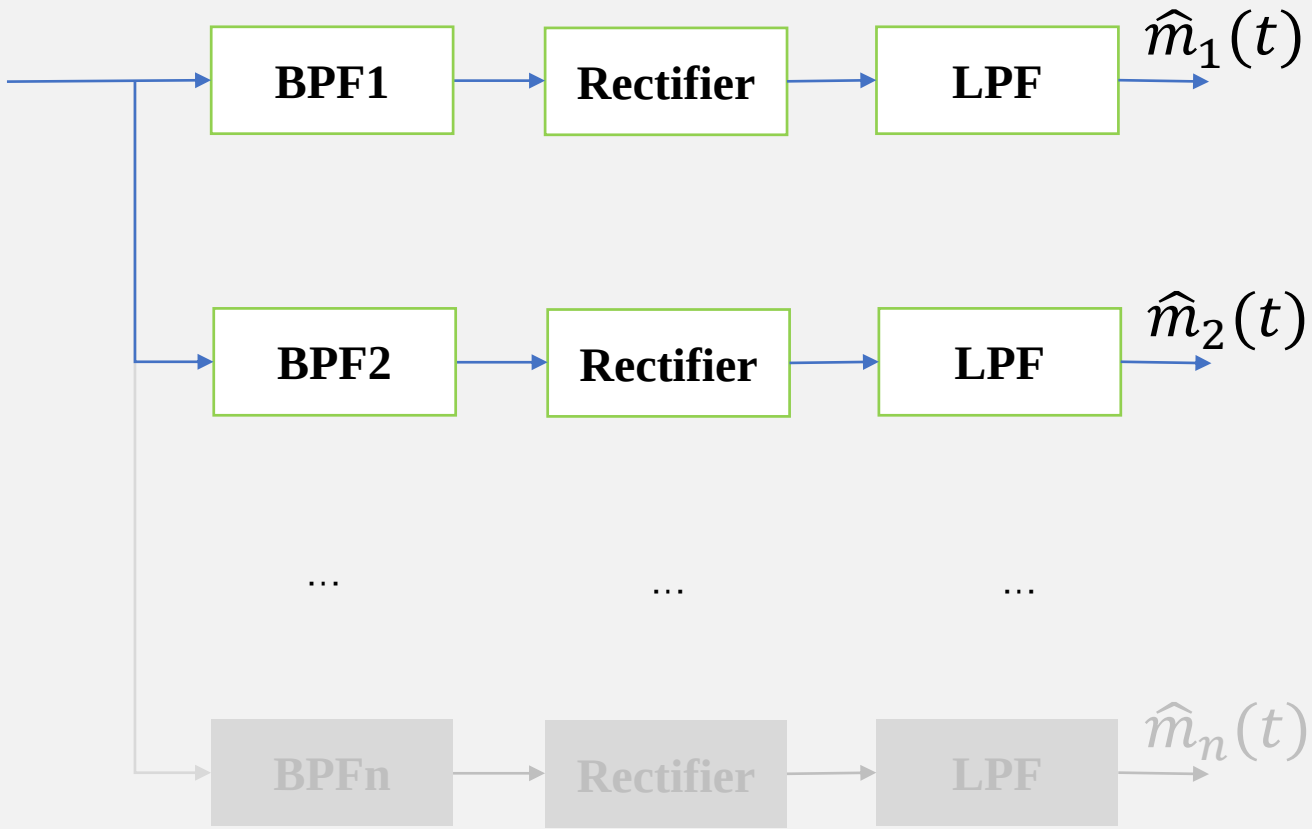
Demo: Multi-Channel System

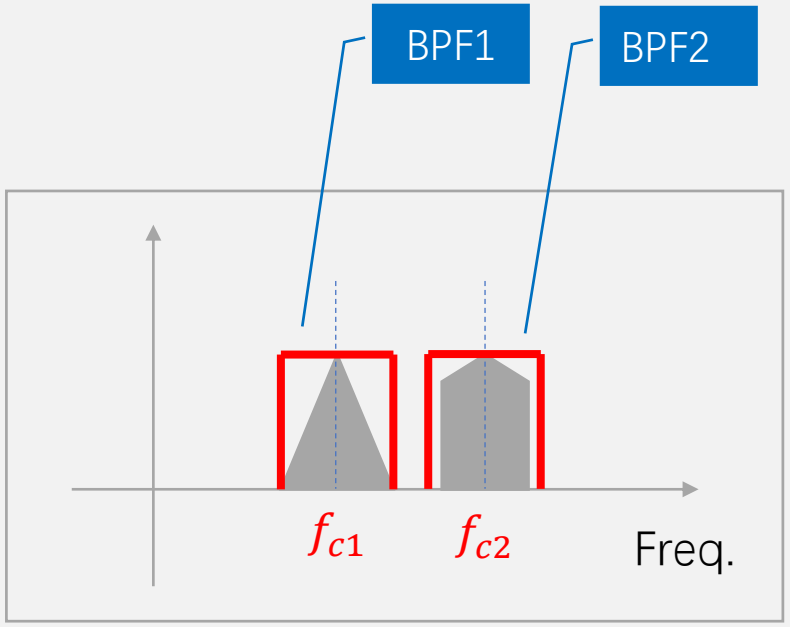
Multi-Channel System





$$s_m(t) = A_c\big(1 + k_{a1}m_1(t)\big)\cos(2\pi f_{c1}t) + A_c\big(1 + k_{a2}m_2(t)\big)\cos(2\pi f_{c2}t)$$


BPF1
Rectifier
LPF
$\hat{m}_1(t)$
BPF2
Rectifier
LPF
$\hat{m}_2(t)$
...
...
...
BPFn
Rectifier
LPF
$\hat{m}_n(t)$


BPF1
BPF2
f_{c1}
f_{c2}
Freq.

- Question ?

【通信新说】