University of Bahrain

Department of Electrical and Electronics Engineering

EENG372

Communication Systems I

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Topic 2:

Frequency Modulation (FM)

This Topic will cover

- FM Generation
- FM Receivers

Frequency Modulation: Generation

Indirect FM Generation

Q: What is an indirect FM modulator?

First a NB-FM is generated with small m_f and then using frequency Multipliers WB-FM is generated with larger m_f

$$v_m(t) \qquad v_{NB-FM}(t) \qquad v_{WB-FM}(t)$$

NB FM Generation

Q: What is NB-FM?

Going back to the defining equation:

$$v_{FM}(t) = V_c \cos\left(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} v_m(\tau)\,d\tau\right)$$

Using trigonometric identities:

$$v_{FM}(t) = V_c \cos(2\pi f_c t)\cos\left(2\pi k_f \int_{-\infty}^{t} v_m(\tau)\,d\tau\right)$$
$$- V_c \sin(2\pi f_c t)\sin\left(2\pi k_f \int_{-\infty}^{t} v_m(\tau)\,d\tau\right)$$

NB FM Generation

Q: What if the modulation index m_f is small ?

Then:

$$\cos\left(2\pi k_f \int_{-\infty}^{t} v_m(\tau)d\tau\right) \approx 1$$

$$\sin\left(2\pi k_f \int_{-\infty}^{t} v_m(\tau)d\tau\right) \approx 2\pi k_f \int_{-\infty}^{t} v_m(\tau)d\tau$$

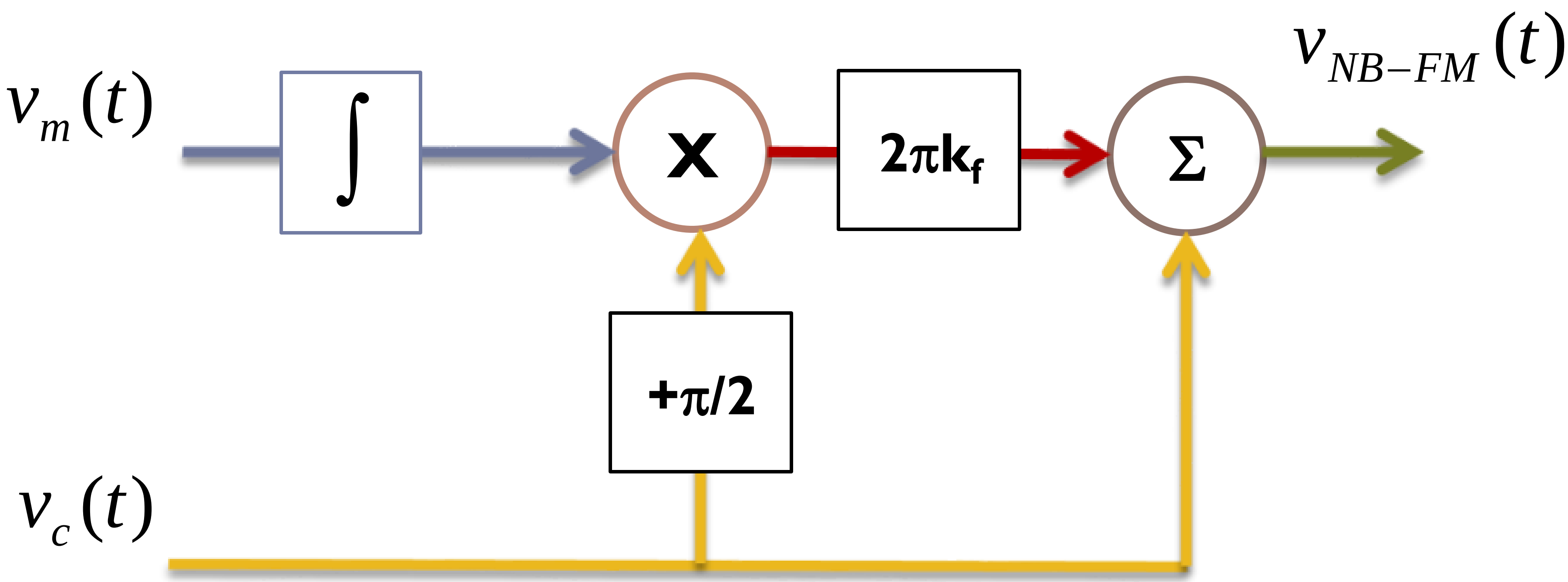
Substituting:

$$v_{FM}(t) \approx V_c \cos(2\pi f_c t) - V_c \sin(2\pi f_c t)\left(2\pi k_f \int_{-\infty}^{t} v_m(\tau)d\tau\right)$$

$$v_{FM}(t) \approx V_c \cos(2\pi f_c t) - 2\pi k_f V_c \sin(2\pi f_c t)\left(\int_{-\infty}^{t} v_m(\tau)d\tau\right)$$

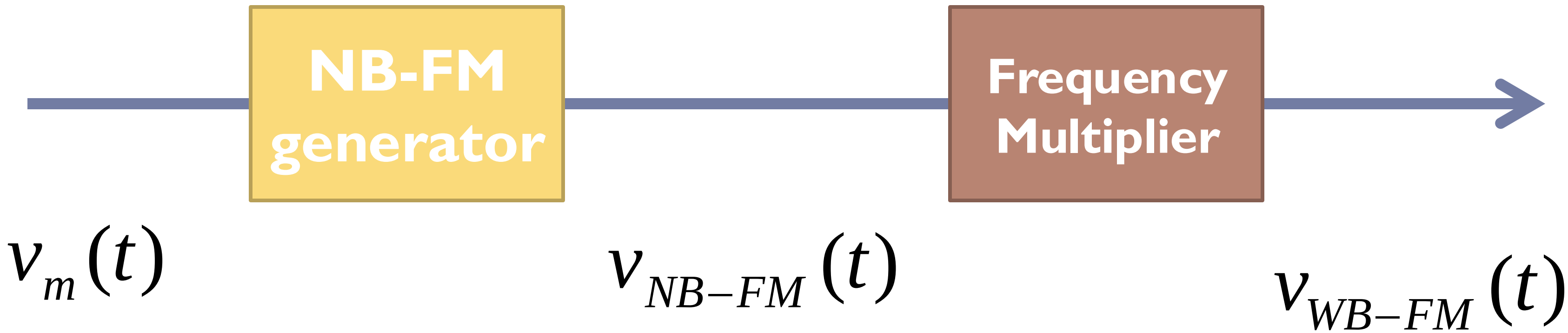
NB FM Generation

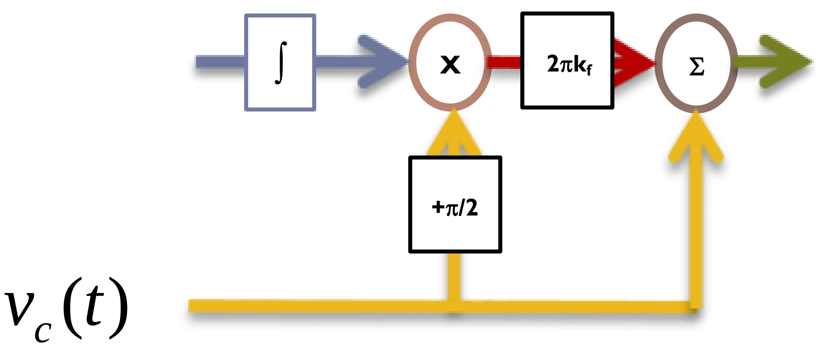
$$v_{FM}(t) \approx V_c \cos(2\pi f_c t) - 2\pi k_f V_c \sin(2\pi f_c t)\left(\int_{-\infty}^{t} v_m(\tau)d\tau\right)$$



Indirect FM Generation

Q: What is an indirect FM modulator?

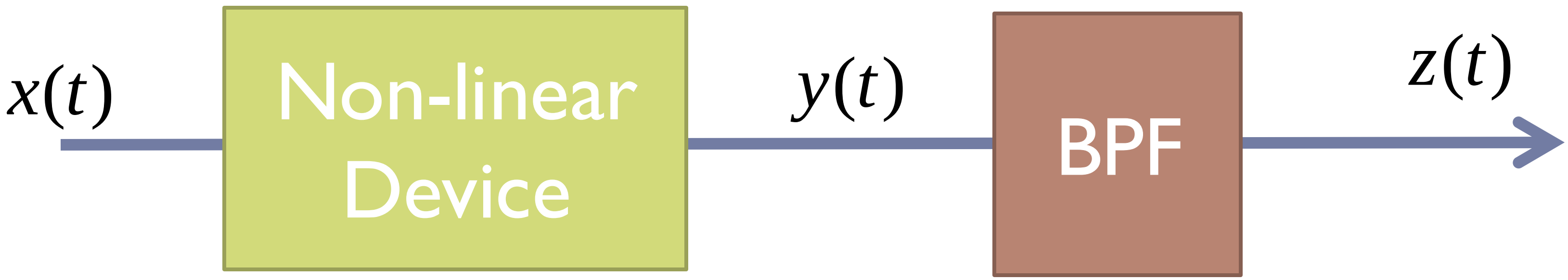




Frequency Multiplier

Q: What is a Frequency Multiplier?

It is a non linear device followed by a Band pass filter (BPF)



The output of the NLD is:

Signal multiplied by itself

$$y(t) = a_0 + a_1 x(t) + a_2 x^2(t) + a_3 x^3(t) + ...$$

$$y(t) \approx a_2 x^2(t)$$

Frequency Multiplier

Q: What if x(t) is a NB-FM signal?

The output of the NLD will be

$$y(t) \approx a_2 x^2(t) \approx a_2 {v_{NB-FM}}^2(t)$$

$$y(t) \approx a_2 \left(V_c \cos(2\pi(f_c t + k_f \int_{-\infty}^{t} v_m(\tau) d\tau)) \right)^2$$

$$y(t) \approx a_2 V_c^2 \cos^2(2\pi(f_c t + k_f \int_{-\infty}^{t} v_m(\tau) d\tau))$$

$$y(t) \approx \frac{a_2 V_c^2}{2} \left(1 + \cos\left(4\pi \left(f_c t + k_f \int_{-\infty}^{t} v_m(\tau) d\tau \right) \right) \right)$$

$$y(t) \approx \frac{a_2 V_c^2}{2} \left(1 + \cos\left(2\pi \left(2 f_c t + 2k_f \int_{-\infty}^{t} v_m(\tau) d\tau \right) \right) \right)$$

an FM signal with double the carrier frequency and double the modulation index:

Frequency Multiplier

Q: What is the output of the NLD?

The output of the NLD is an FM signal with double the carrier frequency and double the modulation index:

$$y(t) \approx \frac{a_2 V^2{}_c}{2} + \frac{a_2 V_c^2}{2}\cos\left(2\pi f_c' t + 2\pi k_f' \int_{-\infty}^{t} v_m(\tau)d\tau\right)$$

$$f_c' = 2 f_c$$

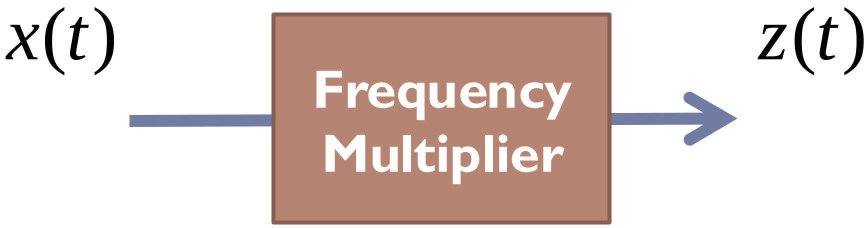
$$k_f' = 2k_f \Rightarrow m_f' = 2m_f$$

After a BPF centered at $2f_c$ and with BW $2\Delta f$

$$z(t) = \frac{a_2 V_c^2}{2}\cos\left(2\pi f_c' t + 2\pi k_f' \int_{-\infty}^{t} v_m(\tau)d\tau\right)$$

Frequency Multiplier

Q: What is a Frequency Multiplier?



Doubler

$$x(t) \approx V_c \cos\left(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} v_m(\tau) d\tau \right)$$

$$z(t) \approx \frac{a_2 V_c^{\,2}}{2} \cos\left(2\pi f_c' t + 2\pi k_f' \int_{-\infty}^{t} v_m(\tau) d\tau \right)$$

$$f_c$$

$$f_c' = 2 f_c$$

$$m_f = \frac{k_f V_m}{f_m}$$

$$m_f' = 2 m_f$$

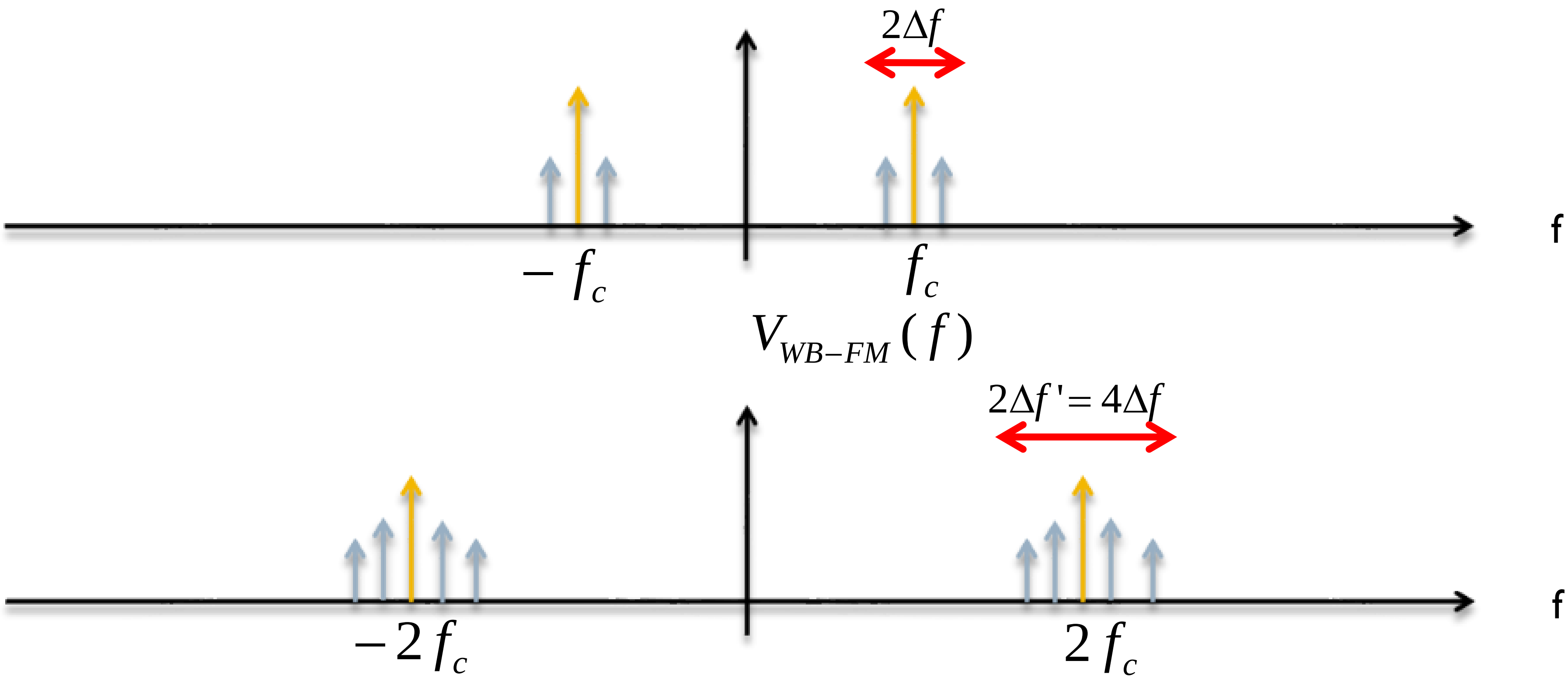
$$\Delta f = k_f V_m$$

$$\Delta f' = 2 \Delta f$$

Frequency Multiplier

Q: What is the output of the multiplier for single modulation?

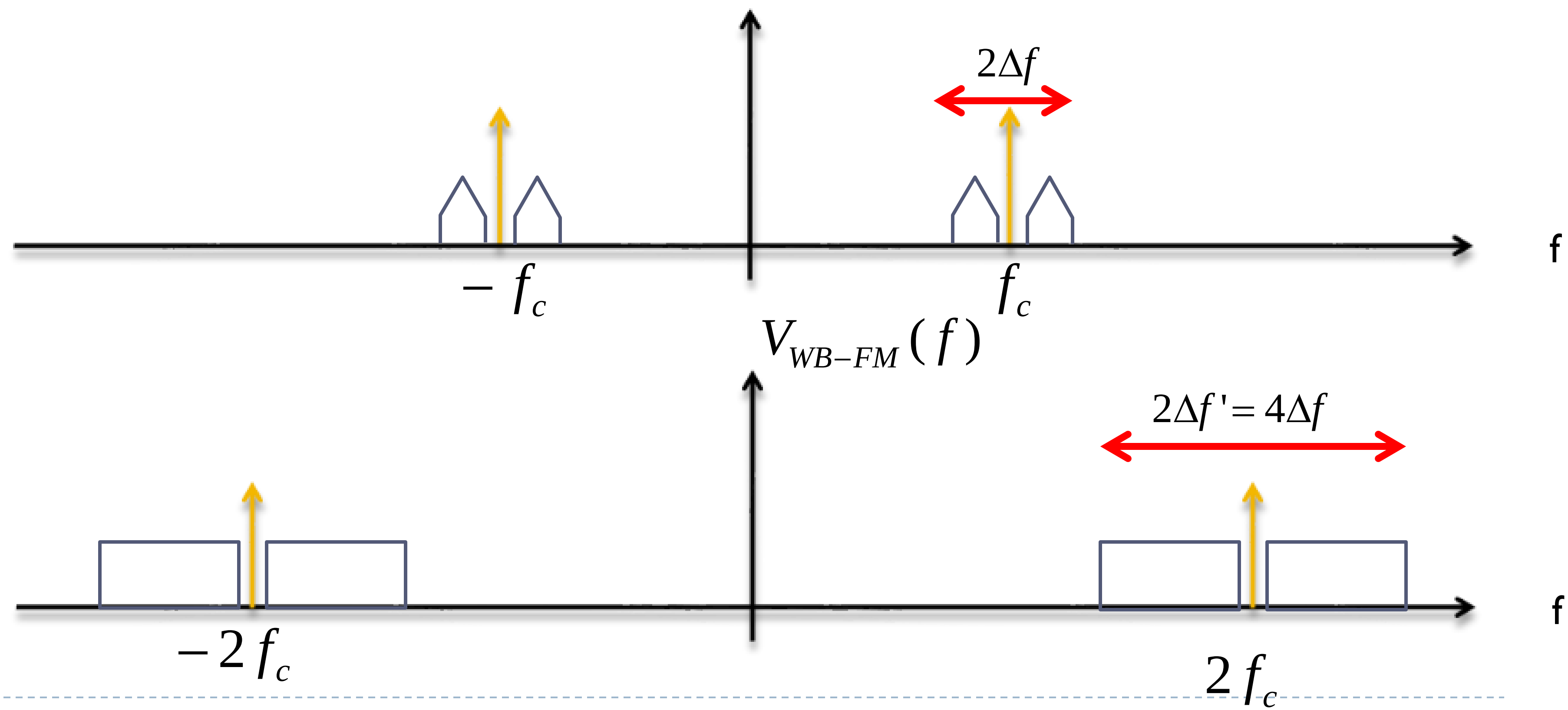
The output of the multiplier is : $V_{NB-FM}(f)$



Frequency Multiplier

Q: What is the output of the multiplier for any message signal?

The output of the multiplier is : $V_{NB-FM}(f)$



Armstrong FM Modulator

$v_m(t)$ $v_{NB-FM}(t)$ $v_{WB-FM}(t)$

$f_m = 50Hz - 15kHz$

$f_{c1} = 200kHz$, $\Delta f_1 = 25Hz$

$f_{c2} = 12.8MHz$, $\Delta f_2 = 1.6kHz$

$f_{c3} = 1.9MHz$, $\Delta f_3 = 1.6kHz$

$f_{c4} = 91.2MHz$, $\Delta f_4 = 76.8kHz$

$f_{c1} = 200kHz$

$f = 10.9MHz$

5.3-1 Design (only the block diagram) an Armstrong indirect FM modulator to generate an FM carrier with a carrier frequency of 98.1 MHz and $\Delta f = 75$ kHz. A narrowband FM generator is available at a carrier frequency of 100 kHz and a frequency deviation $\Delta f = 10$ Hz. The stock room also has an oscillator with an adjustable frequency in the range of 10 to 11 MHz. There are also plenty of frequency doublers, triplers, and quintuplers.

5.3-2)

Design (only the block diagram) an Armstrong indirect FM modulator to generate an FM carrier with a carrier frequency of 96 MHz and $\Delta f = 20$ kHz. A narrowband FM generator with $f_c = 200$ kHz and adjustable Δf in the range of 9 to 10 Hz is available. The stock room also has an oscillator with adjustable frequency in the range of 9 to 10 MHz. There is a bandpass filter with any center frequency, and only frequency doublers are available.

Topic 2:
SH Receivers

Receiver

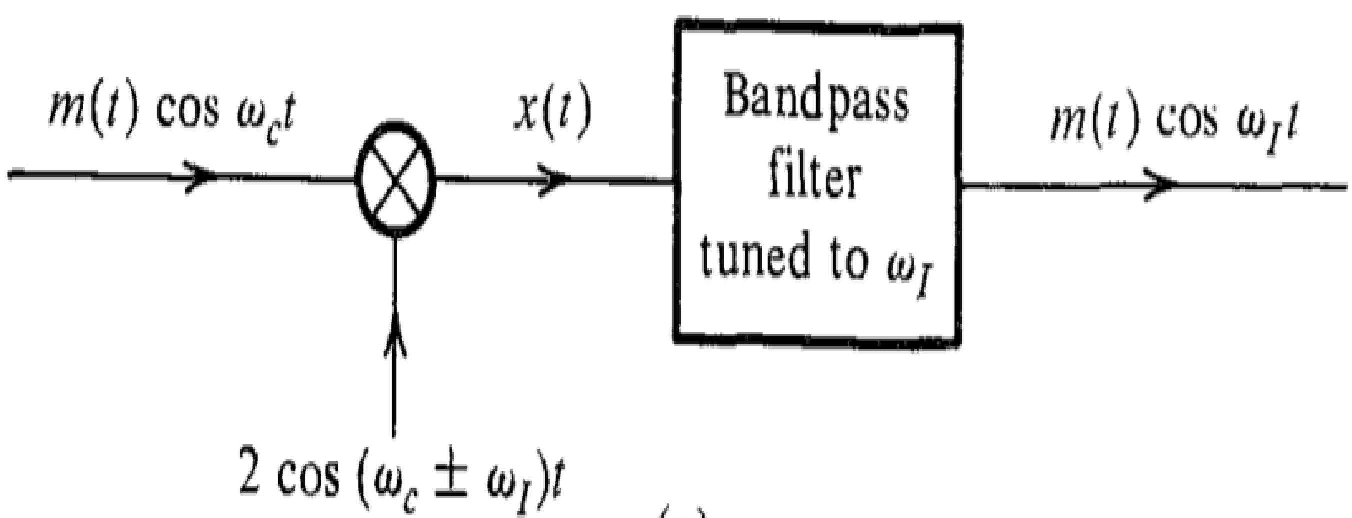
Q: What is a Receiver?

It is the circuit that receives (selects), amplifies and detects the communication signal.

Q: What are the requirements of a Receiver?

1. Selectivity: the ability of the receiver to select a desire communication signal and reject other frequencies.
2. Sensitivity: the ability of the receiver to pick up weak signals. (in the presence of Noise)

Frequency Mixer or Converter (Ex 4-2)



(a)

We shall analyze a frequency mixer, or frequency converter, used to change the carrier frequency of a modulated signal $m(t)\cos\omega_c t$ from ω_c to some other frequency ω_I.

This can be done by multiplying $m(t)\cos\omega_c t$ by $2\cos\ \omega_{\text{mix}} t$, where $\omega_{\text{mix}} = \omega_c + \omega_I$ or $\omega_c - \omega_I$, and then bandpass-filtering the product, as shown in Fig. 4.7a.

The product $x(t)$ is

$$\begin{aligned} x(t) &= 2m(t)\cos\ \omega_c t\cos\ \omega_{\text{mix}} t \\ &= m(t)[\cos\ (\omega_c - \omega_{\text{mix}})t + \cos\ (\omega_c + \omega_{\text{mix}})t] \end{aligned}$$

If we select $\omega_{\text{mix}} = \omega_c - \omega_I$,

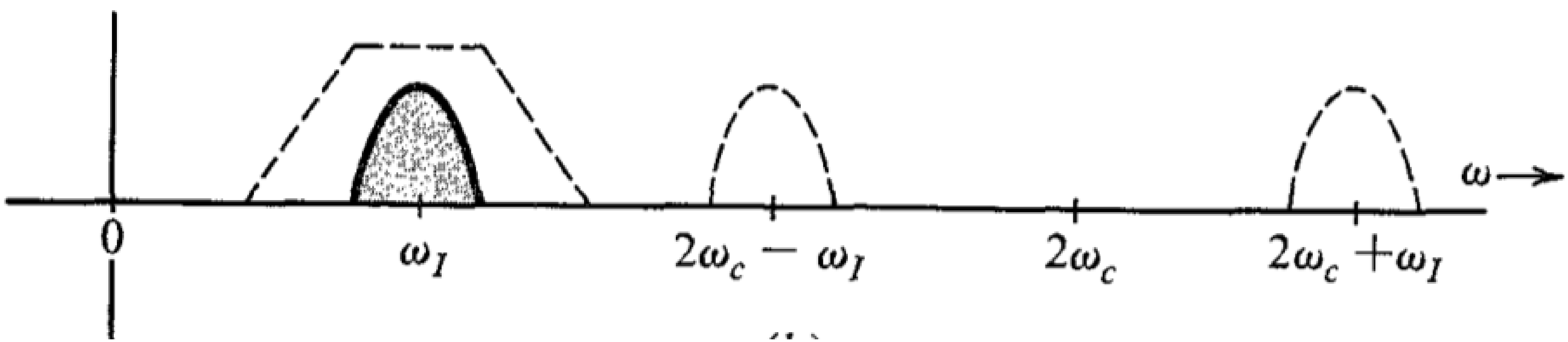
$$x(t) = m(t)[\cos\ \omega_I t + \cos\ (2\omega_c - \omega_I)t]$$

If we select $\omega_{\text{mix}} = \omega_c + \omega_I$,

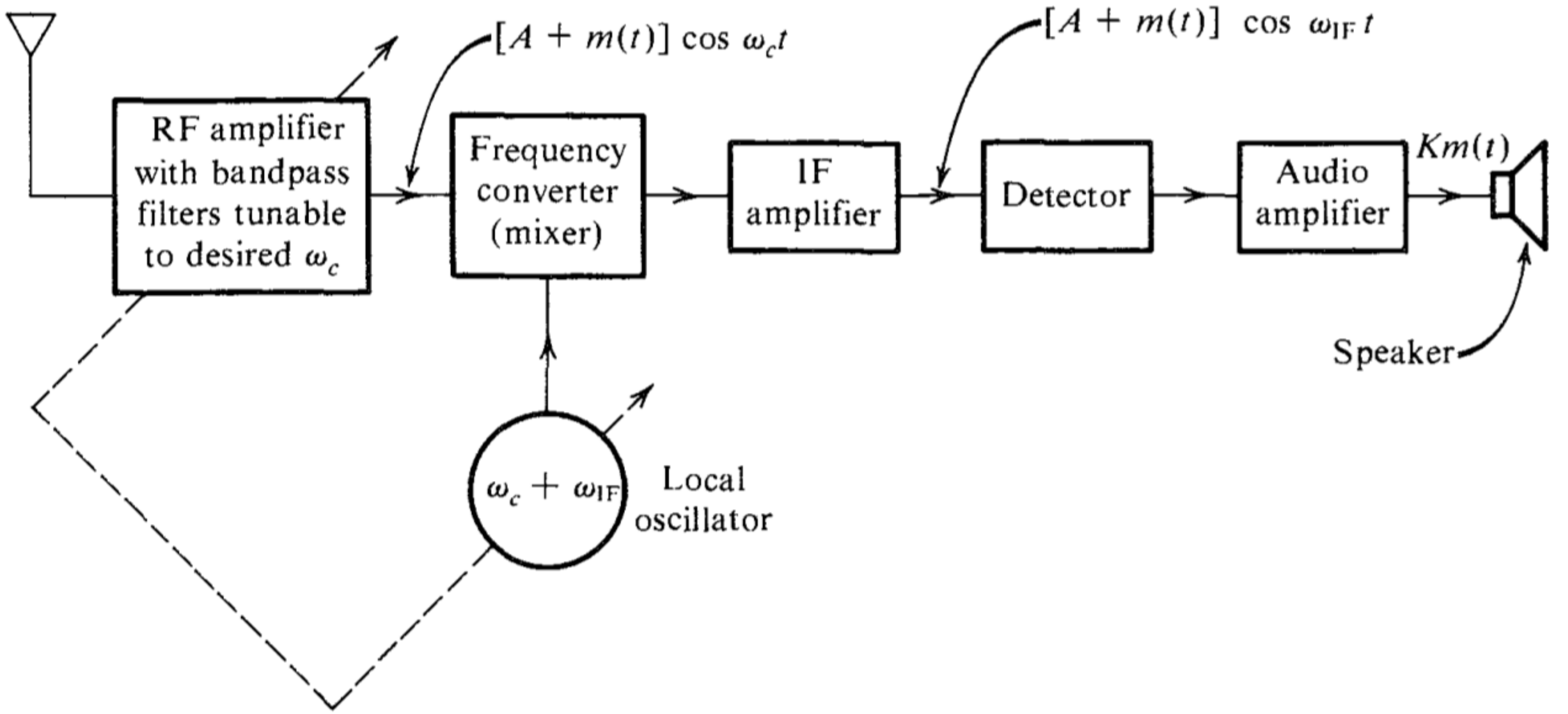
$$x(t) = m(t)[\cos\ \omega_I t + \cos\ (2\omega_c + \omega_I)t]$$

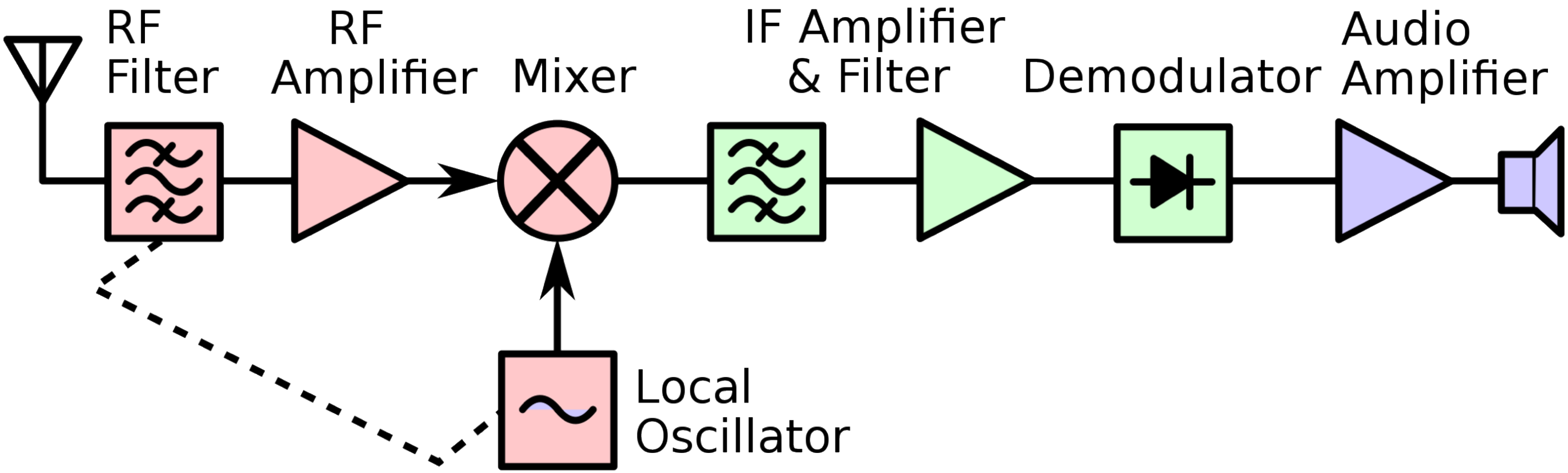
In either case, a bandpass filter at the output, tuned to ω_I, will pass the term $m(t)\cos\ \omega_I t$ and suppress the other term, yielding the output $m(t)\cos\ \omega_I t$.* Thus, the carrier frequency has been translated to ω_I from ω_c.

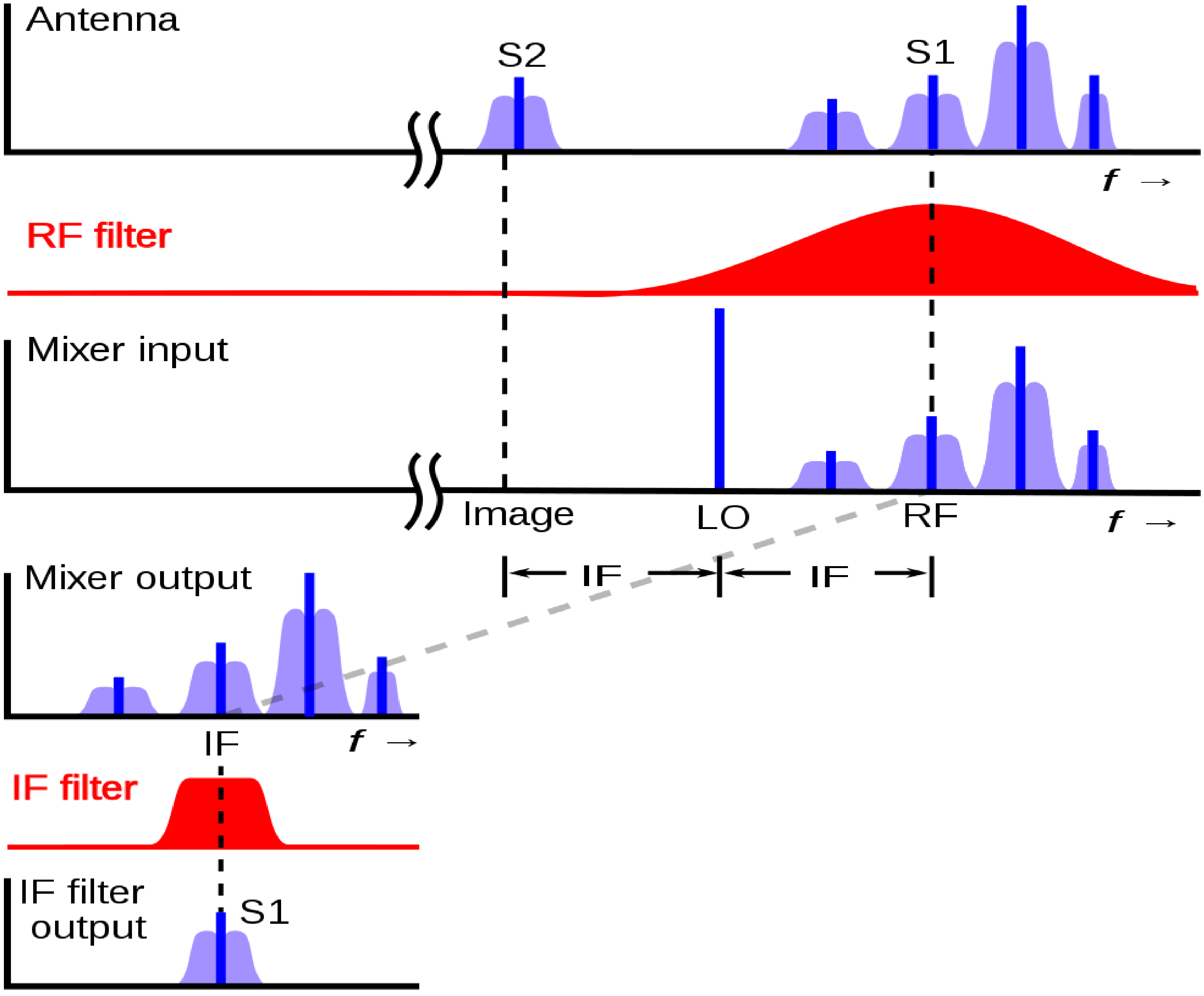
The operation of frequency mixing, or frequency conversion (also known as heterodyning), is identical to the operation of modulation with a modulating carrier frequency (the mixer oscillator frequency ω_{mix}) that differs from the incoming carrier frequency by ω_I. Any one of the modulators discussed earlier can be used for frequency mixing. When we select the local carrier frequency $\omega_{\text{mix}} = \omega_c + \omega_I$, the operation is called **up-conversion**, and when we select $\omega_{\text{mix}} = \omega_c - \omega_I$, the operation is **down-conversion**.



Superheterodyne Analog AM/FM Receiver




RF
Filter
RF
Amplifier
Mixer
IF Amplifier
& Filter
Demodulator
Audio
Amplifier
Local
Oscillator



Antenna
S2
S1
f →
RF filter
Mixer input
Image
LO
RF
f →
IF
IF
Mixer output
IF
f →
IF filter
IF filter
output
S1