Amplitude Modulation and Frequency Modulation problems

1. Determine from Figure 1.

   (a) Modulation Index

   From the diagram, A=0.5V, K=0.9V. Hence m=0.555

   (b) The frequency of the modulating signal, assuming $f_c = 45$ kHz

   The carrier signal undergoes 8 cycles in the time the message undergoes 1 cycle. Hence f_m=45/8=5.625kHz

   (c) The carrier power (for a 75 Ω load)

   $P_C=K^2/2R$ = 5.4mW

   (d) The Power in one sideband (for a 75 Ω load)

   $P_{SB}=A^2/8R$= 0.4mW

   (e) Total power dissipated (for a 75 Ω load)

   $P_T=P_C+2P_{SB}$=6.23mW

   (f) The carrier power as a percentage of the total

   P_C/P_T=87%

   (g) The bandwidth required to transmit this signal

   $B=2f_m$=11.25kHz

   (h) The spectrum of a SSB SC-AM signal with the same message and carrier frequencies

   This spectrum consists of a single tone at a frequency of 50.625kHz

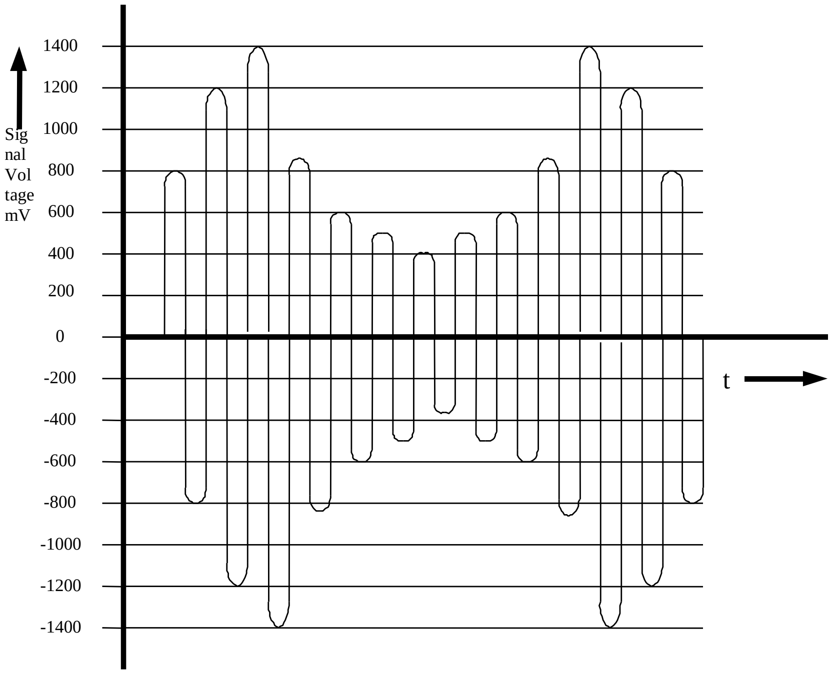
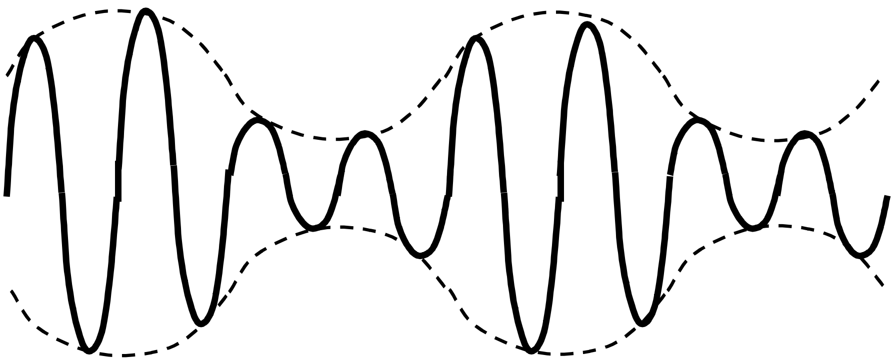


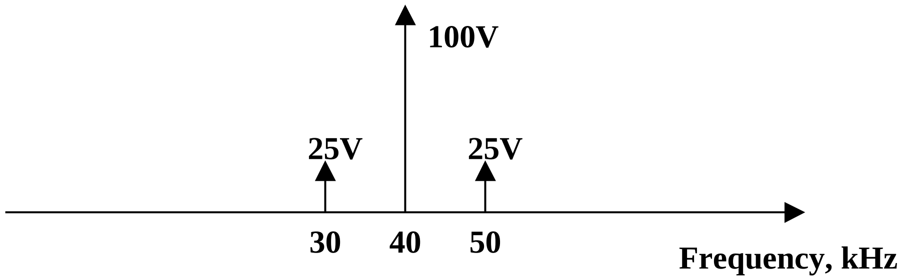
Figure 1

2. The peak amplitude of an unmodulated 40kHz cosine carrier signal is 100V. This is then modulated by a 10kHz cosine tone to an index of 50%:
   (a) Sketch the signal over a 0.2 millisecond period

   The signal envelope will vary between 50V and 150V and the carrier will go through four cycles for every cycle of the message signal. The message signal will undergo 2 cycles in 2ms. Hence:



   (b) Sketch the frequency spectrum of this AM signal. Include the frequency and peak voltage of each component



(c) Write the mathematical expression of this signal in a form that shows the carrier, Lower Sideband and Upper Sideband (Again include the actual numerical frequencies and peak voltages)

$s(t)=100\cos(80{,}000\pi t)+25\cos(60{,}000\pi t)+25\cos(100{,}000\pi t)$

(d) How much bandwidth is required to transmit the signal.

$B=2f_m=20\text{kHz}$

(e) Calculate the power delivered to a 50 Ω load for the following:

i. P_C

$P_C=K^2/2R = 100\text{W}$

ii. P_{USB}

$P_{USB}=A^2/8R= 6.25\text{W}$

iii. P_{total}

$P_T=P_C+2P_{USB}=112.5\text{W}$

3. The instantaneous voltage of a frequency modulated signal is given by:

$$v(t)=V_C.\sin\left(2\pi 10^7.t+37.5\sin\left(2\pi 12.6\times 10^3.t\right)\right)$$

Determine the carrier frequency, the modulation signal frequency and the peak frequency deviation.

$f_c=10\text{MHz}$, $f_m=12.6\text{kHz}$, $\beta=37.5$
$f_{dev}=\beta f_m=472.5\text{kHz}$

4. Two approximations for the bandwidth of wideband and narrowband FM are given as:

$B=2.(\beta+1).f_m$ for $\beta>>1$ (Wideband FM)

$B = 2 f_m$ for $\beta << 1$ (Narrowband FM)

Consider frequency modulation of a 10 MHz carrier by a 5 kHz tone that has a deviation of:

i. 1.25 kHz

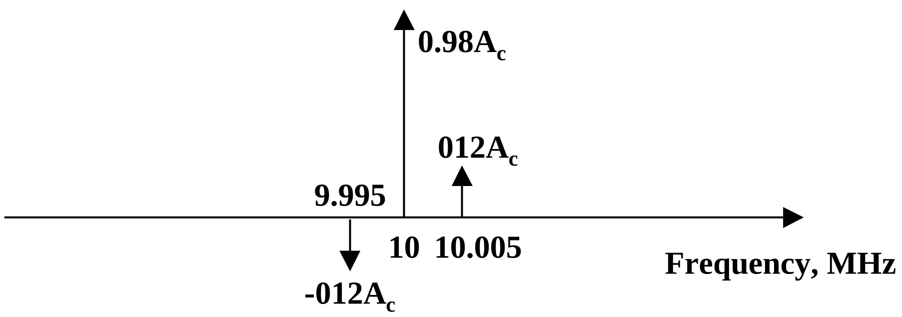
$\beta = f_{dev}/f_m = 0.25$

ii. 40 kHz

$\beta = f_{dev}/f_m = 8$

(a) Calculate and sketch the frequency spectrum for the Narrowband case

From the table of Bessel functions for β=0.25, J_0=0.98 and J_1=0.12. There are no harmonics beyond the first. The lower sideband has an inversion associated with it and will hence have an amplitude of -0.12. Hence the spectrum looks like:



(b) Check the accuracy of the bandwidth of the predicted by the above eqations for both Narrowband and Wideband cases.

For the Narrowband case, the bandwidth is found to be twice the modulating frequency and the above equation is thus very accurate.

For the wideband case, we can see from the table of Bessel functions for β=8, that there are 11 significant harmonics. The bandwidth is thus 22 times the message bandwidth. The equation above suggests a bandwidth of 18 times the message bandwidth and is thus not very accurate.