EE 215C
RF Circuits & Systems

H.W. 4

50/50

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(a) Determine the values of L_1 and L_2 to obtain resonance at 5.2 GHz and 1.7 GHz at the LNA output and RF mixer output, respectively.

From simulations, L1 and L2 are chosen to be 5nH and 23nH respectively as shown in figure 1 and figure 2.

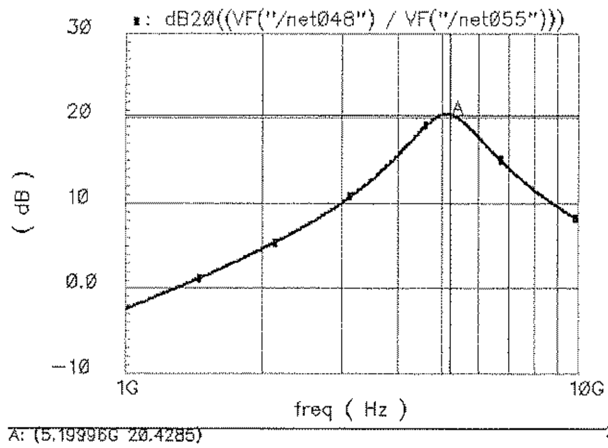

Figure 1. L_1 for resonance at 5.2GHz

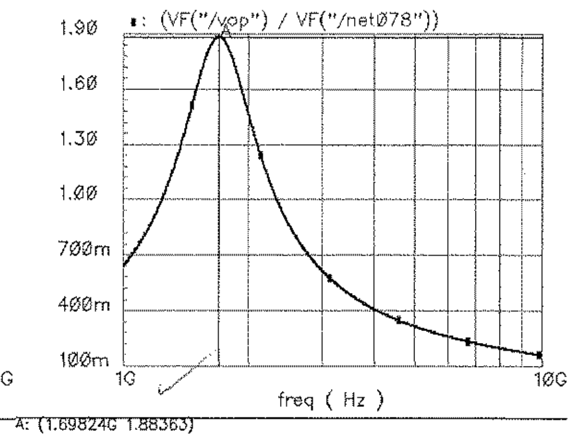

Figure 2. L_2 for resonance at 1.7GHz

(b) Compute the total voltage gain of the receiver, with the input level defined as $V_{in}/2$.

Figure 3 and figure 4 represents power of several tones at the input and at the output.

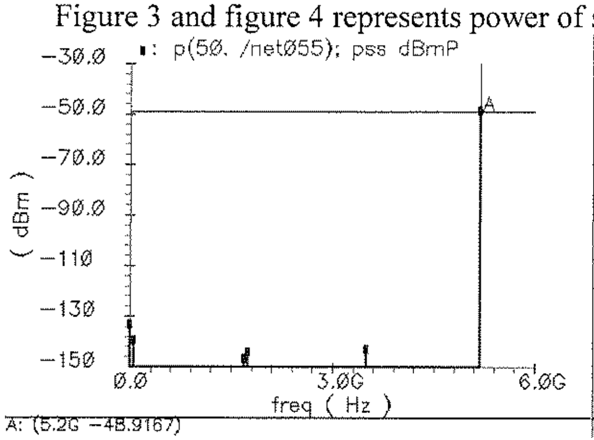

Figure 3. Power of tones at the input

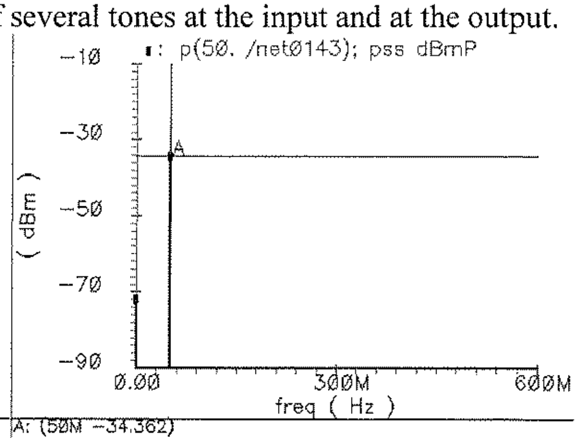

Figure 4. Power of tones at the output

As shown in the figures, the input to output voltage conversion gain is 14.5547dB. Although -50dBm is applied to the input port, the actual input power is -48.9dBm due to input impedance of higher than 50 ohms. The voltage gain of the first stage is 20.4dB as depicted in figure 1. We lose 1.2dB of power because of ac coupling capacitance, 500fF.

The voltage conversion gain of the first active mixer is -6dB. Since the sizes of switching NMOS is too small and the amplitude of LO1 is not big enough, switching NMOSs are not actually switching. They are always turned on and signal current generated by M2 is split to both branches at the same time to be cancelled at the differential output. We can improve the mixer performance by either increasing the size of switching NMOSs or increasing the LO1 amplitude.

The conversion gain of the second mixer is -1.8dB. Although the sizes of switching PMOSs are small, it shows better voltage conversion gain due to large LO2 swing. In 14.5547dB voltage conversion gain is obtained.

(c) Determine the image-reject ratio of the receiver.

To find out image rejection ratio, -50dBm 5.3GHz input signal is applied to the input port. 5.3GHz will be down-converted to 1.8GHz by the first mixer and again down-converted to 50MHz by the second mixer. Since we used quadrature down-conversion, we have image rejection ratio. The 50MHz output power measured at the output is -62dBm as shown in figure 5.

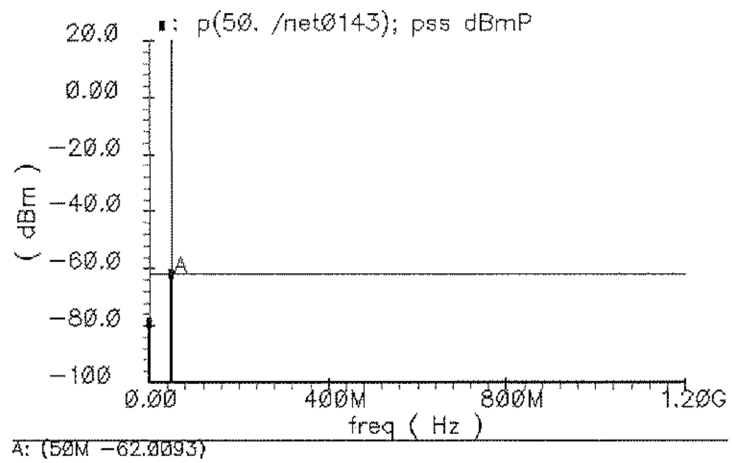

Figure 5. Image signal output power (applied the same input power, -50dBm)

If we compare this result with real signal case, we can find image rejection ratio.

$$IRR = \frac{\text{Desired Signal Power}}{\text{Image Signal Power}} = -34.36dBm - (-62dBm) = 27.64dB$$

(d) Identify two mechanisms through which the receiver translates an interferer at 8.7 GHz to baseband. Assume no mismatches or even-order harmonics. Determine the gain experienced by such a component and normalize the result to the gain found in (a).

8.7GHz interferer can be translated to baseband following two cases.

$$(1)\ 8.7GHz \xrightarrow{\text{1st Mixer Fundamental (3.5GHz)}} 5.2GHz \xrightarrow{\text{2nd Mixer 3rd Harmonicl (5.25GHz)}} 50MHz$$

$$(2)\ 8.7GHz \xrightarrow{\text{1st Mixer 3rd Harmonic (10.5GHz)}} 1.8GHz \xrightarrow{\text{2nd Mixer Fundamental (1.75GHz)}} 50MHz$$

Since the power of 5th harmonic of LO signals are smaller than 3rd harmonic of LO signals, two cases above are most relevant. From simulation, the power translated from 8.7GHz to baseband, 50MHz is -84dBm as shown in figure 6.

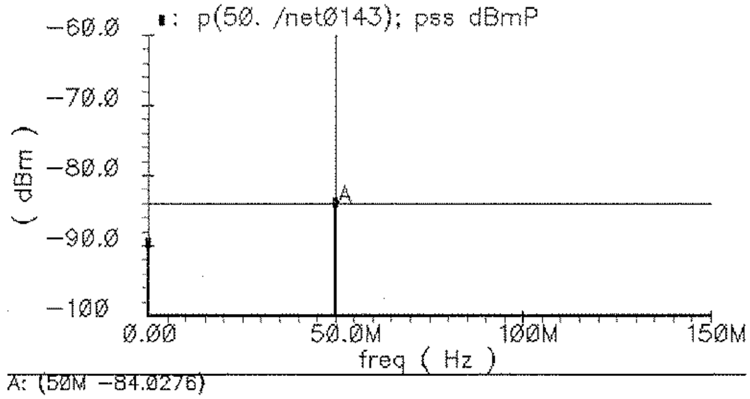

Figure 6. Power translated from 8.7GHz to baseband (-50dBm input)

If we find the gain from input to output, a 8.7GHz signal experiences -35.13dB gain while 5.2GHz signal experiences 14.5547dB. If we normalize the result to the gain,

Normalized Gain = -35.13dB - 14.5547dB = −49.6847dB

Therefore, if the power of the interferer at 8.7GHz is not 50dB higher than the signal at 5.2GHz, it does not degrade the performance of the receiver too much. Its gain is -50dB at the output