Problem set: mixers

Problem 1: If the radio receiver has a 10.7 MHz IF, and is tuned to receive an 88 MHz signal frequency, what are your two possible choices of LO frequency? For each choice, what is the frequency of the image, i.e. what undesired signal frequency at the antenna falls at the center of the IF pass band?

Problem 2: continuing with the parameters of problem 1, if we choose an LO **below** the RF frequency, and wish to tune the 88-108 MHz RF band, will a 85-110 MHz bandwidth of a fixed-tuned RF front-end filter be sufficient if we wish to always reject the image response?

Problem 3: You are measuring an amplifier you have built. At -10 dB input power per tone, the output power at each of the input frequencies are 0 dBm, while the output signal powers at $(2f_1 - f_2)$ and $(2f_2 - f_1)$ are both -30 dBm. Find the amplifier gain and the input-referred and output referred third-order intercepts.

Problem 4: (harder, graduate level). A component has 10 dB gain and an 0 dBm input-referred third-order intercept. Tones of amplitudes -20 dBm, -30 dBm, and -40 dBm are input at signal frequencies $f_1$, $f_2$, and $f_3$ (0.99, 1.0, and 1.01 GHz). Ignoring responses near DC and near 3 GHz, find the frequencies and power levels of the output tones near 1 GHz.
Problem 5: The diode bridge mixer has ideal diodes (zero on-resistance, infinite off-impedance). The transformer ratios are all 1:1. The LO is a cosine wave at 1.0 GHz. The IF port is loaded in 50 Ohms. If \( V_{RF}(t) \) is a 100 MHz sine wave of 1 mV peak amplitude, (a) make a graph of \( V_{IF}(t) \). (b) find the Fourier amplitudes of the mixer output at the sum and difference frequencies and (c) find the mixer input impedance (takes some thought...)

Problem 6: Continuing with the parameters of problem 5, let us now assume that the diode on-resistances are each 0.5 Ohms (hence a total of 1 Ohms for the series combination). We further apply band-pass filters at the two ports as indicated. Assume a 1.5 GHz RF and a 500 MHz IF, with a 1 GHz LO. Find the 2-port parameters of the mixer. This is a graduate-level problem----218b students only

Problem 7: In the mixer at right, the LO power is sufficient to drive the diodes into zero ohms in forward conduction and infinity ohms in reverse bias. The Fourier series of a squarewave is given to the right. The RF frequency is 60 GHz, while the IF frequency is 10 GHz.

\[
V_{sq}(t) = \frac{4}{\pi} \left[ \cos(\omega t) + \frac{\cos(3\omega t)}{3} + \frac{\cos(5\omega t)}{5} + \ldots \right]
\]

In order to save cost on the LO design, we choose to use the \( \cos(3\omega t) \) term for mixing of
the 60 GHz received signal to the 10 GHz IF. Given this, there are two possible choices for LO frequency. Again, to save cost pick the lower of these. What would it be? What would be the effect upon the *voltage gain* of the mixer by using the $\cos(3\omega t)$ term instead of the $\cos(\omega t)$ term? Considering only the first three terms of the Fourier series, as shown above, there are now *multiple* image frequencies. What are they?

Problem 8: The two FETs each have 100 mS transconductance. Each IF LC filter is loaded externally with 1 kOhm load resistance (not shown). Treat the mixer quad as a set of ideal switches. If the mixer differential input voltage $V_{RF}$ is 10 mV R.M.S., find the RMF IF output voltage.