

The purpose of this lab is to explore two examples of applications of cross-correlation function, $\rho_{xy}(k)$, which is simply the cross-correlation of two signals, $x(n)$ and $y(n-k)$, where k is called the lag value. For detailed explanation, please read the attached description of cross-correlation.

1. Range estimation of targets (using a Radar)

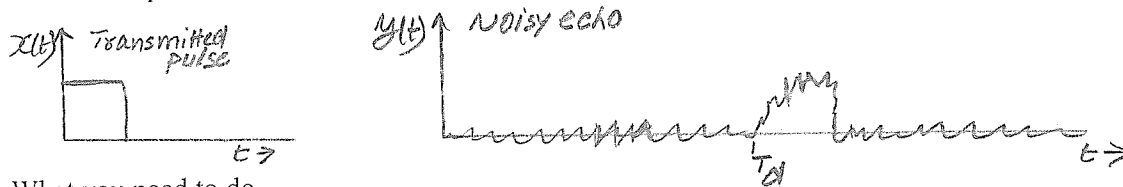
The basic idea of range estimation involves transmitting a pulse, detecting an echo from a target using cross-correlation technique, and estimating its range as,

$$R = cT_d/2$$

where

c = velocity of electromagnetic waves = 3×10^8 m/sec, and
 T_d = Time delay between the transmitted pulse and the received echo.

The problem of range detection becomes a challenging one in presence of random noise, which is always encountered (due to both natural and man-made causes). Most of the signal samples received in a Radar receiver are actually random noise samples, whereas the true echoes from targets are the desired signals buried in noise. Since a deterministic signal, such as a transmitted Radar pulse, and random noise are uncorrelated with each other, their cross-correlation will be zero for most of the samples, except at locations where true echoes are present. Thus, the cross-correlation of the received signal and the transmitted pulse can reveal the locations of the true echoes. The following picture illustrates the idea.



What you need to do

1. Assume a 11-point Barker sequence is used as the transmitted pulse:

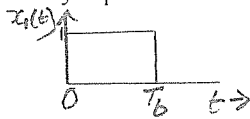
$$B(n) = [+1 +1 +1 -1 -1 -1 +1 -1 -1 +1 -1].$$

Generate a vector, x , of length 2000 that contains the above sequence at sample locations, $1 \leq n \leq 11$, and zeros elsewhere.

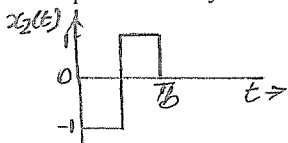
2. Now load the given data file, lab308dat1.mat, that contains a noisy received signal, $y(n)$, of length 2000.
3. First compute the cross-correlation of lag = 0 between $x(n)$ and $y(n)$. Next, slide $x(n)$ over $y(n)$ one sample at a time to simulate different lag values, $1 \leq k \leq 1999$, and for each k , compute the cross-correlation, $\text{corr}(k)$, between $x(n-k)$ and $y(n)$.
4. Plot $\text{corr}(k)$ as a function of k , and locate the targets.

2. Detection of 1s and 0s using a Correlation Receiver

Consider the baseband transmission of a binary bit stream consisting of 1s and 0s, where each bit is represented by a pulse of duration, T_b . Suppose a “1” is represented by the following pulse, x_1 :



and a “0” is represented by the following one, x_2 :



Since the received signal is usually noisy, we can compute cross-correlation between the received signal, $y(t)$ and the above templates at intervals of T_b . Suppose r_{1y} denotes the cross-correlation between x_1 and $y(t)$, and r_{2y} denotes the cross-correlation between x_2 and $y(t)$. A correlation receiver decides between 0 or 1 by examining the values of r_{1y} and r_{2y} as follows:

If $r_{1y} > r_{2y}$, decide the bit to be a “1”, and

if $r_{2y} > r_{1y}$, decide the bit to be a “0”.

The above decision rule is called an optimum detector that minimizes the probability of error. This will be discussed later in the class.

What you need to do

1. Assume that each 1 and 0 is represented by the following discretized pulses of duration 4:

A “1” is represented by $x_1 = [1 \ 1 \ 1 \ 1]$, and

a “0” is represented by $x_2 = [-1 \ -1 \ 1 \ 1]$;

Also, assume $T_b = 4$ samples.

2. Load the data file lab308dat2.mat that contains two noisy received pulse sequences, $y1(n)$, $y2(n)$, one of which more noisy than the other. For each pulse sequence, compute cross-correlations, r_{1y} and r_{2y} , at sample intervals of 4, and decode the received bit stream using the decision rule mentioned above. You should find two bit streams, each containing 25 bits.