Advanced Digital Signal Processing

MATLAB Homework #1 (Due: 25/03/2017)

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Problems:

Time delay estimation in radar:
Let $x_a(t)$ be the transmitted signal and $y_a(t)$ be the received signal in a radar system, where

$$y_a(t) = ax_a(t - t_d) + v_a(t)$$

and $v_a(t)$ is random noise. The signals $x_a(t)$ and $y_a(t)$ are sampled in the receiver, according to the sampling theorem, and are processed digitally to determine the time delay and hence the distance of the object. The resulting discrete-time signals are

$$\begin{aligned} x(n) &= x_a(nT) \\ y(n) &= y_a(nT) = ax_a(nT - DT) + v_a(nT) \\ &\triangleq ax(n - D) + v(n) \end{aligned}$$

(a) Explain how we can measure the delay D by computing the crosscorrelation $r_{xy}(l)$.
(b) Let $x(n)$ be the 13-point *Barker sequence*

$$x(n) = \{+1, +1, +1, +1, +1, -1, -1, +1, +1, -1, +1, -1, +1\}$$

and $v(n)$ be a Gaussian random sequence with zero mean and variance $\sigma^2 = 0.01$. Write a program that generates the sequence $y(n), 0 \leq n \leq 199$ for $a = 0.9$ and $D = 20$. Plot the signals $x(n), y(n), 0 \leq n \leq 199$.
(c) Compute and plot the crosscorrelation $r_{yx}(l), 0 \leq l \leq 59$. Use the plot to estimate the value of the delay D.
(d) Repeat parts (b) and (c) for $\sigma^2 = 0.1$ and $\sigma^2 = 1$.
(e) Repeat parts (b), (c) and (d) for the signal sequence

$$x(n) = -1, -1, -1, +1, +1, +1, +1, -1, +1, -1, +1, +1, -1, -1, +1$$

which is obtained from the four-stage feedback shift register shown in Figure 1. Note that $x(n)$ is just one period of the periodic sequence obtained from the feedback shift register.

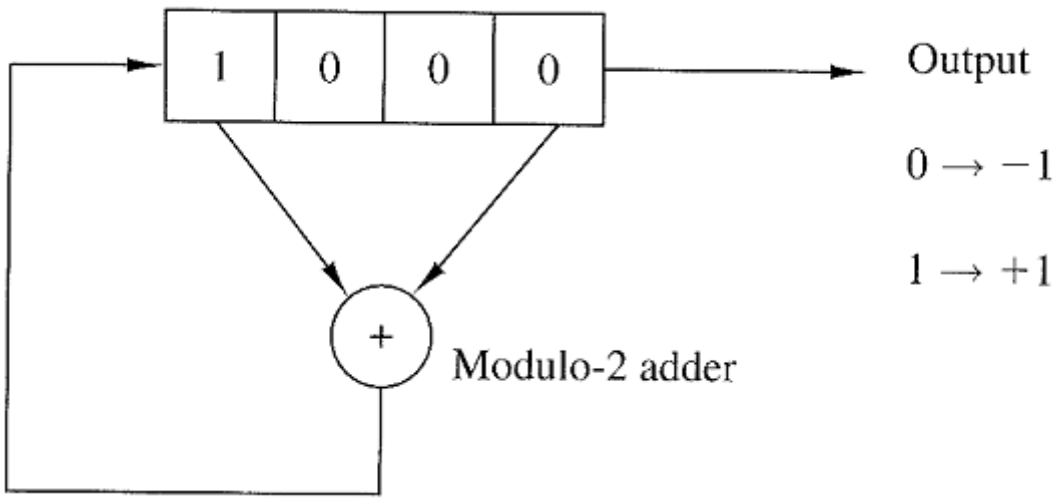

Figure 1: Linear feedback shift register

Table 1: Shift register connections for generating maximal-length sequences

m	Stages Connected to Modulo-2 Adder
1	1
2	1,2
3	1,3
4	1,4
5	1,4
6	1,6
7	1,7
8	1,5,6,7
9	1,6
10	1,8
11	1,10
12	1,7,9,12
13	1,10,11,13
14	1,5,9,14
15	1,15
16	1,5,14,16
17	1,15

(f) Repeat parts (b), (c) and (d) for a sequence of period $N = 2^7 - 1$, which is obtained from a seven-stage feedback shift register. Table 1 gives the stages connected to the modulo-2 adder for (maximal-length) shift register sequences of length $N = 2^m - 1$.