Lesson 09
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<sub>I</sub> component— the same phase component orthogonal to Quadrature component
- IS-95 cdmaOne quadrature and in-phase component code sequences PN<sub>Q</sub> and PN<sub>I</sub>
Linear feedback shift register (LFSR) for $\text{PN}_Q$
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 set of 15 registers for $\text{PN}_Q$

- $r_{14}, \ldots, r_1, r_0$ for $G_Q$—initial vector is $\{000\ 1110\ 0011\ 1100\}$
- $r_{11}, r_{10}, r_9, r_5, r_4, r_3,$ and $r_2$ 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

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Initial State Vector

- After \( n \) sequences, the same sequence as the first one is used to generate the next output sequence of bits after \( n \cdot T \), 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 \( n \cdot T \).
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 ($m_{15}, m_{14}, m_{13}, \ldots, m_{2}, m_{1}, m_{0}$)
Mask vector

- \{000 0000 0001 0000\} for PN_Q defines shift parameter = 4 (because \(m4 = 1\))
- The next sequence will start after \(n \cdot T\) from register r4 in place of r0
IS-95 PN_Q for generating multiple sequences

- \( GQ = z^{15} + z^{12} + z^{11} + z^{10} + z^6 + z^5 + z^4 + z^3 + 1 \). 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
• Maximum number of terms in an $n$ degree polynomial is $n + 1$
• $G_Q$— 16 terms, but coefficients of 7 terms are 0s
• $G_Q = \{1001 \ 1100 \ 0111 \ 1001\}$ or $(15, 12, 11, 10, 6, 5, 4, 3, 0)$
$PN_1$

- $G_1 = z^{15} + z^{13} + z^9 + z^8 + z^7 + z^5 + 1$
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 $1/1.2288\text{ Mchip/s}^{-1} = 0.814\ \mu s$
- Spread factor = 64

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IS-95 Example

- Output sequence for each user symbol is divided into 64 chips, then the output appears every $0.814 \mu s$
- Symbols and Sequences repetition at the rate $= 1.2288 \text{ Mchips/s} \div 64 = 19.2 \text{ kSymbol/s}$
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 09
Pseudo Noise Codes