1. [24%] The superheterodyne receiver shown in Figure PR-1 is to be used to receive SSB (upper sideband) signals with carrier frequencies between 2 MHz and 3 MHz. The carrier frequencies are spaced 5 kHz apart. The IF frequency is 455 kHz.

(a) [12%] Assuming low-side conversion is used, what is the range of local oscillator frequencies in order to receive signals between 2 MHz and 3 MHz?

\[ f_{LO_{(\text{min})}} = \cdots \]

\[ f_{LO_{(\text{max})}} = \cdots \]

(b) [12%] When tuning in a station at 2.2 MHz what is the local oscillator frequency? Where is the image located?

\[ f_{LO} = \cdots \]

\[ f_{\text{IMAGE}} = \cdots \]
2. [24%] The 20 MHz upper sideband signal shown in Figure PR-2(a) is to be converted to a 50 MHz lower sideband signal shown in Figure PR-2(b) using the system shown in Figure PR-2(c).

(a) [14%] Sketch the spectrum of \( w(t) \) (the output of the mixer). Indicate the value of all significant frequencies and amplitudes on the graph.

(b) [10%] What is the minimum BW and the corresponding value of \( f_o \) (the bandwidth and center frequency of the band pass filter) in order to generate the desired lower sideband signal?

![Figure PR-2: Sideband Conversion](image-url)
3. [32%] An FM transmission system transmits at a carrier frequency of \( f_c = 102 \) MHz. The modulating signal has a bandwidth of \( W = 20 \) kHz. The frequency deviation of the transmitted signal is \( \Delta f = 50 \) kHz. The indirect FM system shown in Figure PR-3 is used to generate the transmitted signal. The narrowband FM (NBFM) component uses a carrier frequency of \( f_{c1} = 200 \) kHz and has a maximum frequency deviation of 100 Hz. (The NBFM frequency deviation is adjustable.)

(a) [5%] What is the deviation ratio, \( \beta \), of the transmitted signal \( y(t) \)?

(b) [5%] Use Carson's rule to estimate the bandwidth of the transmitted signal \( y(t) \).

(c) [7%] How many frequency triplers are needed in the multiplier stage?

(d) [7%] To what value should the frequency deviation of the NBFM component be adjusted?

(e) [8%] What value of \( f_{LO} \) is required?

Figure PR-3: Indirect FM Generation System
4. [20%] Answer the following questions by circling the correct answer.

(a) [2%] DSB-SC modulation is the method used in standard AM radio.
   i. TRUE       ii. FALSE

(b) [2%] A message has a bandwidth of 10 kHz. The corresponding bandwidth of the DSB-SC modulated signal is _________.
   i. 10 kHz    ii. 20 kHz

(c) [2%] AM uses less bandwidth than DSB-SC.
   i. TRUE       ii. FALSE

(d) [2%] Traditional TV (NTSC) sets use synchronous demodulation to demodulate the video signal.
   i. TRUE       ii. FALSE

(e) [2%] A phase-locked loop (PLL) can track changes in frequency but not changes in phase.
   i. TRUE       ii. FALSE

(f) [2%] NTSC audio is _____ modulated at a frequency 4.5 MHz above the video carrier.
   i. AM         ii. FM

(g) [2%] FM uses a smaller bandwidth than AM or DSB.
   i. TRUE       ii. FALSE

(h) [2%] A frequency converter (mixer) alters the carrier frequency but not the frequency deviation.
   i. TRUE       ii. FALSE

(i) [2%] Sinusoids with frequencies equal to 10 MHz and 20 MHz are input to a mixer. A possible output frequency is __________.
   i. 20 MHz    ii. 10 MHz

(j) [2%] In a superheterodyne receiver, adjacent channel suppression is performed by the _____ amplifier.
   i. RF         ii. IF