Signals & Noise Homework W6

(1) You have a lab experiment in which a very weak continuous (in time) beam of photons (counts of photons per second is your signal) goes into a noisy detector. The detector outputs a voltage proportional to the power of the incident light. Unfortunately the amplified output of your detector V(t) is dominated by the noise in the detector and is so noisy that the positive DC contribution due to any detected light is buried in the noise. Finally, the gain of the amplifier chain is drifting with time. What technique can you introduce to detect the signal? Draw and describe your setup.

(2) You have a telescope and photodetector (one pixel – not an imager) at the focus. You are trying to detect a very faint star. The noise contribution from the detector is small compared with that due to the sky: the amplified output of your detector is dominated by the shot noise of the night sky background photons. What can you do to detect the star?

(3) You have a situation in which you are trying to detect a known single rectangular pulse of duration T seconds of known arrival time T0. But your detector is very noisy with a "1/f" spectrum of noise of power spectral density Sn(f) = S0/f. Design a signal-matched filter H(f). What different kind of optimal filter can you use if the arrival time is unknown and you simply want to maximize the signal-to-noise ratio given the time averaged spectra of the signal and noise on the output of your detector and no other information? What if the noise is a mix of 1/f and Johnson noise: Sn(f) = S0/f + Sj.

(4) In 2000 the Navy deployed a new high power low frequency sonar with ocean-wide search capability. Listen to this sonar and whales in the file Week6/Whales+Sonar.WAV
Rather than treating the sonar as the signal and the whales as noise, suppose you want to listen to the whales [given a spectrum Whales(omega)]. i.e. you want to design a filter that maximizes the signal-to-noise where the signal is Whales(omega) and the "noise" is Sonar(omega). You know nothing other than these spectra, and you want to listen to the whales during the sonar transmission. What is your optimal filter H(omega)? [note this is very different from the classic problem of a pulse sonar, where a different question is posed]. More humpback whale sounds/spectra: http://www.dosits.org/audio/interactive/#/46

(5) Pulses from the sky: The Crab pulsar emits a pulse train in the radio with period about 33 ms. You have access to a radio telescope output voltage R(t) which represents the magnitude of the detected radio power vs time. Assume no noise on R(t). You want to find out if this pulsar is emitting in the optical! You have only a small telescope in your back yard and you live in the city (bright sky). You are using a photodectector such as a photomultiplier tube that has fast time response and negligible internal noise. You point your telescope to the correct position on the sky and see nothing but sky noise. Using techniques you learned in class, describe briefly an optimal detection setup. Extra credit: given that there is likely information in the signal at multiples the Crab pulse frequency (including the second harmonic), briefly discuss what problems you might run into and suggest solutions.