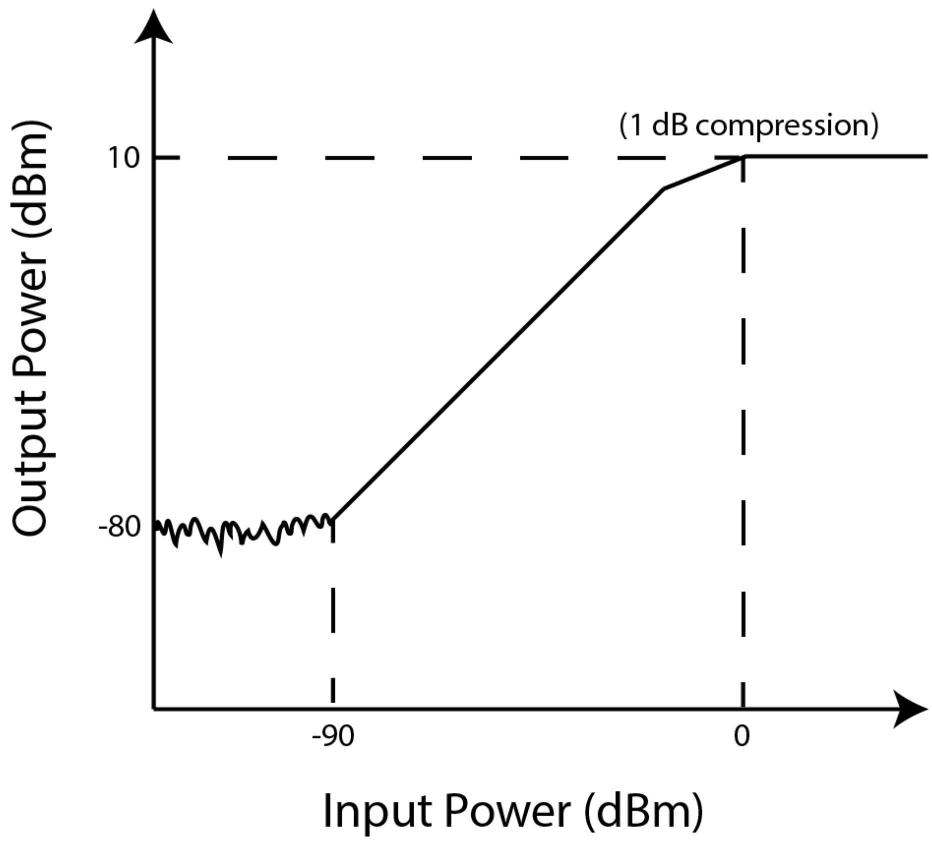
Problems for Week 2: Radar Systems

1) Assume that the chirped waveform for an ice penetrating radar has a center frequency of 60 MHz, a bandwidth of 15 MHz, and a pulse length of 1μs. For a short-pulse radar system, the bandwidth of the transmit waveform is: $\beta = 1 / T$, where β is in Hz and T is the pulse length in seconds.
    a. How short must the pulse length of the short-pulse system be in order to achieve the same range resolution as the chirped system?
    b. If both waveforms are transmitted through the same 1 kW transmitter, how many times more energy is contained in the bed echo for the chirped system than for the short-pulse system.

2) Assume that you are trying to build an ice penetrating radar that transmits a chirped waveform with a center frequency of 60 MHz and a bandwidth of 15 MHz. You have one signal generator that can generate chirped waveforms but has a maximum output frequency of 50 MHz. You have a second signal generator that can only produce sine waves, but can generate frequencies as high as 70 MHz. You also have a mixer that you can assume behaves ideally and a Gaussian band-pass filter with a 3 dB pass-band from 50 MHz to 70 MHz.
    a. Draw a diagram of how you would hook up the components to produce the desired output?
    b. What should each of your waveform generators output in order to produce the desired output with the least noise and why?

3) Assume that you are trying to build an ice penetrating radar system with two digitized channels (one with low gain to detect the surface and one with high gain to detect the bed). Both channels have 12 bit digitizers and are attached to the output of a low noise amplifier (through 50 Ω) coaxial cable with the gain curve shown below.



a. What should the saturation voltage of each digitizer be set at (in volts peak-to-peak) in order to maximize the total combined dynamic range while maintaining 1dB clearance above the 1dB compression point for surface saturation and 2 bits of overlap between the channels?
b. What is that combined dynamic range?
c. If coherent stacking M times can reduce the effective noise by a factor of 1/M, how many coherent stacks can be performed before the rms noise drops below the quantization level?
d. What is the total dynamic range for this level of stacking

4) Assume that you are trying to build a low-noise/high-dynamic range amplifier for your ice penetrating radar receiver. You need this amplifier to have a total gain of 20 dB, a 1 dB compression point of -5 dBm (referenced to output), and the maximum possible linear dynamic range. Assume your receiver will be fed by an antenna with a noise temperature T_a = 150 k and that your reciver has a bandwidth of 100 MHz. In order to build this receiver, you have the four amplifiers listed below (you may use any number of them) and a large kit of attenuators with any quantities and values your might need.

Amplifiers Name:	Quantity:	Gain (dB):	1dB compression (ref to output):	Noise Figure(dB):
A	**1**	**30**	**-5**	**2**
B	**1**	**30**	**-5**	**5**
C	**1**	**35**	**15**	**5**
D	**1**	**35**	**15**	**10**

a. Draw the design for your amplifier and label the amplifier names and attenuator values that you used.
b. What is the total linear dynamic range of your system?

5) Assume that you are trying to design an ice penetrating radar system with a fixed total transmit power, but a variable number of antennas to be deployed as an uniformly spaced dipole array. Your goal is to improve both the signal-to-noise ratio of the nadir returned energy and the signal-to-clutter ratio for off-nadir returns. Use the m-script (MATLAB or Octave) file provided (HW_2_5.m) to produce a nadir-facing beam pattern for a two-element array (N = 2) and edit the script to test the effect of different numbers of elements (N). Assume that the total transmitted energy (T_0) is constant, so each antenna transmits T_0/N and that the return from each channel is coherently summed with a SNR gain of $N^{1/2}$. Assume that the signal come from the nadir direction and experiences the nadir-directed antenna gain twice. Assume that the clutter comes from the highest gain angle in the beam pattern between 15° and 45° off-nadir and experiences that gain twice. (Plots by hand are fine)

a. Plot the signal-to-noise ratio for antenna arrays with 1 to 12 elements.
b. Plot the clutter-to-noise ratio for antenna arrays with 1 to 12 elements.
c. Based on these results, what do you think is the ideal number of elements and why?