Lesson 06
Direct Sequence Spread Spectrum (DSSS)
A transmission technique that provides a novel solution to the interference problem
- Direct sequence spread spectrum (DSSS)
- Frequency hopping spread spectrum (FHSS)
- 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

- $s_0(t) = S_0 \sin (2\pi f_{c0} t + \phi_{t0})$
- $s_1(t) = S_0 \sin \{2\pi (f_{c0} + f_s) t + \phi_{t0}\}$
- $s_{n-1}(t) = S_0 \sin \{2\pi (f_{c0} + (n-1) f_s) t + \phi_{t0}\}$
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 used as per the code
XORing

• B XORed with each of the \( n \) chips of code
• XORing—if \( B = 1 \) and \( S = 1 \) or \( B = 0 \) and \( S = 0 \) then the amplitude is 0, else it is 1
• \( i_{th} \) chip—The second term after the multiplication sign \([(s0 / \sqrt{n}) \sin\{2\pi \cdot (f_{c0} + (i - 1) \cdot f_S) t + \phi_{t0}\}]\)
• First term \([(B \cdot \operatorname{XOR} S_{i-1}) \text{ for the } i^{th} \text{ chip}]—the operation performed at the spreader
DSSS frequency signals after chipping with user symbol B

- \( s_0(t) = \left( \frac{S_0}{\sqrt{n}} \right) (B \oplus S_0) \sin \left( 2\pi f_{c0} t + \phi_{t0} \right) \) in time interval \( t = 0 \) to \( t_{\text{chip}} \)
- \( s_1(t) = \left( \frac{S_0}{\sqrt{n}} \right) (B \oplus S_1) \sin \left( 2\pi (f_{c0} + f_s) t + \phi_{t0} \right) \) in time interval \( t = t_{\text{chip}} \) to \( 2t_{\text{chip}} \)
- \( s_{n-1}(t) = \left( \frac{S_0}{\sqrt{n}} \right) (B \oplus S_{n-1}) \sin \left( 2\pi \left( f_{c0} + (n-1)f_s \right) t + \phi_{t0} \right) \) in time interval \( t = (n-1)t_{\text{chip}} \) to \( nt_{\text{chip}} \)
$i^{th}$ chip of user symbol B

- $S_i (0 < i < n - 1)$, is the 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. $t_{\text{chip}}$
- The frequency spread is between $f_{c0}$ and $f_{c0} + (n-1) . f_s$
Example of chips for a symbol code

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

Chipping frequencies carrying the code
Spread factor, $D_{dsss}$ 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 $t_{\text{chip}}$
- $t_{\text{chip}} = \frac{1}{f_{\text{chip}}}$
- $D_{dsss} = \frac{t_{\text{symbol}}}{t_{\text{chip}}}$
- Bandwidth of DSSS data $= D_{dsss} \times f_s$
Example

- DSSS at a rate of 0.0192 Msymbol/s
- Chipping rate is 1.2288 Mchip/s
- $t_{\text{symbol}} = (1/0.0192) \mu s = 52 \mu s$
- $t_{\text{chip}} = (1/1.2288) \mu s = 0.81452 \mu s$
- Spread factor $D_{\text{dsss}} = 52 \mu s / 0.81452 \mu s = 64$
- 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.

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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

- $b_0 = (S'_0 \text{ XOR } S0)$, ...
- $b_{n-1} = (S'_{n-1} \text{ XOR } S_{n-1})$
- $b_0 = b_{n-1} = 0$ if user data symbol = 0
- $= 1$ if user data symbol = 0
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