ECE 405 - ANALOG COMMUNICATIONS - INVESTIGATION 9
INTRODUCTION TO FREQUENCY MODULATION - PART II

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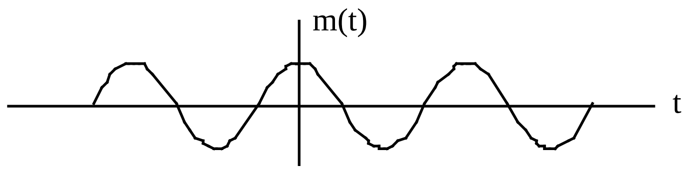
To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs and tables.

From the last Investigation we know what FM signals look like and how to calculate their bandwidths. The main objective of this Investigation is to introduce how FM signals can be generated and show how they can be demodulated with discriminator circuits.

1. We begin with some review questions. Given the following message signal $m(t)$



and a carrier with $f_c >> f_m$

a. Sketch the corresponding AM signal
b. Sketch the corresponding FM signal
c. Describe how the AM and FM signals are different

2. Given a message signal $m(t) = 10\cos\left(2\pi 10^4 t\right)$

a. Find the bandwidth of the corresponding AM signal
b. Find the bandwidth of the corresponding FM signal if $k_f = 2x10^3$
c. Find the bandwidth of the corresponding FM signal if $k_f = 2x10^4$

3. What's the distance between the spectral lines in an FM signal with $m(t) = 10\cos\left(2\pi 10^4 t\right)$

4. Find and plot the spectral lines of an FM signal with $k_f = 2x10^3$ and $m(t) = 10\cos\left(2\pi 10^4 t\right)$

5. The objective of this problem is to review narrowband FM. Suppose in particular that

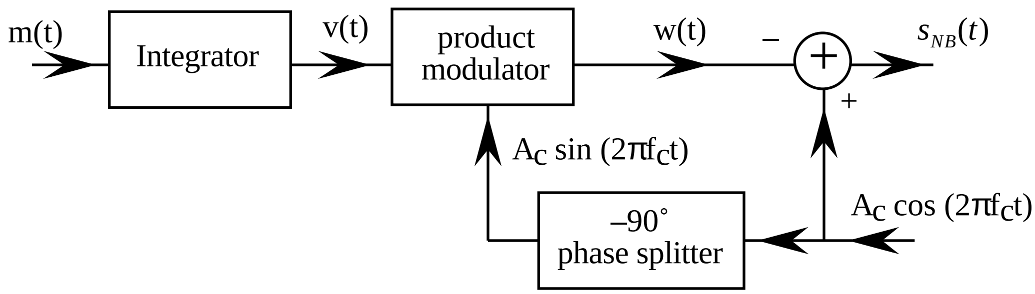
$$s_{NB}(t) = A_c \cos\left(2\pi f_c t\right) - \beta A_c \sin\left(2\pi f_c t\right)\sin\left(2\pi f_m t\right)$$

is a narrowband FM signal for $m(t) = 10\cos\left(2\pi f_m t\right)$

a. How does the size of β differ between narrowband and wideband FM signals
b. Sketch the spectrum of $s_{NB}(t)$
c. What is the bandwidth of $s_{NB}(t)$
d. Make use of the result from the last Investigation that narrowband FM signals for $m(t) = A_m \cos\left(2\pi f_m t\right)$ can be approximated as follows

$$s_{NB}(t) = A_c \cos\left(2\pi f_c t\right) - \beta A_c \sin\left(2\pi f_c t\right)\sin\left(2\pi f_m t\right)$$

to show that a narrowband FM signal can be generated by a system with the following block diagram



Hint - First find $v(t)$ and then $w(t)$

6. The objective of this problem is to introduce the *indirect method* for generating wideband FM signals. Suppose in particular that we wish to generate

$$s_{FM}(t) = 10\cos\left(2\pi 10^8 t + 3\sin\left(2\pi f_m t\right)\right)$$

The trick is to

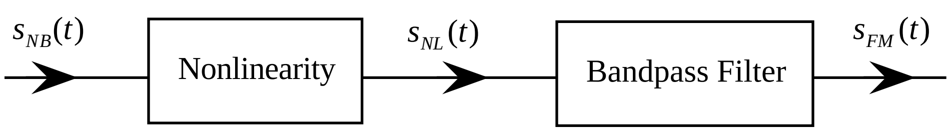
(1) First use the circuit of Problem (5) to generate a corresponding narrowband FM signal as follows

$$s_{NB}(t) = 10\cos\left(\frac{2\pi 10^8}{30} t + \frac{3}{30}\sin\left(2\pi f_m t\right)\right)$$

we obtain by dividing the frequency of $s_{FM}(t)$ by 30 and then

(2) Pass $s_{NB}(t)$ through a frequency multiplier as follows

consisting of a nonlinearity that generates harmonics followed by a bandpass filter as follows



to obtain $s_{FM}(t) = 10\cos\left(2\pi 10^8 t + 3\sin\left(2\pi f_m t\right)\right)$ from $s_{NB}(t)$

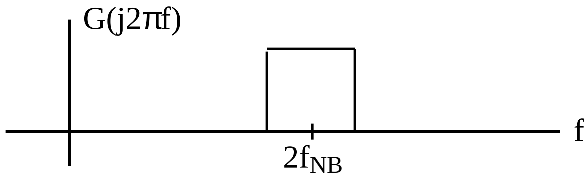
In order to see how this all works suppose $s_{NB}(t) = A_c \cos\left(2\pi f_{NB} t + \beta_{NB}\sin\left(2\pi f_m t\right)\right)$ is a narrowband FM signal

a. Sketch the spectrum of $s_{NB}(t)$
b. Find $s_{NL}(t)$ if the output of the nonlinearity is equal to the square of its input as follows

$$s_{NL}(t) = s_{NB}^2(t)$$

c. Sketch the spectrum of $s_{NL}(t)$

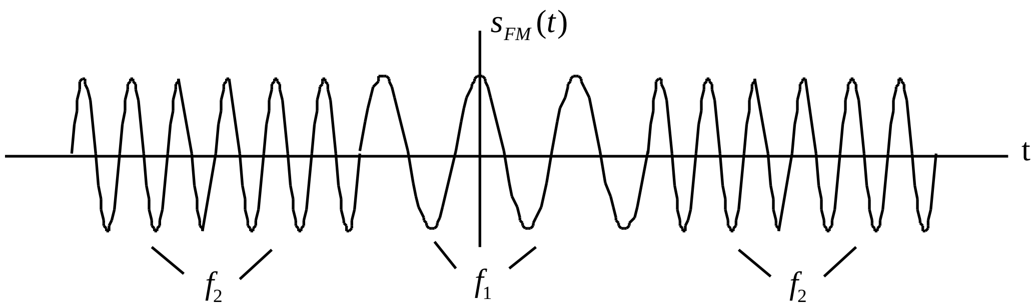
d. Make use of your result in part (c) to find $S_{FM}(f)$ if the ideal bandpass filter has the following frequency response



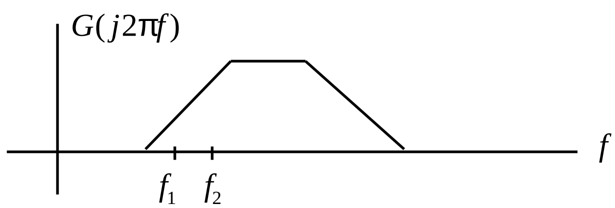
e. How are f_{NB} and β_{NB} of the narrowband signal $s_{NB}(t)$ related to f_c and and β of $s_{FM}(t)$

7. Suppose we want to generate an FM signal with $f_c = 100MHz$ and $\beta = 4$ from a narrowband signal with $\beta_{NB} = 0.1$ What's the corresponding narrowband carrier frequency f_{NB}

8. The objective of this and the next problem is to show how FM discriminator circuits demodulate FM signals like the following



a. Sketch $y(t)$ equal to the response of the following filter to $s(t)$



b. Describe how the magnitude of the filter response is related to the frequencies f_1 and f_2 of the input $s_{FM}(t)$
c. Generalize on your result in part (b) to describe how the magnitude of the signal at the output of the filter is related to the instantaneous frequency of $s_{FM}(t)$
d. How is the output of the filter related to the AM modulated signal of $m(t)$

9. From Problem (8) we see that if we pass an FM signal through a filter in the right way we can generate the AM modulated signal of $m(t)$ which we can then obtained with a simple AM demodulator. Use this scheme to obtain a sketch of $m(t)$ for the signal of Problem (8)