ECE 4880 RF Systems Fall 2016
Homework 7
Due on 10/28 5pm in the Phillips Hall Dropbox

Reading before homework:

- Lecture summary on Nonlinearity and Interplay Between Noise and Nonlinearity
- Egan's book, Chaps. 4 and 5.

1. (**Single Side Band Nonlinear and Noise Interplay**) A single-side band (SSB) signal can be approximated by the positive and negative frequency domain as below after the mixer and filter. This signal is fed into a power amplifier where only IM2 nonlinearity is important. Assume $a_1 > a_2 v_{in}$, give the shape and rough size estimation of the output voltage with noise and nonlinearity interplay. Hint, for the positive frequency, use the interaction between any two frequencies between ($f_c - BW$, f_c). (**10 pts**)

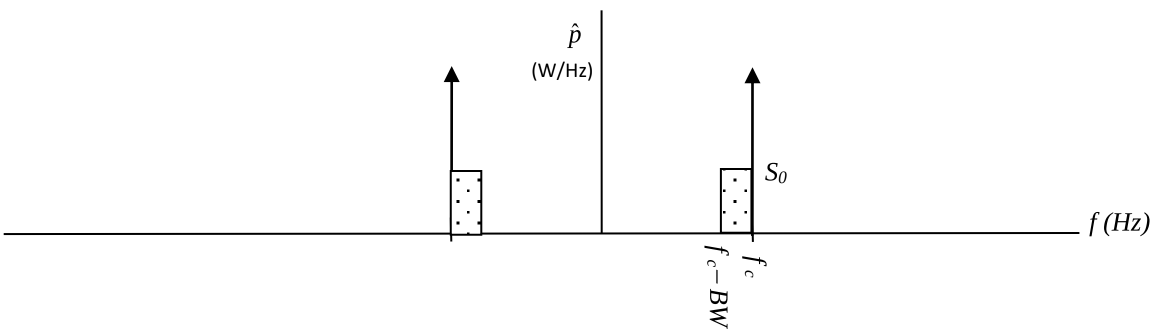

Fig. P.1**.** Spectral influence from noise and nonlinear interplay.

2. (**1-dB compression**) For a power amplifier with 20dB gain, IIP_{IM3} = 30 dBm and IIP_{H2} = 20dBm (same PA from Homework 6) for the band 800MHz – 1.2GHz,
   (a) Assume the VTC is only valid for the given bandwidth and outside the band the gain is much smaller, which or both 2nd and 3rd-order nonlinearity is important for obtaining 1-dB compression point? (**5 pts**)
   (b) Give $I_{1dBcomp}$ and $O_{1dBcomp}$. (**10 pts**)
   (c) Calculate the magnitudes of Taylor coefficients a_1, a_2 and a_3 for the VTC. Use the standard impedance of 50Ω. The Taylor expansion of v_{out} is expressed in volts. (**15 pts**)

3. (**Transfer function to IP**) For a power differential amplifier whose VTC can be described by: $v_{out} = 20 \times v_{in} + 0.1 \times v_{in}^3$ with v_{in} and v_{out} in V and I/O impedance Z_0 of 50Ω in all frequency of interest,
   (a) What is the linear voltage and power gain in dB? (**5 pts**)
   (b) What is the unit of 0.1 in the VTC description? If f_a = 1GHz and f_b = 1.1GHz, what are the IM3 frequencies? (**5 pts**)
   (c) Find IIP_{IM3}, OIP_{IM3}, IIP_{H3}, OIP_{H3} and $I_{1dBcomp}$. (**10 pts**)

4. (**Signal desensitization and jamming**) An LNA as the first stage in the receiver has 15dB gain and noise figure of 3dB. The LNA designer did not anticipate large input signal, so the nonlinearity was not carefully designed with a low IIP_{IM3} = 10 dBm. We will still use Z_0 = 50Ω in all frequency of interest,
   (a) In the two-tone signal, if a smaller signal $A\cos(\varphi_a)$ is received at –60dBm, will the IM3 term be an important distortion consideration when no other signal is present? (**5 pts**)
   (b) What will be the large signal voltage $B\cos(\varphi_b)$ that will desensitize this small signal? The large signal B may be from an in-band jammer, although $\varphi_a \neq \varphi_b$ and B does not cause a direct

interference as it could be rejected by the mixer without the LNA nonlinearity. The desensitized point is defined when the interfering voltage generates a distortion magnitude at the signal frequency that is half of the originally intended signal voltage. Does the desensitized point depend on p_{in}? (**10 pts**)

(c) Recalculate the jamming desensitization voltage B if LNA has a better design with IIP_{IM3} = 40dBm. (**5 pts**)

5. (**Cascade with gain, noise figure and OIP3**) Module 1 is an amplifier with g_1 = 20dB; F_1 = 10dB; $OIP3_1$ = 38 dBm. Module 2 is a filter with pass band g_2 = –0.5dB; F_2 = 3dB (more noise than that of attenuator); $OIP3_2$ = 30 dBm as ferromagnetic inductor is used. Assume all IM terms add up coherently.
   (a) Calculate the cascade gain, noise figure and OIP3 for Module 1 – 2 and Module 2 – 1. (**10 pts**)
   (b) If we hope for the least nonlinearity, which cascade should be chosen? If we hope for the least noise, which cascade should be chosen? (**10 pts**)