

# WIRELESS MEDIUM ACCESS CONTROL AND CDMA, 3G AND 4G COMMUNICATION

## Lesson 06

### Direct Sequence Spread Spectrum (DSSS)

# SPREAD SPECTRUM (DSSS AND FHSS)

- A transmission technique that provides a
- Direct sequence spread spectrum (DSSS) for novel solution to the spectral efficiency
- Frequency hopping spread spectrum (FHSS) for novel solution to the spectral efficiency and interference problem

# SPREAD SPECTRUM

- CDMA systems use DS spread spectrum
- Signals at frequencies  $f_{c0}$ ,  $f_{c0} + f_s$ ,  $f_{c0} + 2f_s$ ,  
...,  $f_{c0} + (n-2)f_s$ ,  $f_{c0} + (n-1)f_s$

# SPREAD SPECTRUM

- Spectrum widens by a factor of  $n$
- Spread between  $f_{c0}$  and  $f_{c0} + (n-1)f_s$ , where  $n$  is the number of chipping frequencies used and  $f_s$  is symbol frequency (symbol/s, number of symbols chipped/s)
- The spread in the present case =  $n \times f_s$

# DSSS FREQUENCY SIGNALS FOR CHIPPING

- $s_0(t) = S_0 \cdot \sin(2\pi \cdot f_{c0} \cdot t + \phi_{t0})$
- $s_1(t) = S_0 \cdot \sin\{2\pi \cdot (f_{c0} + f_s) \cdot t + \phi_{t0}\}$
- $s_{n-1}(t) = S_0 \cdot \sin\{2\pi \cdot (f_{c0} + (n-1) f_s) \cdot t + \phi_{t0}\}$

# DSSS

- A symbol in DSSS using the code transmits as such after chipping when transmitting the symbol 0 and using the code's complement when transmitting 1
- This means XORing between the user-signal symbols and chips
- The chips are as per the code used by DSSS transmitter

# XORING

- Let  $B$  is bit of source signal being transmitted.
- $B$  XORes with each of the  $n$  chips of code
- XORing— When  $B = 1$  and  $S = 1$  or  $B = 0$  and  $S = 0$  then the peak amplitude is  $-S_0$ , else it is  $+S_0$

# XORING

- $i_{th}$  chip— The second term after the multiplication sign  $[(s_0 / \sqrt{n}) \sin \{2\pi \cdot (f_{c0} + (i - 1) \cdot f_s)t + \phi_{t0}\}]$
- First term  $[(B \cdot \text{XOR } S_{i-1})]$  for the  $i^{th}$  chip— the operation performed at the spreader



# DSSS FREQUENCY SIGNALS AFTER CHIPPING WITH USER SYMBOL B

- $s_0(t) = (S_0/\sqrt{n}) (B.XOR.S_0) \sin (2\pi .f_{c0} .t + \phi_{t0})$  } in time interval  $t = 0$  to  $t_{chip}$
- $s_1(t) = (S_0/\sqrt{n}) (B.XOR.S_1) \sin \{2\pi .(f_{c0} + f_s) .t + \phi_{t0}\}$  in time interval  $t = t_{chip}$  to  $2.t_{chip}$
- $s_{n-1}(t) = (S_0/\sqrt{n}) (B.XOR.S_{n-1}) .\sin \{2 \pi .(f_{c0} + (n-1) f_s) .t + \phi_{t0}\}$  in time interval  $t = (n-1) .t_{chip}$  to  $n .t_{chip}$

# $i^{\text{TH}}$ CHIP OF USER SYMBOL B

- $S_i$  ( $0 < i < n - 1$ ), is the  $i$ th chip in the sequence (code),  $f_s$  is symbol frequency and  $f_{\text{chip}}$  is the number of chips of user symbols per second
- $t_{\text{chip}} = f_{\text{chip}}^{-1}$  and  $t_s = n \times t_{\text{chip}}$

# NUMBER OF CHIPS FOR EACH SYMBOL

- $n$  chips, if there are  $n$  chipping intervals for spreading
- The signals are transmitted after modulation with a carrier frequency  $f_{c0}$

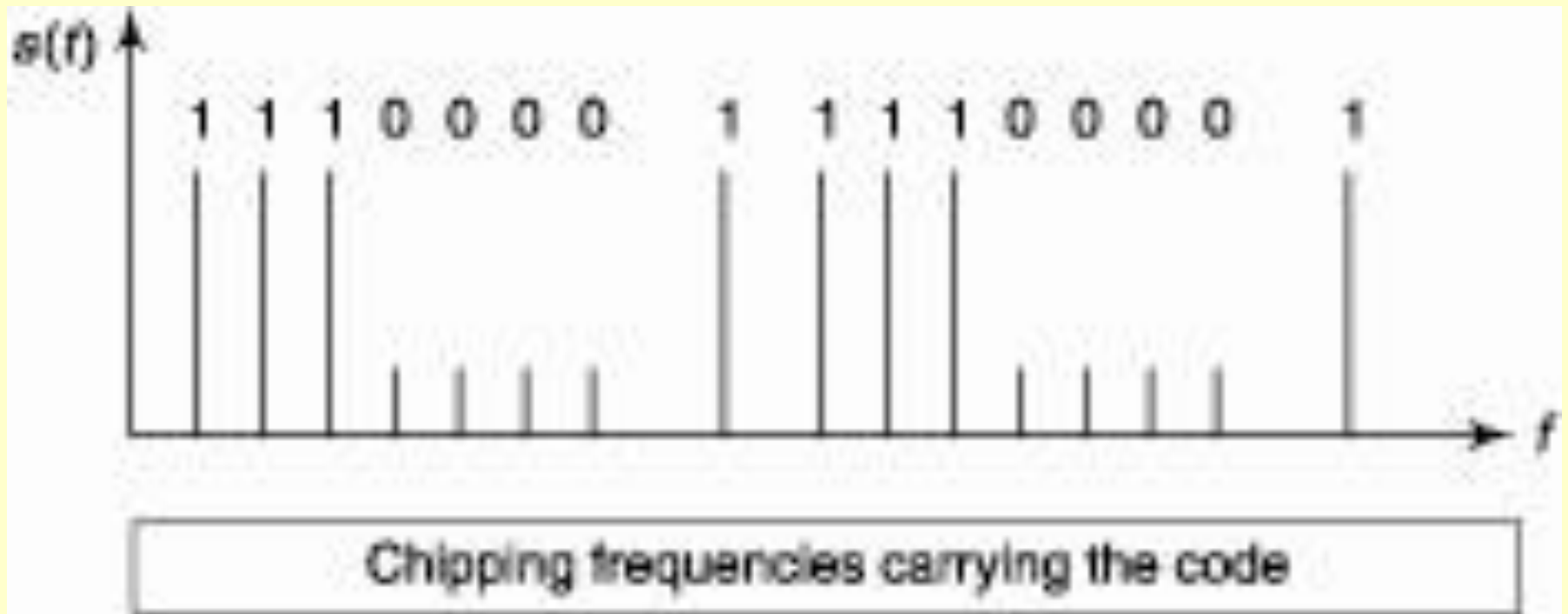
# DSSS (DIRECT SEQUENCE SPREAD SPECTRUM) TECHNIQUE)

- All the frequencies simultaneously, in direct sequence during interval =  $n \cdot t_{\text{chip}}$
- The frequency spread is between  $f_{c0}$  and  $f_{c0} + (n-1) \cdot f_s$

# EXAMPLE OF CHIPS FOR A SYMBOL CODE

- The frequency spread and signal strengths for an exemplary code  
1110000111100001 consisting of 16 chips

# CODE 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 1 CONSISTING OF 16 CHIPS



# SPREAD FACTOR, $D_{\text{DSSS}}$ FOR THE BANDWIDTH IN DSSS

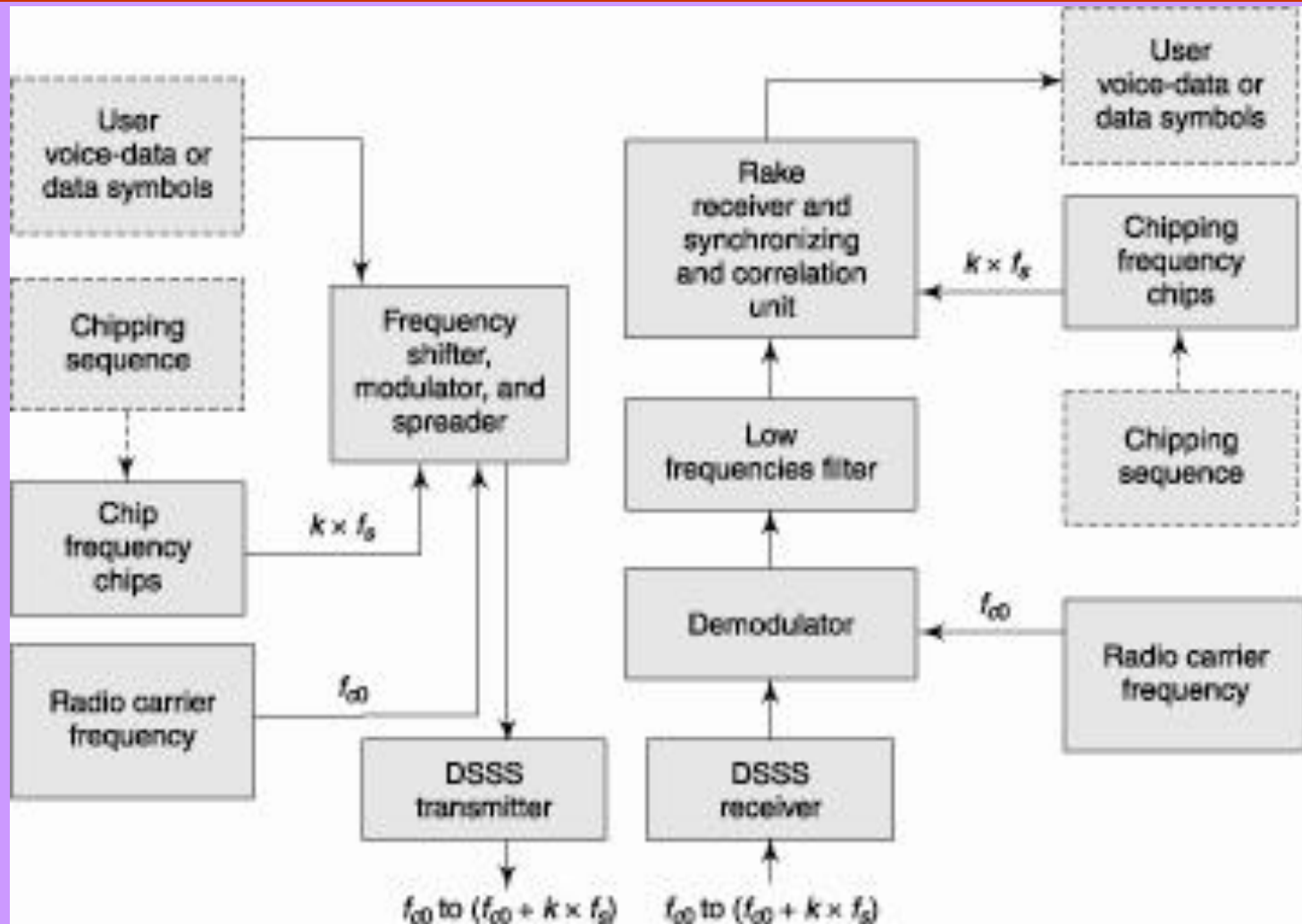
- Defined as the ratio of the period of a bit,  $t_{\text{symbol}}$ , in the data to be transmitted to the chipping time interval  $t_{\text{chip}}$
- $t_{\text{chip}} =$  The frequency band used by one symbol for chipping  $f_{\text{chip}}^{-1}$
- $D_{\text{dsss}} = t_{\text{symbol}} / t_{\text{chip}}$
- Bandwidth of DSSS data =  $D_{\text{dsss}} \times f_s$

# EXAMPLE

- DSSS at a rate of 0.0192 Msymbol/s
- Chipping rate is 1.2288 Mchip/s
- $t_{\text{symbol}} = (1/0.0192)\mu\text{s} = 52\ \mu\text{s}$
- $t_{\text{chip}} = (1/1.2288)\ \mu\text{s} = 0.814\ 52\ \mu\text{s}$
- Spread factor  $D_{\text{dsss}} = 52\ \mu\text{s} / 0.814\ 52\ \mu\text{s} = 64$
- bandwidth =  $19.2\ \text{ksymbol/s} \times D_{\text{dsss}} = 1.2288\ \text{Mchip/s}$



# A CDMA DSSS TRANSMITTER AND RECEIVER



# LOW PASS FILTER

- Step 1: Input of the DSSS receiver demodulated
- Step 2: Given to a low frequency filter to separate the  $f_{c0}$  carrier

# RAKE RECEIVER

- Step 3: Rake receiver with synchronizing and correlation units gets the input chips as per the chipping sequence used by the transmitter
- The output from the rake receiver—the user voice-data or data symbols

# RAKE RECEIVER

- The receiver might be receiving the transmitted signals through multiple paths
- A rake receiver— is a specialized receiver, which selects the signals of the strongest paths
- Reconstructs the signal by accounting for the variable delays in these paths
- Correlates with the chip sequences used for transmission

# RAKE RECEIVER

- The user voice-data or data symbols retrieved in DSSS even in the presence of multiple path delays and narrow band and co-channel interferences

# CORRELATION UNIT

- Performs the XOR operation between the demodulator output and the filtered output using the same chipping sequence as used by the transmitter

# CORRELATION UNIT

- When the result of XORing either 0 or a value expected from the chipping code, then there is correlation between the transmitted and received data and the user symbol is correctly interpreted as 0 or 1

# AUTOCORRELATION

- Even if the correlation is not perfect the user symbol can be correctly found for a certain range of errors
- This happens when the code chosen is such that it results in autocorrelation, even when there is some chipping interval delay between the received signal and the receiver generated chipping sequence



# BITS AFTER DESPREADING

- $b_0 = (S'_0 \text{ .XOR. } S_0), \dots$
- $b_{n-1} = (S'_{n-1} \text{ .XOR. } S_{n-1})$
- $b_0 = b_{n-1} = 0$  if user data symbol = 0
- $= 1$  if user data symbol = 1

# SUMMARY

- DSSS uses chipping frequency  $f_s$
- Spread = Spread factor  $\times f_s$
- XORing of user symbol with the code at chipping frequencies
- Receiver low pass filter and rake receiver
- Synchronizing and correlation units

**End of Lesson 06**  
**Direct Sequence Spread Spectrum**