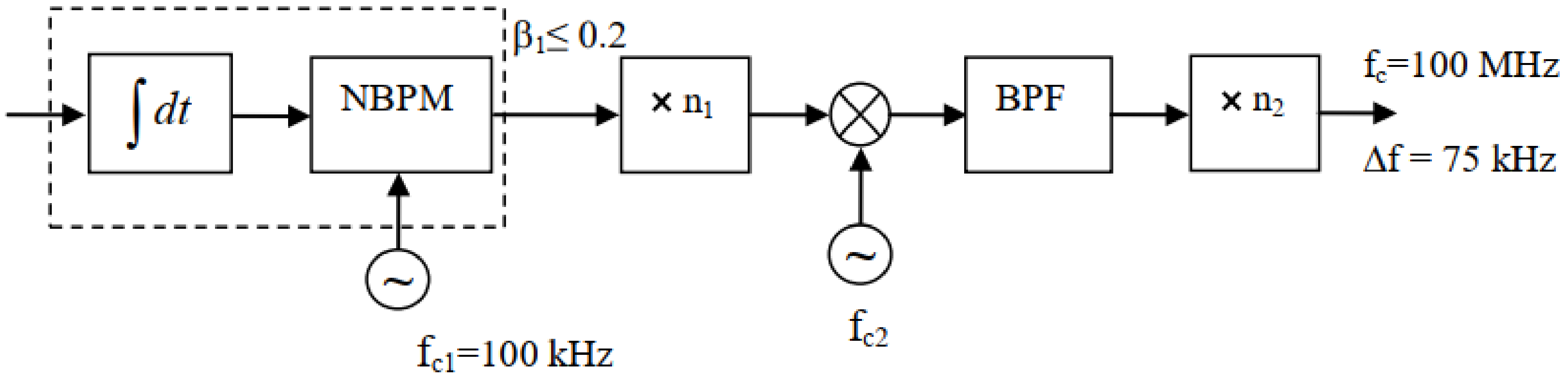
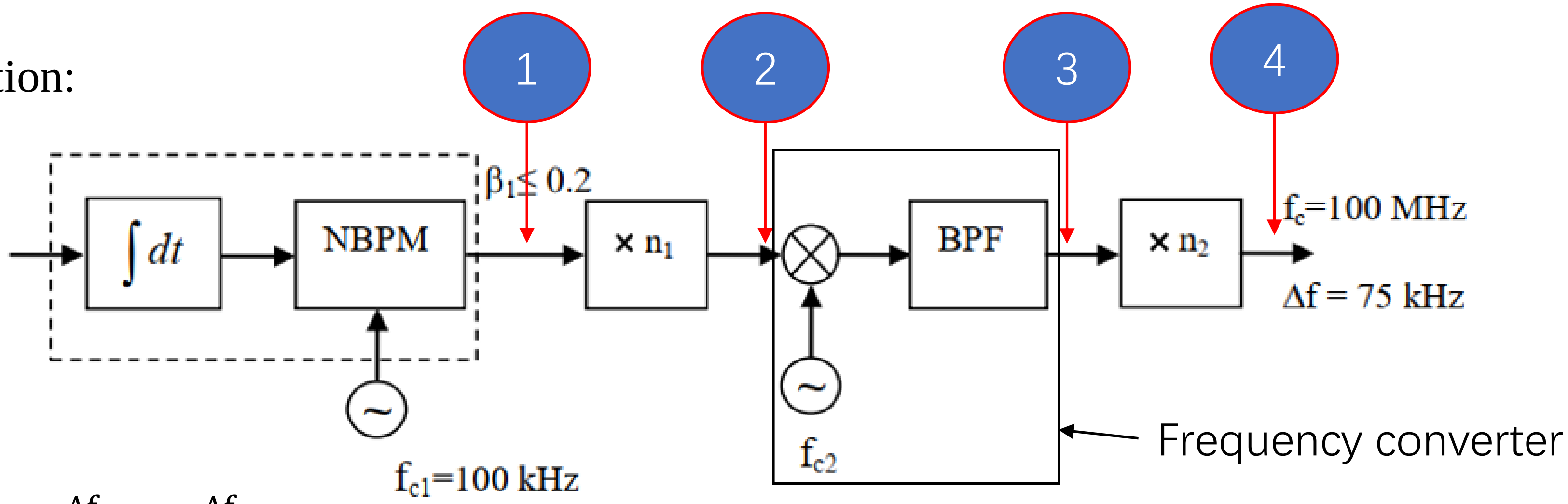
1. The indirect FM system shown below is used to transmit a single-tone signal with frequency of 100 Hz. The desired FM signal at the transmitter output has carrier frequency of 100 MHz and maximum frequency deviation of 75 kHz. The modulation index of the narrowband frequency modulator, β_1, is restricted to a maximum value of 0.2 in order to keep distortion level low. Determine the suitable values of n_1, n_2 and f_{c2}.



Solution:



1： $\beta_1 = \frac{\Delta f_1}{f_m} = \frac{\Delta f_1}{100Hz} \le 0.2 \Rightarrow \Delta f_1 \le 20Hz$

$fc_1 = 100kHz$

2: $f = n_1 fc_1$

$\Delta f = n_1 \Delta f_1$

3: $fc_3 = f - fc_2$

$\Delta f_3 = \Delta f$

混频后会有 $f + fc_2$ 和$f - fc_2$ 两个频率成分。 保留低频成分即对应（ $f - fc_2$),低频信号相较高频信号容易处理。

4: $f_c = n_2 fc_3 = n_2 n_1 fc_1 - n_2 fc_2 = 100MHz$

$\Delta f = n_2 \Delta f_3 = n_2 n_1 \Delta f_1 = 75kHz$

One example:

suppose $\Delta f_1 = 10$Hz

Then

$n_2 n_1 = 7500$

7500*100kHz- $n_2 fc_2$ = 100MHz => $n_2 fc_2$ = 650MHz

$n_1$100KHz > fc_2

==> we can let n_1=75 n_2=100 fc_2 =6.5MHz

2. Design a wideband FM modulator that uses the indirect method for generating a WBFM signal with the carrier frequency of 50 MHz. The peak frequency deviation of the FM modulator is 50 KHz when modulated by a single tone signal of frequency 10 kHz. Show a complete block diagram of your design, indicating all necessary frequencies and peak frequency deviations of the signals at various points of the modulator. Assume that no frequency converter is used in the system and the modulation index of the involved NBFM modulator is 0.1.

Solution:

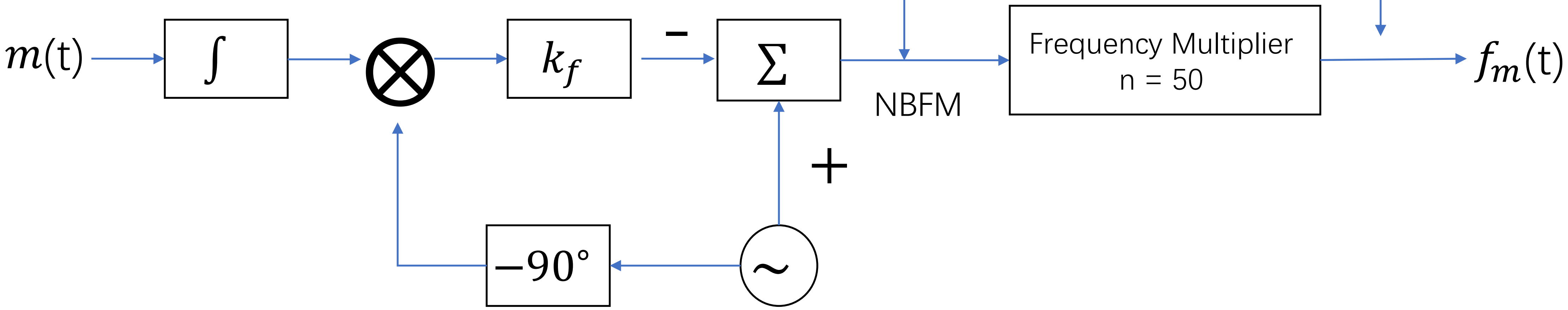
Using $f_{NBFM} = A_c \cos(w_c t) + A_c \sin(w_c t)\, \beta sin(w_m t)$

$\beta_1 = \frac{\Delta f_1}{f_m} = 0.1 \Rightarrow \Delta f_1 = 1KHz$

f_1

$\Delta f = n\Delta f_1 = 50KHz \Rightarrow n=50$

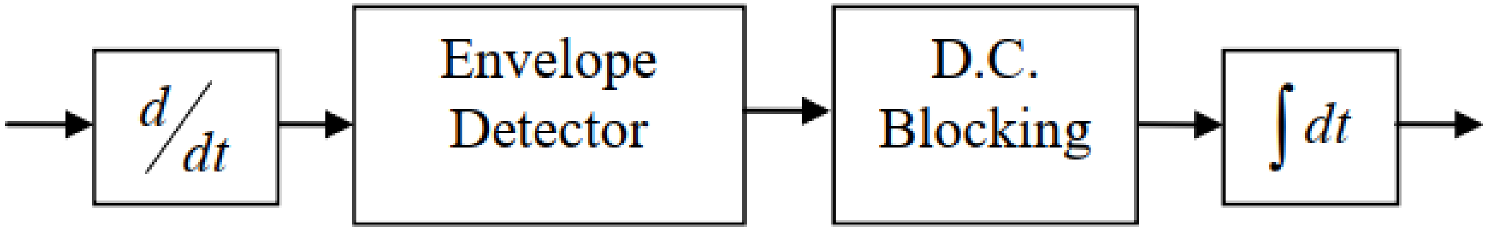
$f = nf_1 = 50MHz \Rightarrow f_1 = 1MHz$

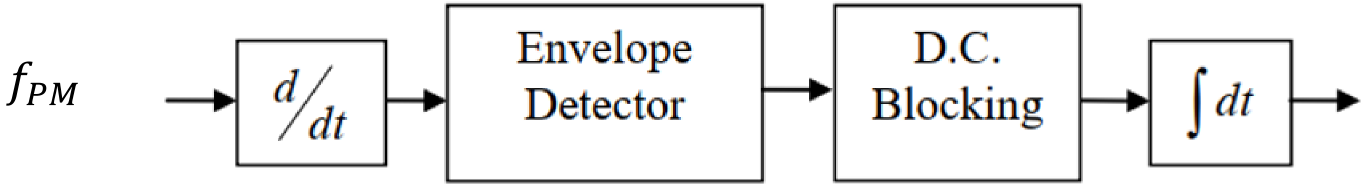


$Acos(2\pi f_1 t)$

$f_1 = 1MHz$

3. A message signal $m(t) = 0.5\cos(2000\pi t)$ phase modulates a carrier signal $f(t)=10\cos(2\pi\, 10^6 t)$ with modulation phase sensitivity $k_p = 5.6$ rad/V. If the PM signal is demodulated using the demodulator shown below, show the demodulating process in which signal $m(t)$ is recovered.





Solution:

$$\beta_p = k_p A_m = 5.6 \times 0.5 = 2.8$$

$$\omega_c = 2\pi \times 10^6, \quad \omega_m = 2\pi \times 10^3, \quad A_c = 10$$

$$f_{PM}(t) = A_c \cos(\omega_c t + \beta_p \cos \omega_m t)$$

$$\frac{d[f_{PM}(t)]}{dt} = -A_c[\omega_c - \beta_p \omega_m \sin \omega_m t]\sin(\omega_c t + \beta_p \cos \omega_m t)$$

The output of envelope detector: $-A_c[\omega_c - \beta_p \omega_m \sin \omega_m t] \quad = -A_c w_c + A_c \beta_p w_m sin w_m t$

The output of D.C. blocking: $A_c \beta_p \omega_m \sin \omega_m t$

The output of integrator: $A_c \beta_p \int \omega_m \sin \omega_m t dt$

$$= -A_c \beta_p \cos \omega_m t$$

$$= -28 \cos 2\pi \times 10^3 t$$