ENSC327 Communications Systems 11: FM Modulation

Jie Liang
School of Engineering Science
Simon Fraser University

Outline

- Two methods of generating FM waves:
  - Direct method
  - Indirect Method: Armstrong's wideband frequency modulator

Review of frequency deviation:

Angle modulation: $$s(t) = A_c \cos(2\pi f_c t + \phi(t))$$

Instantaneous frequency $$f_i(t) = \frac{1}{2\pi}\frac{d\theta_i(t)}{dt} = f_c + \frac{1}{2\pi}\frac{d\phi(t)}{dt}$$

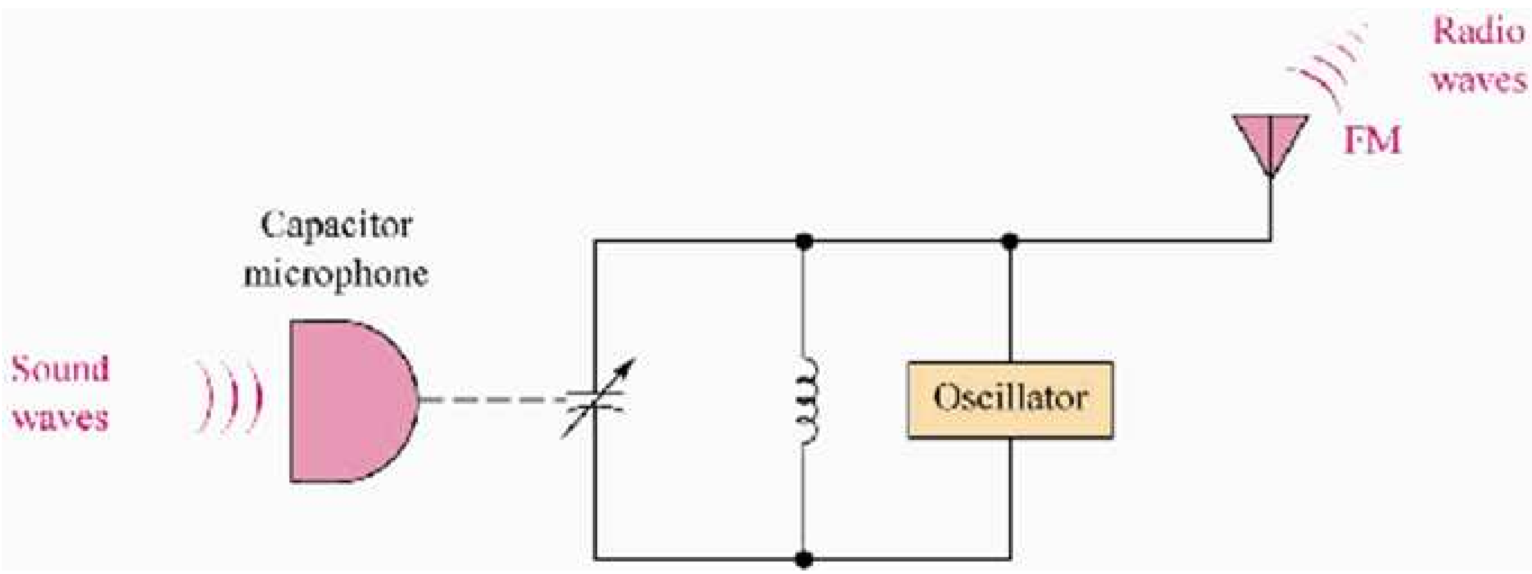
Frequency deviation $$\Delta f = \max\left|\frac{1}{2\pi}\frac{d\phi(t)}{dt}\right|.$$

Frequency deviation for FM signals: $$\Delta f = k_f \max|m(t)|.$$

For example, FM radio allows 75kHz deviation to each side of the carrier.

Direct FM Generation

- The carrier freq is directly varied by the input signal
- Can be accomplished by Voltage-Controlled Oscillator (VCO), whose output frequency is proportional to the voltage of the input signal.
- A VCO example: implemented by variable capacitor

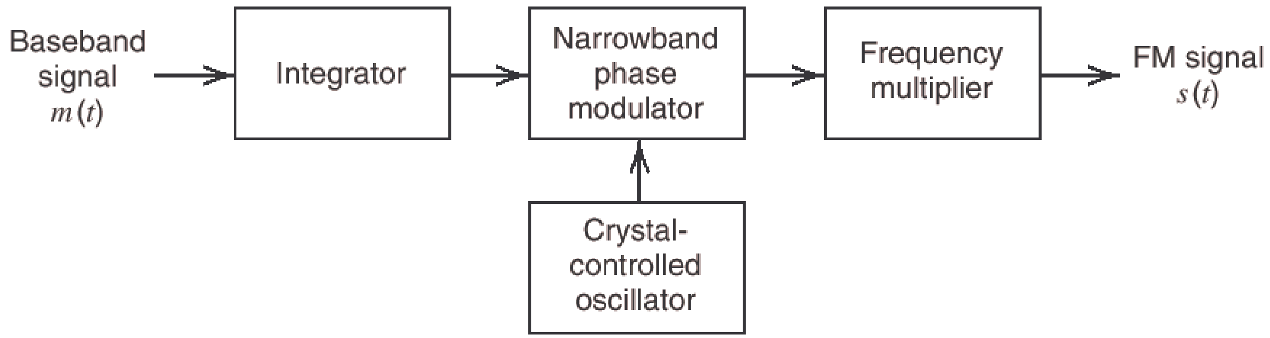


Problems of direct FM generator

- The carrier freq of VCO tends to drift away.
  - (Crystal oscillator cannot be used in direct FM: its freq is too stable, and is difficult to change.)
  - Feedback freq stabilization circuit is required:
    - The complexity is increased.
- The frequency deviation with direct FM is only about 5 KHz, too small for wideband FM:
  - Recall: the max frequency deviation in commercial FM radio is 75kHz.

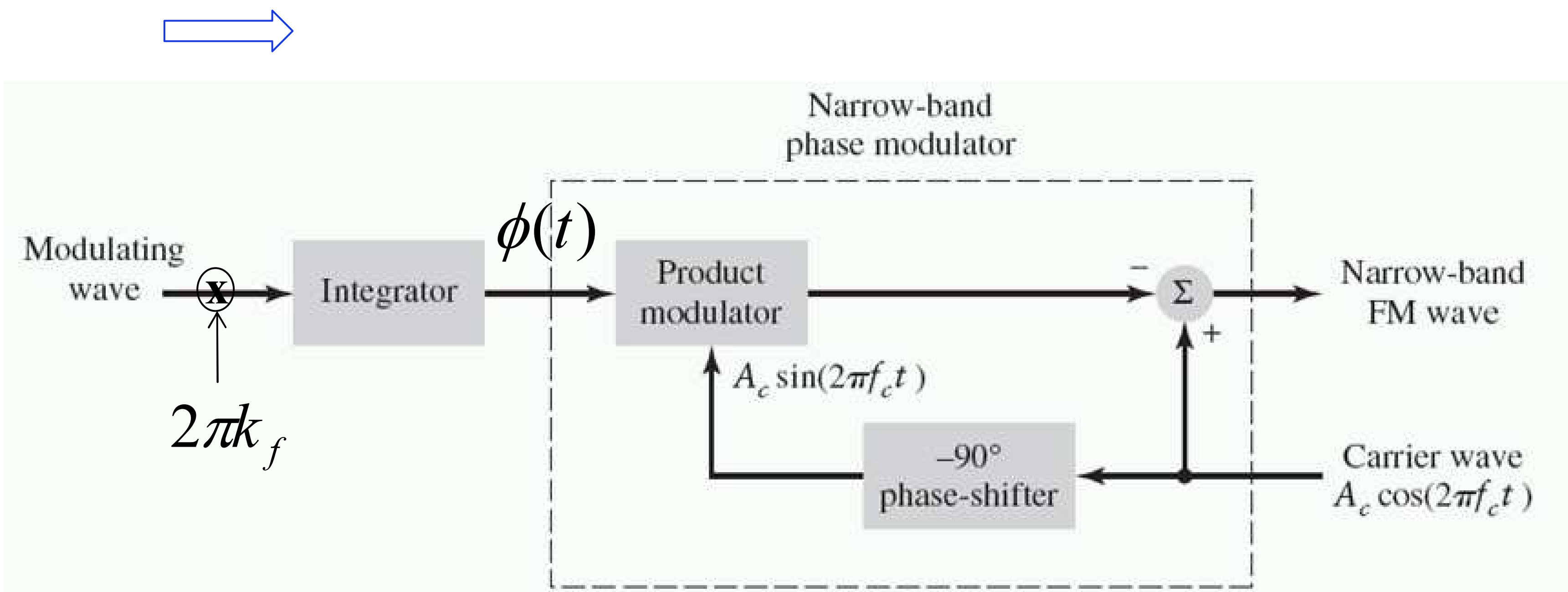
Indirect Method: Armstrong Modulator

- First obtain NBFM via a NBPM circuit with crystal oscillator
- Then apply frequency multiplier
  - Increase both the carrier frequency and the freq deviation
- If necessary, use mixer to concatenate multiple multipliers
  - Mixer only changes the carrier frequency, but not the frequency deviation.
- Indirect FM is preferred when the stability of carrier frequency is of major concern (e.g., in commercial FM broadcasting)



Recall: Narrow-band FM

- if Δf is small: $s(t) = A_c \cos(2\pi f_c t + \phi(t))$



Crystal oscillator can be used to get stable frequency (prevent drifting)

But frequency deviation of NBFM is small.

To get larger one, use freq multiplier…

Frequency Multipliers

- How to increase the frequency deviation ?
- Answer: trigonometric identity!

From $$s(t) = A_c \cos(2\pi f_c t + 2\pi k_f \int_0^t m(\tau) d\tau)$$

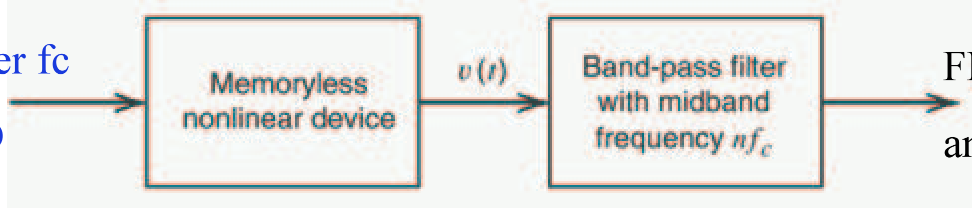
If we can get the squared signal:

Frequency Multipliers

If we can get $s^3(t)$:

Freq Multipliers via Nonlinear Circuit

FM signal with carrier fc and deviation ratio D



FM signal with carrier n fc and deviation ratio n D.

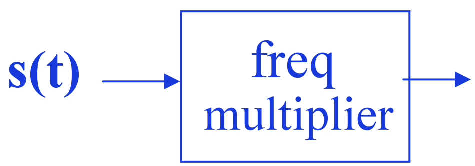
- A general nonlinear circuit produces

$$v(t) = a_1 s(t) + a_2 s^2(t) + \ldots + a_n s^n(t)$$

  - The highest carrier frequency:
- The highest freq sensitivity factor:
- The bandpass filter:
  - Center:
  - Passband width:
  - In practice: n = 2, or 3. Larger n is not efficient.
  - But can concatenate multiple stages to obtain higher orders.

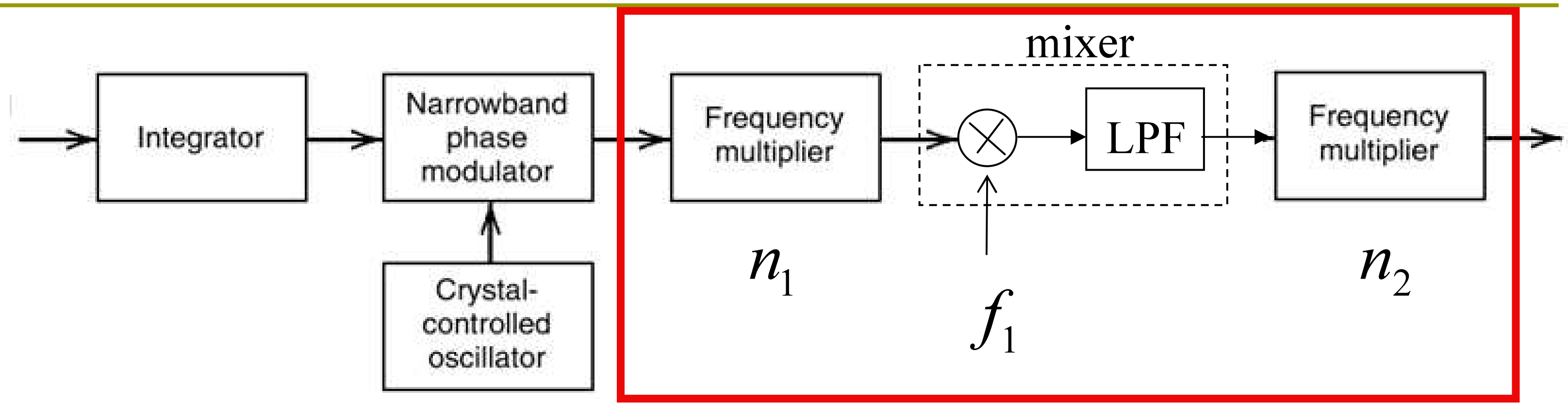
Mixer & Frequency Multiplier

- Frequency multiplier increases the freq and deviation together.
- How to adjust them separately to get more flexibilities?



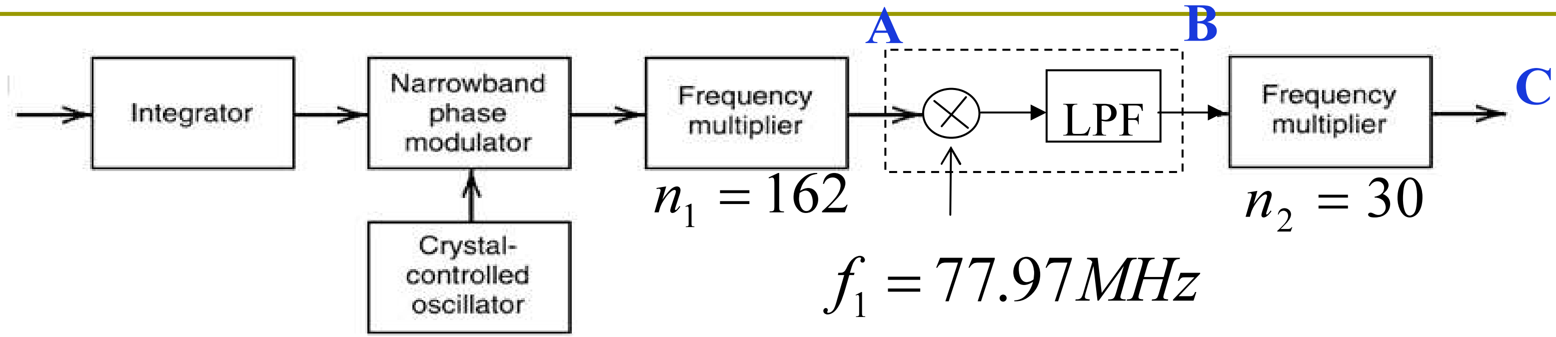
- Input: $s(t) = A_c \cos(2\pi f_c t + \phi(t)),$ with freq deviation Δf.
- After freq multiplier:
- After multiplying with local freq f_1:
- After BPF:

Armstrong's Indirect FM



- Two stages of multiplier and one mixer are used.
  - Allow flexible choices of carrier freq and freq deviation.
  - The first stage multiplier amplifies both fc and Δf.
  - The mixer brings down the central freq.
  - The second stage amplifies fc and Δf again.

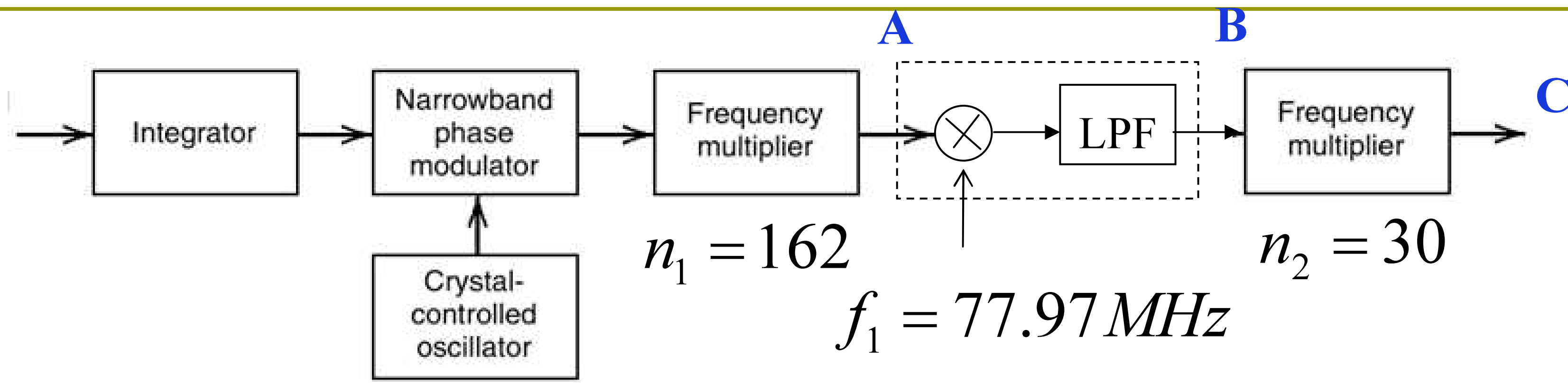
Example



NBPM output : $f = 500kHz$, $\Delta f = 15.432Hz$

Find f and Δf at A, B, C.

Example



Total multiplier for Δf:

Summary

- Direct FM generation:
  - The carrier freq is directly varied by the input signal
  - Frequency drifting is a problem
  - Freq deviation < 5KHz
- Indirect FM generation:
  - NBFM followed by freq multiplier
    - Use nonlinear circuit to get multiplier
  - Can use mixer to change the carrier freq
  - Combination of mixer and multiplier provides flexibilities.

Reference

- Direct FM generation:

http://www.ycars.org/EFRA/Module%20B/directfm.htm

- Indirect FM generation:

http://www.ycars.org/EFRA/Module%20B/indirectfm.htm