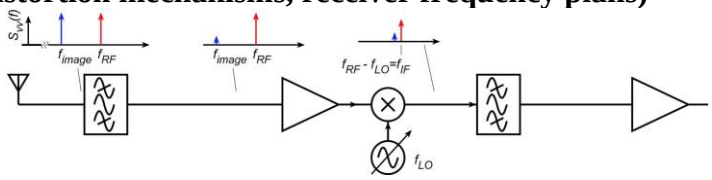
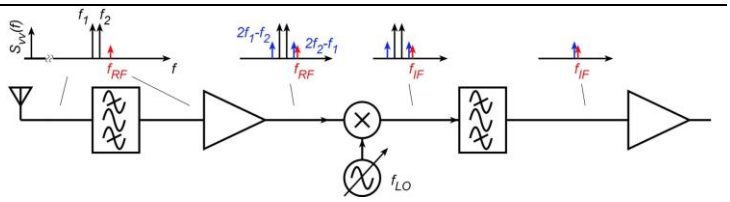
ECE 145b, 218B problem set (distortion mechanisms, receiver frequency plans)

Problem 1: Image response. Consider an FM radio receiver, where the signal frequency to be tuned is 88-108 MHz, and the IF frequency is 10.7 MHz. The local oscillator frequency



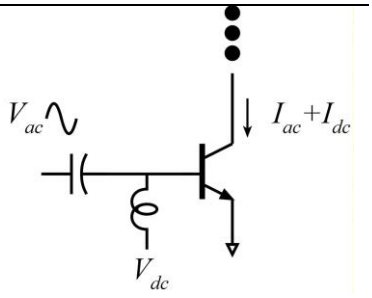
is ***above*** the intended RF signal frequency, not below it. (a) When the receiver is tuned to 88 MHz, what is the LO frequency ? What is the RF image frequency ? (b) When the receiver is tuned to 108 MHz, what is the LO frequency ? What is the RF image frequency ? (c) Based upon the above, can a fixed-tuned RF preselect filter be used for image rejection ? What is the allowable frequency passband of this filter ?

Problem 2: A receiver, designed to receive of problem (1abc) is now tuned to receive a station at 100 MHz RF frequency. The receiver has a -10 dBm input-referred third order intercept.



There are two interfering radio stations, each of -25 dBm amplitude, one 200 kHz below the RF signal of interest, the other 400 kHz below the RF signal of interest. (a) What RF signal power would result in a 20 dB carrier-to-interference ratio, i.e. the IM3 product from the 2 interferers is 20 dB below the desired RF signal ? (b) Compare this to the noise-limited sensitivity of a high-quality FM stereo receiver at about -135 dBm.

Problem 3 **(218B only)**: Consider a bipolar transistor amplifier with $I_C = I_s \exp(qV_{be}/kT)$. The base emitter voltage is the sum of a DC bias voltage $V_{BE,DC}$ and of an AC signal $\delta V_{BE} = 2^{1/2} V_{RMS} \cos(\omega_1 t) + 2^{1/2} V_{RMS} \cos(\omega_2 t)$. As a result of this, the collector current has both an AC and a DC component and has 2-tone distortion products. If $V_{BE,DC}$ is such that the transistor is biased at $I_{E,DC}$=1 mA, $V_{BE} = V_{BE,DC} + \delta V_{be}$ and $I_C = I_{C,DC} + \delta I_C$, and if we truncate to 3rd order, then $\delta I_C = a_1 \delta V_{be} + a_2 (\delta V_{be})^2 + a_3 (\delta V_{be})^3 + ...$



(a) Find the coefficients a_1 and a_3. (b) Considering only the 1st and 3rd order terms, what value of V_{rms} gives equal response for the linear term $a_1 \delta V_{be}$ at frequency ω_1 and for the cubic term $a_3 (\delta V_{be})^3$ at frequency $2\omega_1 - \omega_2$? This is the input-referred third-order intercept in units of volts (RMS).

Problem 4: The FET has characteristics $I_d = K(V_{gs} - V_{th})^2$ where K =20 mA/V^2 and V_{th} =0.3Volts. The FET is biased at 3 mA drain current. With $V_{ac} = V_0 \cos(\omega_1 t) + V_0 \cos(\omega_2 t)$ and V_0 = 1mV, compute the amplitudes of all Fourier components of the drain AC current.