ECE 409 - WIRELESS COMMUNICATION - INVESTIGATION 19
INTRODUCTION TO CDMA - PART II

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To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs and tables.

From the last Investigation we know that to generate Direct Sequence Spread Spectrum (DSSS) signals we need pseudorandom sequences. The objective of this Investigation is to identify the properties of random sequences and then show how pseudorandom sequences can be generated.

1. Before we can attempt to build a circuit to generate pseudorandom sequences we need to identify what it means for a sequence of 1's and 0's to be random. The objective of this problem is to the study the properties of a random sequence from what we observe when we flip a coin a bunch of times.
   a. Flip a coin a fifty times with 1 for head and 0 for tails
   b. What fraction of the sequence would you expect to be 1's
   c. How close does your sequence in part (a) come to your prediction in part (b)
   d. What fraction of successive pairs of bits would you expect to be the same - to be 00 or 11
   e. How close does your sequence in part (a) come to your prediction in part (d)
   f. What fraction of three successive bits would you expect to be the same - to be 000 or 111
   g. How close does your sequence in part (a) come to your prediction in part (f)

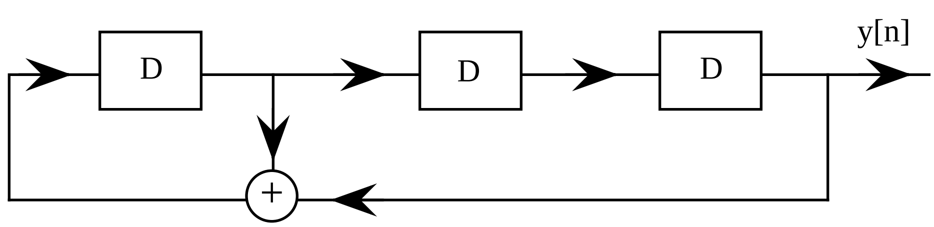
2. Generalize on the test for randomness in Problem (1)

3. In addition to the probabilities of successive bits, random sequences also have the property that if we shift them by k bits then the original and shifted sequences will agree in half the locations. Test your sequence in Problem (1) for a shift of 1 bit to the right

4. Make use of your results in the previous problems to explain why each of the following sequences are not random
   a. 11111110000000
   b. 10101010101010

5. Describe in your own words how to test a sequence for randomness

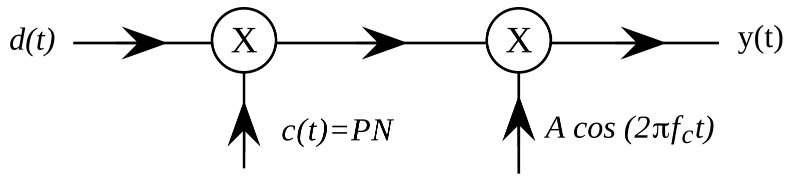
6. We can't of course build a digital circuit that will produce a purely random sequence. But we can build linear feedback shift register (LFSR) circuits like the following



that produce pseudorandom sequences - sequences that for all practical purposes are random even though they're periodic. Note that the adder is a mod 2 adder
   a. Why do the outputs of LFSR circuits have to be periodic
   b. The initial value of the registers is called the **seed**. Why won't a seed of 000 work

c. Find the pseudorandom sequence of the above LFSR circuit starting from the seed 101
d. What's the period of your sequence
e. Find and plot the discrete autocorrelation of your sequence in part (c)
f. Is your result in part (e) consistent with your value for the period in part (d). Explain
g. How close is your pseudorandom sequence to being random

7. The objective of this problem is to estimate the bandwidth of a DSSS system as follows



where d(t) is a polar NRZ data signal

a. Find y(t) as a function of d(t), c(t) and the carrier
b. Assuming d(t) and c(t) are independent it can be shown from the result in part (a) that

$$R_Y(\tau) = \frac{A^2}{2} R_d(\tau) R_c(\tau) \cos(2\pi f_c \tau)$$

and so

$$S_Y(f) = \frac{A^2}{2} S_d(f) \quad S_c(f) \quad F\left[\cos(2\pi f_c \tau)\right]$$

where

$$S_d(f) = T_b \mathrm{sinc}^2(T_b f) \quad \text{and} \quad S_c(f) = T_c \mathrm{sinc}^2(T_c f)$$

Now make use of the fact that

$$S_d(f) \quad S_c(f) \approx S_c(f)$$

to show that

$$S_Y(f) = \frac{A^2 T_c}{4}\left[\mathrm{sinc}^2\left(T_c(f - f_c)\right) + \mathrm{sinc}^2\left(T_c(f + f_c)\right)\right]$$

c. Sketch $S_Y(f)$
d. How does $S_Y(f)$ depend on the data signal

8. Why is the number of users in frequency and time multiplexed systems referred to as hard limited while referred to in CDMA systems as soft limited.