Communication Theory

Assignment - 2

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- 2022102048

1) An AM (DSB-FC)

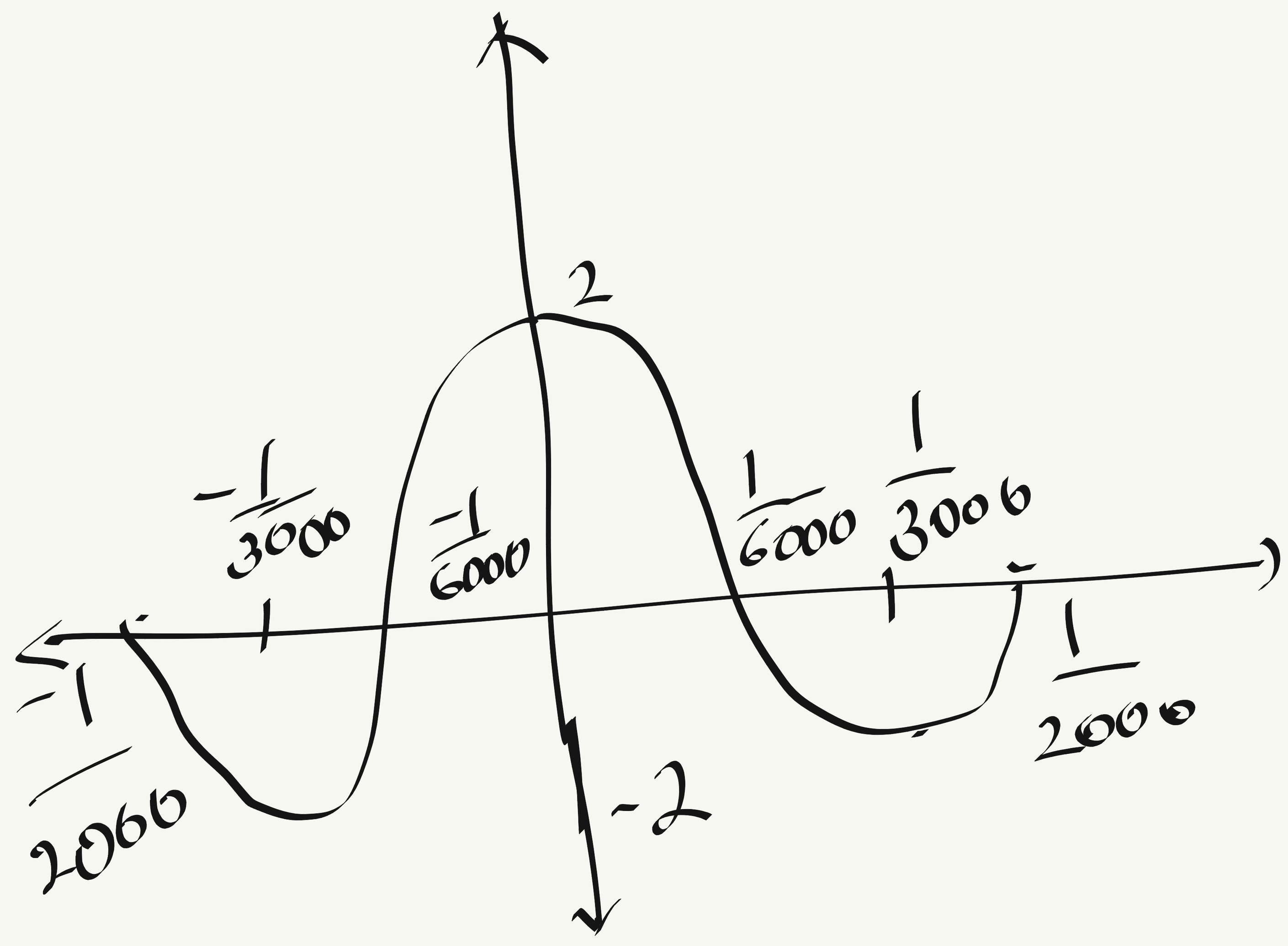
$$u(t) = [20 + 2\cos(3000\pi t) + 10\cos(6000\pi t)]\cos(2\pi f_c t)$$

$$f_c = 10^5 Hz$$

a) Time domain and frequency domain representation of $u(t)$

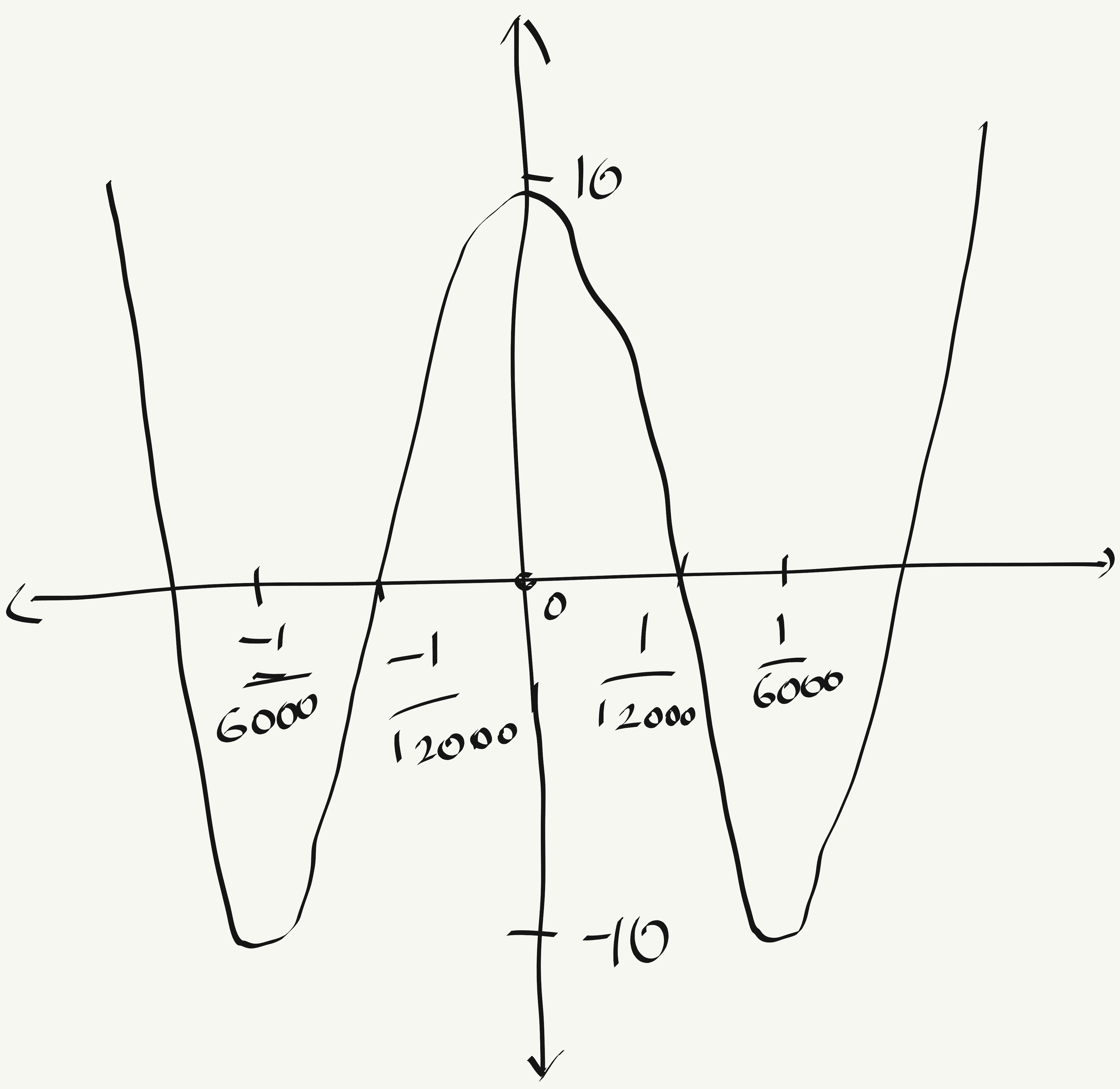
For time domain representation of signals we first look at the graphs individually and then add these graphs and get an approximate function seeing the peaks and zeros.

$2\cos(3000\pi t)$

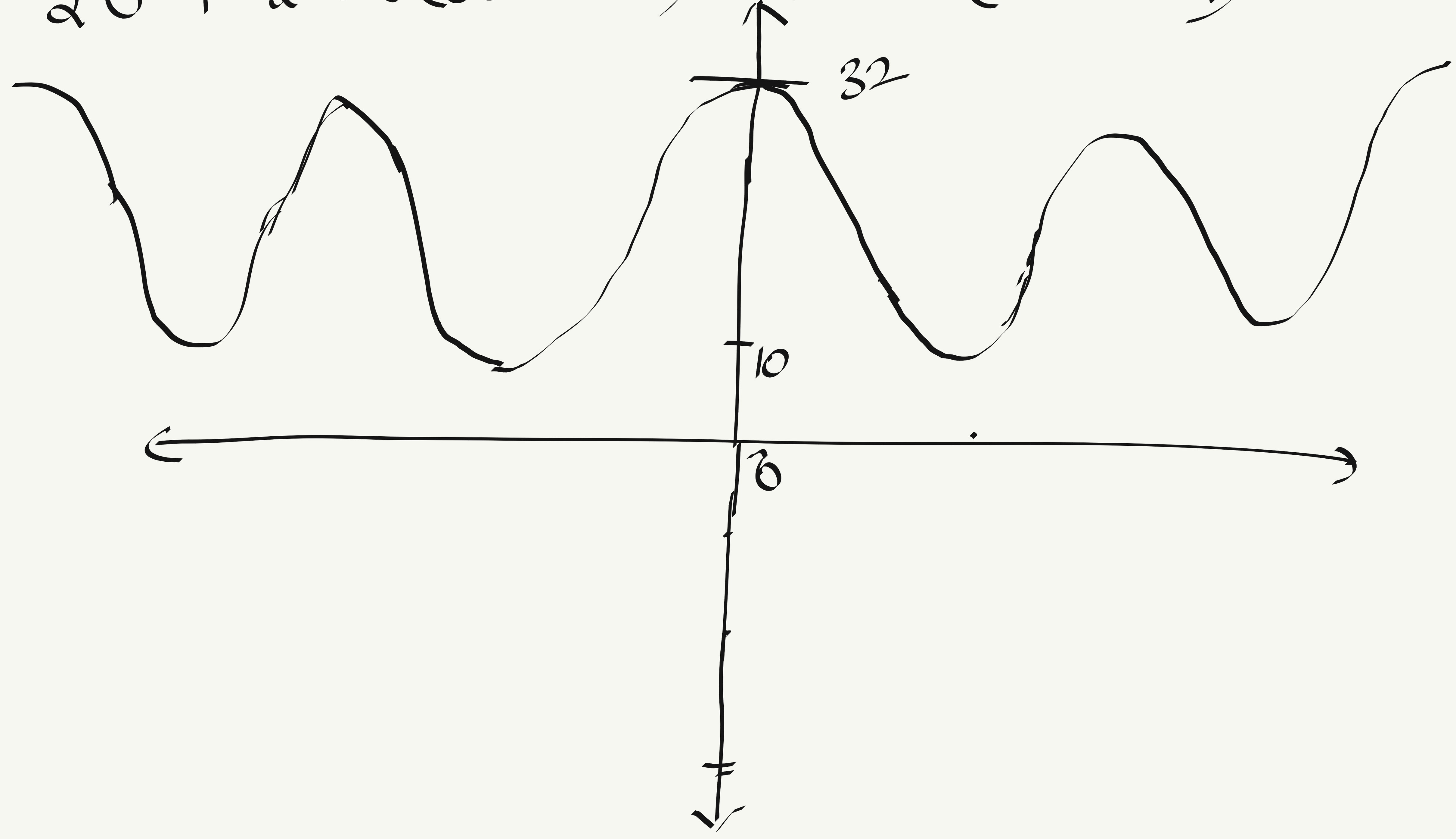


+

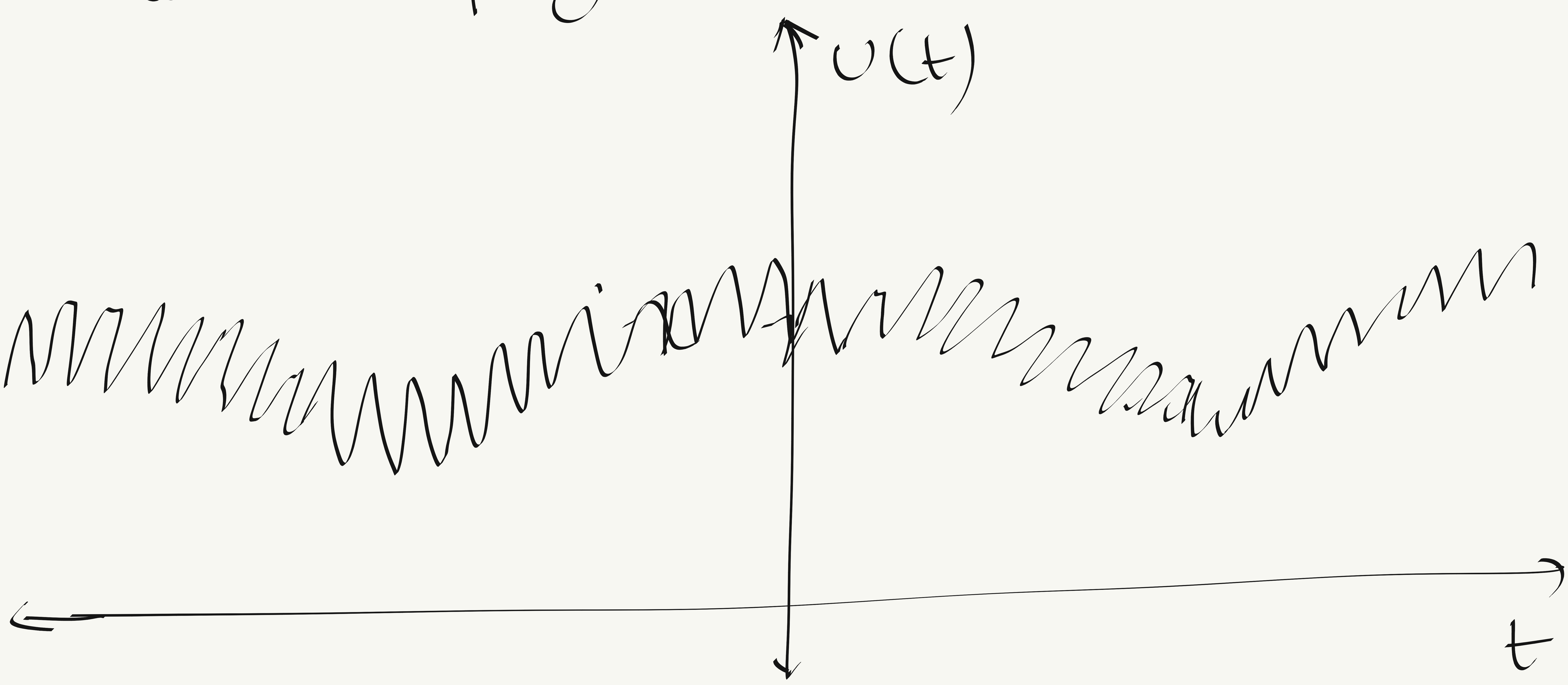
$10\cos(6000\pi t)$



$20 + 2\cos(3000\pi t) + 10\cos(6000\pi t)$



Now keeping the carrier frequency



For frequency domain

Frequency domain for a $\cos(2\pi f_x t)$ is

$$C(f) = \frac{1}{2}\left[\delta(f - f_x) + \delta(f + f_x)\right]$$

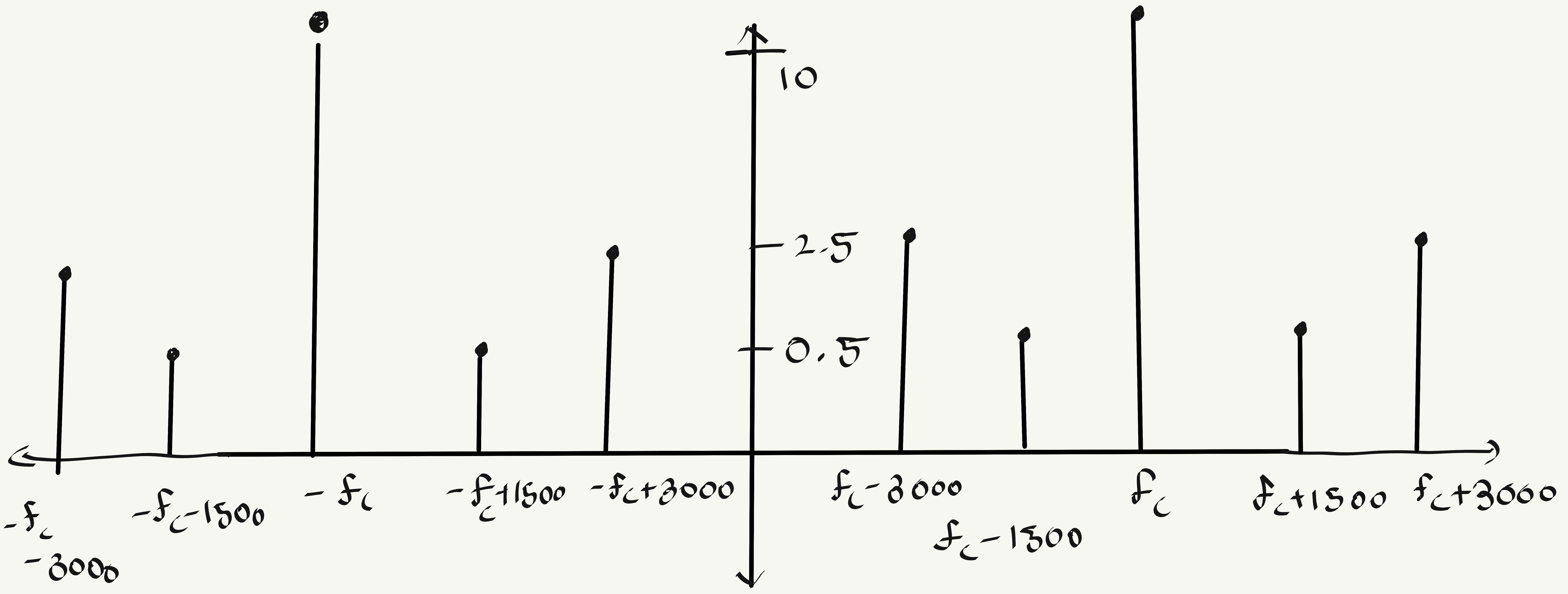
Convoluting them individually

$$U(t) = X(f) * C(f)$$

$$= 20 \times \frac{1}{2}\left[\delta(f - f_c) + \delta(f + f_c)\right] + \frac{1}{2}\left[\delta(f - 1500 - f_c)\right.$$

$$+ \delta(f+1500-f_c) + \delta(f-1500+f_c) + \delta(f+1500+f_c)\Big]$$

$$+\frac{5}{2}\Big(\delta(f-3000-f_c)+\delta(f+3000-f_c)+\delta(f-3000+f_c)+\delta(f+3000+f_c)\Big)$$



b) The power in each of the frequency components

$$P_c = P(f_c) = P(-f_c) = \frac{A^2}{2} = \frac{400}{2} = 200\,W$$

$$P_{SB1} = \frac{\mu_1^2}{4} \times A_c^2 = \frac{1}{4}\times\left(\frac{2}{20}\right)^2\times(20)^2 = 1\,W$$

$$P(f_c-3000) = P(-f_c+3000) = P(-f_c-3000) = P(f_c+3000) = \frac{1}{4}\,W$$

$$P_{SB2} = \frac{\mu_2^2}{4}\times A_c^2 = \left(\frac{10}{20}\right)^2\times\frac{1}{4}\times 20^2 = 25\,W$$

$$P(f_c-1500) = P(-f_c-1500) = P(-f_c+1500) = P(f_c+1500)$$

$$= \frac{25}{4}\,W = 6.25\,W$$

c) the modulation index of

$$u(t) = 20\big(1+\overset{A_1}{0.1}\cos(3000\pi t) + \overset{A_2}{0.5}\cos(6000\pi t)\big)\cos(2\pi f_c t)$$

$$\mu_t = \sqrt{\mu_1^2+\mu_2^2} = \sqrt{(0.1)^2+(0.5)^2}$$

$$= \sqrt{0.26} \approx 0.51$$

d) Power in Side bands

= Total power in all side bands

$$= \frac{25}{4}\times 4 + \frac{1}{4}\times 4$$

= 26W

Total power = $P_T + P_{SB}$

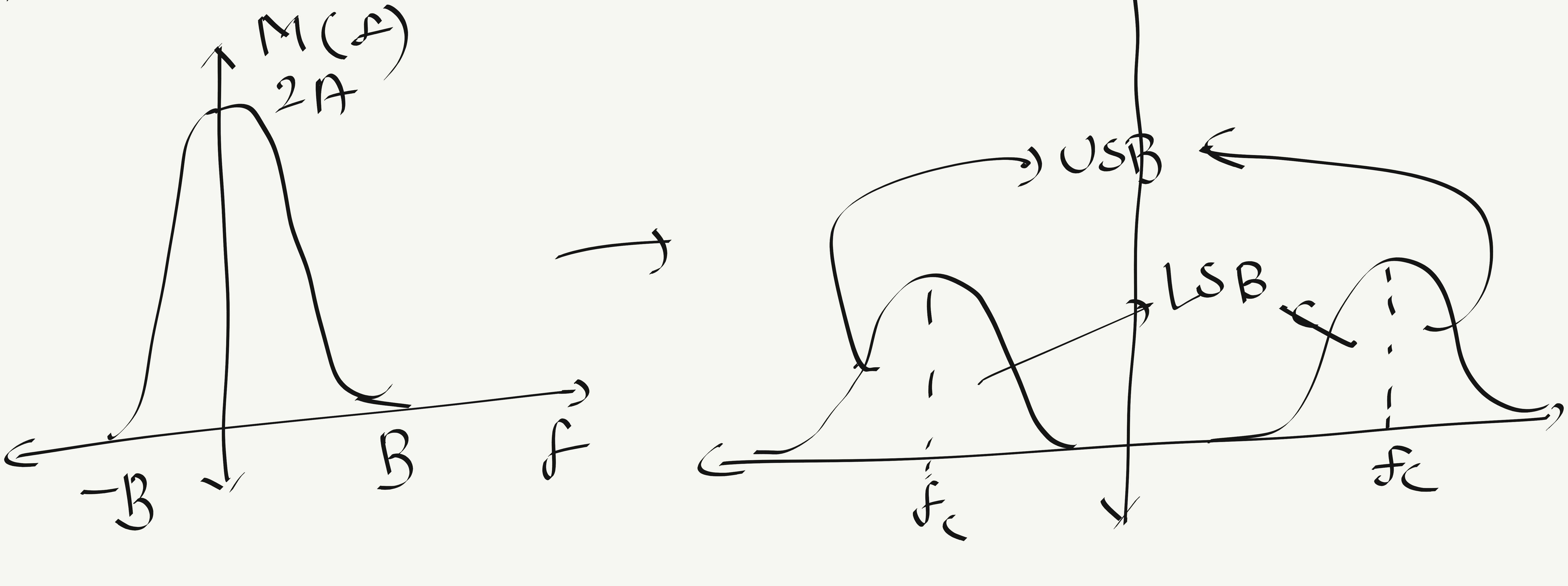
= 200 + 26

= 226

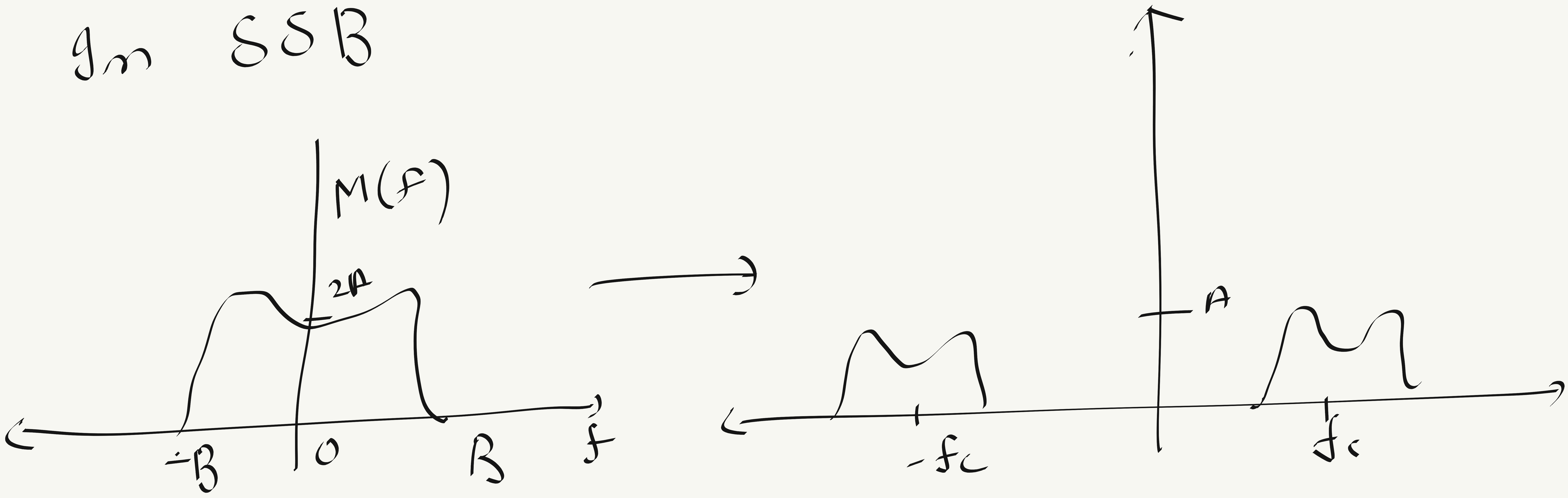
2) Amplitude modulation produces an output signal the bandwidth of which is twice the maximum frequency of the original of the baseband signal. Single side band modulation avoids the bandwidth increase and the power wasted on a carrier.

In sketch

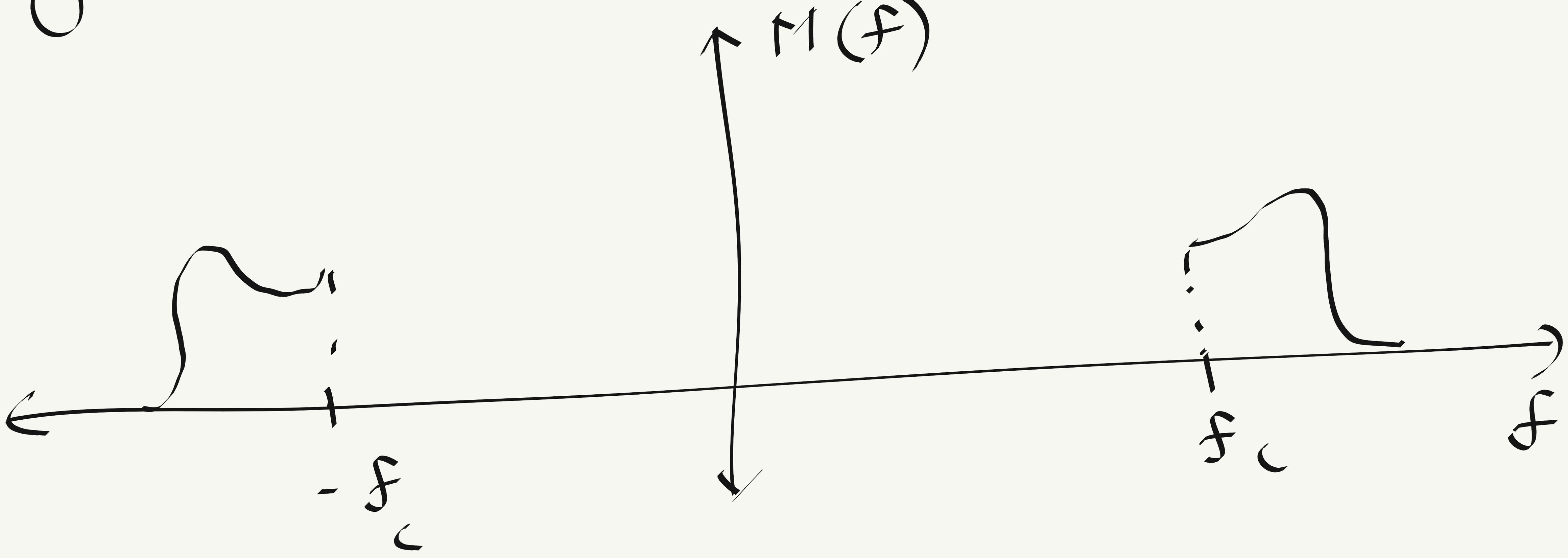
For DSB

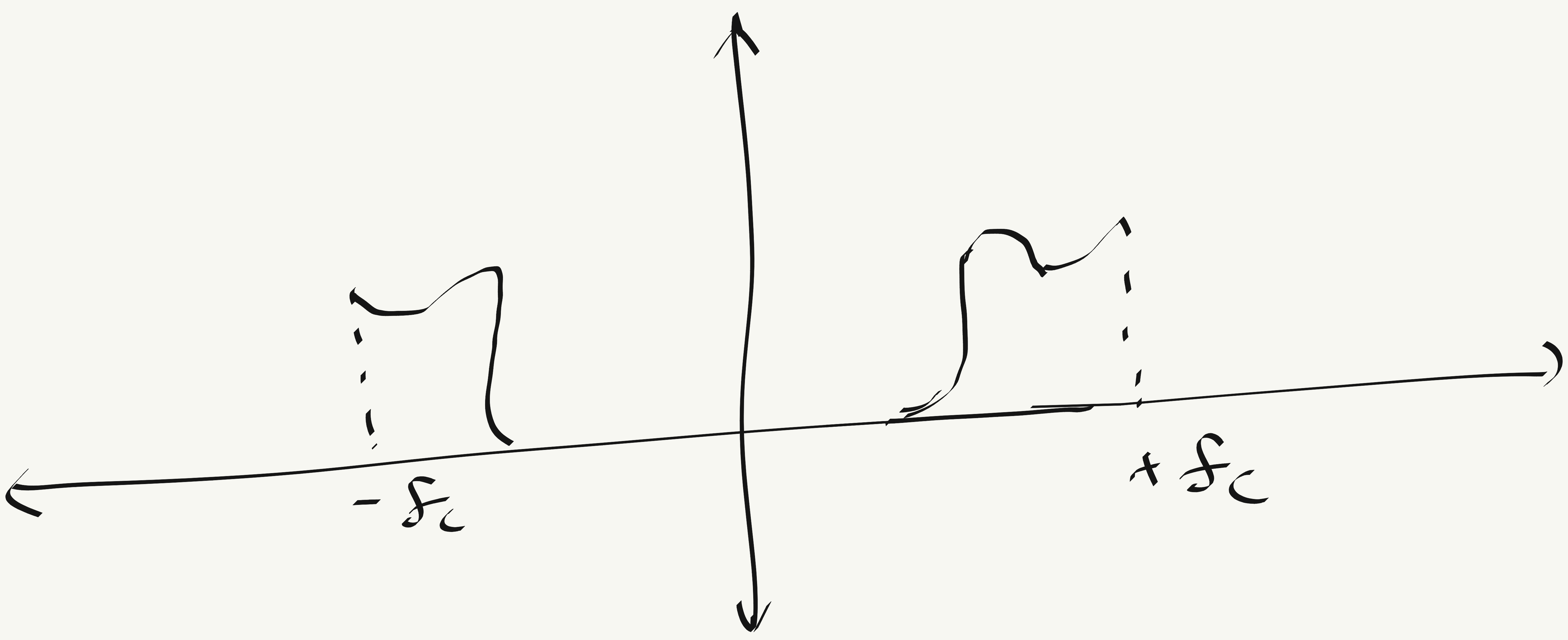


In SSB

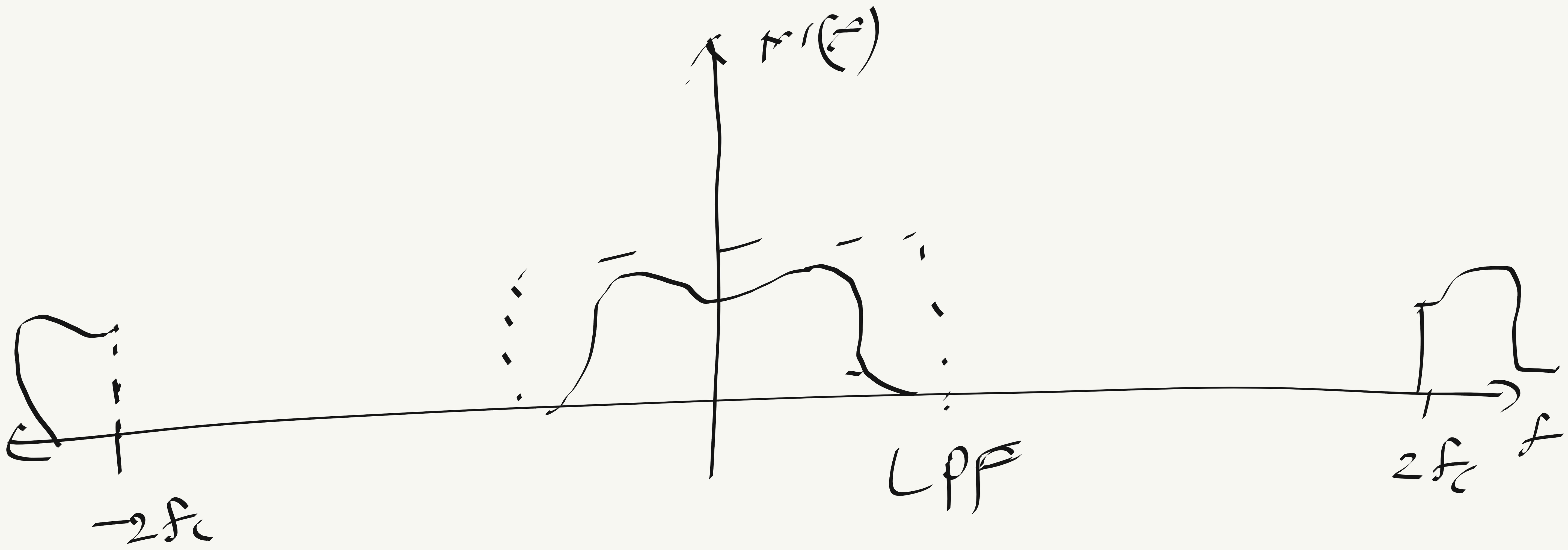


Then it is converted to either only LSB or only USB





Then After Demodulation



The Hilbert function

$$x(t) \rightarrow \mathcal{H}\{x(t)\}$$

$$x_h(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{x(\alpha)}{t-\alpha}\, d\alpha$$

This looks like the convolution of two signals

$$x_h(t) = \int_{-\infty}^{\infty} x(\alpha) \times \frac{1}{\pi(t-\alpha)}$$

$$x_h(t) \Rightarrow x(t) * \frac{1}{\pi(t)}$$

$$F\left(x_h(t)\right) \Longleftrightarrow F\left[x(t) * \frac{1}{\pi(t)}\right]$$

From the property

$$F\left[g_1(t) * g_2(t)\right] \Longleftrightarrow G_1(f)\, G_2(f)$$

$$F\left[x_h(t)\right] = F\left[x(t)\right]\, F\left[\frac{1}{\pi t}\right]$$

From the duality property $\quad g(t) \Longleftrightarrow G(f)$

$G(t) \Longleftrightarrow g(-f)$

$$F\left[\operatorname{sgn}(t)\right] = \frac{1}{j\pi F}$$

$$F\left[\frac{1}{j\pi t}\right] = \operatorname{Sgn}[-f]$$

Signom is a add function

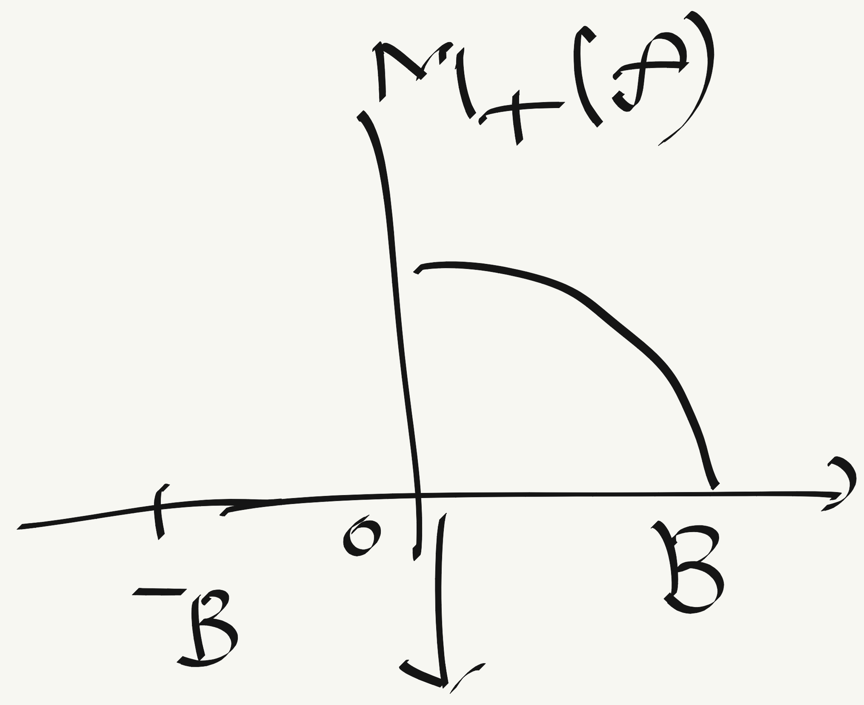
$$F\left[\frac{1}{\pi t}\right] = -j\operatorname{Sgn}[f]$$

$$F[x_h(t)] = X(f)\left[-j\operatorname{Sgn}(f)\right]$$

$$F[x_h(t)] = \begin{cases} -jX(f) & ; f>0 \\ jX(f) & ; f<0 \end{cases}$$

$$= \begin{cases} X(f)e^{-j\frac{\pi}{2}} & f>0 \\ X(f)e^{j\frac{\pi}{2}} & ; f<0 \end{cases}$$

Hence Hilbert transform is ideal phase Shifter which shifts the spectrum of every component by $\frac{\pi}{2}$



$$M_+(f) = M(f)\,U(f)$$

$$U(f) = \frac{1}{2}(1+\operatorname{Sgn}(f))$$

$$M_+(f) = M(f)\,\frac{1}{2}(1+\operatorname{Sgn}(f))$$

$$= \frac{1}{2}M(f) + \frac{1}{2}M(f)\operatorname{Sgn}(f)$$

$$= \frac{1}{2}M(f) + \underbrace{\frac{1}{2}M(f) \times \frac{-jSgn(f)}{-j}}_{\text{hilbert function}}$$

$$M_+(f) = \frac{1}{2}M(f) + j\frac{M_h(f)}{2}$$

Similarly $M_-(f) = \frac{1}{2}M(f) - j\frac{M_h(f)}{2}$

For upper Sideband Modulation

$$\phi_{USB}(f) = M^+(f-f_c) + M_-(f+f_c)$$

$$= \frac{1}{2}\left[M(f-f_c) + jM_h(f-f_c)\right] + \frac{j}{2}\left[M(f+f_c) - jM_h(f+f_c)\right]$$

$$\phi_{USB}(f) = \frac{1}{2}\left[M(f-f_c) + M(f+f_c)\right] - \frac{1}{2j}\left[M_h(f-f_c) - M_h(f+f_c)\right]$$

As we know $g(t)e^{j2\pi f_0 t} \Longleftrightarrow G(f-f_0)$

$$= m(t)\left[\frac{e^{j2\pi f_c t} + e^{-j2\pi f_c t}}{2}\right] + -m_h(t)\left(\frac{e^{j2\pi f_c t} - e^{-j2\pi f_c t}}{2j}\right)$$

$$\phi_{USB} = m(t)\cos(\omega_c t) - m_h(t)\sin(\omega_c t)$$

$$\phi_{LSB} = m(t)\cos(\omega_c t) + m_h(t)\sin(\omega_c t)$$

For Demodulation :-

$\phi_{USB} * 2\cos(2\pi f_c t)$ is sent through a LPF

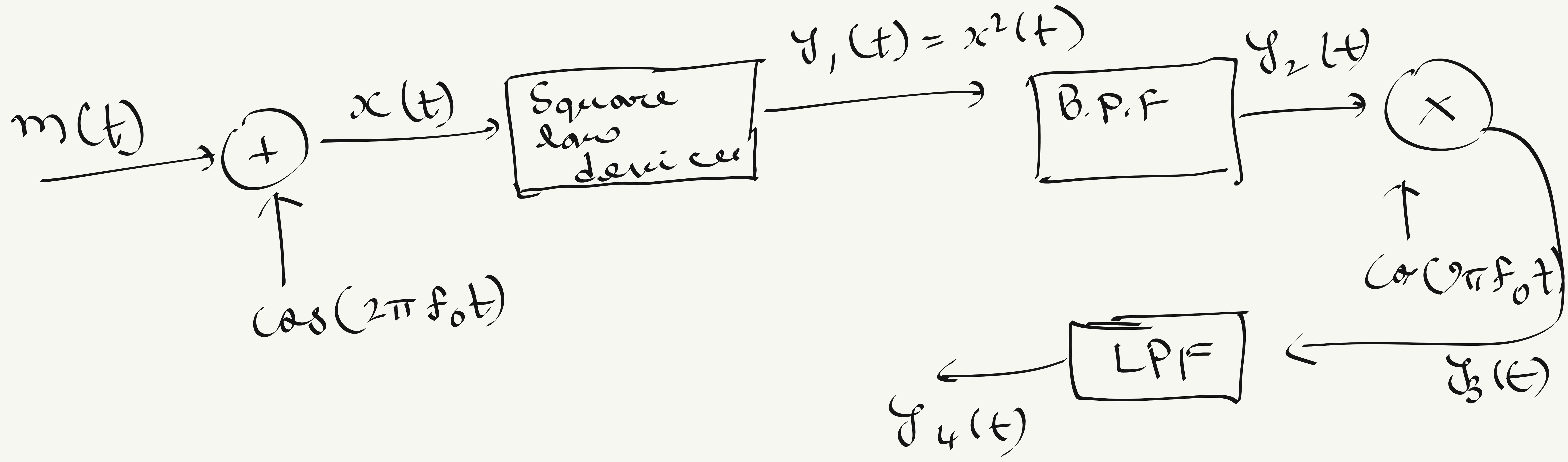
$$m(t)\cos(\omega_c t)\, 2\cos(\omega_c t) - 2 m_h(t)\sin(\omega_c t)\cos(\omega_c t)$$

$$= m(t)\left[1+\cos(2\omega_c t)\right] - m_h(t)\sin(2\omega_c t)$$

$$= m(t) + \left[m(t)\left(\cos(2\omega_c t) - m_h(t)\sin(2\omega_c t)\right]\right.$$

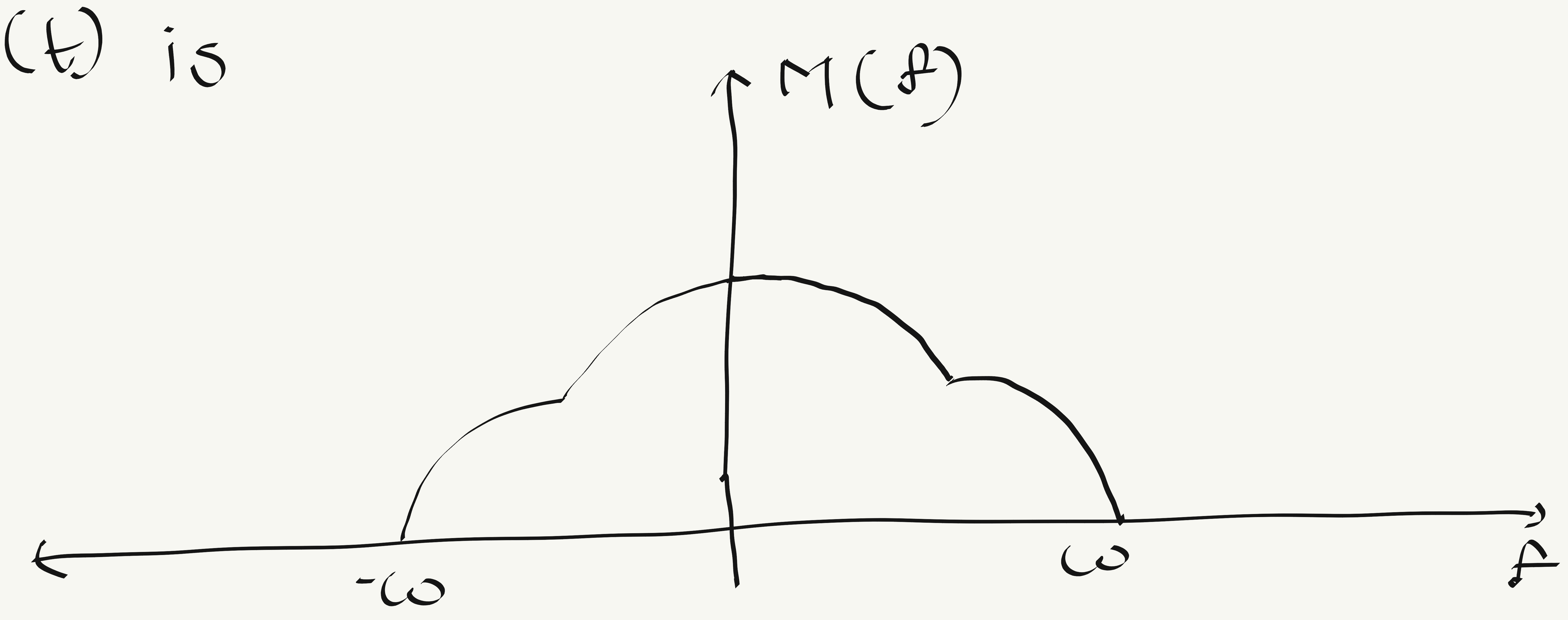
Passing this through a LPF gives back $m(t)$.

3) Bandpass filter has bandwidth $2W$ centered at f_0 and low pass filter has BW W.



Plot $x(t)$, $y_1(t)$, $y_2(t)$, $y_3(t)$ and $y_4(t)$

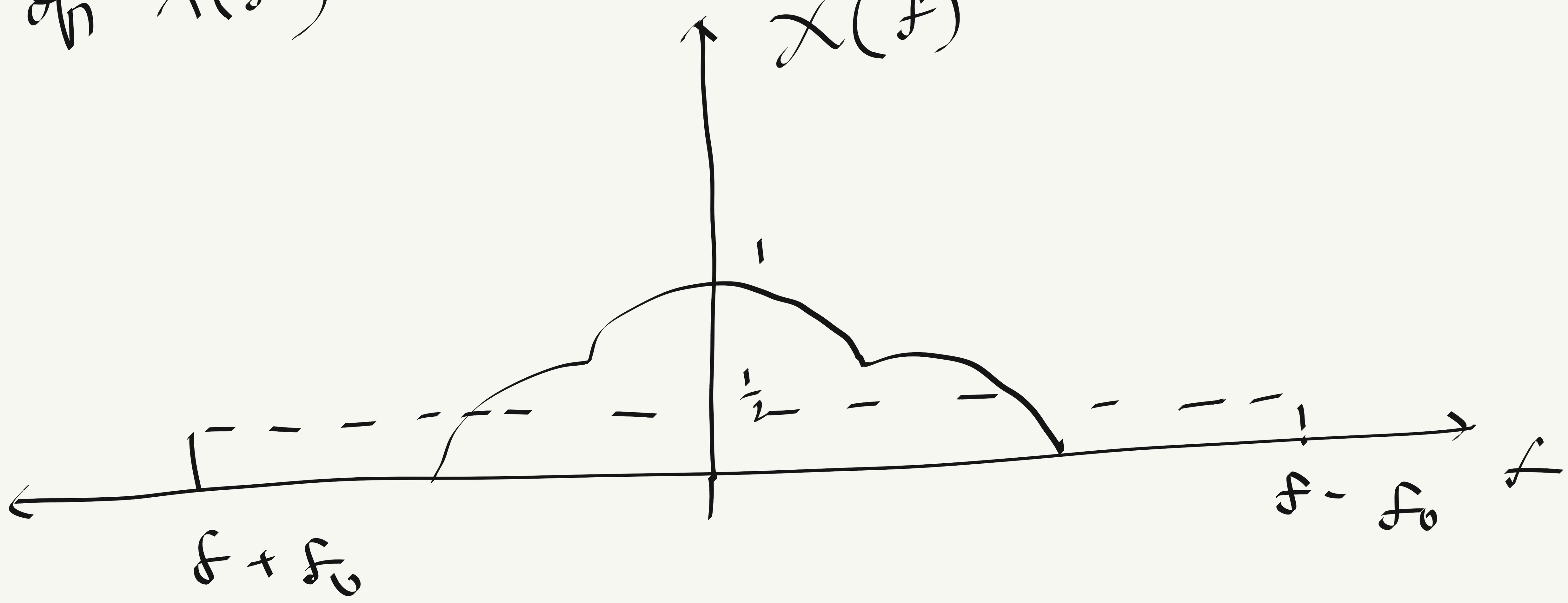
$m(t)$ is



$$x(t) = m(t) + \cos(2\pi f_0 t)$$

$$X(f) = M(f) + \frac{1}{2}\left[\delta(f-f_0) + \delta(f+f_0)\right]$$

Plot of $X(f)$



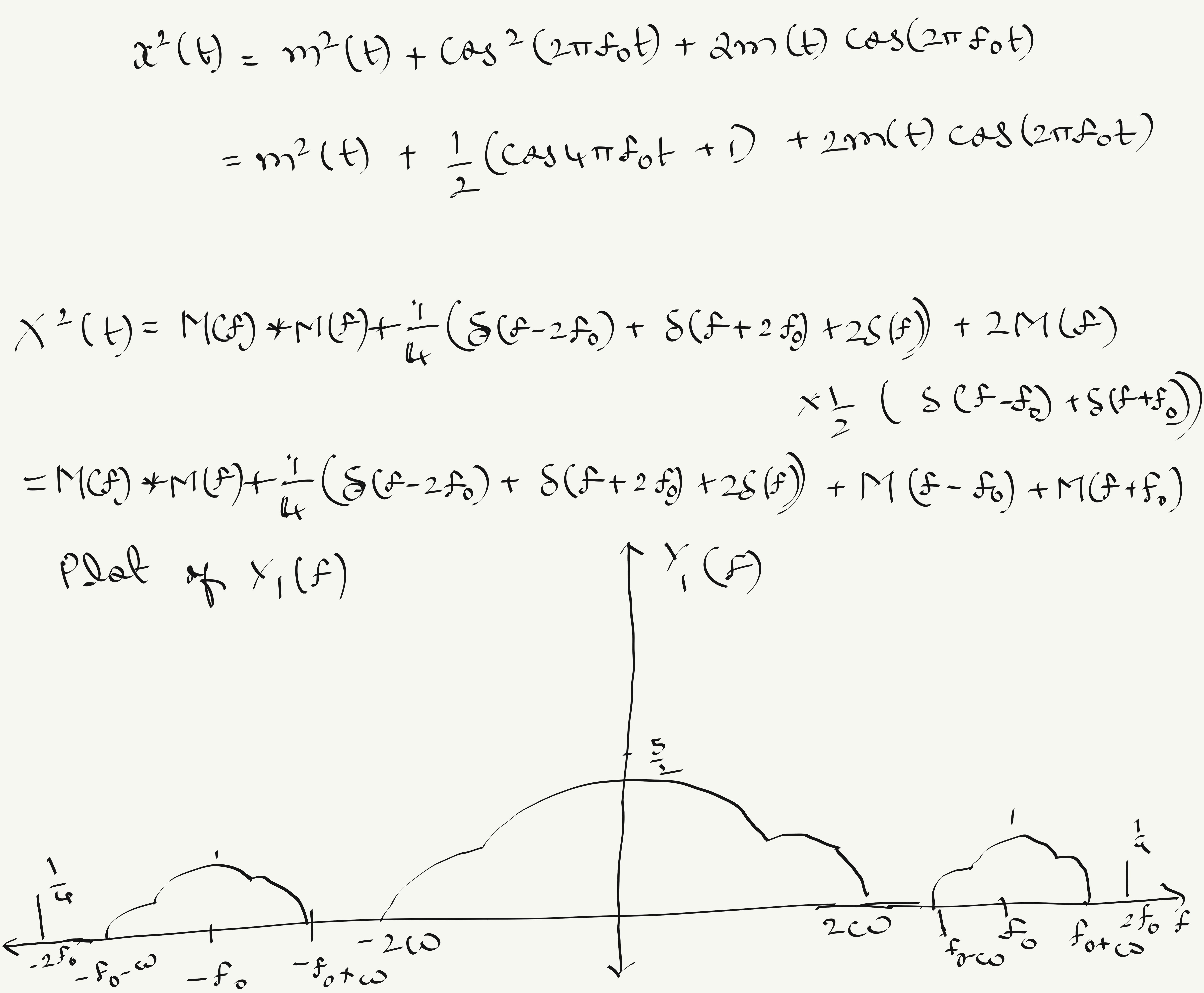
$$x^2(t) = m^2(t) + \cos^2(2\pi f_0 t) + 2m(t)\cos(2\pi f_0 t)$$

$$= m^2(t) + \frac{1}{2}(\cos 4\pi f_0 t + 1) + 2m(t)\cos(2\pi f_0 t)$$

$$X^2(t) = M(f) * M(f) + \frac{1}{4}\left(\delta(f-2f_0) + \delta(f+2f_0) + 2\delta(f)\right) + 2M(f) \times \frac{1}{2}\left(\delta(f-f_0) + \delta(f+f_0)\right)$$

$$= M(f) * M(f) + \frac{1}{4}\left(\delta(f-2f_0) + \delta(f+2f_0) + 2\delta(f)\right) + M(f-f_0) + M(f+f_0)$$

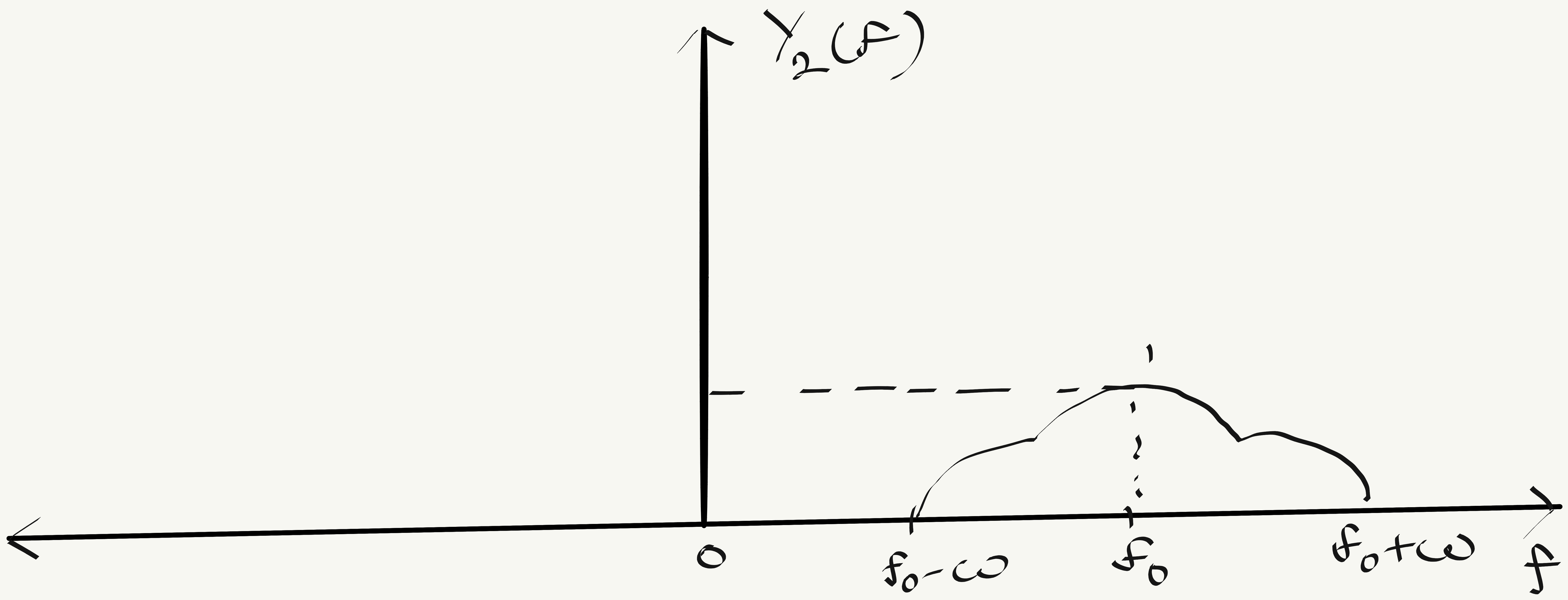
Plot of $Y_1(f)$



This is then sent into a Band pass filter centered at f_0

$Y_2(f)$ then only contains the side band at f_0

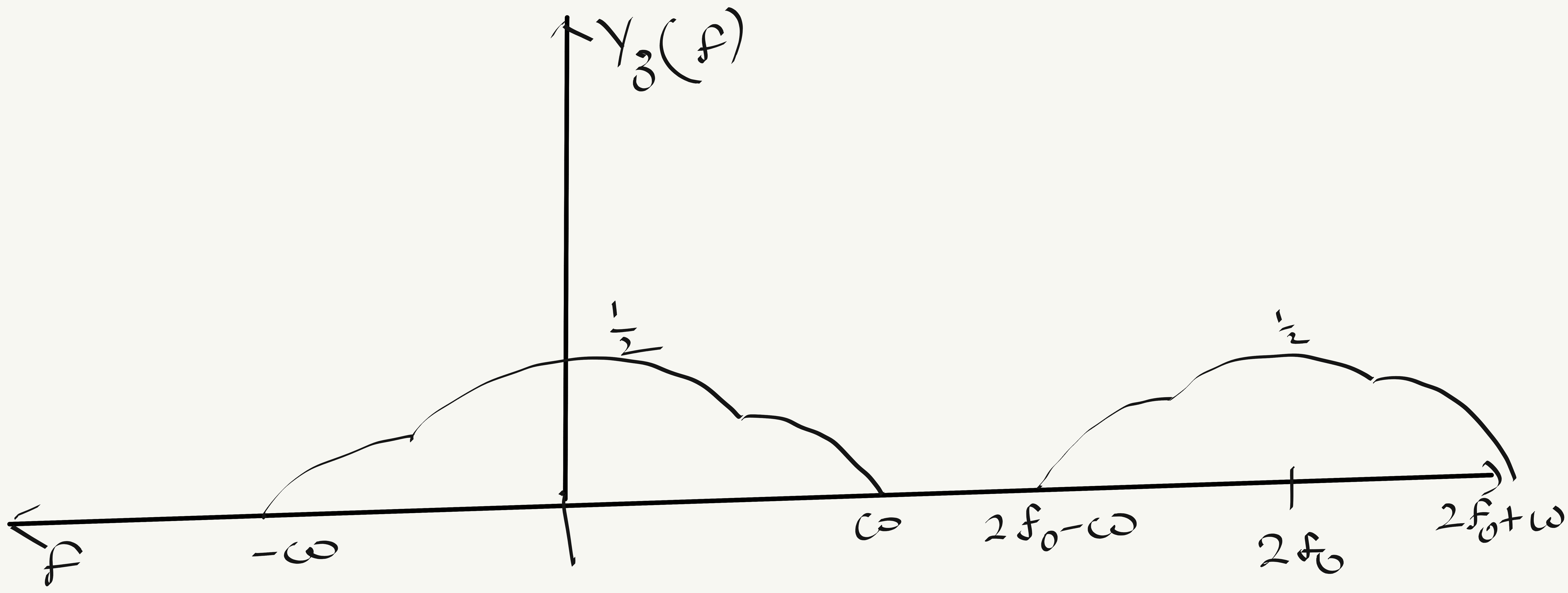
Plot of $Y_2(f)$ is



$$y_3(t) = y_2(t)\cos(2\pi f_0 t)$$

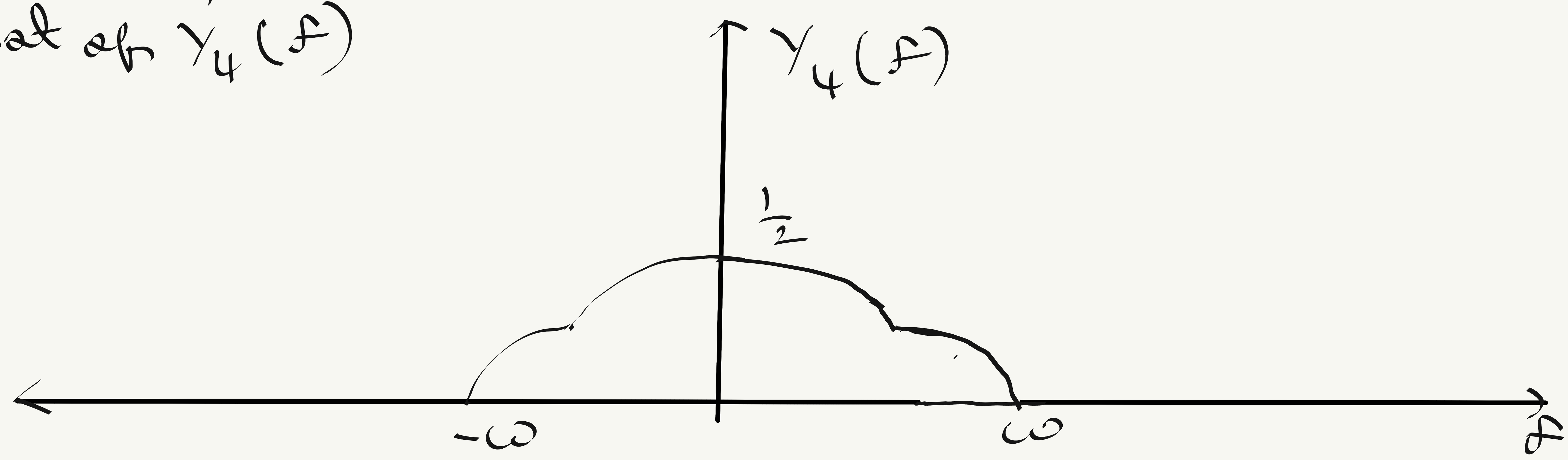
$$Y_3(f) = Y_2(f) * \frac{1}{2}\left[\delta(f-f_0) + \delta(f+f_0)\right]$$

$$= \frac{1}{2}\left[Y_2(f-f_0) + Y_2(f+f_0)\right]$$



Low pass filter centered at f_0

Plot of $Y_4(f)$



4)

$m(t) \rightarrow K_f = 1$ has Fourier transform

$$M(t) = \begin{cases} j2\pi f, & |f| < 1 \\ 0, & \text{otherwise} \end{cases}$$

$$\phi_{FM}(t) = A\cos(2\pi f_c t + \phi(t))$$

f_c is the carrier frequency

a) Find an explicit time domain expression for $\phi(t)$ as a function of time

$$m(t) = \int_{-\infty}^{\infty} G(f) e^{j2\pi f t} df$$

$$G(f) = j2\pi f$$

let $j2\pi f t = v$

$$dv = j2\pi t \, df$$

$$df = \frac{dv}{j2\pi t}$$

$$m(t) = \int_{-\infty}^{\infty} \frac{v}{t} \times e^{v} \times \frac{dv}{j2\pi t}$$

$$= \frac{1}{j2\pi t^2} \int v e^{v} dv$$

$$= \frac{1}{j2\pi t^2} \left[v e^{v} - e^{v} \right]$$

$$= \frac{1}{j2\pi t^2}\left[j2\pi f t\left[e^{j2\pi f t}\right] - e^{j2\pi f t}\right]_{-1}^{1}$$

$$= \frac{1}{j2\pi t^2}\left[j2\pi t\left[e^{j2\pi t}\right] - e^{j2\pi t}\right] - \left[-j2\pi t\left[e^{-j2\pi t}\right] - e^{-2\pi t}\right]$$

Rearranging the terms

$$= \frac{1}{j2\pi t^2}\,(j2\pi t)\left[e^{j2\pi t} + e^{-j2\pi t}\right] - e^{-j2\pi t} + e^{-j2\pi t}\Big]$$

$$= \frac{1}{j2\pi t^2}\left[4j\pi t\left[\frac{e^{j2\pi t} + e^{-j2\pi t}}{2}\right] - 2i\left[\frac{e^{j2\pi t} - e^{-j2\pi t}}{2i}\right]\right]$$

$$= \frac{1}{j2\pi t^2}\left[4j\pi t\cos(2\pi t) - 2j\sin(2\pi t)\right]$$

$$= \frac{\cancel{2j}}{\cancel{j2}\pi t^2}\left[2\pi t\cos(2\pi t) - \sin(2\pi t)\right]$$

$$m(t) = \frac{1}{\pi t^2}\left[2\pi t\cos(2\pi t) - \sin(2\pi t)\right]$$

we got $m(t)$ Now For

$$\phi(t) = k_f\int_{-\infty}^{t} m(x)\,dx \qquad k_f = 1$$

$$= \int_{-\infty}^{t}\frac{2}{\alpha}\cos(2\pi\alpha) - \int_{-\infty}^{t}\frac{1}{\pi\alpha^2}\sin(2\pi\alpha)$$

$$= \int_{-\infty}^{t}\frac{\cancel{2}}{\alpha}\,\frac{\sin(2\pi\alpha)}{\cancel{2}\pi} + \int_{-\infty}^{t}\frac{\sin(2\pi\alpha)}{\alpha\pi} - \int_{-\infty}^{t}\frac{1}{\pi\alpha^2}\sin(2\pi\alpha)\,d\alpha$$

$$= \frac{1}{\alpha} \left. \frac{\sin(2\pi\alpha)}{\pi} \right|_{-\infty}^{t}$$

$$= \frac{\sin(2\pi t)}{\pi t} - \left(\frac{(\text{finite})}{\text{infinite}} \right)$$

$$\downarrow$$

$$0$$

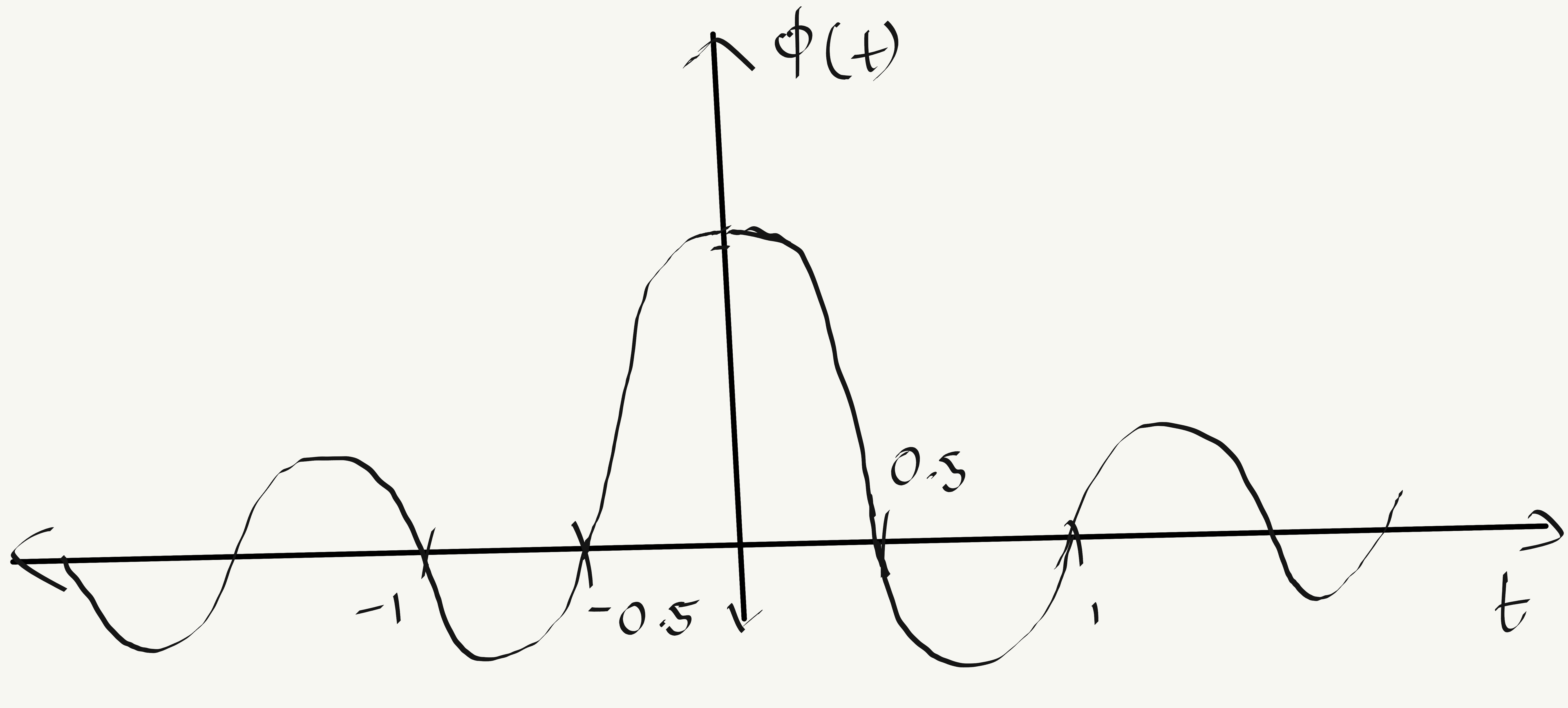
$$= \frac{\sin(2\pi t)}{\pi(t)} = 2\,\text{Sinc}(2\pi t)$$

Graph :-

For zeros $\sin(2\pi t) = 0$

$$2\cancel{\pi} t = n \cancel{\pi}$$

$$t = \frac{n}{2}$$

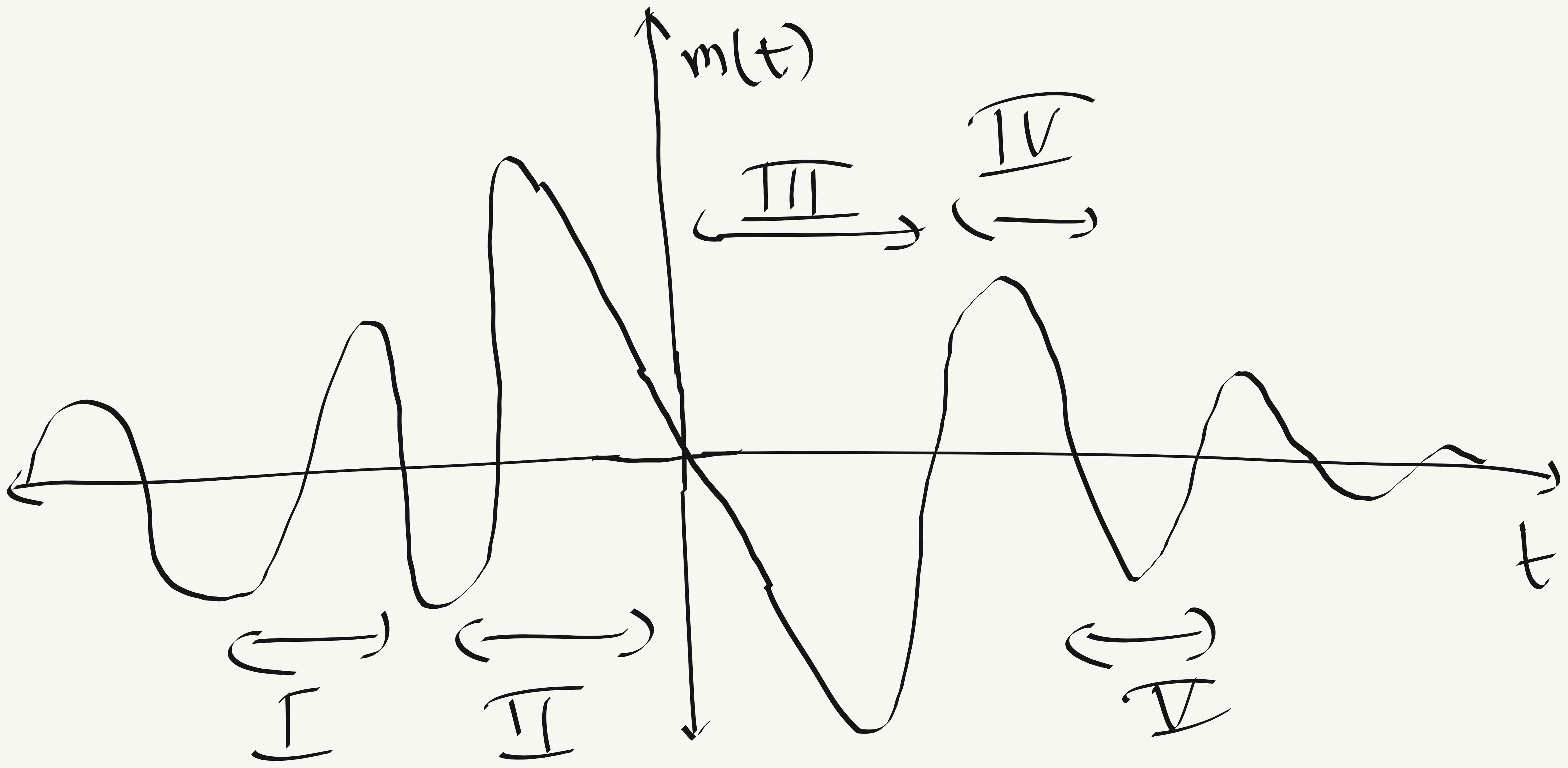


b) Find $\phi_{FM}(t)$, $m(t)$ and plot them both

$$\phi_{FM}(t) = A\cos(2\pi f_c t + \phi(t))$$
$$= A\cos(2\pi f_c t + 2\,\mathrm{Sinc}(\pi t))$$

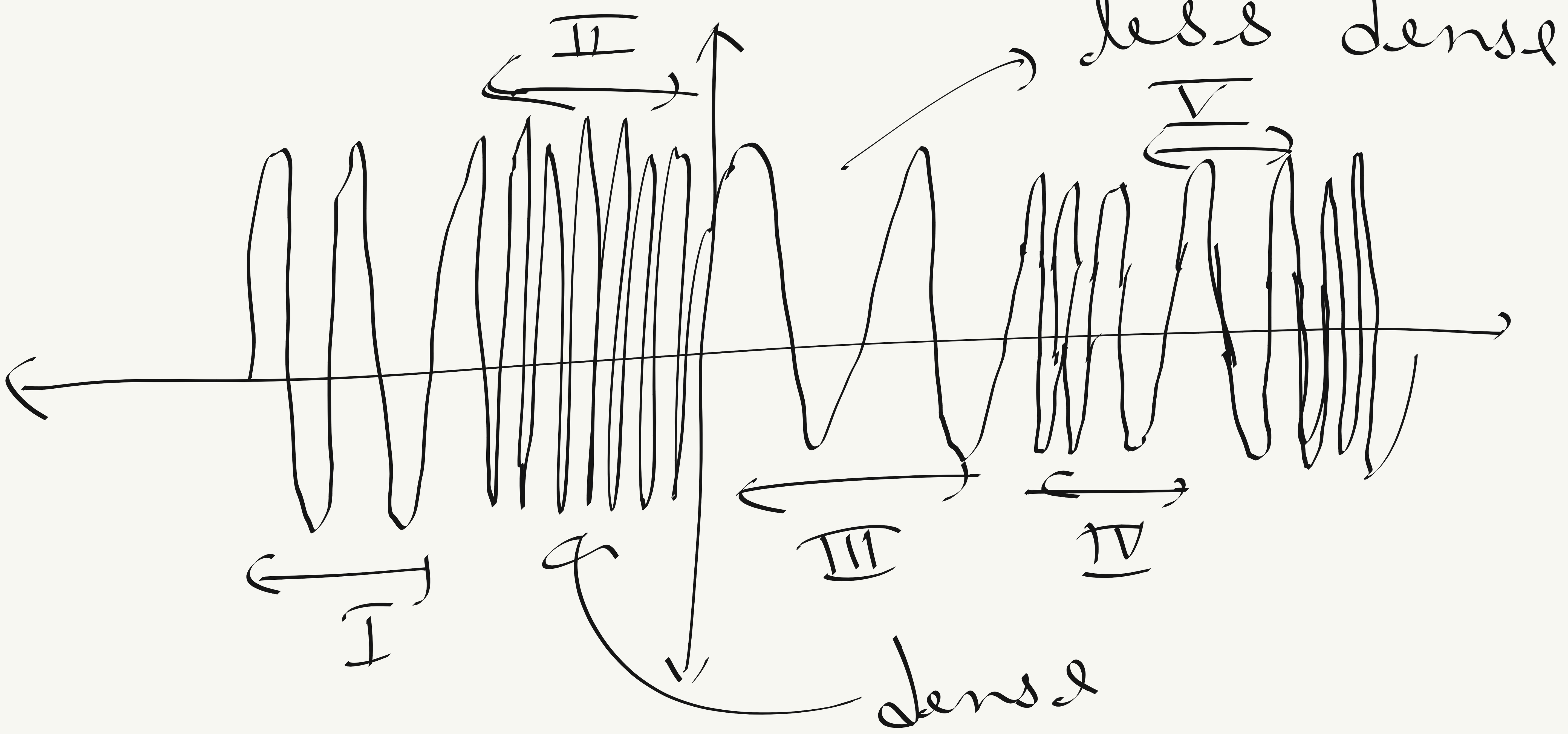
$$m(t) = \frac{1}{\pi t^2}\left[2\pi t\cos(2\pi t) - \sin(2\pi t)\right]$$

$$f_i = f_c + \frac{1}{2\pi}\left(\frac{2}{t}\cos(2\pi t) - \frac{1}{\pi t^2}\sin(2\pi t)\right)$$



The congestion and decongestion depends on the above diagram

Basically frequency increases with increase in m(t) at that point.



c) The magnetude of the instantaneous frequency deviation from the carrier at

$t = \frac{1}{4}$. $f_i = f_c + \frac{K_f}{2\pi} m(t)$

$$f_i(t) = f_c + \frac{1}{2\pi} \underbrace{\left(\frac{2}{t} \cos(2\pi t) - \frac{1}{\pi t^2} \sin(2\pi t) \right)}_{m(t)}$$

$$\Delta f = \frac{1}{2\pi} |m_{max}(t)| \qquad = \frac{1}{4} \qquad K_f = 1$$

$$= \frac{1}{2\pi} \left[\frac{2}{\frac{1}{4}} \cos\left(\frac{\pi}{2}\right) - \frac{16}{\pi} \sin\left(\frac{\pi}{2}\right) \right]$$

$$= \frac{8}{\pi^2} = \frac{8 \times 7 \times 7}{22 \times 22} \simeq 0.8099$$

4) Estimate BW of $U(t)$.

Bandwidth of FM modulator

Total Bandwidth $= 2\pi f + 2B$

$\Delta f = \frac{K_f}{2\pi} m_p \qquad m_p =$ Peak of $m(t)$

From online calculators we get

m_p is approximatly $= 5.5$

$$\Delta f = \frac{1}{2\pi} \times 5.5 = \frac{5.5}{2\pi} \simeq 0.875$$

$$\boxed{\begin{aligned} \text{Bandwidth} &= 2(B + \Delta f) = 2(0.875 + 1) \\ &= 3.751\ Hz \end{aligned}}$$

Q5) A modulating signal $m(t)$ is periodic signal Sawtooth signal.

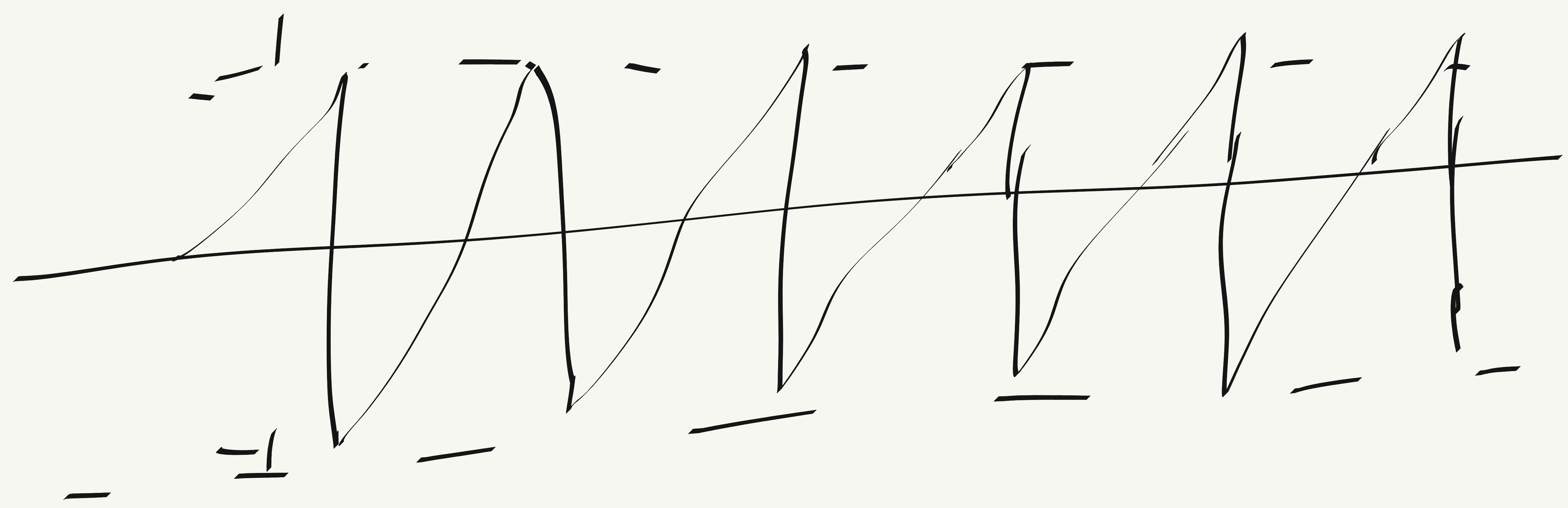
a) To sketch $\phi_{FM}(t)$ and $\phi_{PM}(t)$ for signal $m(t)$ $\omega_c = 2\pi \times 10^6$ $K_f = 2000\pi$

$K_p = \frac{\pi}{2}$

why $K_p < \pi$ is a necessary condition in this case.

Solution:-

A sawtooth signal is



$$\phi_{FM} :- f_i = f_c + \frac{K_f}{2\pi} m(t)$$

The value of f_i is dependent on $m(t)$ as a linear equation with constant f_c.

So

$$f_i = \frac{\omega_c}{2\pi} + \frac{K_f}{2\pi} m(t)$$

$$= 10^6 + \frac{\cancel{2000\pi}^{1000}}{\cancel{2\pi}} m(t)$$

$$= 10^6 + 10^3 m(t)$$

max $m(t)$ is 1 while min is -1

$$(f_i)_{max} = 10^3(10^3+1) = 1001000$$

$$(f_i)_{min} = 10^3(10^3-1) = 999000$$

Now the slope of $m(t)$ in each period

is $= \frac{1-(-1)}{10^{-3}} = 2\times10^3$

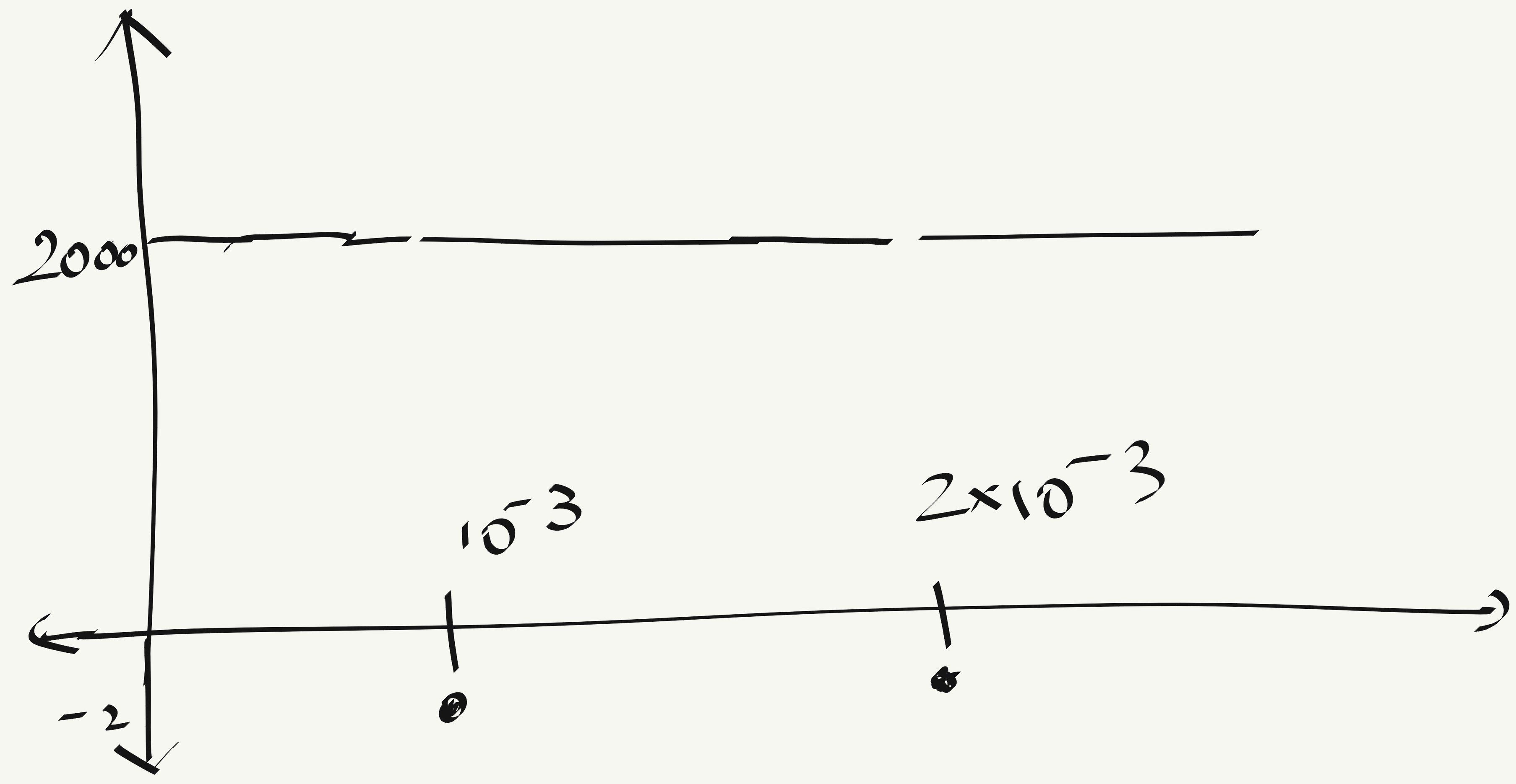
There are discontinuities at the edges

The change in discontinuity is

$$C_d = 1+1 = 2$$

Hence the change in phase is $\frac{\pi}{2}\times 2$

$= \pi$



discontinuity at $n \times 10^{-3}$ where n is an integer

$$\phi_{PM}(t) = A\cos(\omega_c t + K_p m(t))$$

where $K_p = \frac{\pi}{2}$

$$= A\cos\left(\omega_c t + m(t)\frac{\pi}{2}\right)$$

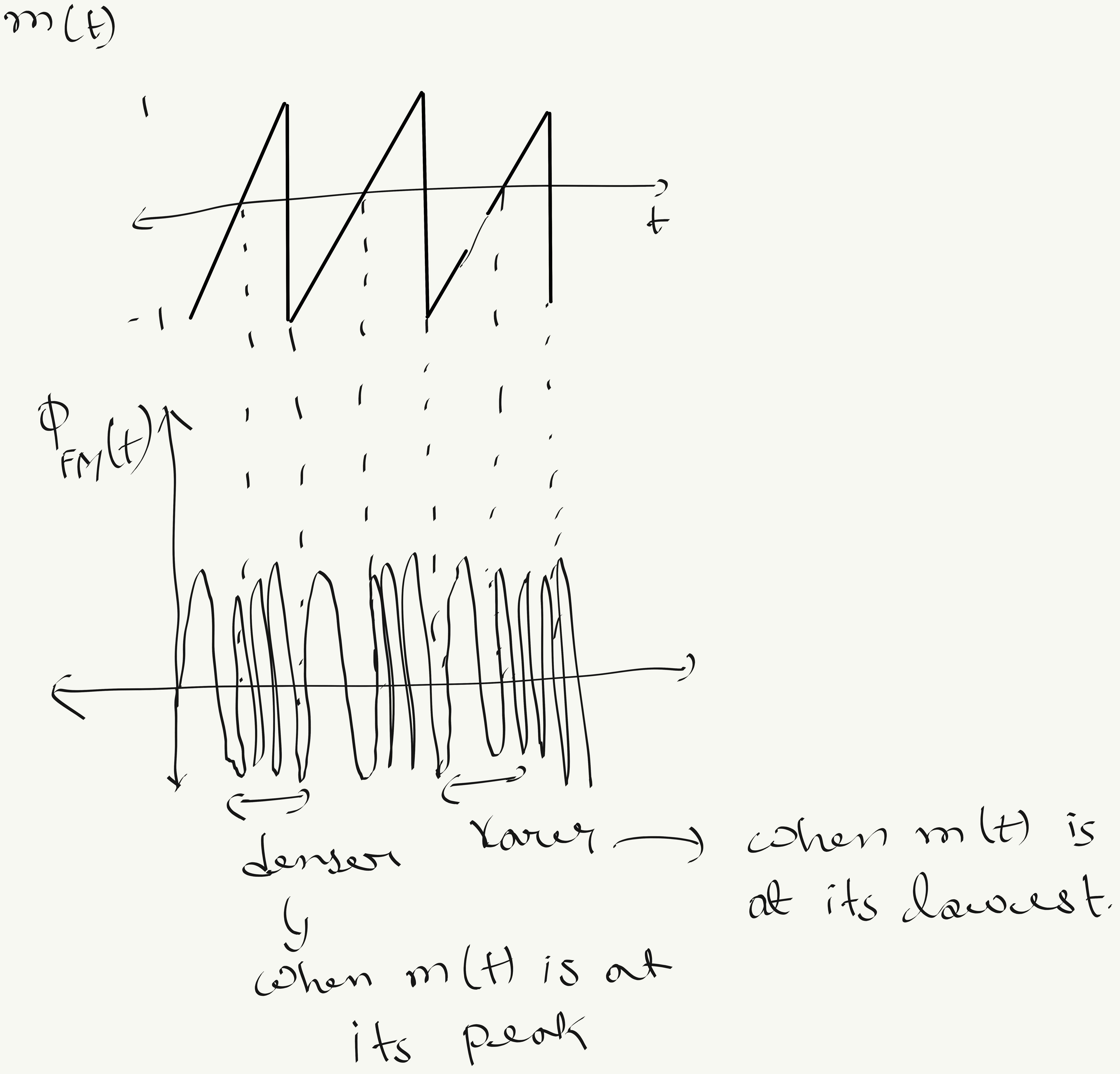
$$f_i = f_c + \frac{K_p}{2\pi}\dot{m}(t)$$

Ignoring the the discontinuity which aren't a major part of the signal

$$f_i = f_c + \frac{K_p}{2\pi} \times 2000t$$

$$= 10^6 + 500t$$

Diagrams of $\phi_{FM}(t)$ and $\phi_{PM}(t)$ with respect to $m(t)$



We see that the change in phase is π from the above calculation.
At the receiver it is easy to detect any anomalies or discontinuities if a shift occurs
Basically it is due to the repetition of values in cos after a phase shift of π.

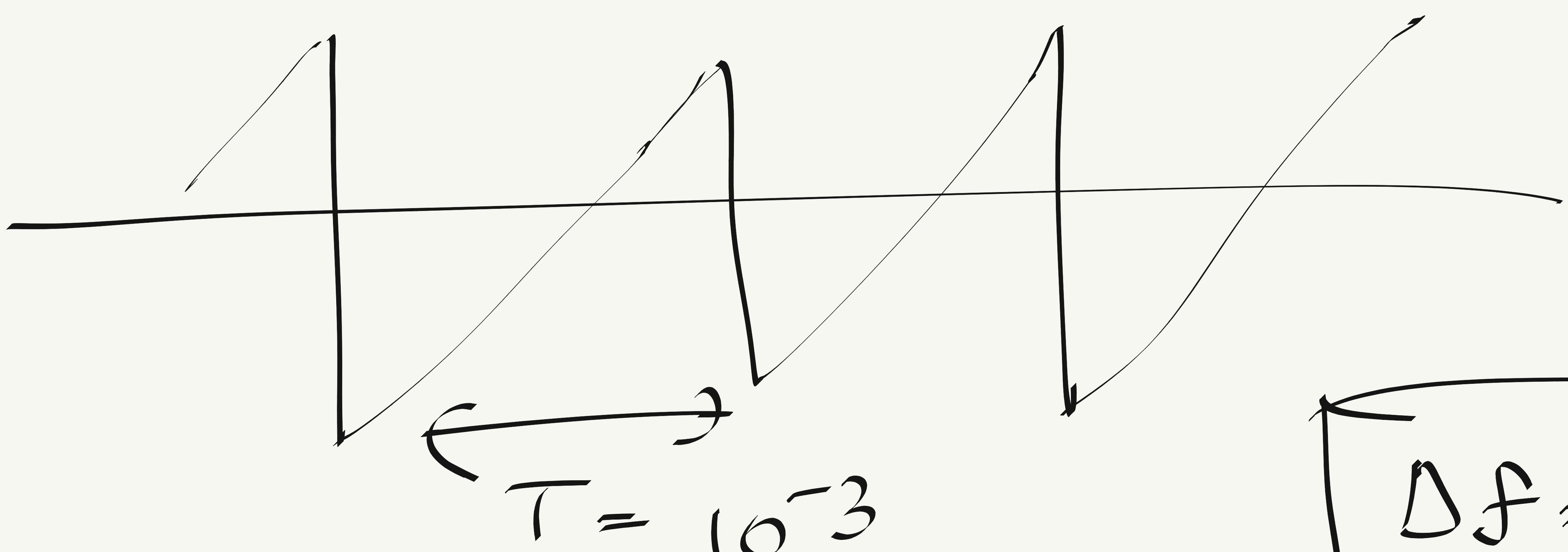
If $\phi_{PM}(t) = A\cos(\omega_c t + \pi m(t))$ if $K_p = \pi$

Let $m(t) = 1$

$$\phi_{PM}(t) = A\cos(\omega_c t)$$

which is same as no shift

b) Estimate BW of $\phi_{FM}(t)$ and $\phi_{PM}(t)$ while considering the BW of modulating signal till it 5th harmonic



$$\boxed{\Delta f = \frac{K_f \times m_p}{2\pi} = \frac{2000\pi}{2\pi} \times 1 = 1000}$$

$f = 1000\ Hz$

Fifth Harmonic is $5f_c$ which is 5000 Hz.

FM Bandwidth

$$BW = 2\Delta f + 2B$$

$$= 2(1000 + 5000)$$

$$= 12000 = 12\ KHz$$

$$\Delta f_m = k_p \times \left(\frac{m_{max} - m_{min}}{2\pi}\right)$$

$$= \frac{\pi}{2 \times 2\pi}\left(\frac{\cancel{2000}^{1000} + \cancel{2}^{1}}{\cancel{2}}\right)$$

$$= 250.25$$

$$BW = 2(B + \Delta f)$$

$$= 2(5000 + 250.25)$$

$$= 10000 + 500.50$$

$$= 10500.50$$

A Bandwidth of 10.6 K is approximated

MATLAB

Question 3:-

FM Generation:-

$$\varphi_{FM}(t) = A\cos\left[\omega_c t + k_f \int_{-\infty}^{t} m(\alpha)\, d\alpha\right]$$

PM Generation:-

$$\varphi_{EM}(t) = A\cos[\omega_c t + \psi(t)]$$

$$= A\cos\left[\omega_c t + \int_{-\infty}^{t} m(\alpha) h(t-\alpha)\, d\alpha\right]$$

Demodulation of FM waves:-

The first step is to differentiate the wave then pass it into a rectifier and finally Passing it through a low pass filter

Demodulation of PM wave

similar to the above case with one additional step i.e integrating the signal that come from the low pass filter

COMMUNICATION THEORY

Assignment-2 MATLAB Report

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Question 1:

We will implement DSB-SC modulation and then perform demodulation, using a few different methods.

The modulation is to be done in 3 different ways:

i) Multiplier modulator
ii) Frequency modulator
iii) Nonlinear modulator

The input message signal we consider is two triangles at origin where one is in positive x axis and negative y axis and other in negative x axis and positive y axis.

The carrier signal is cosine with amplitude 1 and frequency of 1 MHz.

DSB-SC stands for Double Sideband Suppressed Carrier. In this method both upper band and lower bands of the modulated signal are transmitted. but the carrier signal is suppressed. It is relatively simple to implement and can be demodulated using a coherent demodulator.

In the code bandpass filter/ function is used and also low pass filters are used in the process.

i) Multiplier modulator:
This is basically multiplying the message and carrier signals. Which is simple on paper but hard to build the hardware required for this.

```
function output1 = multipliermodulator(message, carrier)
    output1 = message .* carrier;
end
```

The FT of the output1 gives two spikes at f-fc and f + fc.

ii) Nonlinear modulator:

These are more complex compared to multiplier modulators.

X_1 = message + carrier

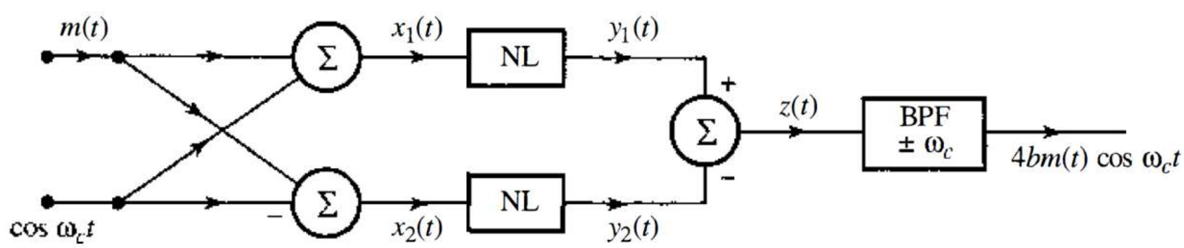
X_2 = carrier - message

$$y(t) = ax(t) + bx^2(t)$$

$$z(t) = y_1(t) - y_2(t) = [ax_1(t) + bx_1{}^2(t)] - [ax_2(t) + bx_2{}^2(t)]$$

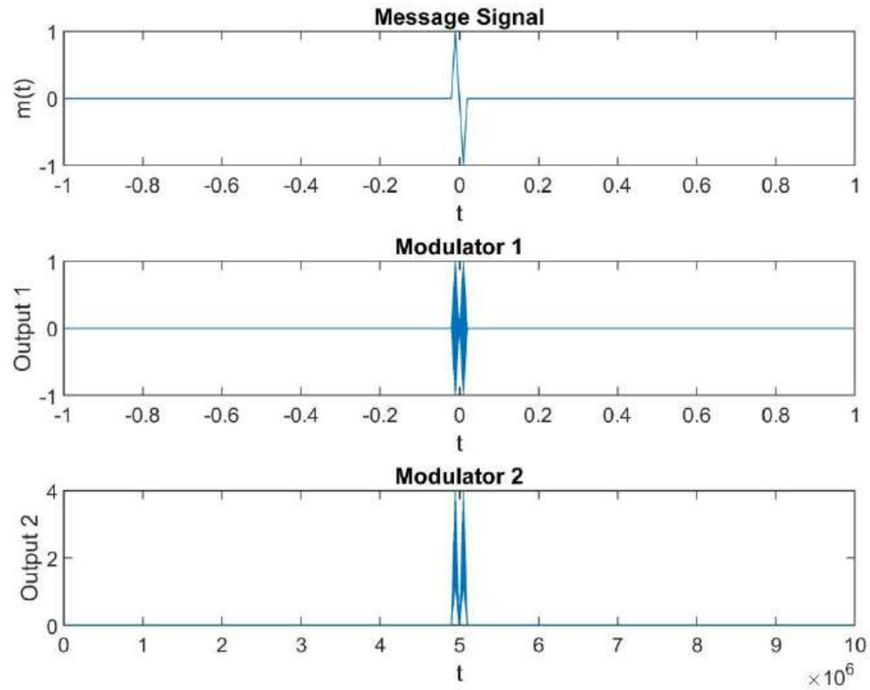
$$z(t) = 2a \cdot m(t) + 4b \cdot m(t) \cos\ \omega_c t$$

Which is then sent into a bandpass filter. The output comes out as 4*bm(t)*cos(w_ct).



The limits of the bandpass filter is found through the FFT of the output function.

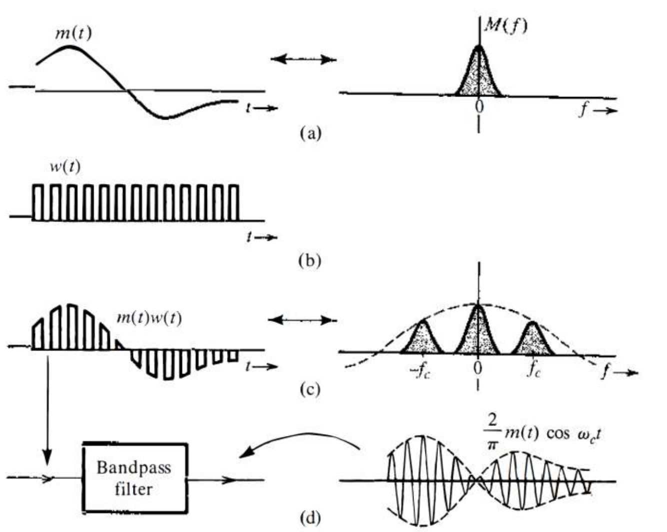
```
function output2 = nonlinearmodulator(carrier, message, t)

    x1 = message + carrier;
    x2 = carrier - message;
    y1 = x1 + (x1).^2;
    y2 = x2 + (x2).^2;
    z = y1 - y2;
    %output2= fft(z);
    output2 = bandpass(z,[1000000,9000000],1/0.0000001);
end
```



Where modulator 1 is the multiplier modulator and the second one is the Nonlinear modulator.

iii) Switching modulator:

A switching modulator, also known as a pulse-width modulation.



Here we take a square pulse with the help of the inbuilt square function in MATLAB.

$$w(t) = \frac{1}{2} + \frac{2}{\pi}\left(\cos\ \omega_c t - \frac{1}{3}\cos\ 3\omega_c t + \frac{1}{5}\cos\ 5\omega_c t - \cdots\right)$$

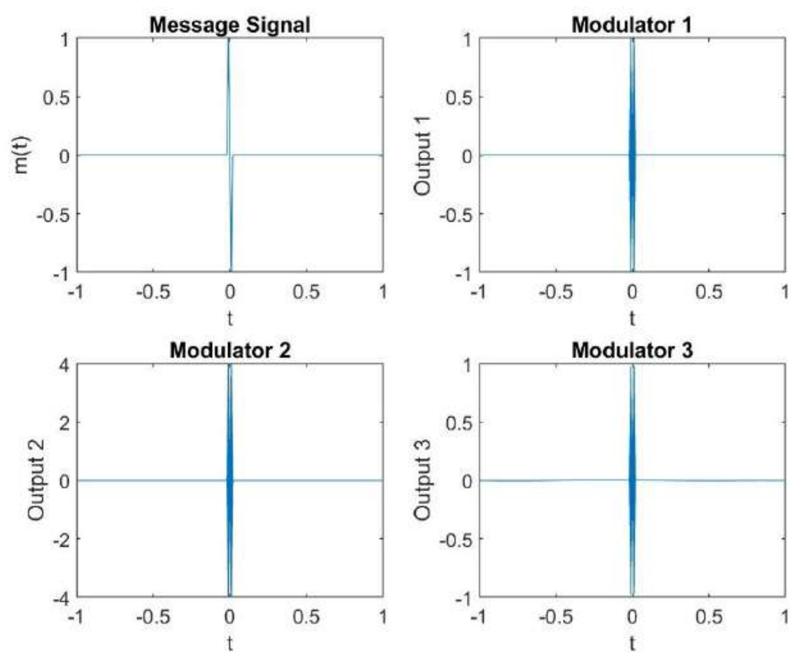
The signal $m(t)w(t)$ is given by

$$m(t)w(t) = \frac{1}{2}m(t) + \frac{2}{\pi}\left[m(t)\cos\ \omega_c t - \frac{1}{3}m(t)\cos\ 3\omega_c t + \frac{1}{5}m(t)\cos\ 5\omega_c t - \cdots\right]$$

As the signal has many frequency we send it through a bandpass filter after taking an FFT to decide the limiting frequecnies.

```
function output3 = switchingmodulator(carrier, message, t)

    pulse_freq = 10^6;
    pulse_width = 0.0000001;
    square_pulse = square(2*pi*pulse_freq*t, pulse_width*100);
    modulated_signal = square_pulse .* message;

    %output3 = fft(modulated_signal);
    output3 = bandpass(modulated_signal,[1,10000000],1/0.0000001);
end
```

The plot of all the above:



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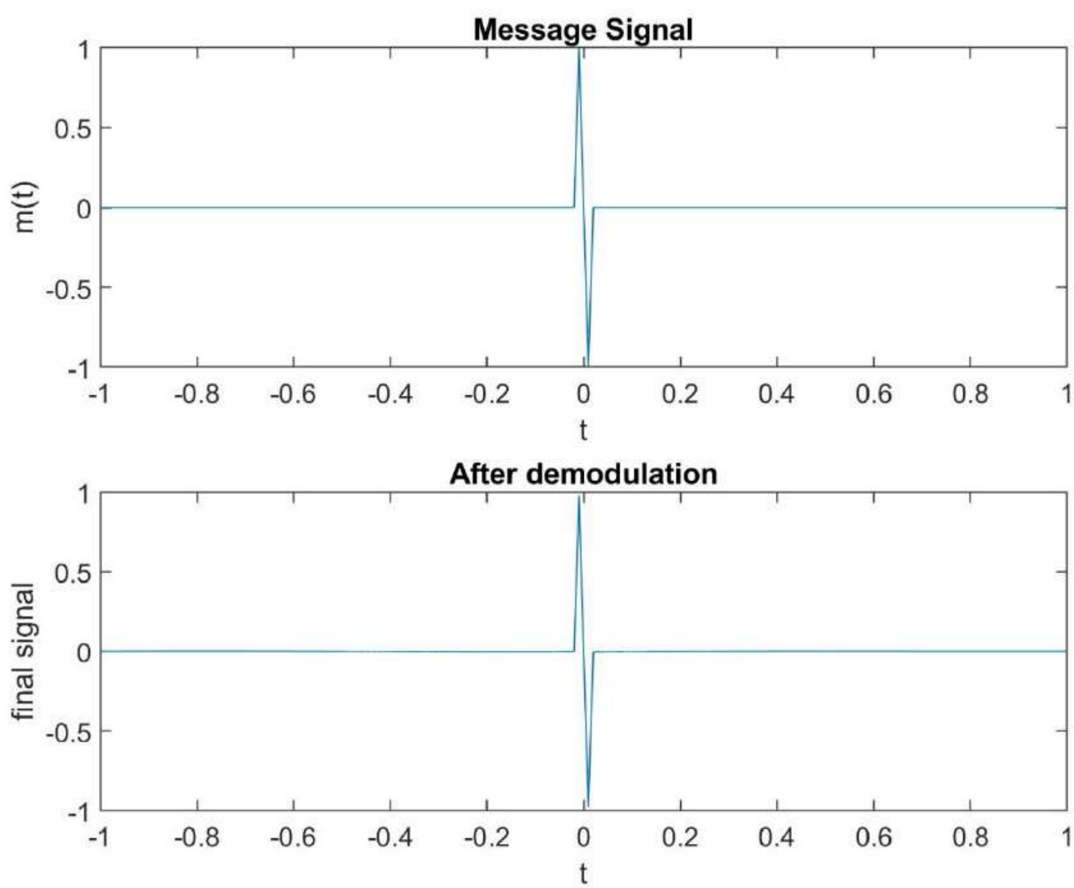
Demodulation:

We need to use a switching demodulator in which we have to multiply the same square pulse to the modulated signals again and then pass them through a low pass filter

```
function output4 = switchingdemodulator(output3,message,t)

    pulse_freq = 10^6;
    pulse_width = 0.0000001;
    square_pulse = square(2*pi*pulse_freq*t, pulse_width*100);
    l = output3.*(square_pulse);
    output4 = lowpass(l,1,1/0.0000001);
end
```

After this we observe the original signal .

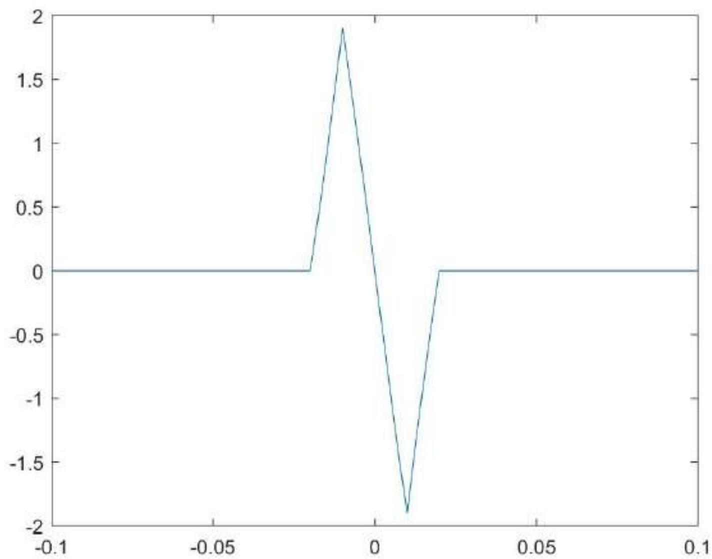


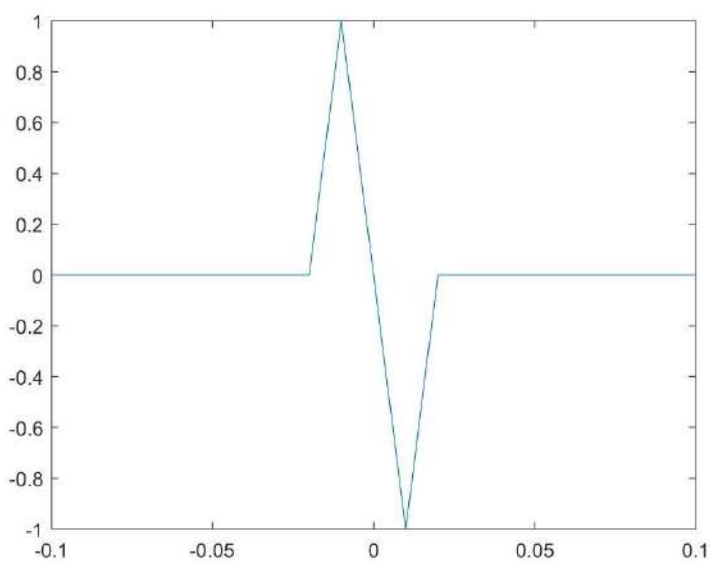
Phase shift effects: This helps to simulate the phase changes that occur during the transmission and the disturbances these changes cause during the demodulation of the signal.

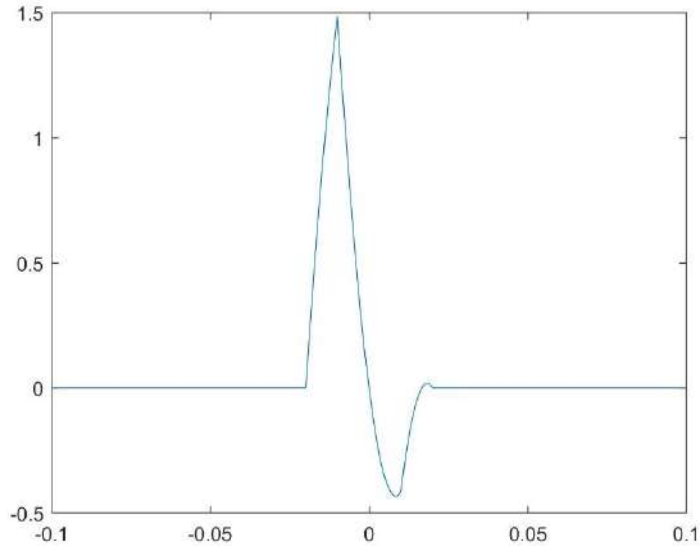
(a) $\Delta f = 0$ and $\Delta\theta = \frac{\pi}{3}$

(b) $\Delta f = 5\text{Hz}$ and $\Delta\theta = 0$

(c) $\Delta f = 5\text{Hz}$ and $\Delta\theta = \frac{\pi}{3}$

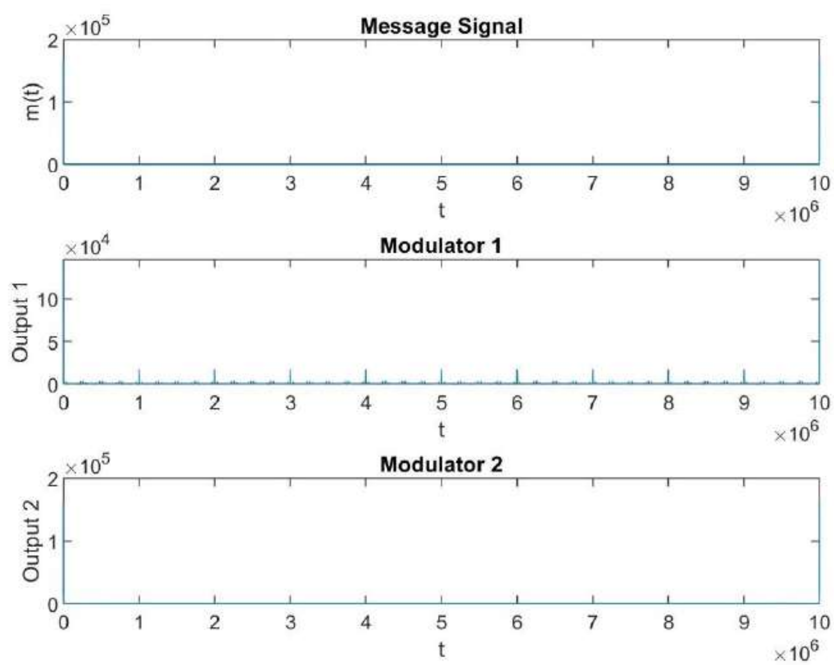






We observe the most distortion is caused when both frequency and phase have changes in them.

Frequency spectrum: The frequency spectrum of the message signal, modulated signal, and demodulated signal.



The message signal and the demodulated waves have similar spectrums.

Question 2:

We should perform DSB-FC modulation, and demodulation using a rectifier detector. Use the same signals as in the previous question. Take kf = kp = 1.

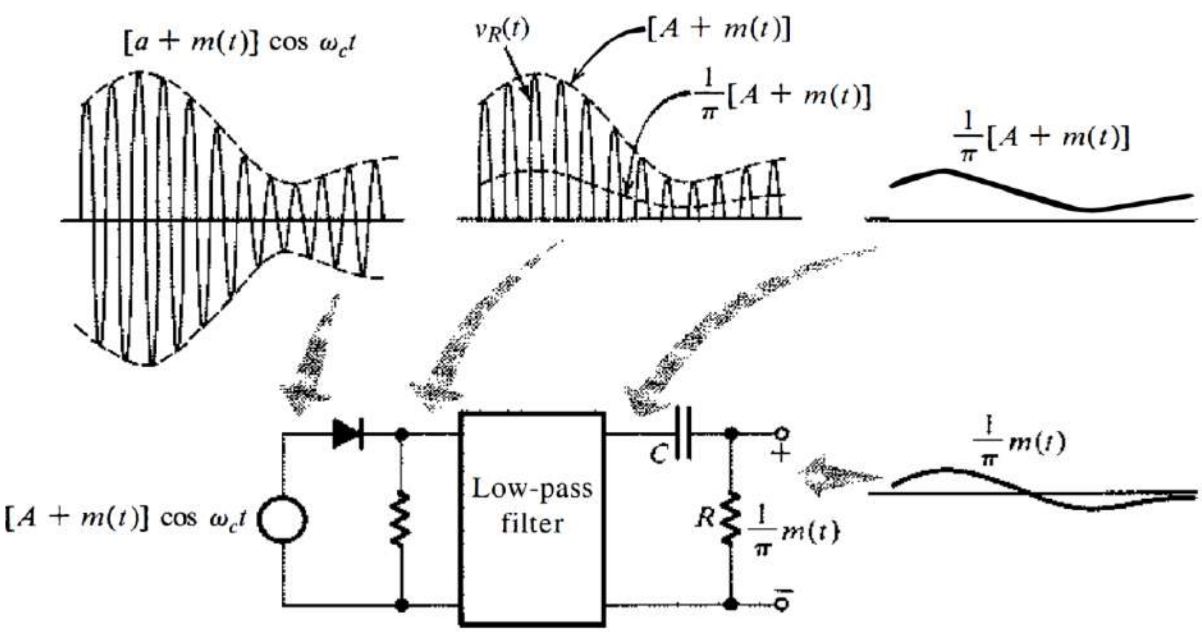
Modulation:

```
 Ac = 1;
carfreq = 10^6;
t = -0.1:0.0000001:0.1;
A = 1;
delta = @(t) (1 - abs(t)) .* ((t >= -1) & (t <= 1));
mess = ((delta((t+0.01)/0.01) - delta((t-0.01)/0.01)));
message = A + mess;
carrier = Ac*cos(2*pi*carfreq*t);

fft_message = fft(message);
output1 = multipliermodulator(message,carrier);
demodsignal = rectifierdemodulator(output1);
```

Her we see that the carrier signal is multiplied with the the sum of a constant A and the message signal (here kf=1)

Demodulation:

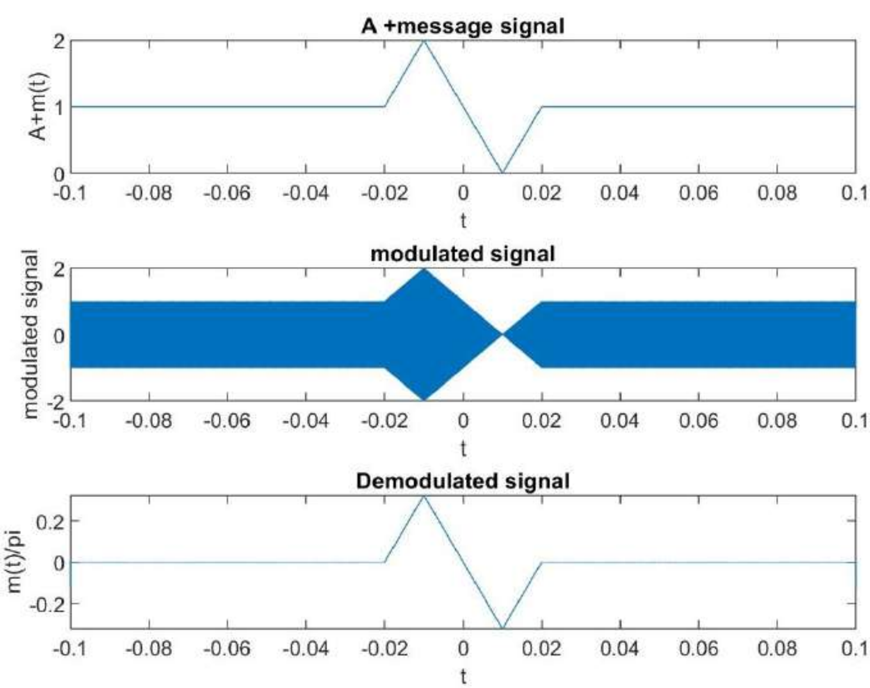
We are specified to use a rectifier demodulator

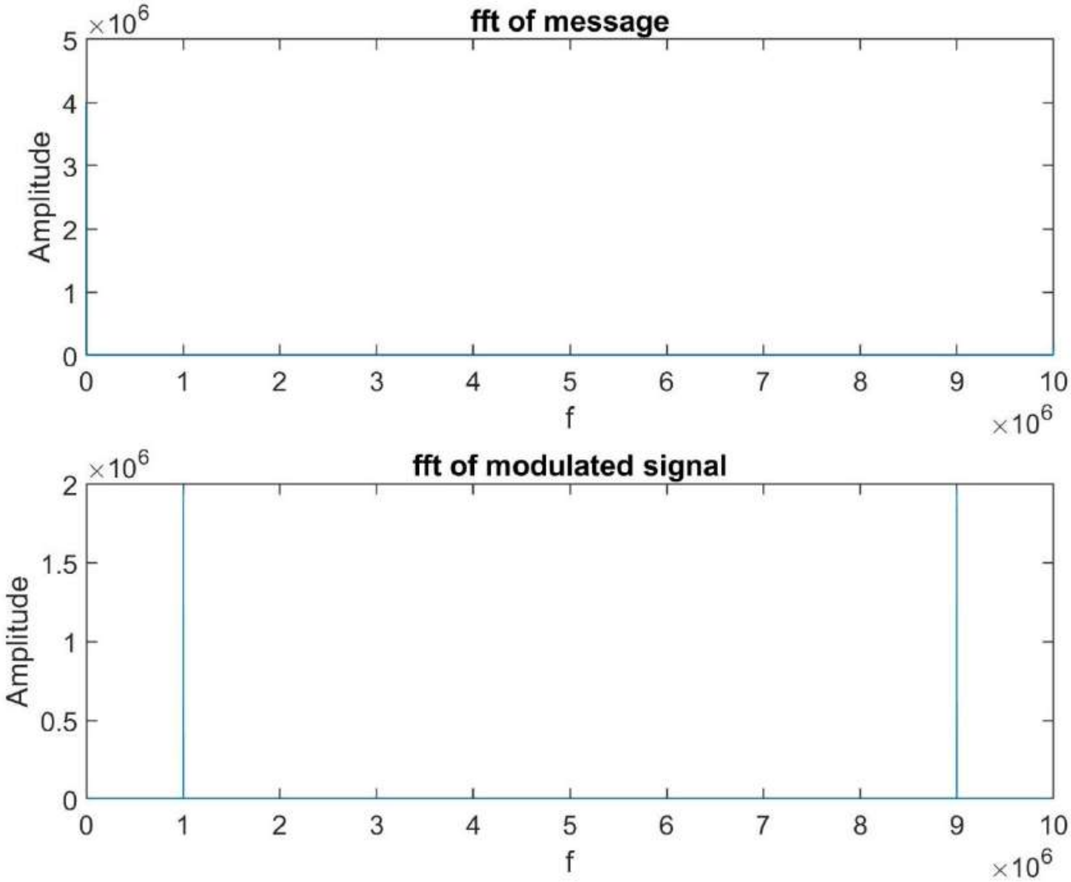


$$
\begin{aligned}
v_R(t) &= \{[A + m(t)] \cos\ \omega_c t\}\, w(t) \\
&= [A + m(t)] \cos\ \omega_c t \left[\frac{1}{2} + \frac{2}{\pi}\left(\cos\ \omega_c t - \frac{1}{3}\cos\ 3\omega_c t + \frac{1}{5}\cos\ 5\omega_c t - \cdots\right.\right. \\
&= \frac{1}{\pi}[A + m(t)] + \text{other terms of higher frequencies}
\end{aligned}
$$

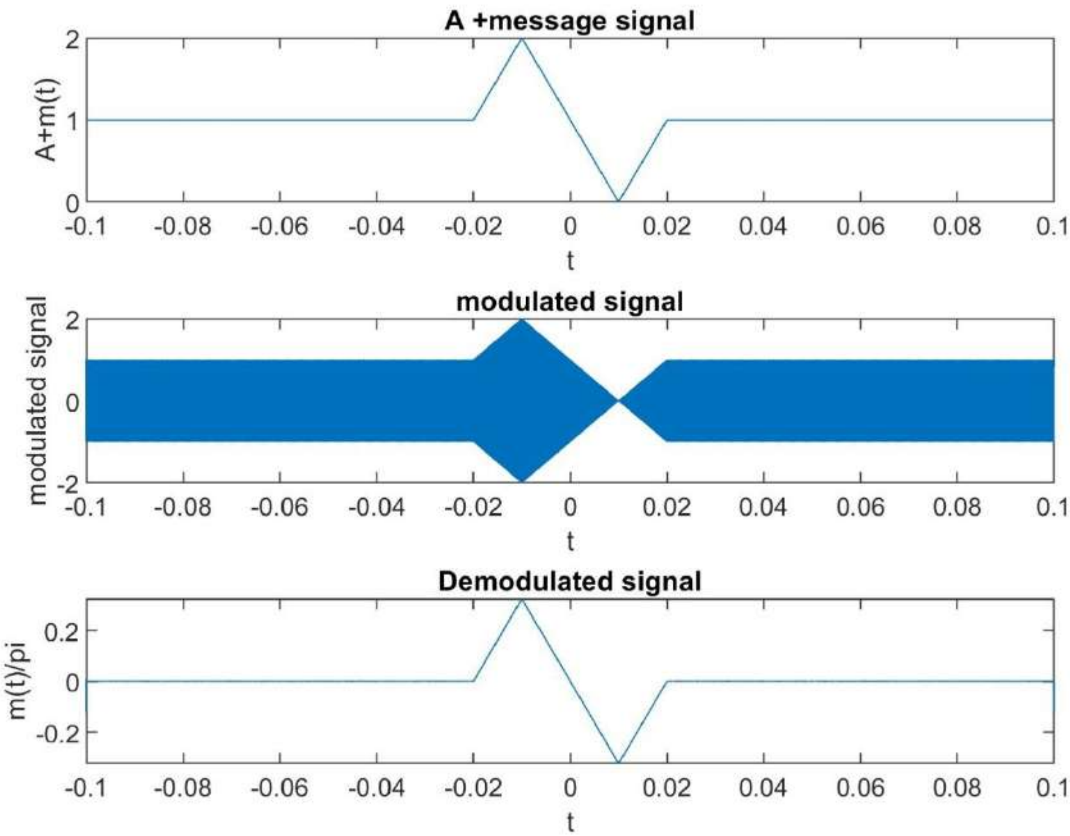
Here we need the low pass filter to remove the unwanted frequencies. And also remove the DC part of the signal to get the original signal. The output comes as m(t)/pi. Hence the reduced value of the peaks. We need to use a amplifier to the original message signal.

```
function demodsignal = rectifierdemodulator(output1)

rectifiedsignal = output1.*(output1>0);
filteredsignal = lowpass(rectifiedsignal,1,1/0.0000001);
demodsignal = filteredsignal - mean(filteredsignal);
%demodsignal = fft(k);

end
```





fft of message
Amplitude
f
×10^6
fft of modulated signal
Amplitude
f
×10^6


A +message signal
A+m(t)
2
1
0
-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
t
modulated signal
modulated signal
2
0
-2
-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
t
Demodulated signal
m(t)/pi
0.2
0
-0.2
-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
t