Mobile Communications

TCS 455

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Lecture 18

Office Hours:
BKD 3601-7
Tuesday 14:00-16:00
Thursday 9:30-11:30

Announcements

- Read
  - Chapter 9: 9.1 – 9.5
- SIIT Job Fair 2010 (Tomorrow)
- No class on Jan 21 (Next Thursday) – university game
- HW5 will be posted next week.
  - Due: After university game
- There will most likely be a quiz (later) today (about m-sequence).

SIIT Job Fair 2010

- **Wednesday January 13**
- Ground Floor & In front of UFM Bakery
- @ SIIT Main Building, Rangsit Campus
- Time: 9.00 – 16.00 hrs.
- Prepare several sets of
  - copy of transcript
  - resume
  - 1 inch photo

Chapter 4

Multiple Access

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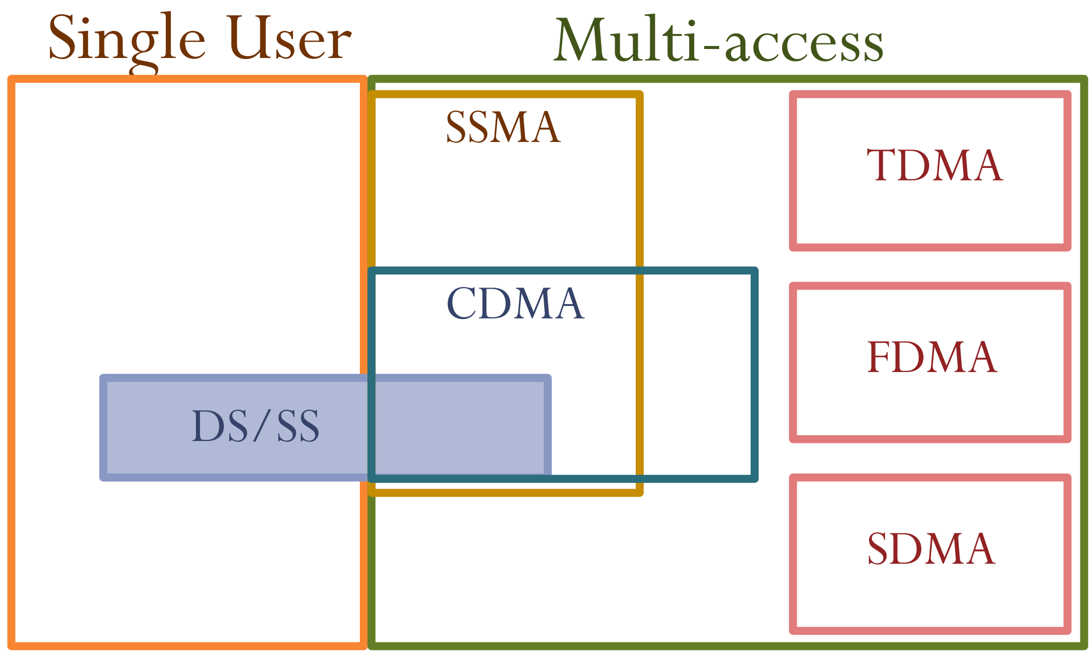
Last time:

- SSMA
- DS/SS
- CDMA

Today

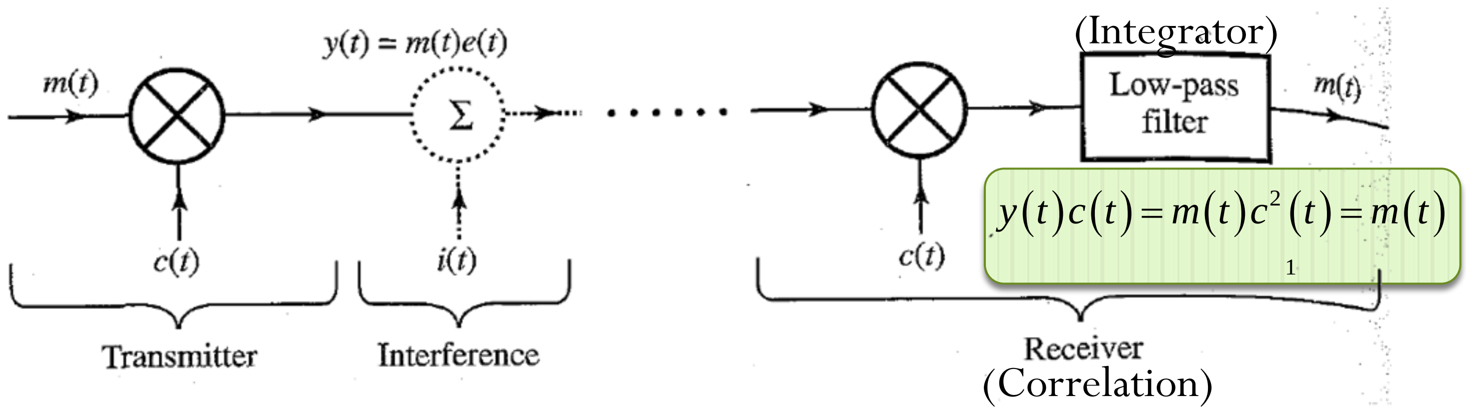
- DS/SS
- CDMA

SSMA, CDMA, DS/SS



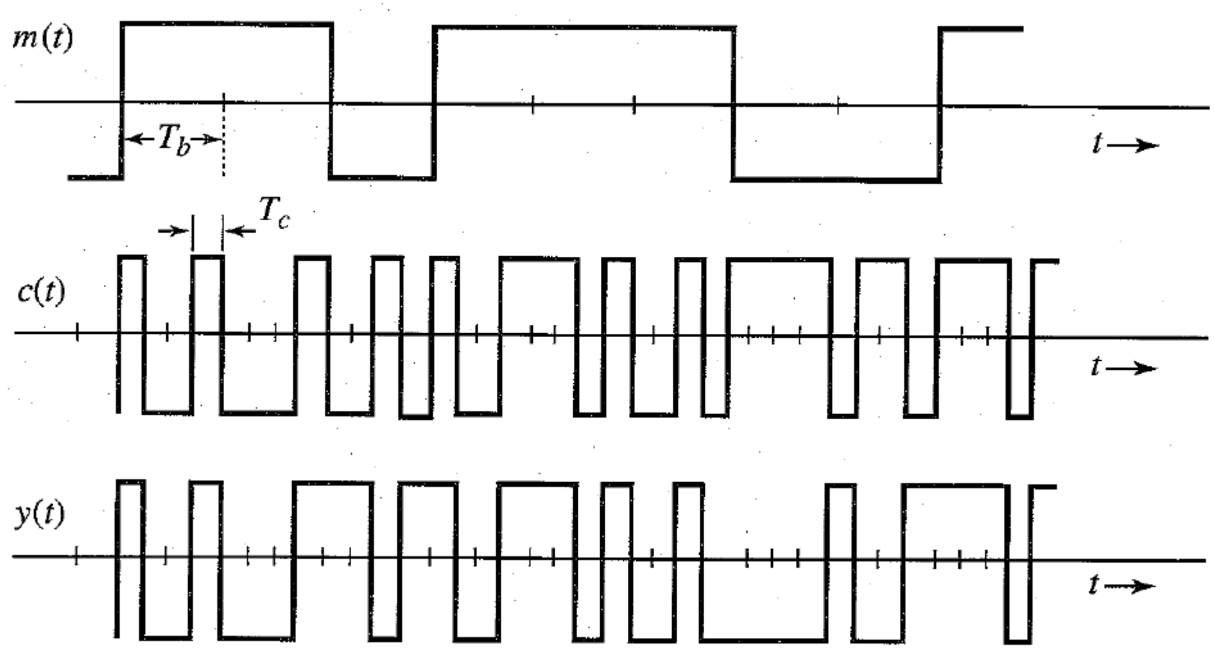
Useful even for single user!

DS/SS System



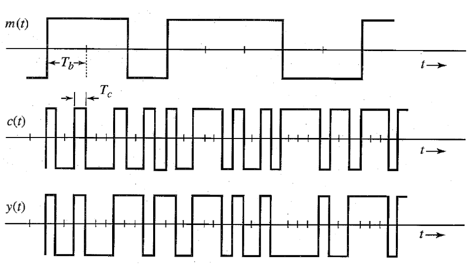
Message signal (polar binary signal)

Polar signal representing **psuedonoise (PN)** sequence. (Think of this as a pseudorandom carrier)



DS/SS

- The spectral spreading signal c(t) is a pseudorandom signal
  - Appear to be unpredictable
  - Can be generated by deterministic means (hence, pseudorandom)
- The bit rate of c(t) is chosen to be much higher then the bit rate of m(t).
- The basic pulse in c(t) is called the **chip**.
- The bit rate of c(t) is known as the **chip rate**.
- The auto correlation function of c(t) is very narrow.
  - Small similarity with its delayed version



- Remark: In multiuser (CDMA) setting, the crosscorrelation between any two codes $c_1(t)$ and $c_2(t)$ is very small
  - Negligible interference between various multiplexed signals.
- Notice that the process of detection (despreading) is identical to the process of spectral spreading.
  - Recall that for DSB-SC, we have a similar situation in that the modulation and demodulation processes are identical (except for the output filter).

Random sequences

- While DSSS chip sequences must be generated *deterministically*, properties of random sequences are useful to gain insight into deterministic sequence design.
- A random binary chip sequences consists of i.i.d. bit values with probability one half for a one or a zero.
- A random sequence of length N can thus be generated, for example, by flipping a fair coin N times as setting the bit to a one for heads and a zero for tails.
- Random sequences with length N asymptotically large have a number of the properties desired in spreading codes
  - **Balanced property** of a code: Equal number of ones and zeros.
  - **Run length property** of a code: The run length in is generally short.
    - half of all runs are of length 1
    - a fraction $1/2^r$ of all runs are of length r for r finite (Geometric)
  - **Shift property** of a code: If they are shifted by any nonzero number of elements, the resulting sequence will have half its elements the same as in the original sequence, and half its elements different from the original sequence.
- A deterministic sequence that has the balanced, run length, and shift properties as it grows asymptotically large is referred to as a **pseudorandom sequence**.

Pseudonoise (PN) signature sequence

- Ideally, one would prefer a random binary sequence as the spreading sequence.
- However, practical synchronization requirements in the receiver force one to use periodic Pseudorandom binary sequences.
- m-sequences
- Gold codes
- Kasami sequences
- Quaternary sequences
- Walsh functions

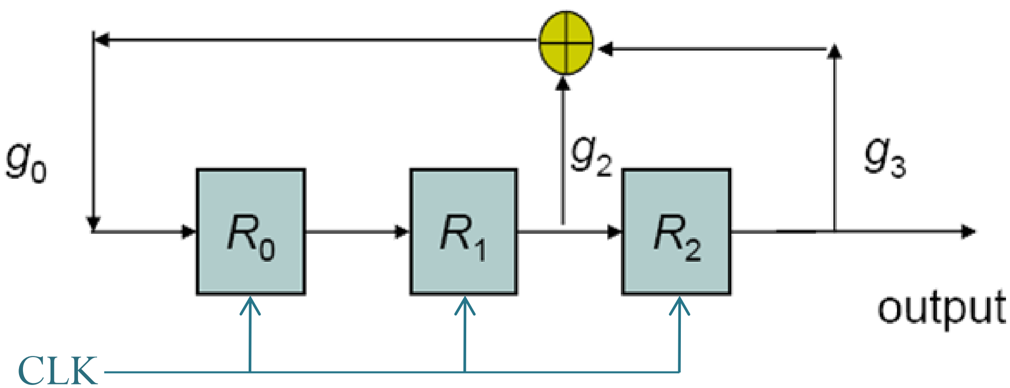
m-Sequences (1)

- **Maximal-length sequences**
- A type of **cyclic code**
  - Generated and characterized by a generator polynomial
  - Properties can be derived using algebraic coding theory
- Simple to generate with **linear feedback shift-register** (LFSR) circuits
  - Automated
- Approximate a random binary sequence in the sense that shifted versions of itself are approximately uncorrelated.
- Relatively easy to intercept and regenerate by an unintended receiver

m-sequence generator

- The feedback taps in the feedback shift register are selected to correspond to the coefficients of a **primitive polynomial**.

Binary sequences drawn from the alphabet {0,1} are shifted through the shift register in response to clock pulses.



$g(x) = x^3 + x^2 + 1$ (Degree: r = 3)

Time	R_0	R_1	R_2
0	1	0	0
1	0	1	0
2	1	0	1
3	1	1	0
4	1	1	1
5	0	1	1
6	0	0	1
7	1	0	0

Sequence repeats from here onwards

The g_i's are coefficients of a primitive polynomial.

1 signifies closed or a connection and
0 signifies open or no connection.

GF(2)

- **Galois field** (finite field) of two elements
- Consist of
  - the symbols 0 and 1 and
  - the (binary) operations of
    - **modulo-2** addition (XOR) and
    - **modulo-2** multiplication.
- The operations are defined by

$$0 \oplus 0 = 0, \quad 0 \oplus 1 = 1, \quad 1 \oplus 0 = 1, \quad 1 \oplus 1 = 0$$

$$0 \cdot 0 = 0, \quad 0 \cdot 1 = 0, \quad 1 \cdot 0 = 0, \quad 1 \cdot 1 = 1$$

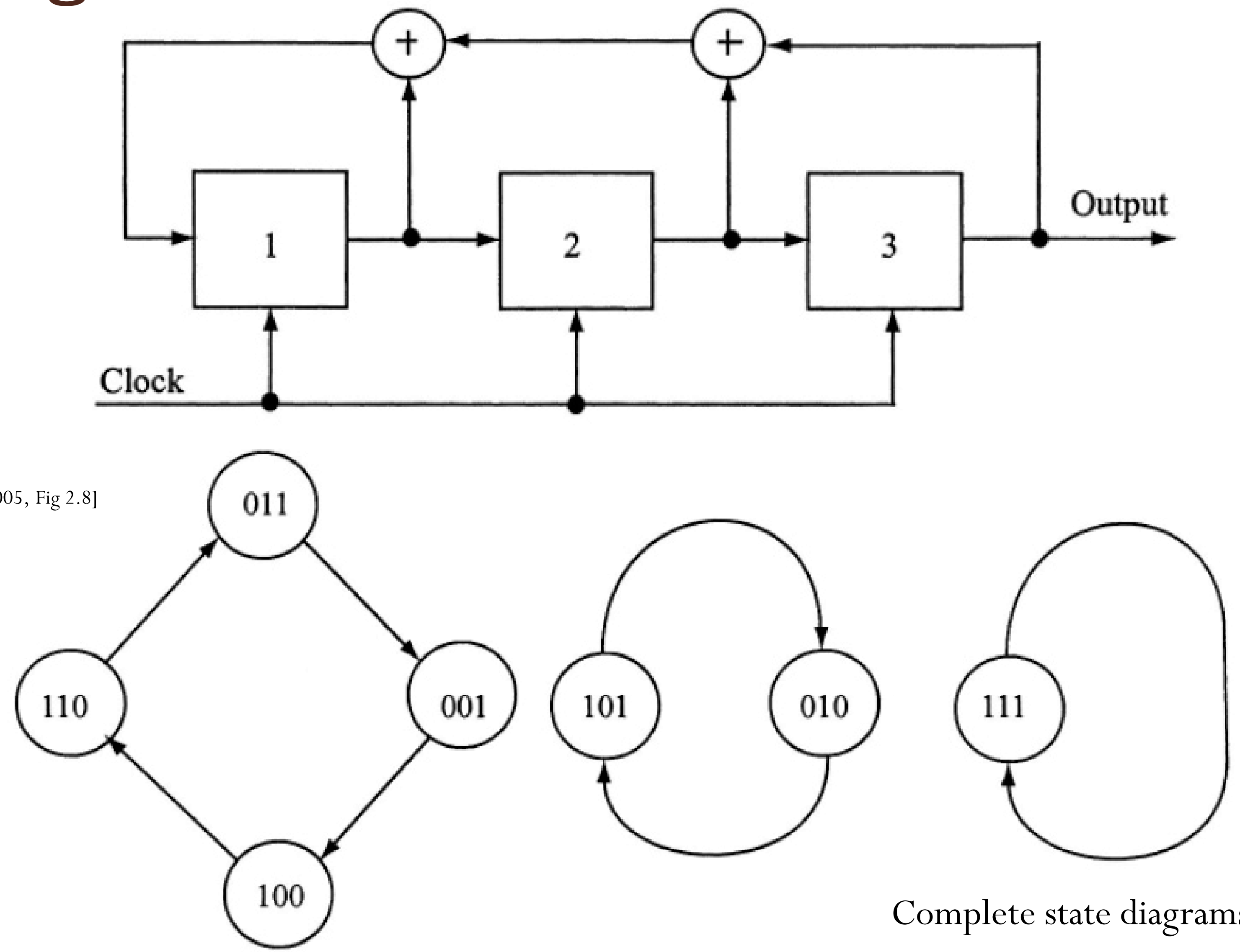
m-Sequences: More properties

- The contents of the shift register will cycle over all possible 2^r-1 nonzero states before repeating.
- Contain one more 1 than 0
- Sum of two (cyclic-)shifted m-sequences is another (cyclic-)shift of the same m-sequence

[S.W. Golomb, *Shift Register Sequences,* Holden-Day, San Francisco, 1967.]

Nonmaximal linear feedback shift register

$$x^3 + x^2 + x + 1$$

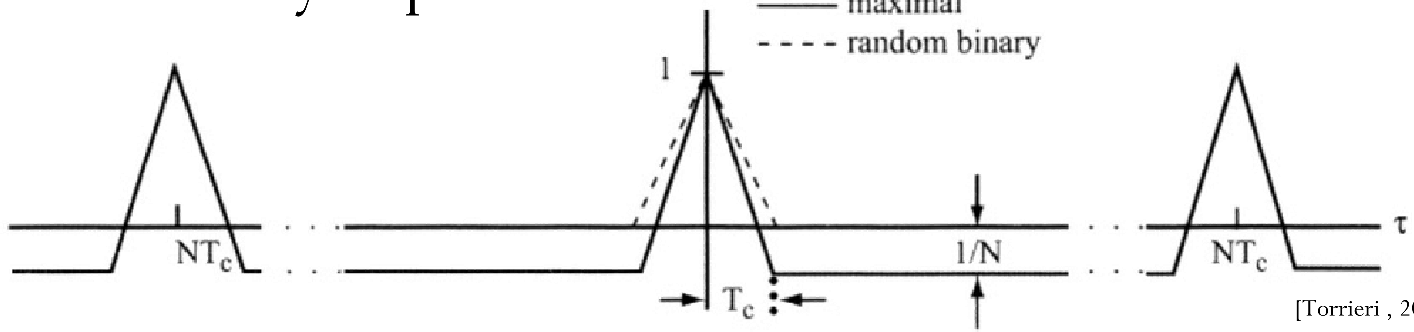


[Torrieri , 2005, Fig 2.8]

Complete state diagrams

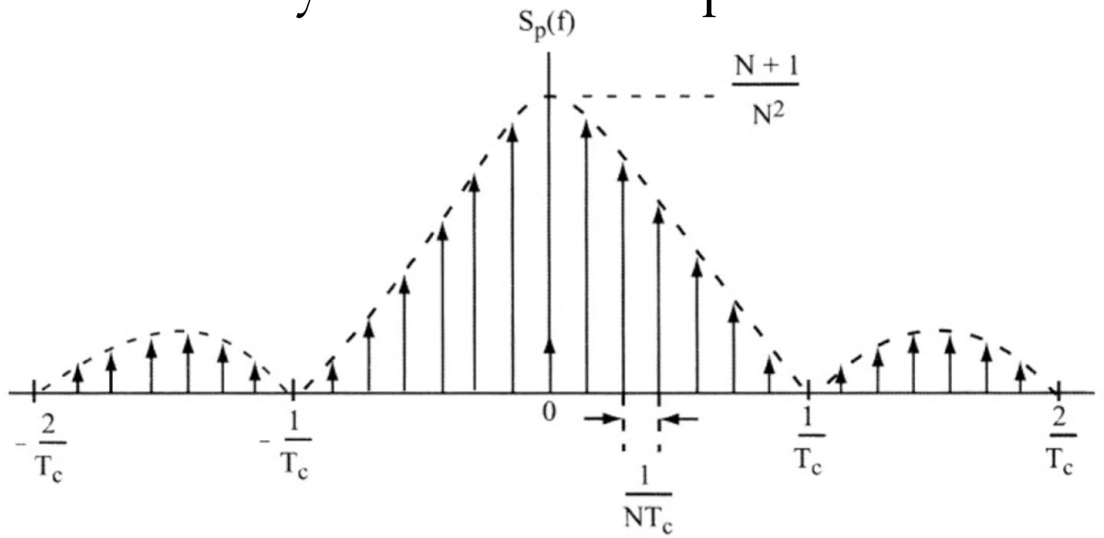
Autocorrelation and PSD

- (Normalized) autocorrelations of maximal sequence and random binary sequence.



[Torrieri , 2005, Fig 2.9]

- Power spectral density of maximal sequence.



[Torrieri , 2005, Fig 2.10]

Quiz

- Closed book. Closed notes. No calculator.
- Separate into groups of no more than three persons.

Draw the complete state diagrams for linear feedback shift registers (LFSRs) using the following polynomials. Does either LFSR generate an m-sequence?

- $x^4+x^3+x^2+x+1$
- x^4+x^3+1

Remark: This was an actual final exam problem @ Cornell