# Wireless Medium Access Control and CDMA, 3G, WiMax and 4G Communication

## Lesson 20

## Orthogonal, Channelization, Scrambling and carrier modulation codes

# Barker Code

- Barker code *C*13— nine 1*s* and four 0*s*
- Shows strong autocorrelation

# Pseudo-noise (PN) codes

- Almost equal number of 0*s* and 1*s*
- PN code shows a strong peak with a few low, non-zero values
- This may result in interference with the other users using the same spread

# Orthogonal Codes

- When there is no effect of interference between the two sets of signals on the received output
- Require synchronization between the transmitter and receiver
- Do not show a strong autocorrelation property

# Orthogonal Codes

- Zero cross-correlation
- Cross-correlation refers to the product of the ith symbol in two codes and the sum of products for all values of *i*

# Orthogonal Codes

- When each transmitter adopts a unique orthogonal code, then there is no effect of interference on the received output because the fact that cross-correlation of two codes = 0 can be used to filter the other transmitter signals out

# Orthogonality condition for two Codes

- SOP of their components = 0
- $\sum p_i . q_i = 0$ when $p_i = q_i$ for $0 \leq i < n$
- $p_i$ = first code
- $q_i$ = second code at the $i^{th}$ chip

# Synchronization

- Instant of the received first bit of coded symbols and first bit of generated code for extracting symbols are in the same phase

# Best codes

- Optimized codes which enable significant correlation
- Do not cause significant interference among the different channels

# Best codes

- A WS can use PN sequences for uplink
- BTS can transmit using orthogonal codes for downlink, because the BTS has special synchronization units
- Auto correlation important for synchronization
- Use codes that are almost orthogonal, i.e. $\sum p_i \,.\, q_i \sim 0$

# Codes

- Orthogonal codes almost zero cross-correlation and are used in identifying the user, user channel, and carrier

# PN Codes

- Long M-sequence PN codes have strong autocorrelation and are used in synchronizing and detecting the user channel signals
- Short PN codes also have strong autocorrelation and are used in synchronizing and detecting the user carriers

# CDMA

- All three coding schemes simultaneously used in a CDMA system
- PN long
- Walsh Orthogonal
- PN short

# Walsh Codes

- Used in IS-95 cdmaOne
- $64 \times 64$ matrix
- All pairs of rows orthogonal
- Generated from a matrix called the Hadamard matrix

# Pilot and Synchronization Channel Walsh Codes

- Pilot channel– W0, zero-th row Walsh code = {0, 0, …,0,0}
- Synchronization channel– W32, 32nd row Walsh code = {0, 0, …,0,0} all 0s for first half columns elements and {1,1,..., 1,1} all ones for next half elements

# Paging channel Walsh Code

- W1, 1st row Walsh code = {0, 0, …,0,0} all 0s for first half columns elements and {1,1, .., 1,1} all ones for next half elements
- IS-95 employs it for the paging channel

# Traffic channel Walsh Codes

- W2–31, 33–63 can be used by traffic channels
- If more than 1 and up to 7 paging channels are being used, then W8-31, 33-63 are used for the traffic channels

# W0 and W2 orthoganilty

- 0th row in the 8 ×8 matrix Walsh code W0 = {0, 0, 0, 0, 0, 0, 0, 0}
- 2nd row Walsh code W2 = {0, 0, 1, 1, 0, 0, 1, 1}
- The codes can be rewritten as {–1, –1, –1, –1, –1, –1, –1, –1} and {–1, –1, +1, +1, –1, –1, +1, +1}
- $\sum p_i \,.\, q_i = 0$

# Variable spread factor by using variable-length Walsh codes

- During multi-rate transmission
- CDMA2000
- Transmitting data at variable rates
- Each user channel uses a distinct Walsh code $W_m$

# Variable spread factor by using variable-length Walsh codes

- The receiver uses the same code $W_m$ for identifying the data and for identifying that user and user channel
- The chipping length of the Walsh code varied
- The code length depends upon the chipping rate and the data rate

# Example user signal transmitting with a chipping interval of 814 ns

- Chipping rate = $(814\text{ ns})^{-1}$ =1.2288 Mchip/s
- Code length for a very low data rate of 4.8 ksymbolps = 1.2288 Mchip/s ÷ 4.8 ksymbolps = 256

# Example

- Chipping rate = $(814 \text{ ns})^{-1}$ =1.2288 Mchip/s
- Code length for a very low data rate of 19.2 ksymbolps = 1.2288 Mchip/s ÷ 19.2 ksymbolps = 64

# Example

- Data rate to transmit files of the CIF picture format at 384 ksymbol/s with a rate matching reduction by a factor of 1.25 = = 384 ksymbol/s ÷ 1.25 = 307.2 ksymbol/s
- Code length = 1.2288 Mchip/s ÷ 307.2 ksymbolps = 4
- Rate matching means reducing bit rate by removing select bits, fifth bit after every 4

# Scrambling Codes

- Long sequence lengths to code a transceiver
- Large number of users and user channels
- Long autocorrelation codes required
- A scrambling code can be a PN *M*-sequence code
- Must exhibit strong autocorrelation property

# Scrambling code

- The long code generator polynomial $G_l = z^{42} + z^{35} + z^{33} + z^{31} + z^{27} + z^{26} + z^{25} + z^{22} + z^{21} + z^{19} + z^{18} + z^{17} + z^{16} + z^{10} + z^{7} + z^{6} + z^{5} + z^{3} + z^{2} + z + 1$ used in cdmaOne scrambling code
- Uplink from an MS, a short-code can also be used, for example, in WCDMA

# Channelization Codes

- Channelization code has a short length sequence and must exhibit the orthogonality property
- Walsh codes used for channelization due to their orthogonality property
- These are scrambled with long codes to achieve orthogonality as well as autocorrelation

# Channelization Codes in cdmaOne as well as CDMA2000 systems

- Walsh code performs the chipping of the signals after a PN M-sequence ($2^{42}$-1) long code scrambles the user channel symbols
- In both cases a processing unit performs XORing of the user symbols (scrambled with a PN long-sequence-code) with the orthogonal coded chips

# Carrier Modulation Codes

- Transceiver can support a limited number of carriers (<< $2^{14}$)
- Short autocorrelation codes PN-short suffice

# Carrier Modulation Codes

- Orthogonal phase modulation (QPSK) performed on the I- and Q-PN short code pilot waveforms XORed with the scrambled and then chipped signals
- The modulated signals transmitted using a carrier

# Carrier Modulation Codes

- Orthogonal phase modulation is in time-space
- Orthogonal code or PN code modulation (spreading) is in code-space

# Carrier Modulation Codes

- The purpose of the Orthogonal code is to synchronize the carriers of different base stations and the purpose of the second is to identify the multiple user channels
- For example, two short PN codes called $PN_Q$ and $PN_I$ form two pilots and are used for orthogonal phase modulation

# Carrier Modulation Codes

- IS-95 cdmaOne as well as CDMA2000 employ orthogonal waveforms
- Which are first coded using a PN short code of ($2^{15}$-1) sequences before modulation

# Summary

- Orthogonal codes
- Channelization codes
- Autocorrelation codes
- Scrambling code– long PN
- Carrier modulation codes– short PN
- cdmaOne and CDMA2000– all three coding- Long PN, Orthognal Walsh and PN-short codes

# End of Lesson 10

## Orthogonal, Channelization, Scrambling and carrier modulation codes