# Lesson 19

## Pseudo Noise Codes

# Pseudo-noise (PN) code

- Autocorrelation characteristics
- A code appearing random like noise but is actually not random
- Used to generate one or multiple sequences
- PN codes useful for soft handover

# Pseudo-noise (PN) code

- A second BTS added for the users on the edge of a cell and new PN code used in new cell for soft handover
- Edge signal quality improves and handover becomes robust in soft-handover

# Soft handover in CDMA

- Adjacent cells of a CDMA system use the same set of carrier and chipping frequencies but different codes
- When the cell changes, an offset is added to the pseudo-noise codes
- Each cell has distinct pseudo-noise code offsets

# Soft handover in CDMA

- Pseudo-noise code offset processing can be done easily
- Only the offset value changes in case of handover when the signal of one cell becomes weak
- The call is not dropped, as the offset can be changed by the BTS depending on which cell has stronger signal at the boundary of two adjacent cells

# GSM

- GSM systems have separate operating frequencies in adjacent cells
- This is required to avoid inter-cell interference
- At the edge of the cells, handover is performed
- Call drop occurs

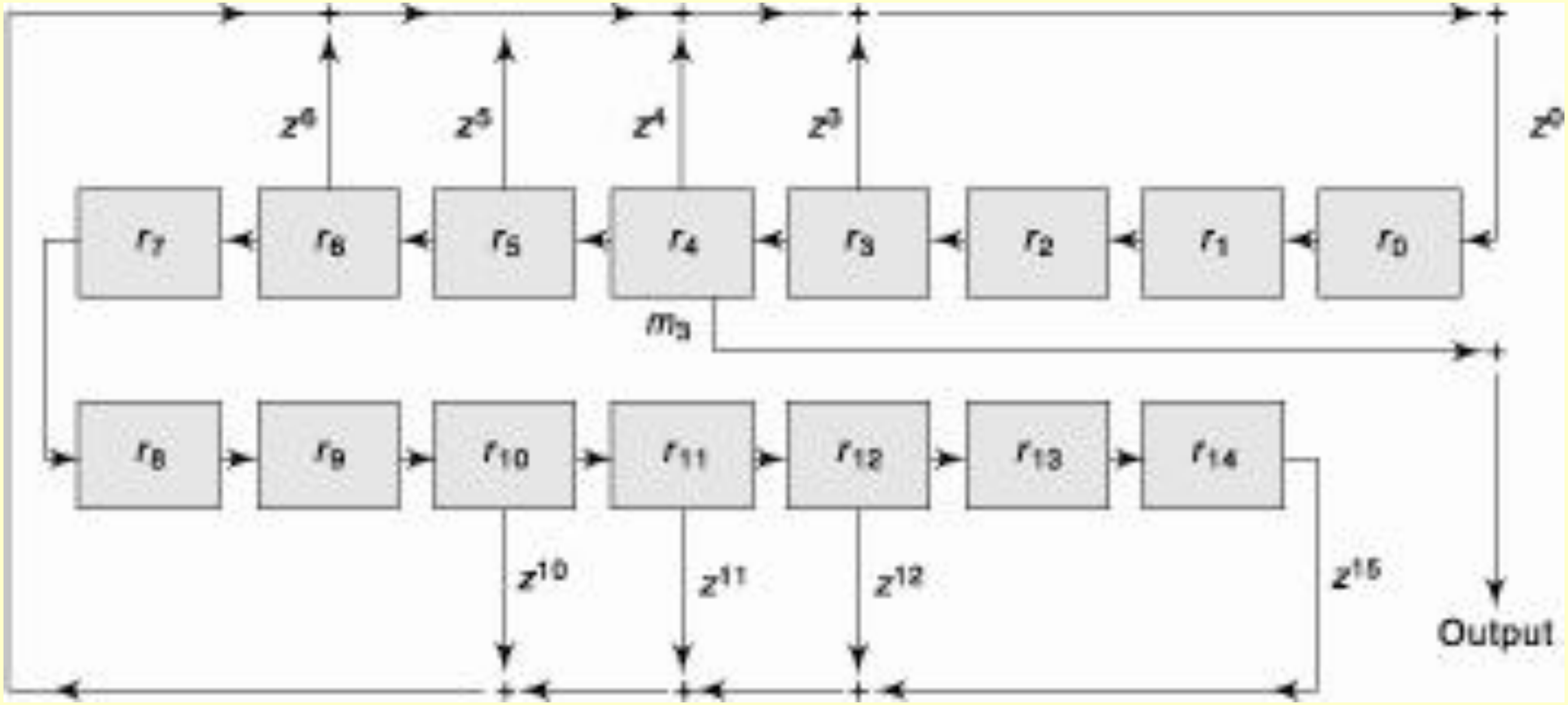
# M-sequences (maximum length sequences) code

- Code generated by using *m* small length shift registers
- The feedback generates a large number of sets, each set having *m* sequences
- Example: a set of 15 registers ($m = 15$) can be used to generate a set of $(2^{15} – 1)$ sequences
- Application as scrambling code

# M-sequence PN codes

- Quadrature component— the 90°-phase-shifted component
- In-phase $PN_I$ component— the same phase component orthogonal to Quadrature component
- IS-95 cdmaOne quadrature and in-phase component code sequences $PN_Q$ and $PN_I$

# Linear feedback shift register (LFSR) for $PN_Q$



# Initial State Vector

- An initial state vector has n bits in case of an n degree polynomial
- A set of n shift registers stores this vector on reset (at the start of the sequence generation)

# Initial State Vector for a a set of 15 registers for $PN_Q$

- r14, …, r1, r0 for $G_Q$— initial vector is {000 1110 0011 1100}
- r11, r10, r9, r5, r4, r3, and r2 store 1s and rest store 0s at the start of a PN sequence
- Starting sequence should not be 0
- At least one of the registers should store 1 and at least one of the binary numbers in the reset vector is 1

# Initial State Vector

- After n sequences, the same sequence as the first one is used to generate the next output sequence of bits after n .T, where T is the clock period
- Since generator polynomial $G_Q$ results in a different input to r0, the sequence changes after each interval of n .T

# Shift Parameter

- Positive integer
- How much should be shifted after each successive *n* sequences
- If = 3, then it means each sequence starts from register r3 in place of r0
- Skipping r0, r1, and r2
- If shift parameter = 0
- Each sequence starts output from register r0

# Mask Vector

- Specifies which register output is to be taken and is not masked and which set of registers output is masked and is not the input in next sequence
- 16 elements (*m*15, *m*14, *m*13, ..., *m*2, *m*1, and *m*0)

# Mask vector

- {000 0000 0001 0000} for $PN_Q$ defines shift parameter = 4 (because $m4 = 1$)
- The next sequence will start after $n \,.\, T$ from register r4 in place of r0

# IS-95 $PN_Q$ for generating multiple sequences

- $G_Q = z^{15} + z^{12} + z^{11} + z^{10} + z^6 + z^5 + z^4 + z^3 + 1$. A generator polynomial must have at least first term $z^n$ present if the degree of the polynomial is $n$ and last term $z^0 = 1$

# IS-95 $PN_Q$ for Generating Multiple Sequences

- $G_Q = z^{15} + z^{12} + z^{11} + z^{10} + z^6 + z^5 + z^4 + z^3 + 1$
- A generator polynomial must have at least first term $z^n$ present if the degree of the polynomial is *n* and last term $z^0 = 1$

# IS-95 $PN_Q$ for Generating Multiple Sequences

- Using generator polynomial $G_Q$ and mask vector (000 0000 0001 0000)
- An output bit is generated on each successive clock pulse
- The + sign shows an XOR operation

# $G_Q$

- Maximum number of terms in an n degree polynomial is *n* + 1
- $G_Q$— 16 terms, but coefficients of 7 terms are 0s
- *GQ* = {1001 1100 0111 1001} or (15, 12, 11, 10, 6, 5, 4, 3, 0)

# $PN_I$

- $G_I = z^{15} + z^{13} + z^9 + z^8 + z^7 + z^5 + 1$

# Sequence Length

- Sequence length of $PN_Q$ is $2^{15} - 1 = 32767$
- Exactly the same sequences of bits are outputted after each interval of $(2^{15} - 1).T$

# IS-95 Example

- Clock frequency to LFSR = 1.2288 MHz
- Chipping rate is 1.2288 Mchip/s
- The shift in the output occurs after each chipping interval of 1/1.2288 Mchip.s $^{-1}$ = 0.814 μs
- Spread factor = 64

# IS-95 Example

- Output sequence for each user symbol is divided into 64 chips, then the output appears every 0.814 μs
- Symbols and Sequences repetition at the rate = 1.2288 Mchips/s ÷ 64 = 19.2 kSymbol/s

# Gold Codes

- WCDMA uses Gold codes
- Created from two M-sequence codes M1 and M2
- M1 and M2 are added modulo 2

# Gold Codes

- M1 and M2 should be separate and distinct
- Different M1 and M2 are created by just using different starting registers
- Different starting registers can be set by setting the mask vector differently

# Summary

- IS-95 PN-Q and PN-I quadrature and in-phase components
- Pseudo noise codes
- Linear feed Shift Register
- Generator polynomial, Initial State Vector and Mask register used for M-Sequence code
- WCDMA Gold Codes

# End of Lesson 19

## Pseudo Noise Codes