Module 4 - Homework 4

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Problem 4.5-2 (a)

A baseband signal m(t) is the periodic sawtooth signal shown in Fig 4.5-2.

Part A

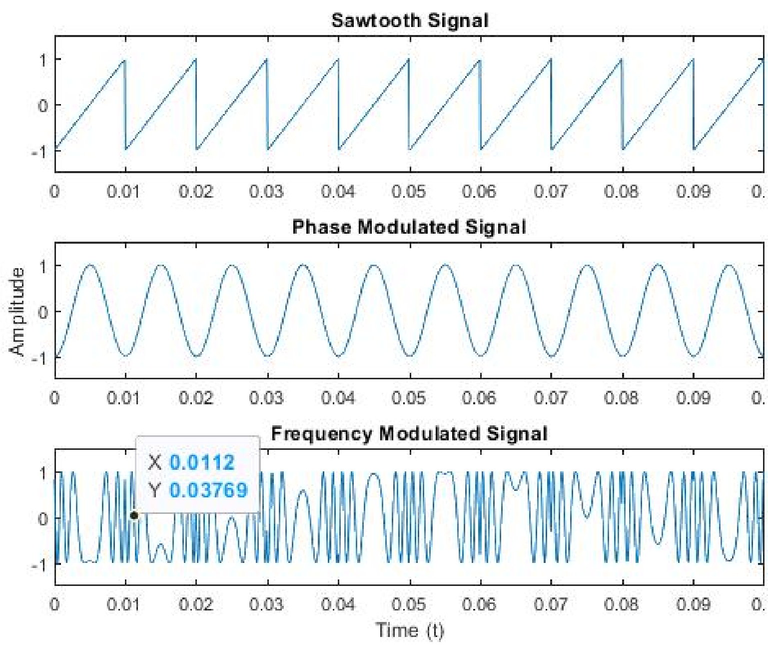
Sketch $\varphi_{FM}(t)$ *and* $\varphi_{PM}(t)$ *for this signal m(t) if* $\omega_c = 2\pi \times 10^6, k_f = 2000\pi,$ *and* $k_p = \frac{\pi}{2}$

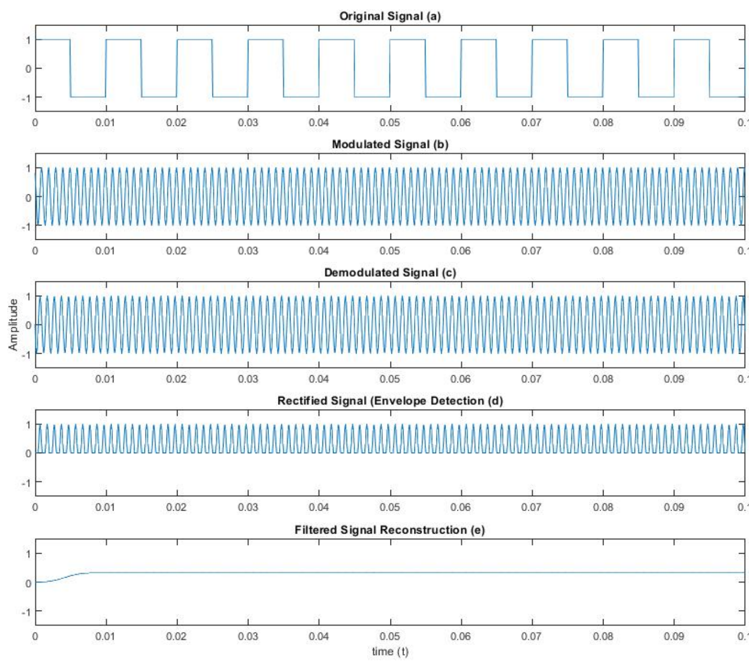
I took the liberty to try this out in Matlab so I'd be able to try other signals in the future. The figure below has the results for the given parameters. Code is in the appendix.

Problem 4.7-2

A periodic square wave m(t) frequency-modulates a carrier of frequency $f_c = 10khz$ *with* $\Delta f = 1kHz$*. The carrier amplitude is A. The resulting FM signal is demodulated, as shown in Fig P4.7-2b by the method discussed in Sec. 4.7 (Fig. 4.28). Sketch the waveforms at points b, c , d, and e.*

I also tried this in Matlab for the same reasons as the previous problem. See the appendix for code, with explanations in the comments. The plots are in the second figure. Note that the filtered reconstructed signal (e) is not a perfect replica of the initial signal (actually, its super distorted). This is because of the time delay of the filter.


Sawtooth Signal
Phase Modulated Signal
Amplitude
Frequency Modulated Signal
X 0.0112
Y 0.03769
Time (t)


Original Signal (a)
Modulated Signal (b)
Demodulated Signal (c)
Amplitude
Rectified Signal (Envelope Detection (d)
Filtered Signal Reconstruction (e)
time (t)

Matlab Code

```
%% Problem 4.5-2

% see pg 267 in the book for a good example of
    implementing FM/PM
f = 1/10e-3;
fs = 100*f; % Sample way above the frequency to catch the
     peak amplitude
t = 0:1/fs:0.1;
m_t = sawtooth(2*pi*(f)*t,1);

w_c = 2*pi*10e6;
kf = 2000*pi;
kp = pi/2;

m_intg = kf*(1/fs)*cumsum(m_t);
s_fm = cos(w_c*t+m_intg);
s_pm = cos(w_c*t+pi*m_t);

figure(1)
subplot(3,1,1);
plot(t,m_t)
ylim([-1.5 1.5]);
title('Sawtooth Signal')

subplot(3,1,2);
plot(t,s_pm)
ylim([-1.5 1.5]);
title('Phase Modulated Signal');
ylabel('Amplitude')
subplot(3,1,3)
plot(t,s_fm)
ylim([-1.5 1.5]);
title('Frequency Modulated Signal');
xlabel('Time (t)');
%% Problem 4.7-2

% see pg 267 in the book for a good example of
    implementing FM/PM
f = 1/10e-3; % our delta f = 1kHz
fs = 100*f; % Sample way above the frequency to catch the
     peak amplitude
ts = 1/fs;
t = 0:ts:0.1;
```

```
m_t = square(2*pi*(f)*t,50); % square wave signal

% FM Parameters
w_c = 2*pi*100e6;
kf = 2000*pi;
kp = pi/2;

% Plot Original Signal
figure(2)
subplot(5,1,1);
plot(t,m_t);
title('Original Signal (a)');
ylim([-1.5 1.5]);

% Modulation
m_intg = kf*ts*cumsum(m_t);
s_fm = cos(w_c*t+m_intg);
subplot(5,1,2);
plot(t,s_fm);
title('Modulated Signal (b)');
ylim([-1.5 1.5]);

% Demodulation
s_fmdem = diff([s_fm(1) s_fm])/ts/kf; % differentiate first
subplot(5,1,3);
plot(t,s_fmdem);
title('Demodulated Signal (c)');
ylabel('Amplitude');
ylim([-1.5 1.5]);

% Envelope Detection
s_fmrec = s_fmdem.*(s_fmdem>0); % Apply envelope detection with a rectifier
subplot(5,1,4);
plot(t,s_fmrec);
title('Rectified Signal (Envelope Detection (d)');
ylim([-1.5 1.5]);

% Filtering - use a high pass filter to block dc
B_m = f/4;
h=fir1(16,[B_m*ts]);
s_dec = filter(h,1,s_fmrec);
subplot(5,1,5);
plot(t,s_dec);
title('Filtered Signal Reconstruction (e)');
```

```
ylim([-1.5  1.5]);
xlabel('time (t)')
```