Problem 3.3

$$x_c = A_c[1 + am_n(t)]\cos(\omega_c t)$$

Demodulate with $2\cos(\omega_c t) + \theta(t)$

$$y = A_c[1 + am_n(t)]\cos(\omega_c t) \cdot \left[2\cos\left(\omega_c t + \theta(t)\right)\right]$$
$$= A_c[1 + am_n(t)](\cos(2\omega_c t) + \cos(\theta(t)))$$

After filtering out the high frequency part

$$y = [1 + am_n(t)](\cos(\theta(t)))$$

Coherent demodulation indicates that $\theta(t)$ is given, therefore, $m_n(t)$ can be recovered

Problem 3.13

a.

$$\mathrm{y(t)} = 4\mathrm{x(t)} + 2x^2(t) = 4(m(t) + \cos(\omega_c t)) + 2(m(t) + \cos(\omega_c t))^2$$
$$= 1 + 4\left(1 + m(t)\right)\cos(\omega_c t) + 2\cos(\omega_c t)^2$$
$$= 1 + 4m(t) + 2m^2(t) + 4\left(1 + m(t)\right)\cos(\omega_c t) + \cos(2\omega_c t)$$

b. using a bandpass filter to get m(t) at ω_c, if spectrum of m(t) is within frequency 0~W, then the BW of the filter is 2W

c.

$$\mathrm{g(t)} = 4\left(1 + m(t)\right)\cos(\omega_c t) = 4\left(1 + Mm_n(t)\right)\cos(\omega_c t)$$

modulation index = M = 0.1

Problem 3.15

$$x_c(t) = \frac{1}{2}A_c[2\cos(2\pi f_m t) + \cos(4\pi f_m t)]\cos(2\pi f_c t)$$
$$\pm \frac{1}{2}A_c[2\sin(2\pi f_m t) + \sin(4\pi f_m t)]\sin(2\pi f_c t)$$

$$x_c(t) = [2\cos(2\pi(f_m + f_c)t) + \cos(2\pi(2f_m + f_c)t) + 2\cos(2\pi(f_m - f_c)t)$$
$$+ \cos(2\pi(2f_m - f_c)t)] \pm [-2\cos(2\pi(f_m + f_c)t)$$
$$- \cos(2\pi(2f_m + f_c)t) + 2\cos(2\pi(f_m - f_c)t) + \cos(2\pi(2f_m - f_c)t)]$$

When the '±' sign is +

$$x_c(t) = [2\cos(2\pi(f_m - f_c)t) + \cos(2\pi(2f_m - f_c)t)]$$
$$+ [2\cos(2\pi(f_m - f_c)t) + \cos(2\pi(2f_m - f_c)t)]$$
$$= 2[2\cos(2\pi(f_m - f_c)t) + \cos(2\pi(2f_m - f_c)t)]$$

Lower subband SSB

When the '±' sign is -

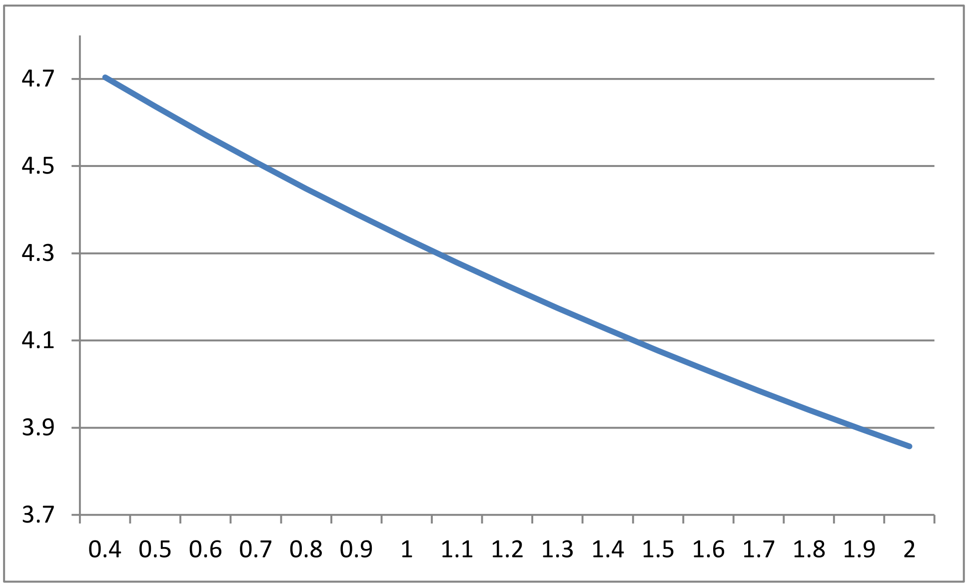
$$x_c(t) = [2\cos(2\pi(f_m + f_c)t) + \cos(2\pi(2f_m + f_c)t)]$$
$$- [-2\cos(2\pi(f_m + f_c)t) - \cos(2\pi(2f_m + f_c)t)]$$
$$= 2[2\cos(2\pi(f_m + f_c)t) + \cos(2\pi(2f_m + f_c)t)]$$

Upper subband SSB

Problem 3.18

$f_{LO} = f_i + f_{IF}$

ratio = $(25 + f_{IF}) / (5 + f_{IF})$

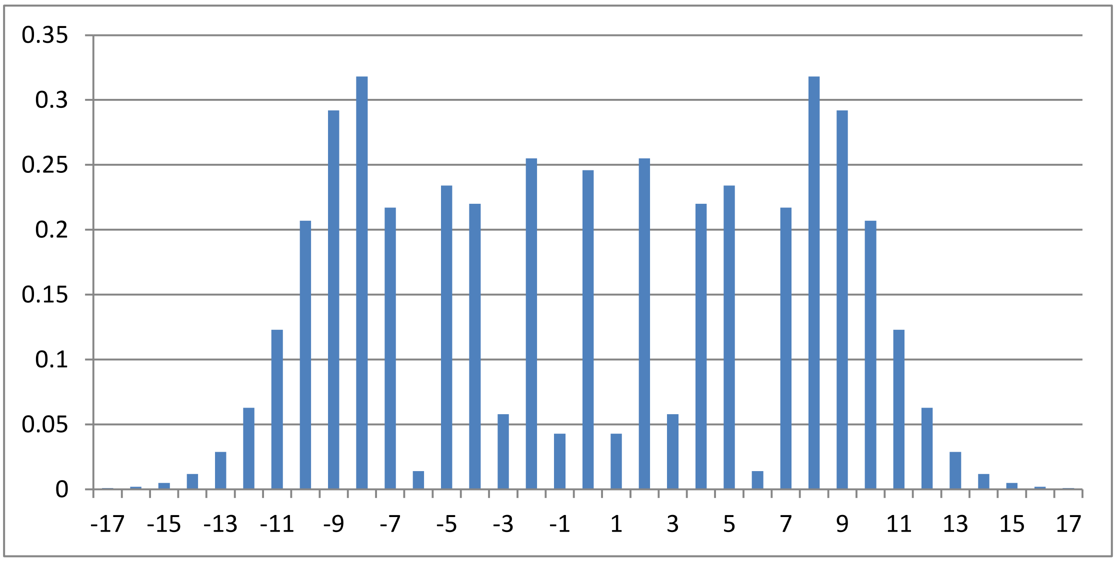


Problem 3.24

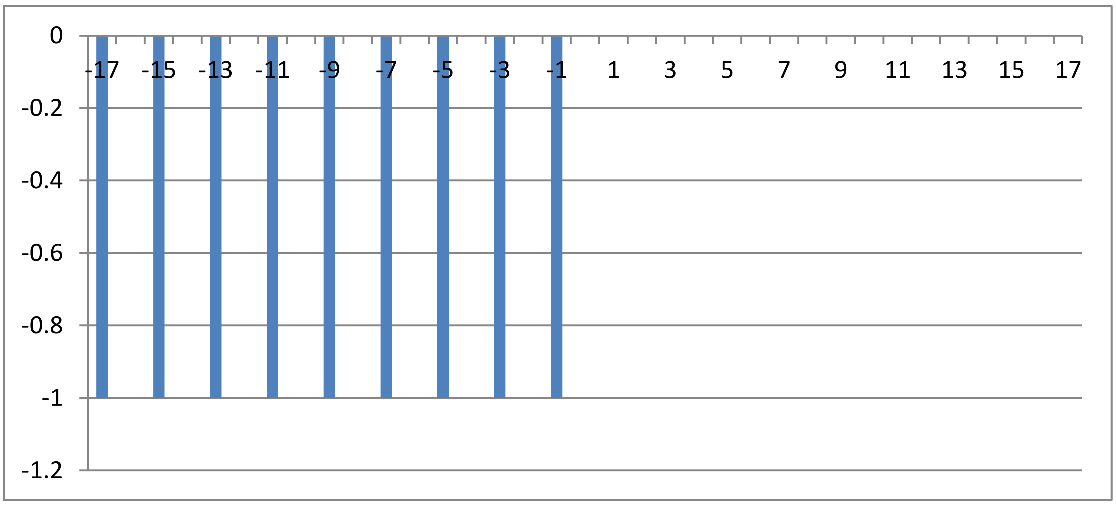
$$x_c(\mathrm{t}) = Re\{A_c e^{j(2\pi f_c t+\beta \sin(2\pi f_m t))}\} = \mathrm{Re}\left\{A_c\left(\sum_{n=-\infty}^{\infty} J_n(\beta)e^{j2\pi n f_m t}\right)e^{j2\pi f_c t}\right\}$$

$$= A_c \sum_{n=-\infty}^{\infty} J_n(\beta)\cos(2\pi n(nf_m + f_c)t)$$

Amplitude: x-axis (n) for $f_c - nf_m$; y-axis is in unit of A_c



Phase: x-axis (n) for $f_c - nf_m$; y-axis is in unit of π



Problem 3.31

a.

$$x_c(\mathrm{t}) = A_c\cos(2\pi f_c t + 2\pi f_d \int_{t} m(\alpha)d\alpha)$$

$$\phi(\mathrm{t}) = 2\pi f_d \int_{t_0}^{t} m(\alpha)d\alpha + \phi_0 = 2\pi \cdot 14 \int_0^t 5\cos\big(2\pi(10\alpha)\big)\, d\alpha$$

$$= \frac{2\pi \cdot 14 \cdot 5}{2\pi \cdot 10}\sin\big(2\pi(10t)\big)$$

modulation index = 7

b.

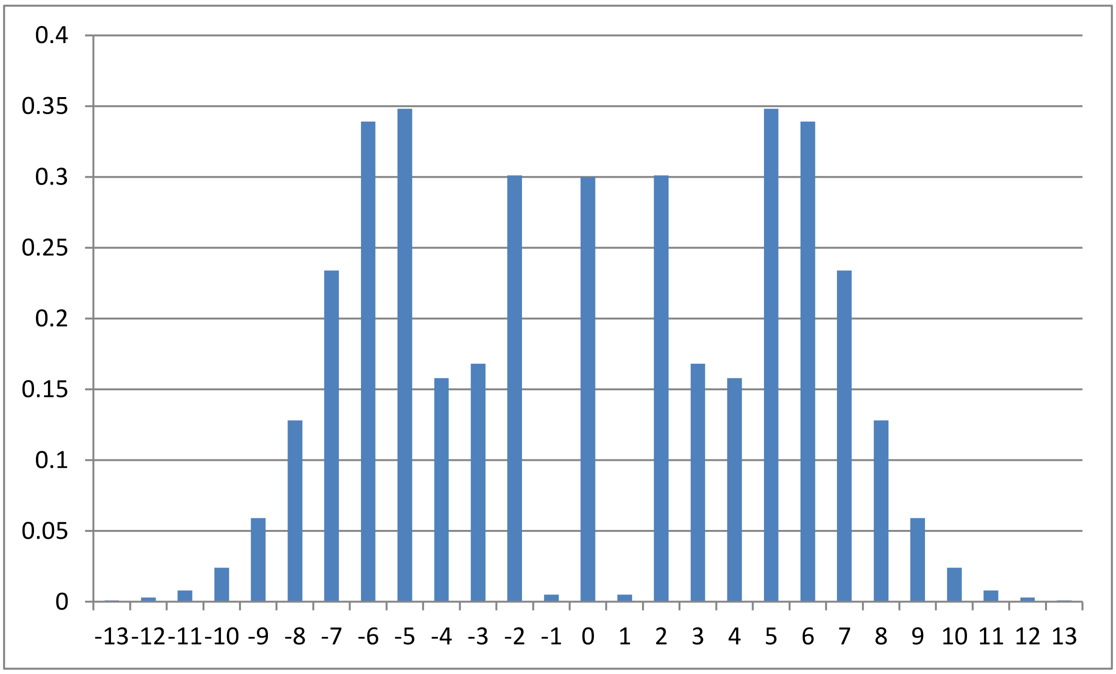
$$x_c(\mathrm{t}) = A_c\cos(2\pi f_c t + \beta\sin(2\pi f_m t))$$

Where β = 7, f_c = 2000, f_m = 10

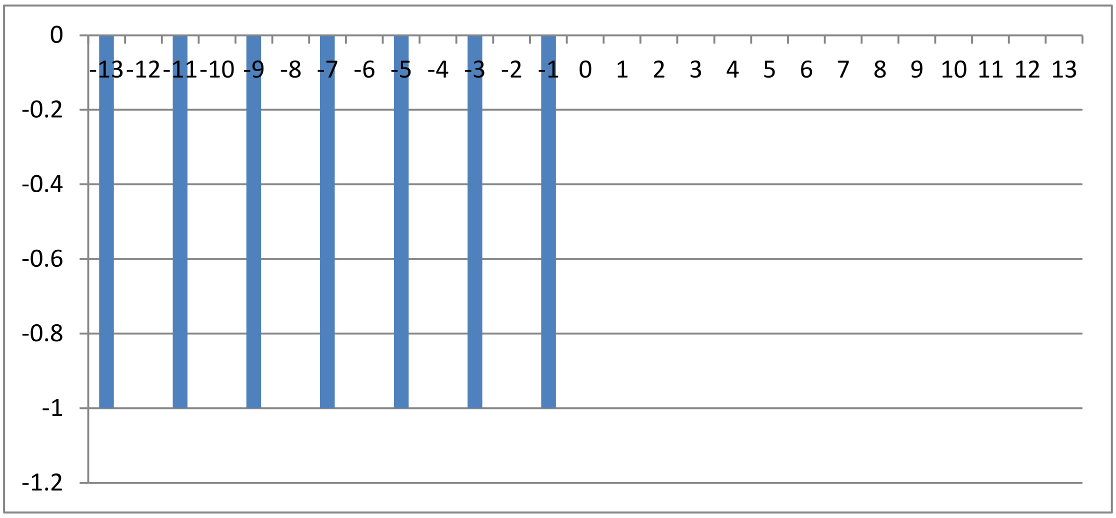
$$x_c(\mathrm{t}) = Re\{A_c e^{j(2\pi f_c t + \beta\sin(2\pi f_m t))}\} = \mathrm{Re}\left\{A_c\left(\sum_{n=-\infty}^{\infty} J_n(\beta)e^{j2\pi n f_m t}\right)e^{j2\pi f_c t}\right\}$$

$$= A_c \sum_{n=-\infty}^{\infty} J_n(\beta)\cos(2\pi n(nf_m + f_c)t)$$

Amplitude: x-axis (n) for $f_c – nf_m$; y-axis is in unit of A_c



Phase: x-axis (n) for $f_c – nf_m$; y-axis is in unit of π



c. β is not << 1, NOT narrow band FM

d.

$$\phi(t) = k_p m(t) = k_p \cdot 5\cos(2\pi(10t))$$

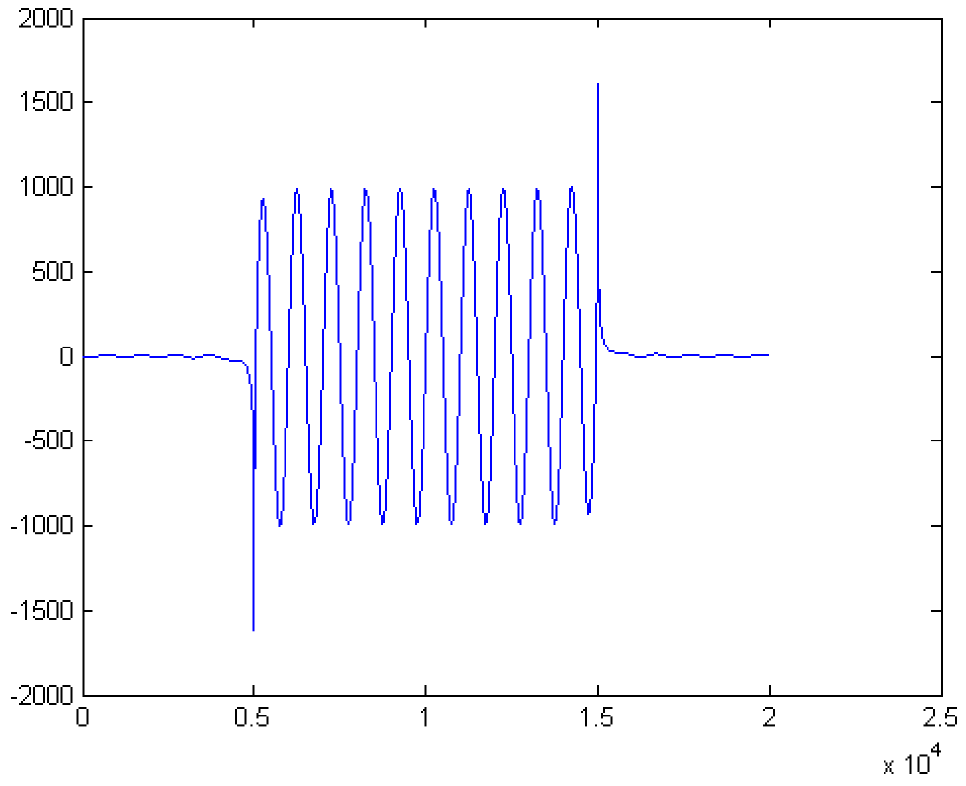
modulation index = 5 · k_p = 7, k_p = 1.4

7.

Matlab code:

```
Ts = 0.001;
t = -5:Ts:5;
h = zeros(size(t));
non_zero = find(t ~= 0;
h(non_zero) = 1 ./ (pi * t(non_zero));
x = cos(2*pi.*t);
for (n = 1: 2*length(t))
   y(n) = 0;
   for (m = 1 : length(t))
      if ((n – m) < length(t) & (n – m) > 0)
         y(n) = y(n) + x(n – m) * h(m);
      end
   end
end
```

output:

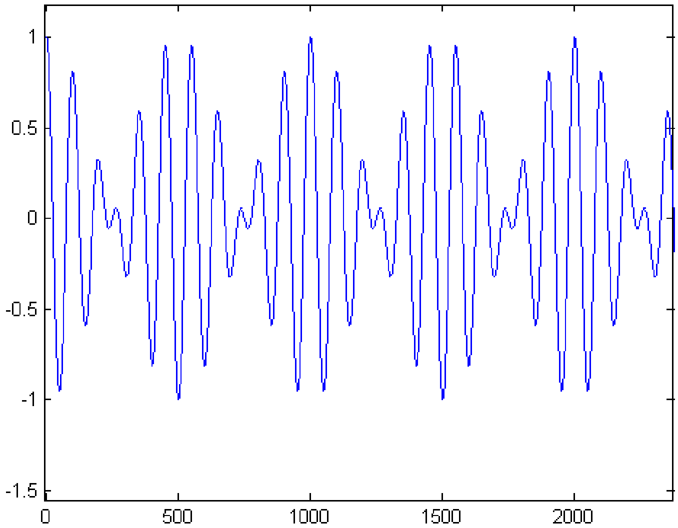


8.

```
Ts = 0.001;
t = -5:Ts:5;
m = cos (2*pi*10.*t);
% modulation
xc = m * cos(2*pi.*t)

% demodulation
yd = xc * cos(2*pi*10.*t);
```

output of modulation



Output of demodulation data yd