Lecture 10

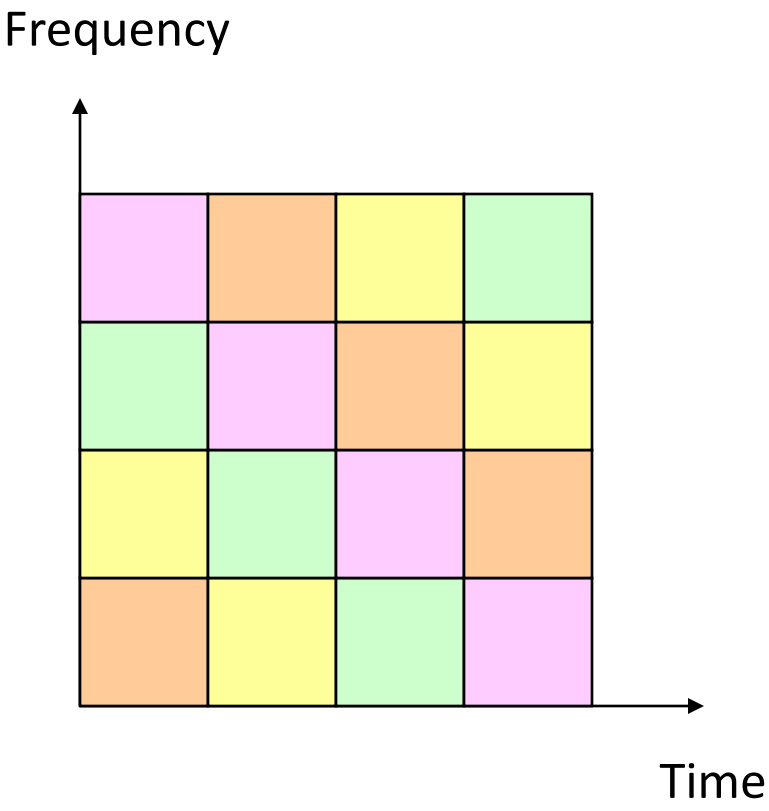
CS 621
Mobile Computing

2G Cellular Systems

Zubin Bhuyan,
Department of CSE, Tezpur University
http://www.tezu.ernet.in/~zubin

Several slides and images in this presentation have been taken from Prof. Nityananda Sarma's class notes/ppt. Several images have been taken from the book Mobile Communication by Jochen Schiller.

Frequency Hopping CDMA



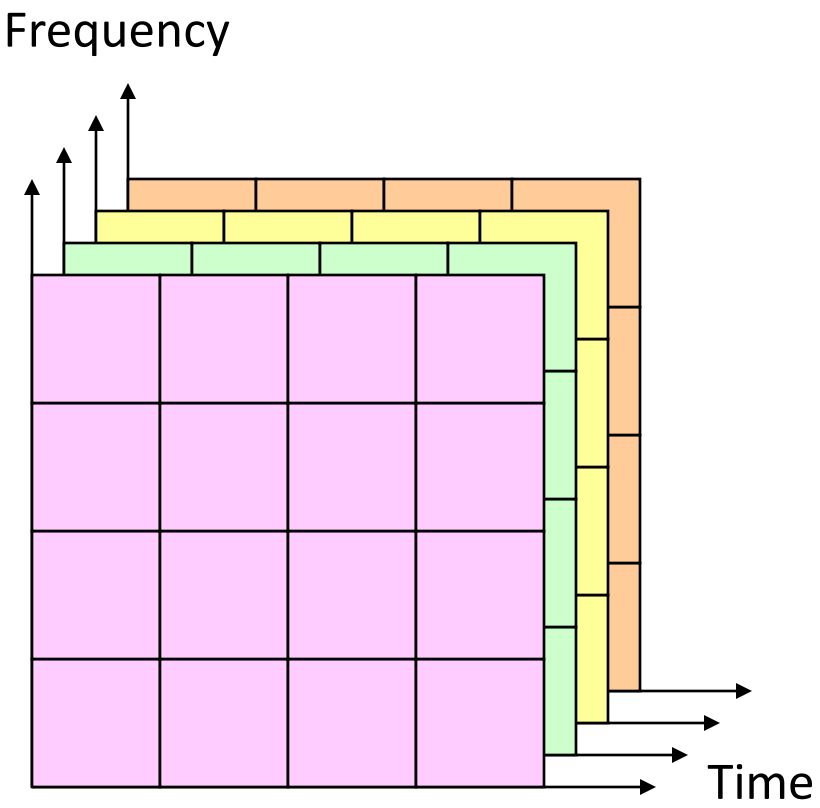
At each successive time slot, the frequency band assignments are reordered.

Each user employs a code that dictates the frequency hopping pattern.

Synchronization

- The previous figure implies that each signal synchronizes with each of the other signals.
- In practice, this is *not the case*.
- Frequency hops may collide, but it does not occur frequently.
  - How often collisions occur depends on the choice of *codes*.

Direct Sequence CDMA



All users occupy the whole bandwidth all the time.

Signals of different users overlap with one other.

How can it be done?

CDMA Encoding

- Each user is assigned a unique signature sequence (or code), denoted by $(c_1, c_2, \ldots, c_M)$. Its component is called a chip.

- Each bit, d_i, is encoded by multiplying the bit by the signature sequence:

$$Z_{i,m} = d_i \, c_m$$

Encoding Example

- Data bit

  $d_1 = -1$

- Signature sequence

  $(c_1, c_2, \ldots, c_8) = (+1,+1,+1,-1,+1,-1,-1,-1)$

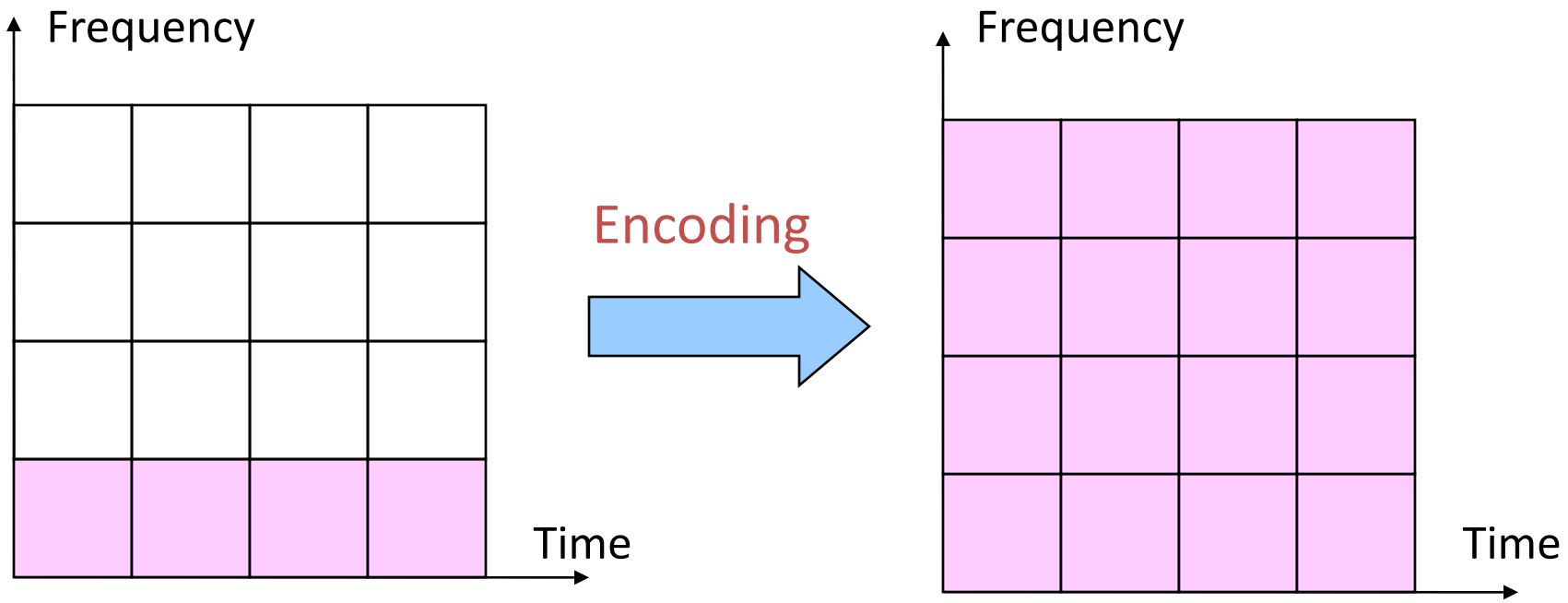
- Encoder Output

  $(Z_{1,1}, Z_{1,2}, \ldots, Z_{1,8}) = (-1,-1,-1,+1,-1,+1,+1,+1)$

Bandwidth

- Note that the *chip rate is much higher than the data rate*.

Spread Spectrum Technique



The bandwidth expands by a factor of M.

M is called spreading factor or processing gain.

CDMA Decoding

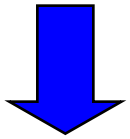
Without interfering users, the receiver would receive the encoded bits, $Z_{i,m}$, and recover the original data bit, d_i, by computing:

$$d_i = \frac{1}{M} \sum_{m=1}^{M} Z_{i,m} c_m$$

CDMA Decoding Example

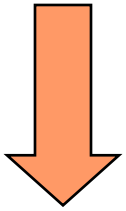
$(c_1, c_2, \ldots, c_8) = (+1, +1, +1, -1, +1, -1, -1, -1)$

$(Z_{1,1}, Z_{1,2}, \ldots, Z_{1,8}) = (-1, -1, -1, +1, -1, +1, +1, +1)$



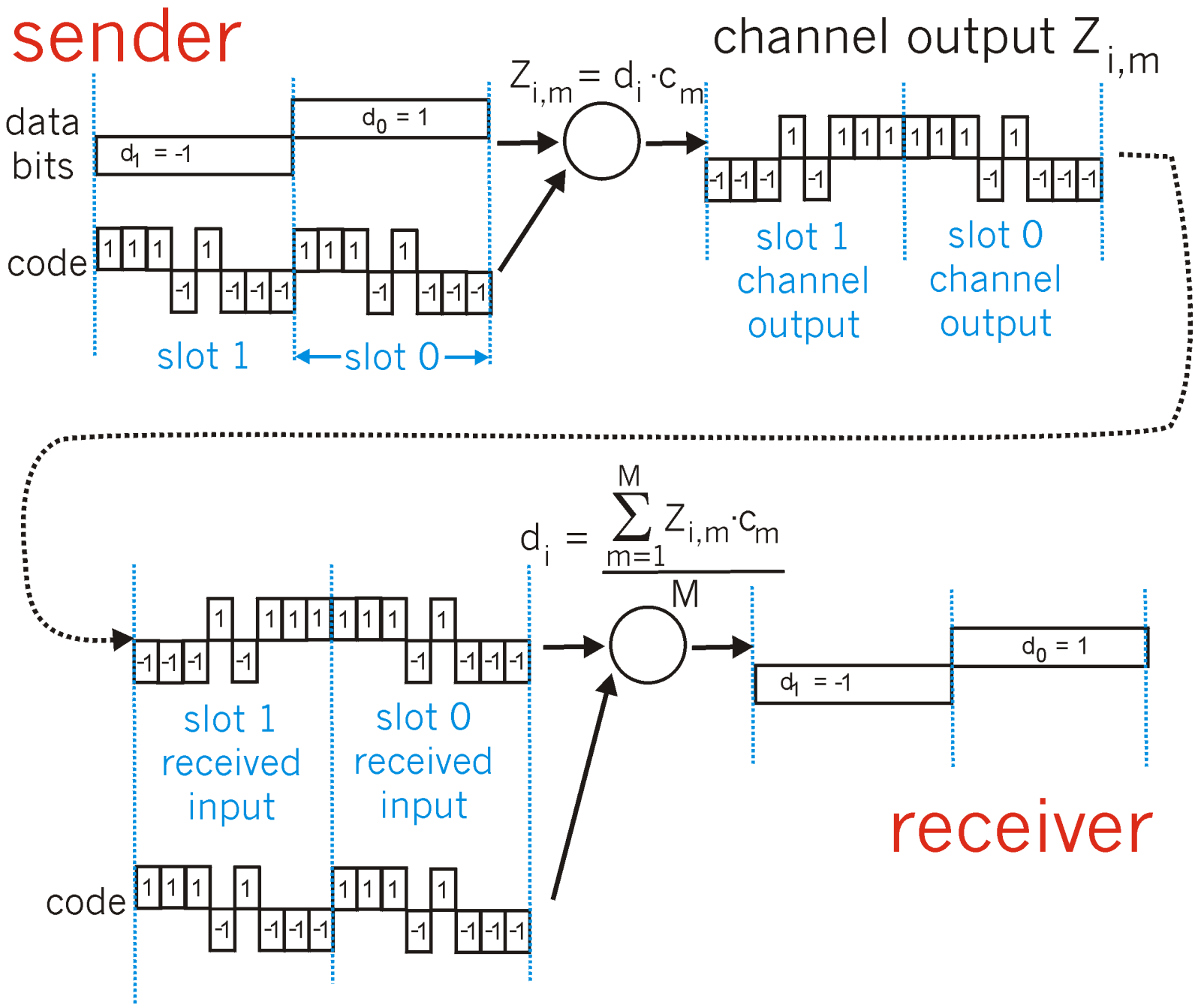
multiply

$(-1, -1, -1, -1, -1, -1, -1, -1)$



add and
divide by M

$d_i = -1$

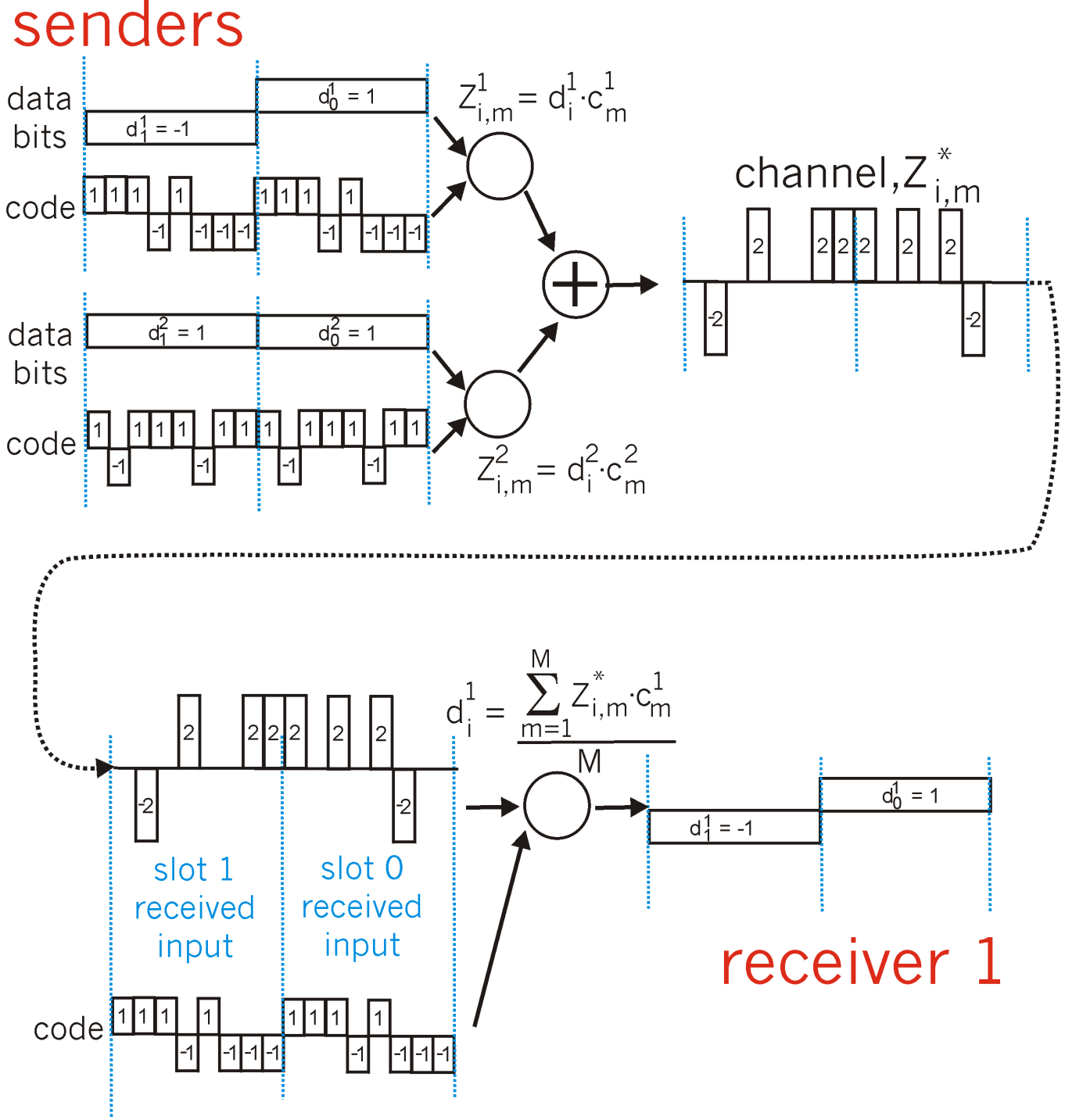

sender
channel output $Z_{i,m}$
$Z_{i,m} = d_i \cdot c_m$
data bits
$d_0 = 1$
$d_1 = -1$
code
slot 1
slot 0
slot 1 channel output
slot 0 channel output
$d_i = \frac{\sum_{m=1}^{M} Z_{i,m} \cdot c_m}{M}$
slot 1 received input
slot 0 received input
code
$d_0 = 1$
$d_1 = -1$
receiver

Multiuser Scenario

If there are *N* users, the signal at the receiver becomes:

$$Z_{i,m}^{*} = \sum_{n=1}^{N} Z_{i,m}^{n}$$

How can a CDMA receiver recover a user's original data bit?


senders
data bits
code
data bits
code
channel, $Z^*_{i,m}$
receiver 1
slot 1 received input
slot 0 received input
code

Multiuser Scenario

If there are *N* users, the signal at the receiver becomes:

How can a CDMA receiver recover a user's original data bit?

Signature Sequences

In order for the receiver to be able to extract out a particular sender's signal, the CDMA codes must be of low correlation.

- Correlation of two codes, $(c_{j,1},\ldots, c_{j,M})$ and $(c_{k,1},\ldots, c_{k,M})$, are defined by inner product:

$$\frac{1}{M}\sum_{m=1}^{M} c_{j,m}c_{k,m}$$

THANKS!