

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





$$s_m(t) = A_c(k_a m(t)) \mathbf{cos}(2\pi f_c t)$$

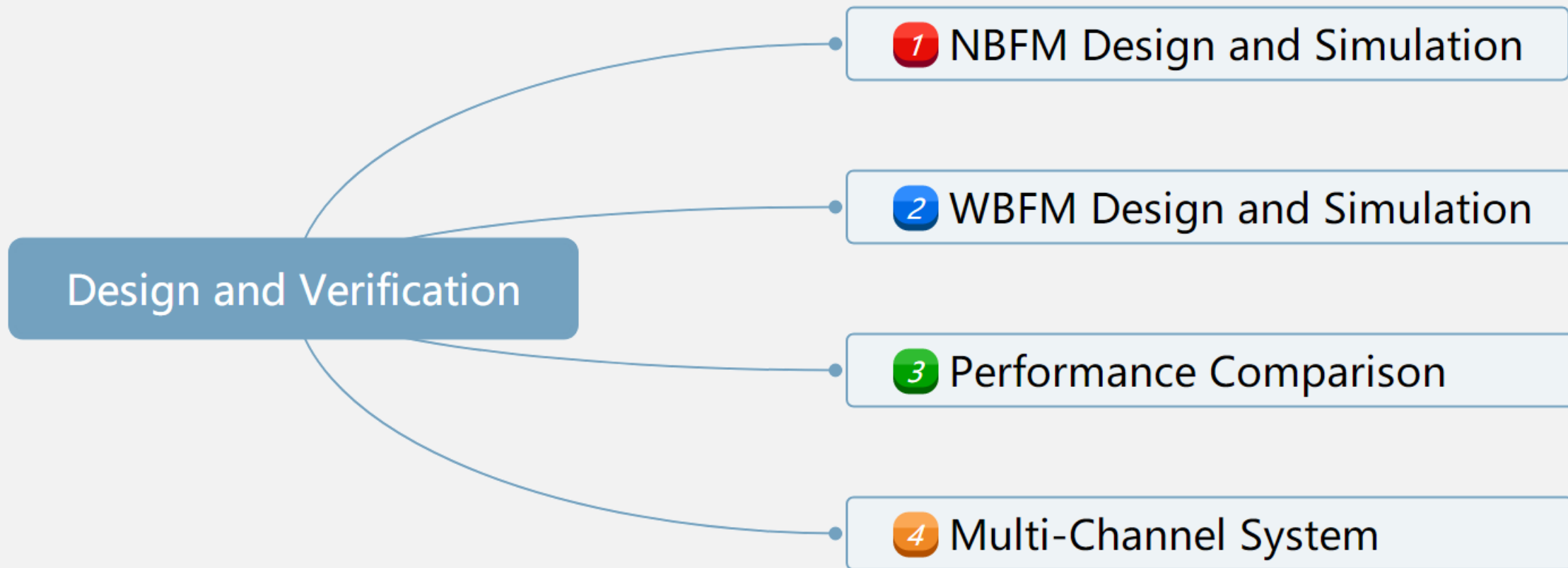
$$s_m(t) = A_c \mathbf{cos}[2\pi f_c t + 2\pi k_f \int m(t) dt]$$
A blue curved arrow originates from a blue dot placed on the $m(t)$ term in the first equation and points towards the integral $\int m(t) dt$ in the second equation, indicating a relationship or transformation between the two expressions.



Lab 4: Frequency Modulation

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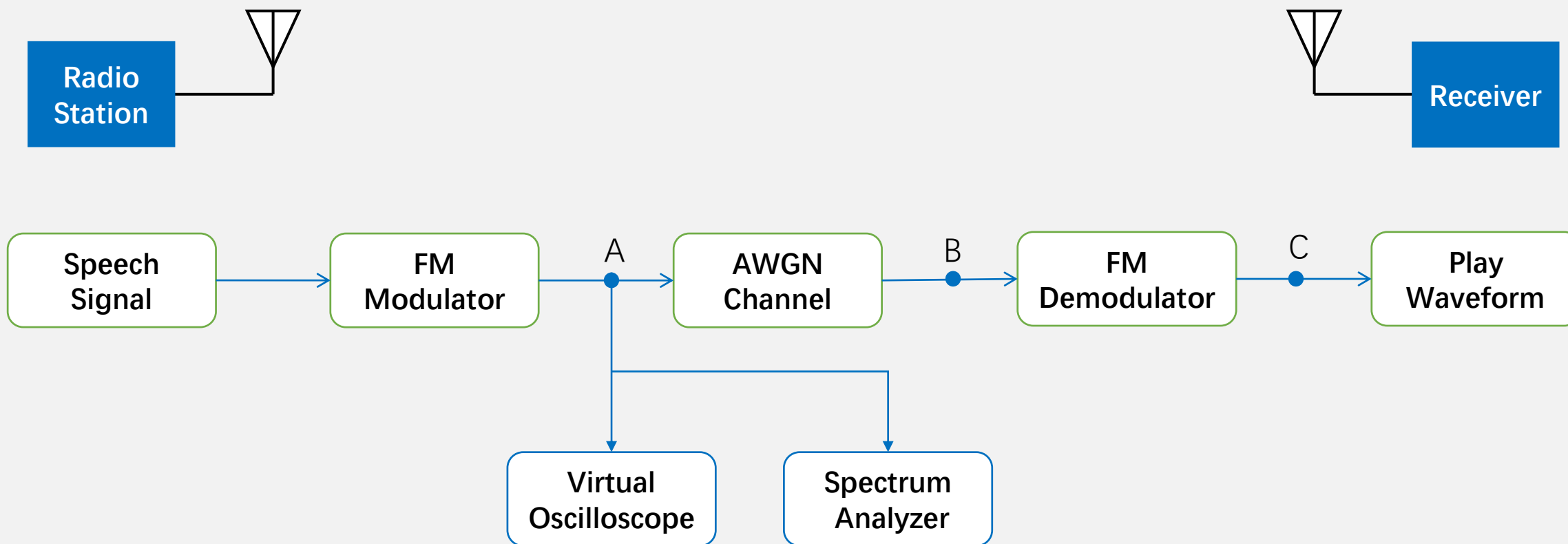
- 1、FM调制系统——抗噪声性能强
- 2、是否可以通过增加传输带宽的方式，换取性能



Demo: NBFM Simulation (Single Tone)



Simulation Model of FM System





$$\cos(\alpha + \beta) = \cos \alpha \cos \beta - \sin \alpha \sin \beta$$



$$s_{\text{FM}}(t) = A_c \mathbf{cos}[2\pi f_c t + 2\pi k_f \int m(t) dt]$$

$$\cos(\alpha + \beta) = \cos \alpha \cos \beta - \sin \alpha \sin \beta$$

$$s_{\text{FM}}(t) = A_c \cos \left[2\pi k_f \int m(\tau) d\tau \right] \cos(2\pi f_c t) - A_c \sin \left[2\pi k_f \int m(\tau) d\tau \right] \sin(2\pi f_c t)$$



$$f_i = 2\pi f_c + 2\pi k_f m(t)$$



$$\cos \left[2\pi k_f \int m(\tau) d\tau \right] \approx 1$$

$$\sin \left[2\pi k_f \int m(\tau) d\tau \right] \approx \left[2\pi k_f \int m(\tau) d\tau \right]$$



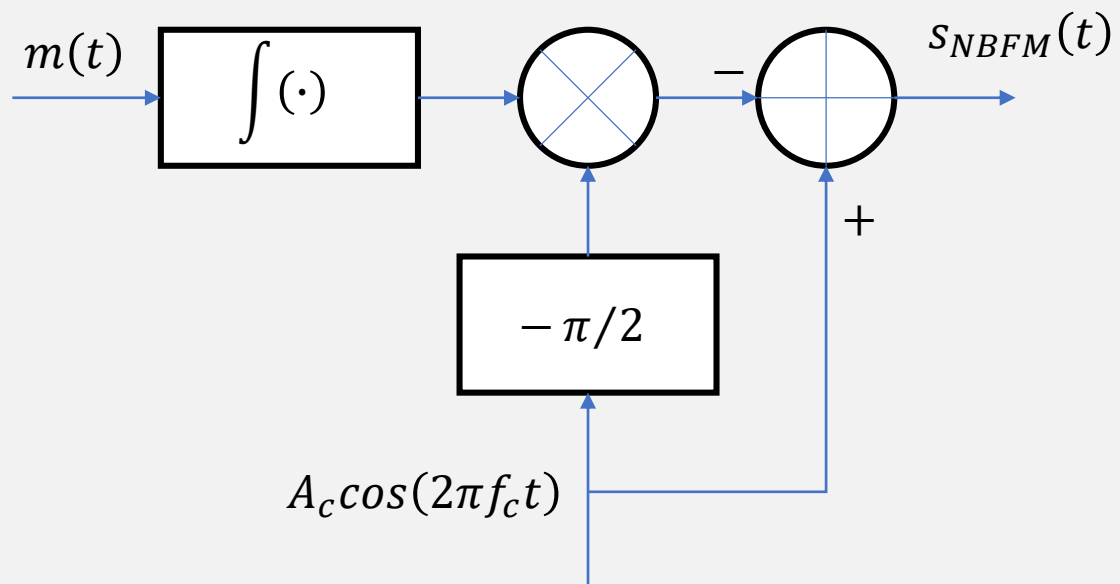
$$s_{\text{FM}}(t) = A_c \cos \left[2\pi k_f \int m(\tau) d\tau \right] \cos(2\pi f_c t) - A_c \sin \left[2\pi k_f \int m(\tau) d\tau \right] \sin(2\pi f_c t)$$

$$s_{\text{NBFM}}(t) = A_c \cos(2\pi f_c t) - A_c \left[2\pi k_f \int m(\tau) d\tau \right] \sin(2\pi f_c t)$$



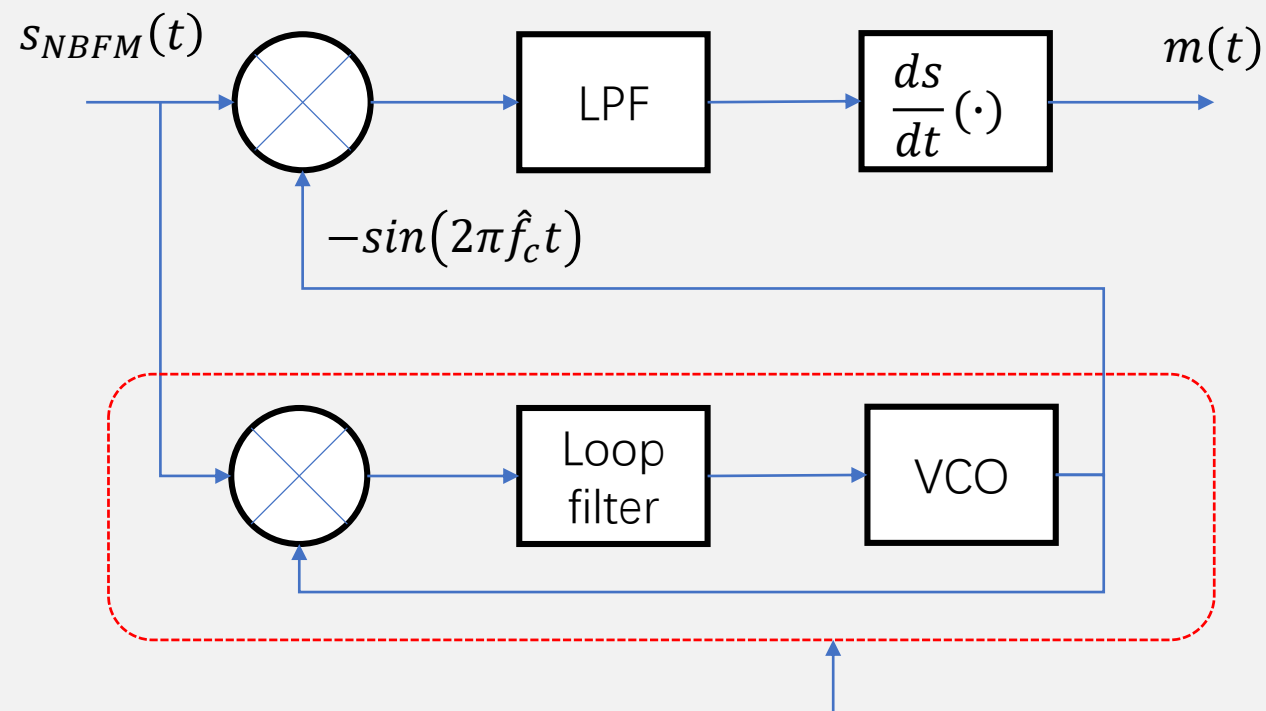
Pre-Lab: NBFM Mathematical Model

Modulator



$$s_{NBFM}(t) = A_c \cos(2\pi f_c t) - A_c \left[2\pi k_f \int m(\tau) d\tau \right] \sin(2\pi f_c t)$$

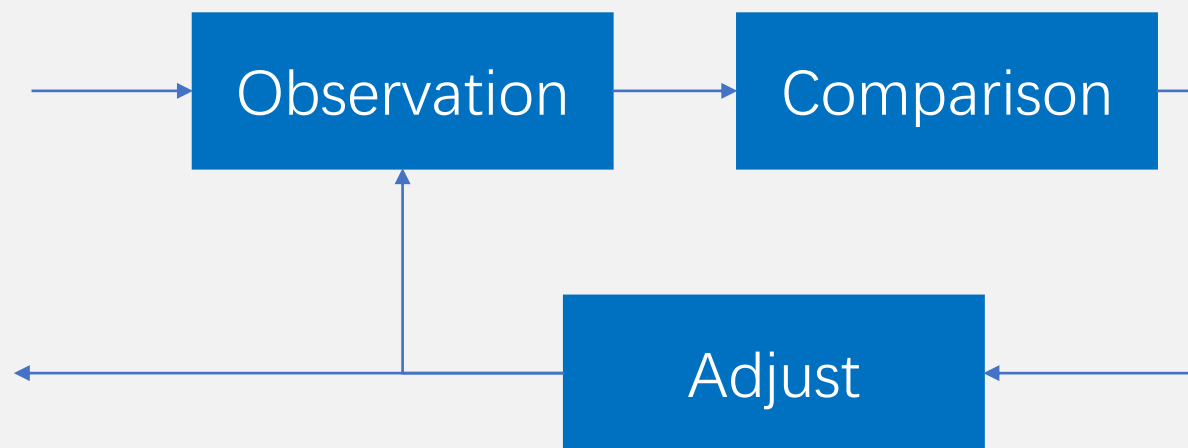
Demodulator



Phase Locked Loop (PLL)

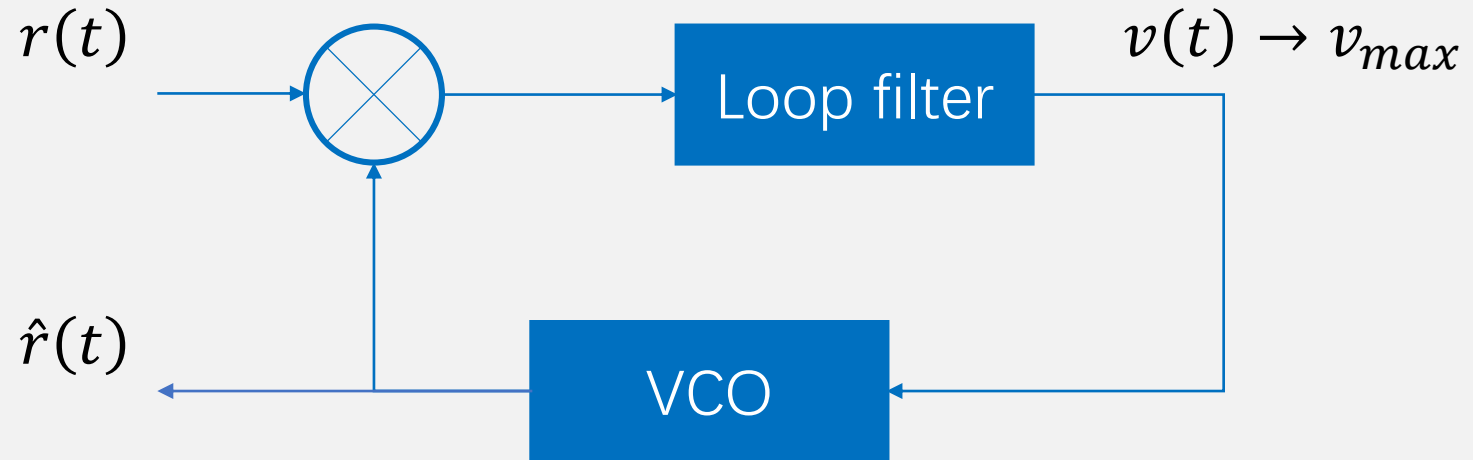


Feedback Control System

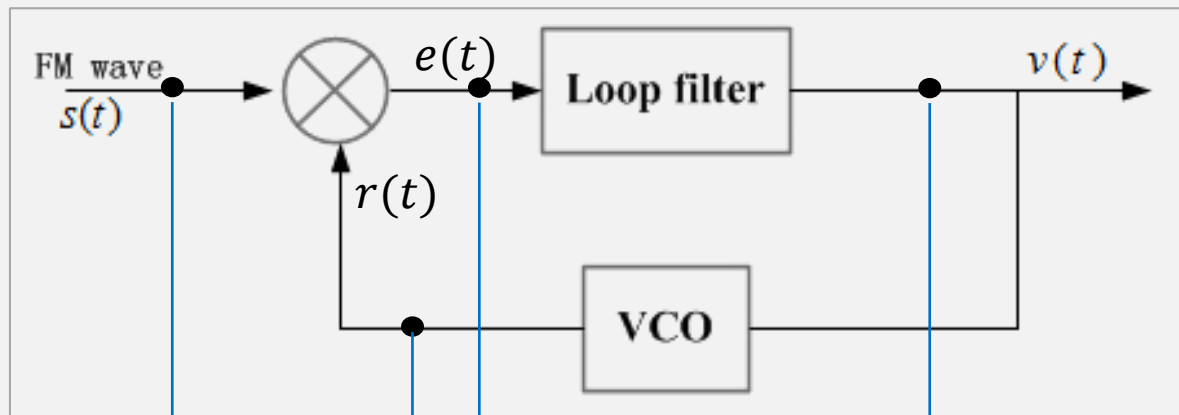




Analysis: Phase-Locked Loop



Analysis: Phase-Locked Loop

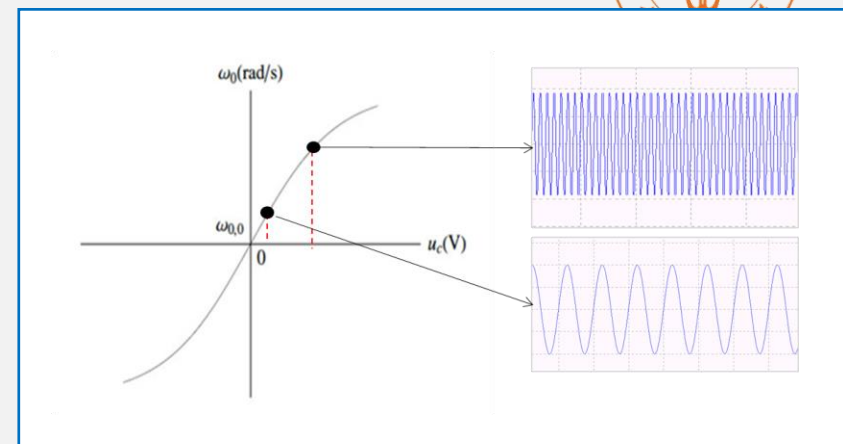


$$s(t) = \cos(2\pi f_c t + \varphi)$$

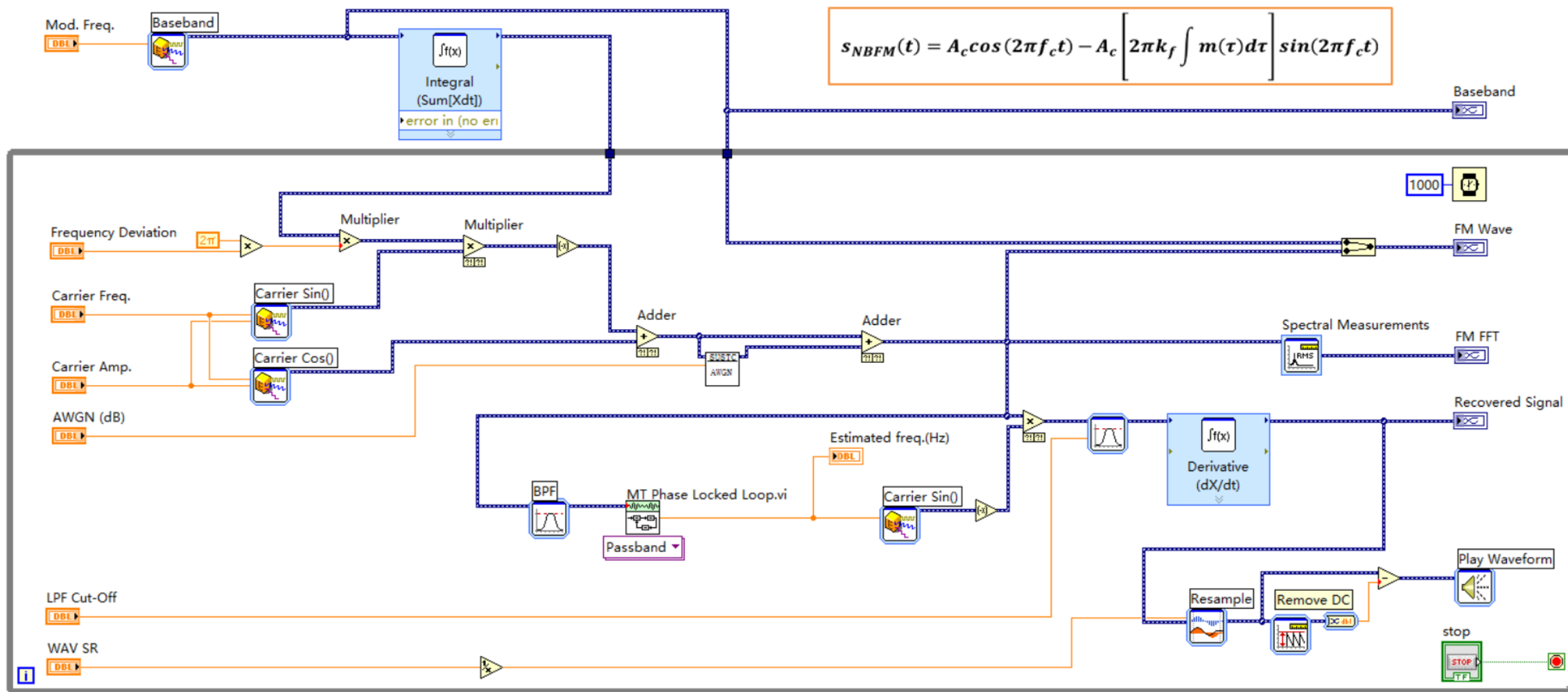
$$v(t) = \frac{1}{2} \cos[2\pi(f_c - \hat{f}_c)t + (\varphi - \hat{\varphi})]$$

$$r(t) = \cos(2\pi \hat{f}_c t + \hat{\varphi})$$

$$e(t) = \frac{1}{2} \{ \cos[2\pi(f_c - \hat{f}_c)t + (\varphi - \hat{\varphi})] + \cos[2\pi(f_c + \hat{f}_c)t + (\varphi + \hat{\varphi})] \}$$



VCO
Voltage Controlled Oscillator



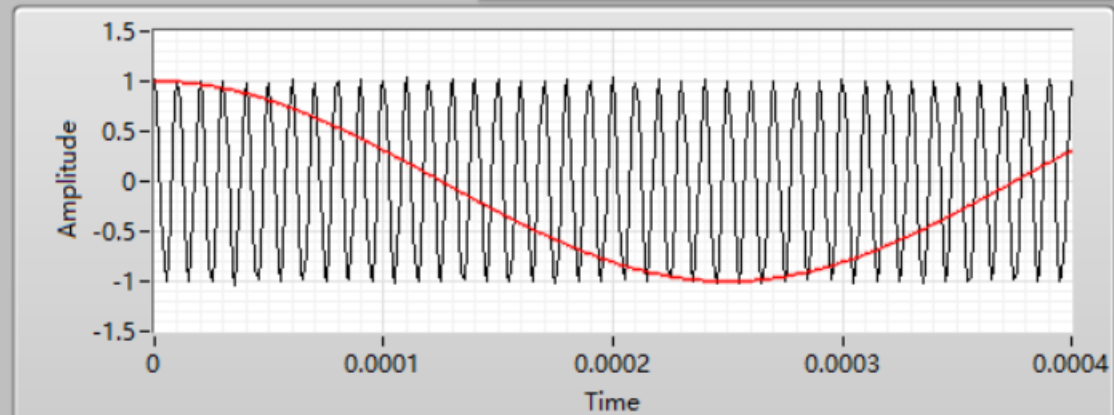
Frequency Modulation

FM Wave

Baseband Signal

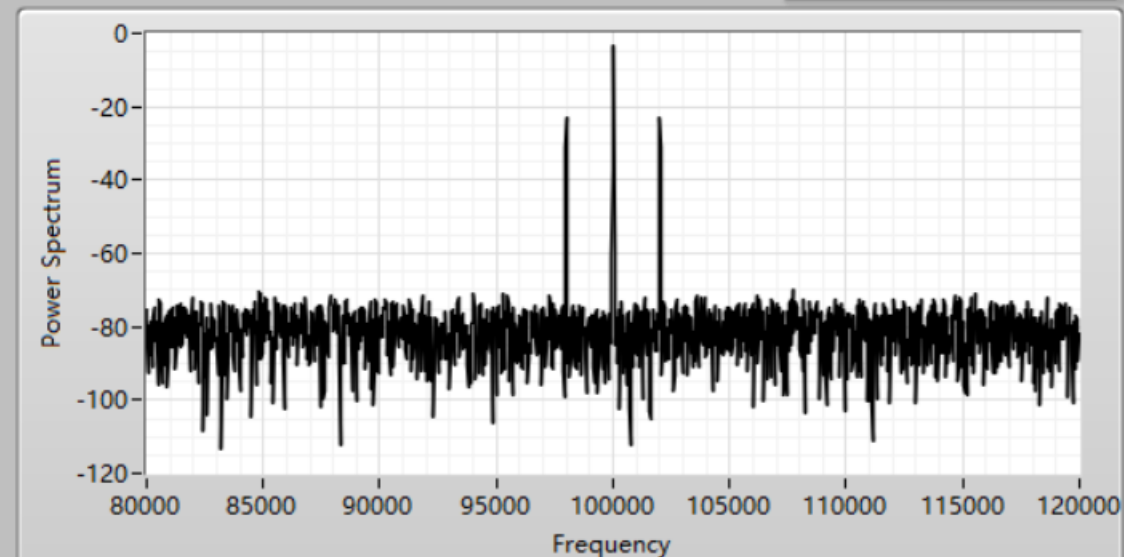


Modulated Signal



FM FFT

Sine (FFT - (RMS))



Carrier Amp.

1

Carrier Freq.

100000

WAV SR

44100

Mod. Freq.

2000

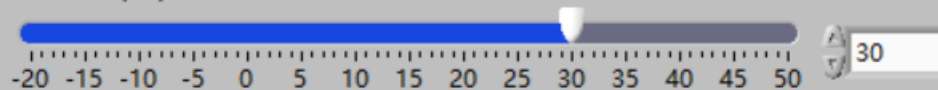
LPF Cut-Off

10000

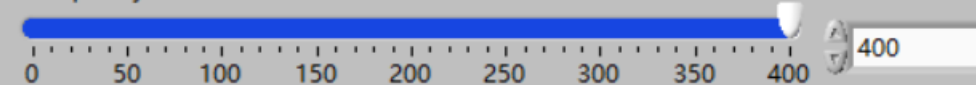
Estimated freq.

100000

AWGN (dB)



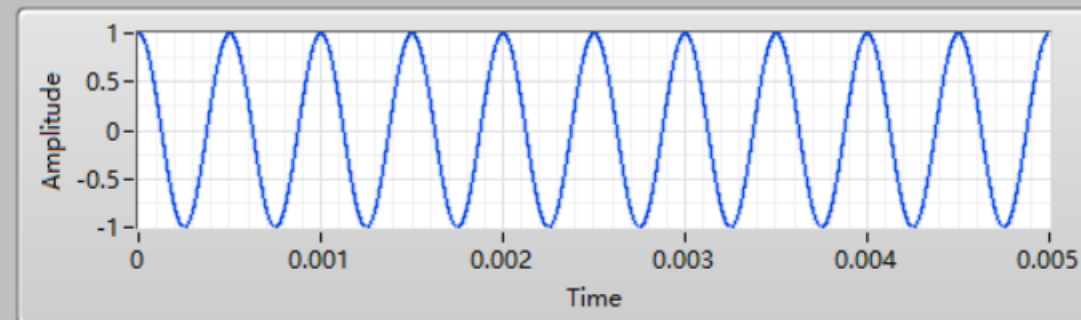
Frequency Deviation



stop

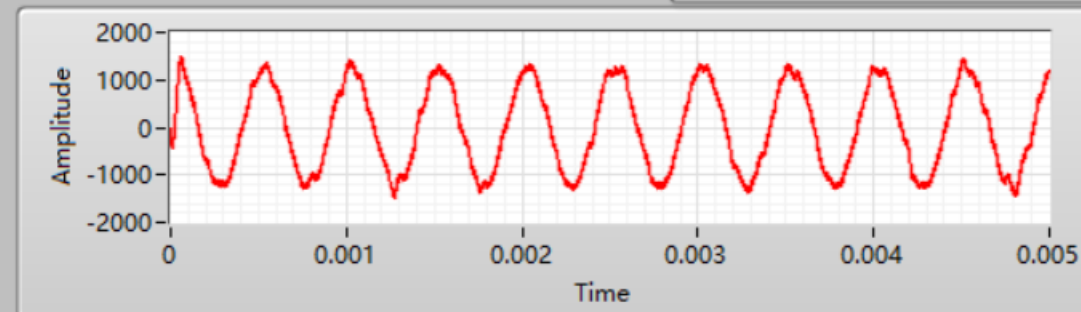
STOP

Baseband



Recovered Signal

Sine (Derivative (dX/dt))



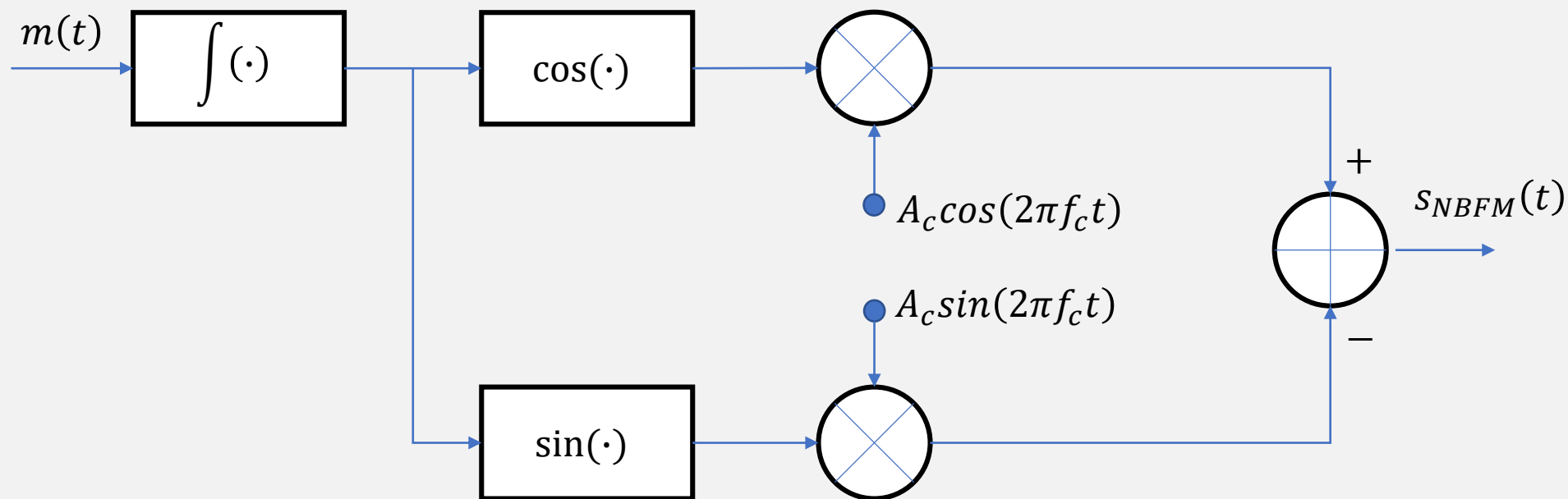


Demo: NBFM Simulation (Music)



Pre-Lab: **General** Mathematical Model

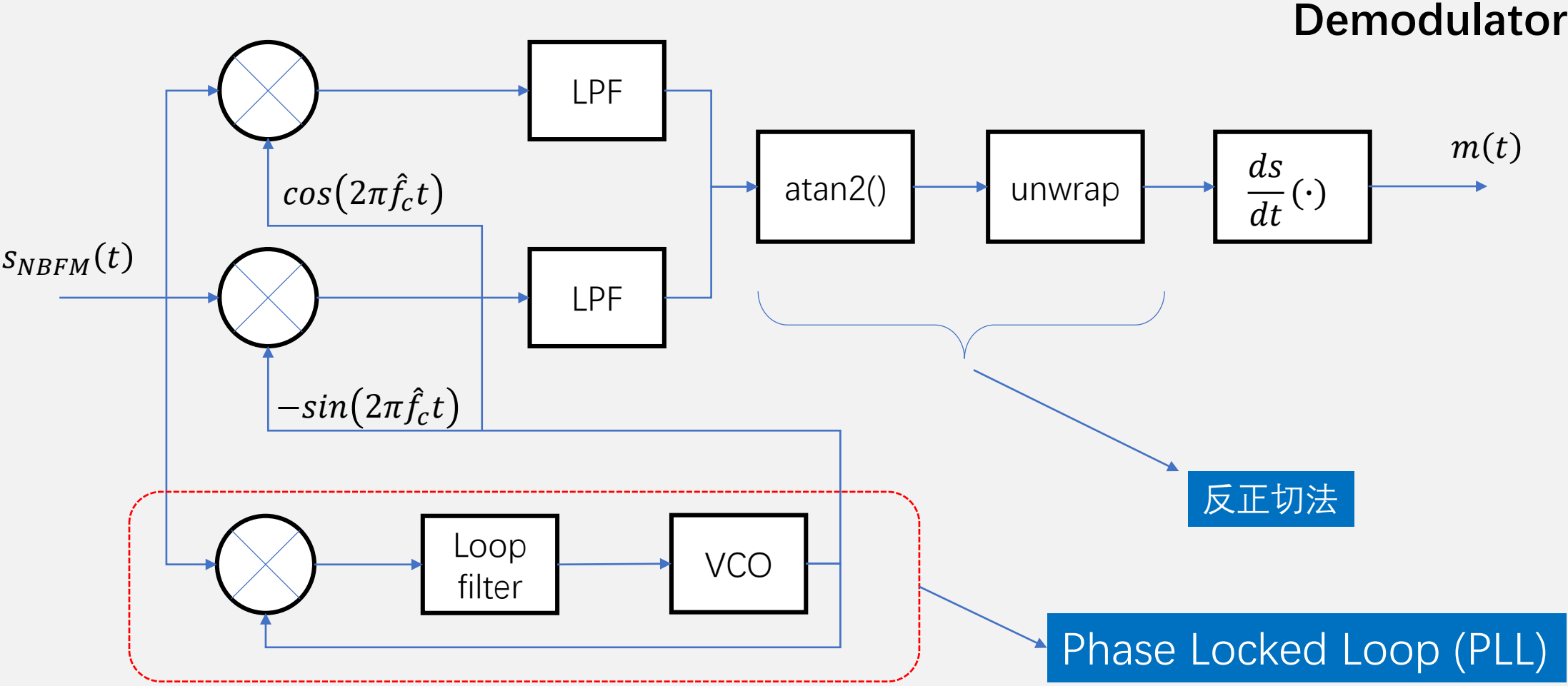
Modulator

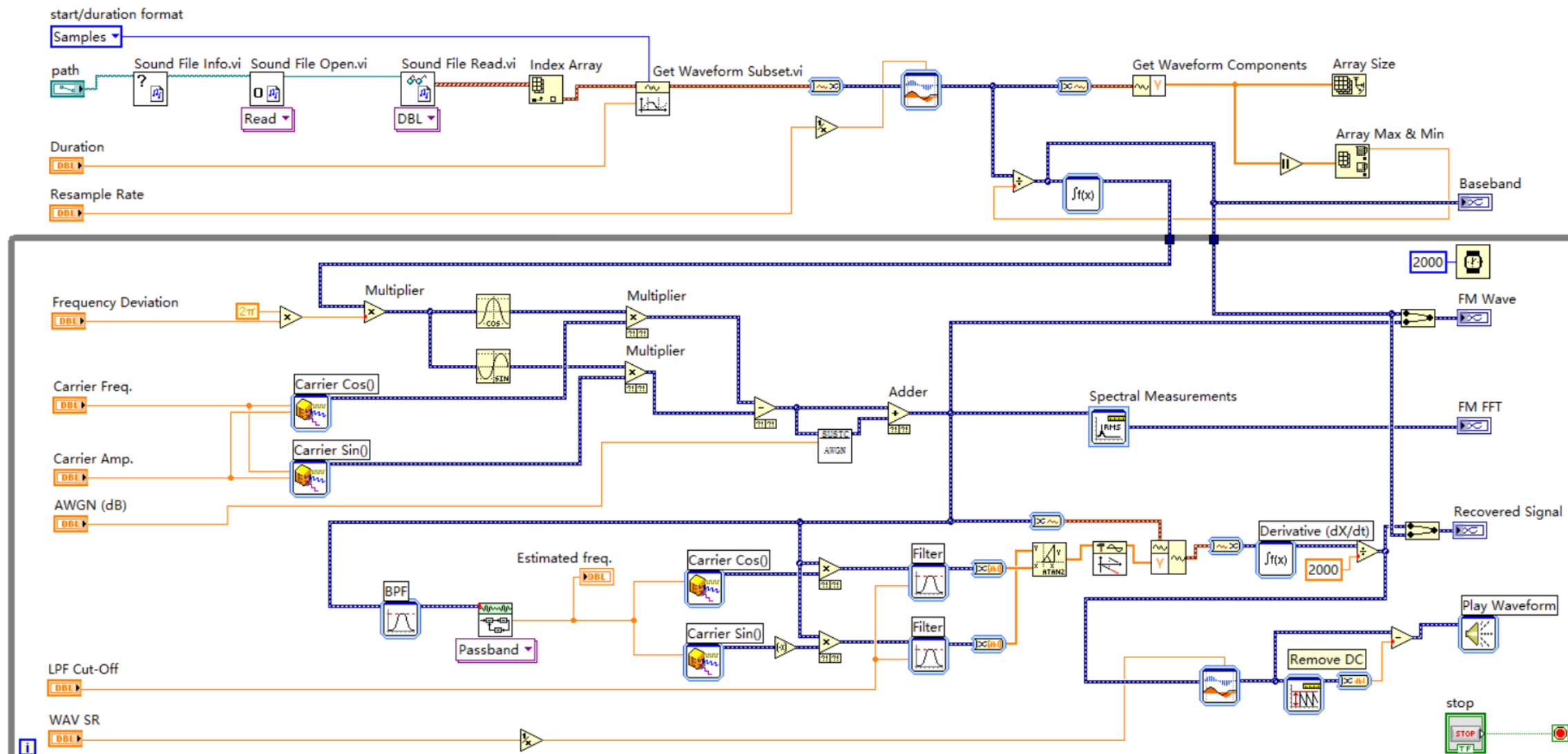


$$s_{NBFM}(t) = A_c \cos \left[2\pi k_f \int m(\tau) d\tau \right] \cos(2\pi f_c t) - A_c \sin \left[2\pi k_f \int m(\tau) d\tau \right] \sin(2\pi f_c t)$$



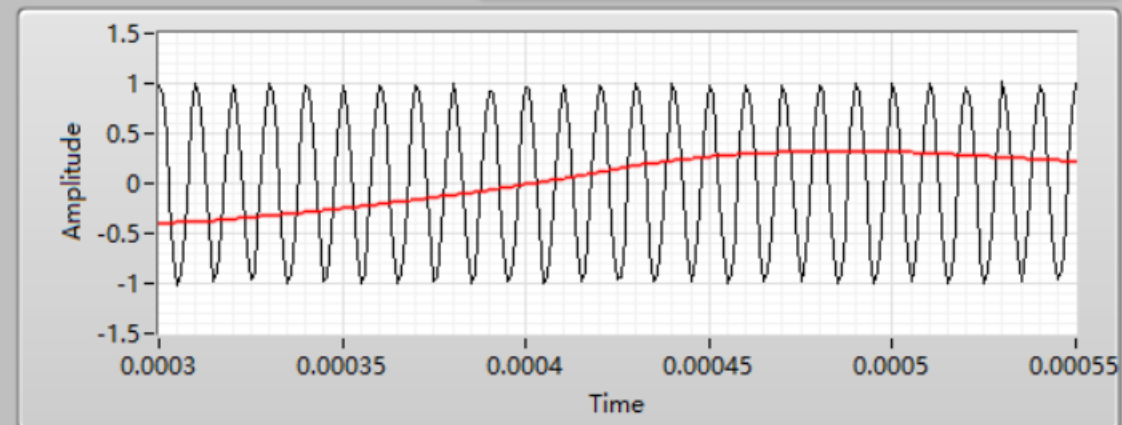
Pre-Lab: **General** Mathematical Model



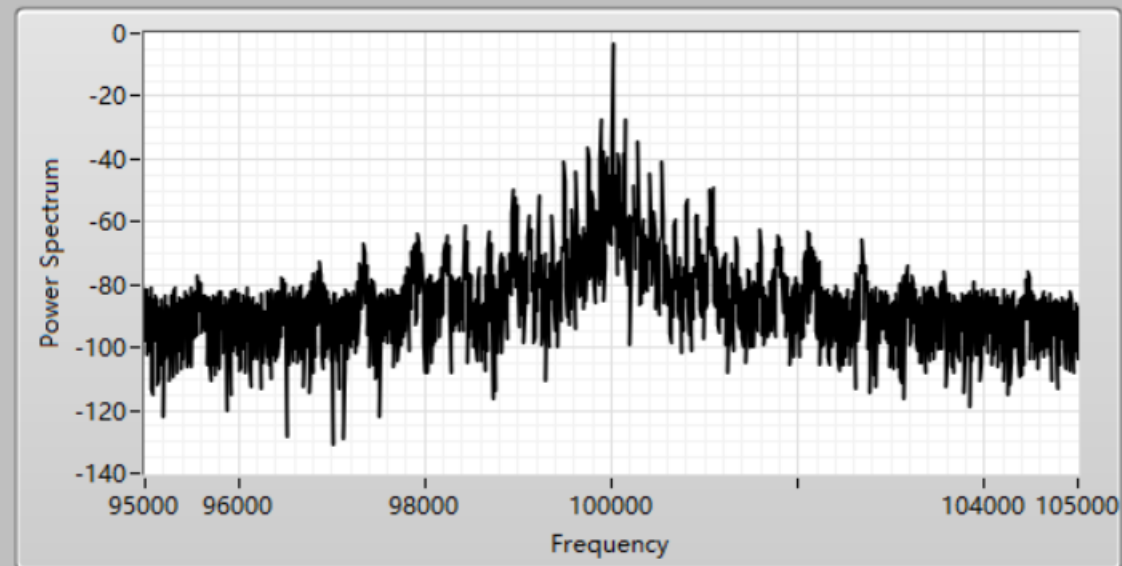


Frequency Modulation

FM Wave



FM FFT



path

D:\File\mozart.wav

Duration

44101

LPF Cut-Off

5000

Carrier Amp.

1

Carrier Freq.

100000

WAV SR

44100

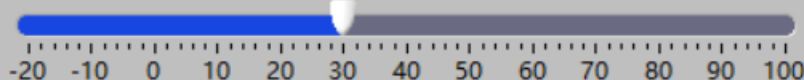
Resample Rate

1000000

Estimated freq.

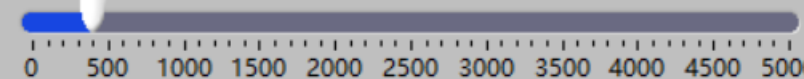
100016

AWGN (dB)



30

Frequency Deviation

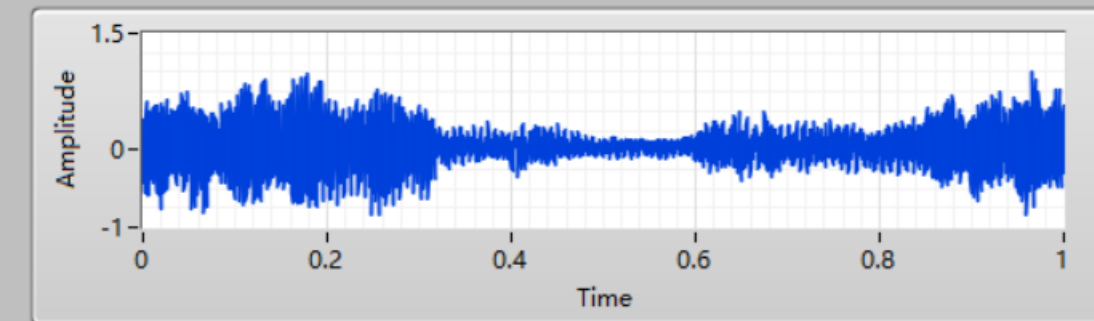


400

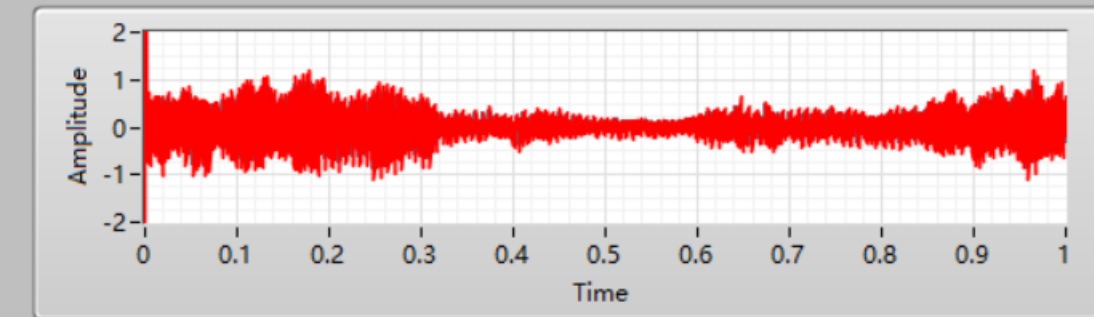
stop

STOP

Baseband



Recovered Signal





- Question ?





【通信新说】



腾讯课堂