# Lecture 18

## PRINCIPLES OF SATELLITE COMMUNICATION

# Spreading Codes



- It is desired that each user's transmitted signal appears noise like and random. Strictly speaking, the signals should appear as Gaussian noise
- Such signals must be constructed from a finite number of randomly preselected stored parameters; to be realizable
- The same signal must be generated at the receiver in perfect synchronization
- We limit complexity by specifying only one bit per sample i.e. a binary sequence

# Desirable Randomness Properties



- Relative frequencies of "0" and "1" should be ½ (Balance property)

- Run lengths of zeros and ones should be (Run property):
  - Half of all run lengths should be unity
  - One - quarter should be of length two
  - One - eighth should be of length three
  - A fraction $1/2^n$ of all run lengths should be of length n for all finite n

# Desirable Randomness Properties (contd...)



- If the random sequence is shifted by any nonzero number of elements, the resulting sequence should have an equal number of agreements and disagreements with the original sequence (Autocorrelation property)

# PN Sequences



- A deterministically generated sequence that nearly satisfies these properties is referred to as a Pseudorandom Sequence (PN)
- Periodic binary sequences can be conveniently generated using linear feedback shift registers (LFSR)
- If the number of stages in the LFSR is r, $P \leq 2^r - 1$ where P is the period of the sequence

# PN Sequences (contd…)



- However, if the feedback connections satisfy a specific property, $P = 2^r - 1$. Then the sequence is called a Maximal Length Shift Register (MLSR) or a PN sequence.

- Thus if r=15, P=32767.

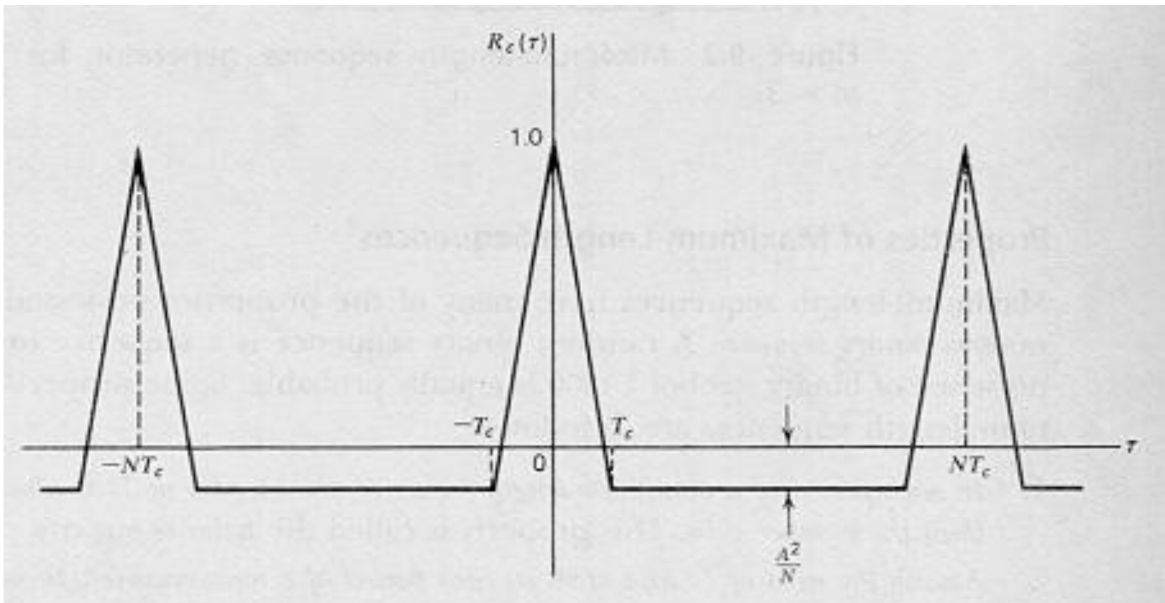
# Randomness Properties of PN Sequences



- *Balance property -* Of the $2^r - 1$ terms, $2^{r-1}$ are one and $2^{r-1}-1$ are zero. Thus the unbalance is 1/P. For r=50; $1/P \cong 10^{-15}$
- *Run property -* Relative frequency of run length n (zero or ones) is $1/2^n$ for $n \leq r-1$ and $1/(2^r - 1)$ for n = r
- One run length each of r-1 zeros and r ones occurs. There are no run lengths for n > r
- *Autocorrelation property -* The number of disagreements exceeds the number of agreements by unity. Thus again the discrepancy is 1/p

# Randomness Properties of PN Sequences (contd.)

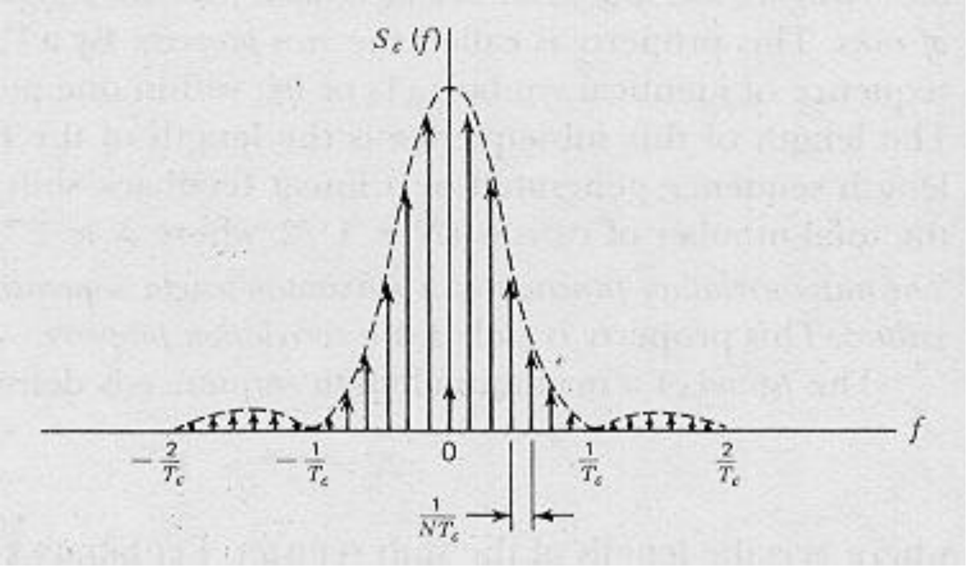





Autocorrelation function

# Randomness Properties of PN Sequences (contd…)






Power Spectral Density

# SR Implementation of PN Sequences

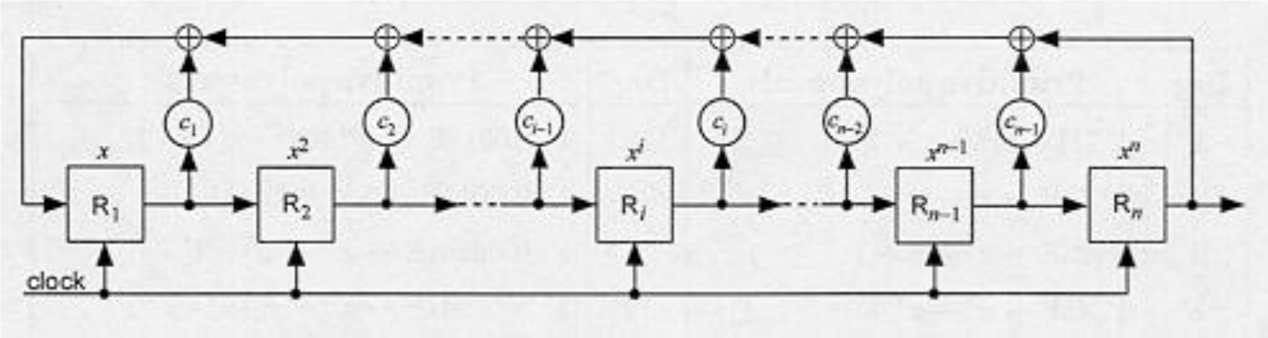


- The feedback connection should correspond to a primitive polynomial.
- Primitive polynomials of every degree exist. The number of primitive polynomials of degree r is given by :

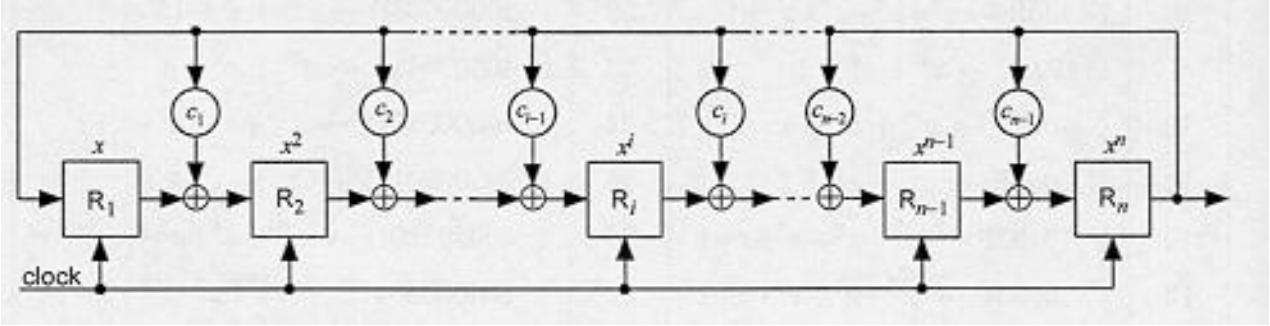
- Simple Shift Register Generator (SSRG) - Fibonacci configuration.
- Modular Shift Register Generator (MSRG) - Galois configuration.

# SR Implementation of PN Sequences






SSRG configuration of $f(x)=1 + c_1x + c_2x^2 + ..... + c_ix^i + ... + c_{n-1}x^{n-1} + x^n$




MSRG configuration of $f(x)=1 + c_1x + c_2x^2 + ..... + c_ix^i + ... + c_{n-1}x^{n-1} + x^n$

# PN Sequences Specified in IS-95



- A "long" PN sequence (r =42) is used to scramble the user data with a different code shift for each user

- The 42-degree characteristic polynomial is given by:
  - $x^{42}+x^{41}+x^{40}+x^{39}+x^{37}+x^{36}+x^{35}+x^{32}+x^{26}+x^{25}+x^{24}+x^{23}+x^{21}+x^{20}+x^{17}+x^{16}+x^{15}+x^{11}+x^{9}+x^{7}+1$

- The period of the long code is $2^{42} - 1 \approx 4.4*10^2$ chips and lasts over 41 days

# PN Sequences Specified in IS-95 (contd…)



- Two "short" PN sequences (r=15) are used to spread the quadrature components of the forward and reverse link waveforms

- The characteristic polynomials are given by :
  - $x^{15}+x^{10}+x^{8}+x^{7}+x^{6}+x^{2}+x$ (I-channel)
  - $x^{15}+x^{12}+x^{11}+x^{10}+x^{9}+x^{5}+x^{4}+x^{3}+1$ (Q-channel)

- The period of the short code is:

  $2^{15} - 1 = 32767$ chips $\equiv 80/3$ ms

# Orthogonal Spreading Codes – Walsh Codes



Walsh functions of order N are defined as a set of N time functions denoted as $\{W_j(t); t \in (0,T), j=0,1,\ldots N-1\}$ such that:

- $W_j(t)$ takes on the values {+1, -1} except at the jumps, where it takes the value zero
- $W_j(t) = 1$ for all j
- $W_j(t)$ has precisely j sign changes in the interval (0,T)

- Each $W_j(t)$ is either even or odd with respect to T/2 i.e. the mid point