Personal Communication Systems (Lecture 14)

Code Division Multiple Access (CDMA)

- Sometimes CDMA is referred to as Direct Sequence Spread Spectrum (DS-SS)

* Communication is in full duplex - FDD used (wideband)

- CDMA channels are relatively wide
- There are two communication bandwidths for CDMA channel
  - SIMHA (Wideband CDMA, W-CDMA)
  - ISIMHA (CDma2000)

* In CDMA all users are on the same channel and at the same time
  - The signals from different users are separated by using brilliant codes (spreading codes)

Common activity
- TDMA - conversations between people in different rooms
- CDMA - people are in the same room but not one at the time
- CDMA - people are in the same room. They talk at the same time but using different languages
Outline of a DS-SS communication system

There are 3 basic processing blocks:

1) DS Spreading on the TX side
2) RF uplink (RF modulation on the TX side)
   RF demodulation on the RX side)
   CDMA TX
3) DS de-spread on the RX side
   CDMA RX

RF uplink delims CDMA signal from TX to RX. Even though it is the part of
the system it is not CDMA specific - so it can be modified from circumstances.

Above figure presents the communication as a path from a single user.
In CDMA multiple users are accessing the system at the same time.
Each user has a unique code that would separate it from all other
users.
From multiple users are sent at the same time through the channel.

The codes used for spreading are orthogonal to each other.

Example: \( C_1 \times C_2 \Rightarrow \) dot product

\[
[1, 1, 1, 1] \cdot [1, 1, -1, -1] = 1 \cdot 1 + 1 \cdot 1 + (-1) \cdot (-1) + 1 \cdot (-1) = 0
\]

The number of users that can be sent simultaneously is equal to the number of orthogonal codes.

It turns out that if the code is of length \( n \), one can design at most \( n \) orthogonal codes.

The most commonly used are Walsh–Hadamard codes. (Walsh codes).

Walsh codes are generated using the following recursive procedure:

\[
W_{c_2} = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}
\]

\[
W_{c_4} = \begin{bmatrix} W_{c_2} & W_{c_2} \\ W_{c_2} & -W_{c_2} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 \end{bmatrix}
\]

\[
W_{c_8} = \begin{bmatrix} W_{c_4} & W_{c_4} \\ W_{c_4} & -W_{c_4} \end{bmatrix} \ldots
\]

One needs to remember: For spreading & de-spreading the following mapping applies:

Mapping applies:

\[
1 \rightarrow (1) \\
0 \rightarrow (1)
\]

Note: Consider two codes used in the example. Comparing the codes in the example and the Walsh codes given above, one easily identifies:

\[
C_1 \leftrightarrow W_{c_4}, \quad C_2 \leftrightarrow W_{c_4}
\]
The ratio \( \frac{T_c}{R_c} \) is referred to as spreading ratio. In example, the spreading ratio is 4.

**Quantity**

\[ P_s = \log_2 \left( \frac{T_c}{R_c} \right) = \log_2 \left( \frac{R_c}{R_b} \right) \]

Is referred to as the processing gain.

**Use of Coda in Cellular Systems**

There need to be two levels of coding:

* Within each cell, users are sequenced using Walsh orthogonal codes.
  (usually Walsh codes): Codes C in the figure.

* Signals from different cells are encoded with orthogonal codes as well.
  - P codes in the figure.

* RX cells to depend with respect to P and then with respect to C as well.