ES 442 Homework # 9
(Spring 2017 – Due May 8, 2017)
Print out homework and do work on the printed pages.

Problem 1 US Digital Cellular Standard Data Rate (20 points)

Bandwidth efficiency \( \eta \) is computed from the data rate \( R \) divided by the channel bandwidth \( B \). Remember from an earlier homework assignment that Shannon’s channel capacity equation is given by

\[
C = B \left[ \log_2 \left( 1 + \frac{S}{N} \right) \right] \text{ in bits/second}
\]

where \( C \) is the capacity, \( B \) is bandwidth and \( (S/N) \) is the signal-to-noise ratio as usual. Capacity \( C \) may be thought of as the maximum data rate estimate for a communication channel (or maximum bandwidth efficiency \( \eta_{max} \) for the channel).

The US Digital Cellular Standard (established in 1991) calls for a data rate of 48.6 kbps with a channel bandwidth of 30 kHz and signal-to-noise ratio of 20 dB. By the way, US Digital Cellular operates from 824 MHz to 894 MHz (including both uplink and downlink).

(a) Calculate Shannon’s capacity \( C \) for the US Digital Cellular Standard with the above parameters.

(b) How does your answer from part (a) above compare to 48.6 kbps?

Problem 2 Serial to Parallel Parser (20 points)

When an input bit stream drives a quadrature modulator, we need to parse the input bit stream into two bit sequences intended to drive the in-phase and quadrature mixers. Thus, each pair of bits representing a symbol must be separated into an I-sequence of bits and a Q-sequence of bits. Let \( m_i(t) \) be the input bit stream of data and you are to separate it into the in-phase data sequence \( m_i(t) \) and quadrature sequence \( m_q(t) \). Be
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Problem 3 PN Codes in Spread Spectrum (20 points)
(Note: Refer to Section 12.4 on Direct Sequence Spread Spectrum in Lathi and Ding; pages 724 to 728)

In direct sequence spread spectrum a pseudo-noise bit code (also known as pseudo-random or chip code or bit sequence; PN code for brevity) is used to spread the spectrum. The PN code is quasi-random and has an autocorrelation function with a value of unity when it is coincident with itself and of negligible value when shifted in time over its full length.

Let \( m(t) \) be the digital message to be communicated, \( c(t) \) is the PN code used to spread \( m(t) \), and \( n(t) \) is random noise added as the modulated signal travels across the channel.

The transmitter multiplies \( m(t) \) and \( c(t) \) together to form \( \phi_{ss}(t) \) which is the signal launched onto the channel. The received signal from the channel is \( \phi_{ss}(t) + n(t) \).
representing the modulated signal plus added noise. In some cases the noise \( n(t) \) may be larger than the signal \( \varphi_{ss}(t) \).

Let the received signal be \( r(t) = \varphi_{ss}(t) + n(t) \). The receiver takes \( r(t) \) and multiplies it by an exact replica of \( c(t) \). The length of the PN code is not important for this problem.

Given that \( \varphi_{ss}(t) = m(t)c(t) \); show that the data output of the receiver is \( m(t) \), as it would be for any good receiver.

**Problem 4 Frequency Hopping Spread Spectrum** (20 points)

In class we discussed Frequency Hopping Spread Spectrum (FHSS). In the world of FHSS the terms “fast hopping” and “slow hopping” are commonly used. Hint: You might have to Google this question.

**(a)** What are the definitions of these two terms?

**(b)** If one wanted to jam or intercept a FHSS signal, which one would be easier to jam or intercept?
Problem 5  Synchronization (20 points)

In class we have discussed the need to synchronize the receiver to the transmitter for reliable communication to occur. In the communication systems literature there are three categories of synchronization: (1) phase or frequency, (2) symbol and (3) frame.

What does this mean and what is the difference? Note: You may use examples to describe the difference.