# Mitigation of Interference in Wireless Systems

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## INTRODUCTION

The purpose of this study is to determine the effectiveness of various approaches in mitigating the effects of wireless interference using simulation data.

## BACKGROUND

One of the most important factors contributing to the acceleration of scientific process is the access to information. From the invention of the printing press to the advent of digital communication, faster methods of information transfer allow researchers to collaborate more efficiently. In the last half century access to information has boomed, leading historians to refer to our age as the "Information Era".

Since the invention of radio technology in the late 19th century, wireless communication has increased in both bandwidth and connection distance, with massive cuts in cost. Development in the last 40 years in cellular connections has propelled bandwidth from 14.4 Kbps to up to 300 Mbps, an increase of over 20,000 times (Teknocrat). As wireless communication begins to play a larger and larger role in society, methods to minimize data loss while maximizing transfer rate and range become even more important.

## METHOD

### Transmitter

The first component of the simulation is the equivalent of a transmitter. This code generates a set of binary data to transmit. The data is then modified to consist of values of -1 and 1 rather than 0 and 1, so every bit transmitted has energy associated with it. This set of data is generated for every value of signal to noise ratio (the independent variable) being tested. In this case, that would be the set of values of 10^(n/10), where n is the set of integers between 0 and 10. Each set of data will be treated with noise differently, depending on the value of the SNR associated with the set. When multiple bits of information are sent in one symbol, a sine and cosine wave are layered and individual values for wave amplitude are designated using a constellation diagram (see Discussion). The symbol is then treated with noise.

### Propagation of Noise

Another array of same size is generated, with random normally distributed values with mean of 0 and standard deviation of 1. These values are multiplied by the square root of bit energy over signal to noise ratio times two (N=sqrt(No/2)*randn(1,num_bit), where No is Eb/SNR). This set represents random noise generated independent of the signal being transmitted. This would include interference with other wireless networks and electromagnetic noise in the transmitter and receiver circuits. The set of simulated noise is added to the set of data.

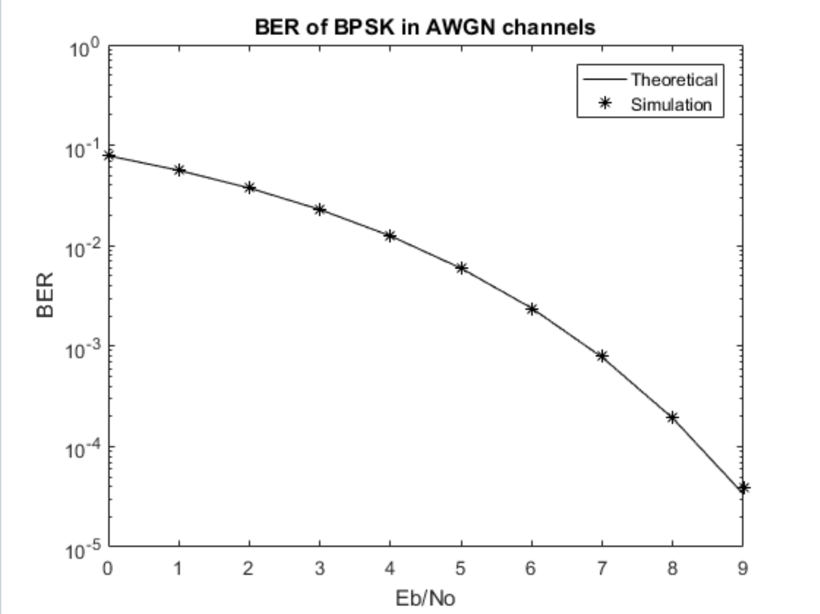
### Receiver

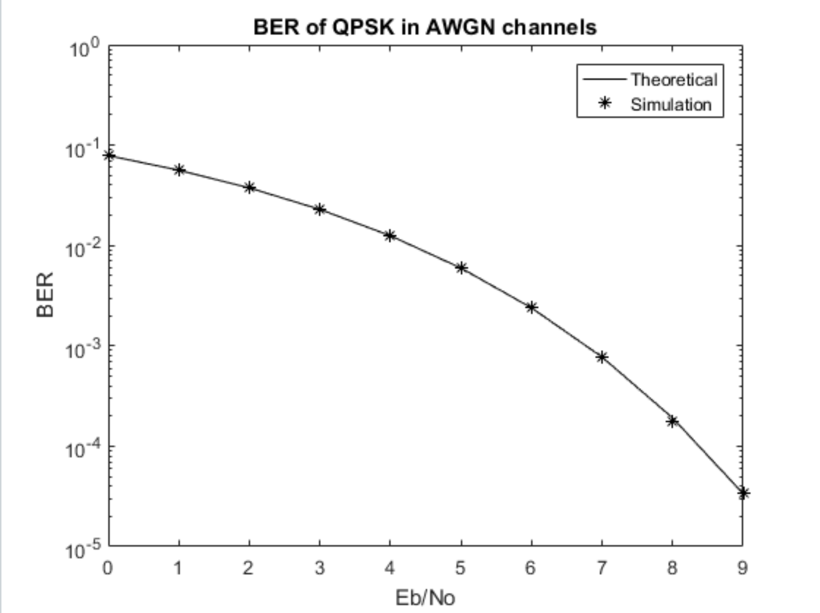
The receiver parses the data and noise set and compares it to the original set of data, finding the bit error rate (BER). With a binary system, this calculation is done by interpreting received values less than 0 as -1 and greater than 0 as 1. When more than one bit is being transmitted per single, the angle and magnitude of the wave must be found, with the cosine component as the x-value and the sine component as the y-value, before the original value can be determined.

## RESULTS

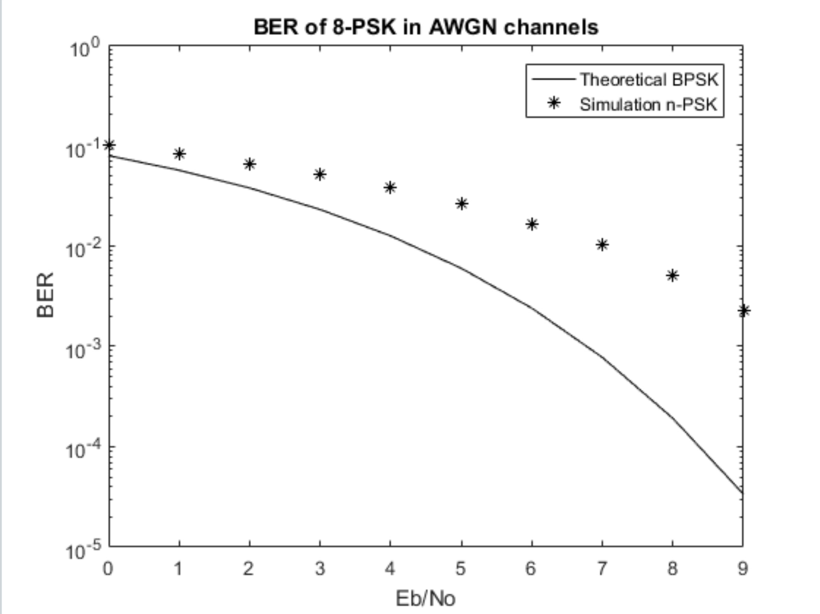
The most basic simulation is one of the bit error rate of a binary phase-shift keying in an additive white gaussian noise channel, or BER of BPSK in AWGN channels (top left). In this simulation, one bit of information is sent every symbol, and can be thought of as a simple sine or cosine wave.

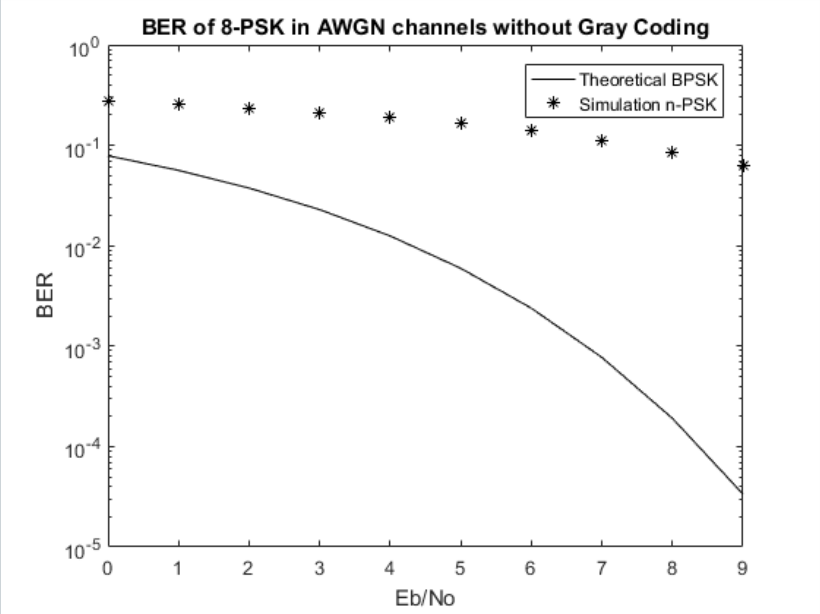
Next is BER of QPSK, or quadrature phase-shift keying. This involves sending two bits of information every symbol, by laying two out of phase waves over each other. As these waves are independent, error rate is constant.



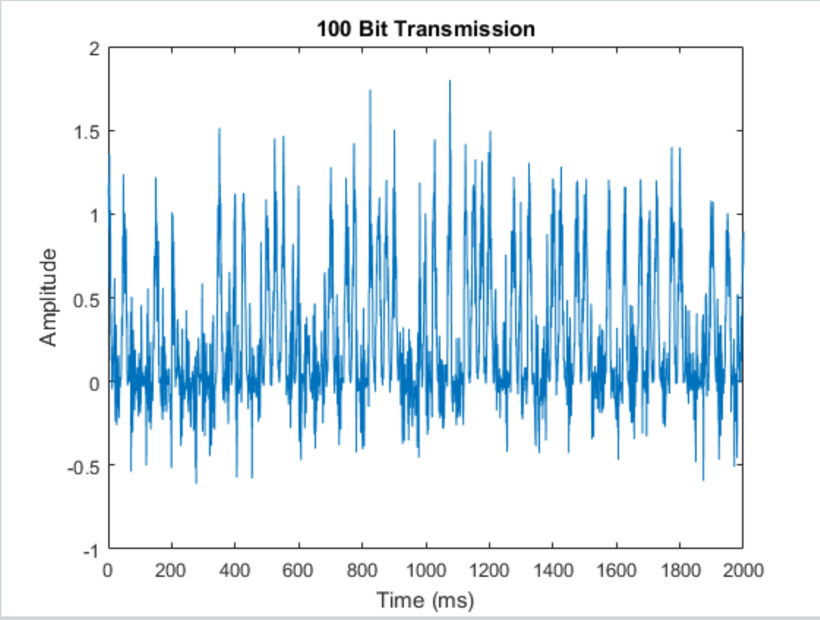



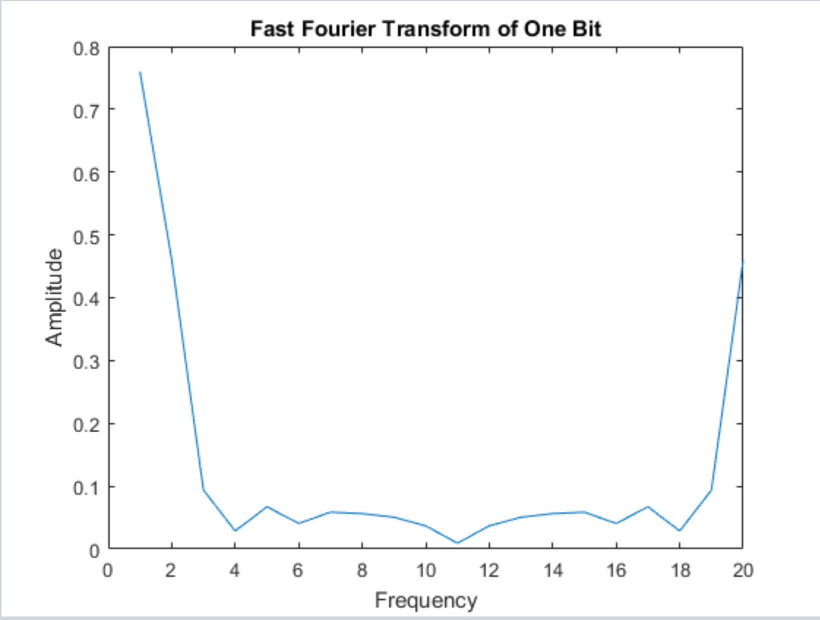

The following simulations involved creating a generalized system to send *n* number of bits every symbol, in this case three. This is done by independently changing the amplitude of two out of phase waves. The figure on the left utilizes Gray code, while the one on the right does not.




The figure on the left is a visual representation of the transmission of one hundred bits through BPSK with AWGN, where each bit is transmitted for 20 periods. The figure on the right is a fast fourier transform of one bit.




## DISCUSSION

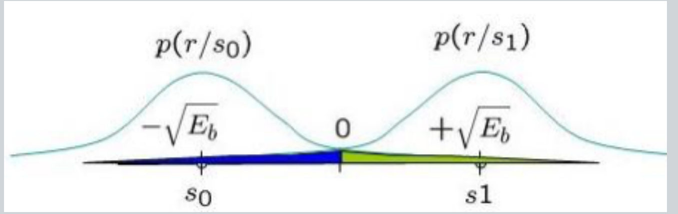
The first two figures illustrate the expected and simulated noise in a simple wireless system. The theoretical curve is derived from the equation for normal distributions, as seen below. As the random numbers generated in the simulation were normally distributed, the simulated points should fit on the theoretical curve. The accuracy of the simulation is due to a very large sample size: in this case two million bits were sent. These graphs are used as a baseline to which other methods of encoding are compared.

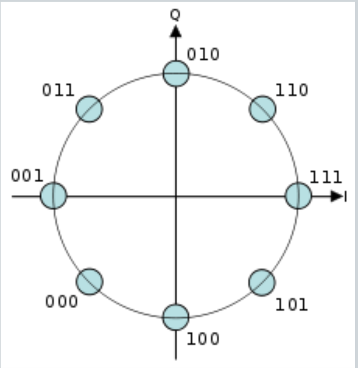
$$p(e|s_1) = \frac{1}{\sqrt{\pi N_0}} \int_{-\infty}^{0} e^{\frac{-(y-\sqrt{E_b})^2}{N_0}} dy = \frac{1}{\sqrt{\pi}} \int_{\sqrt{\frac{E_b}{N_0}}}^{\infty} e^{-z^2} dz = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right)$$

As can be seen by the middle figures, interference with 8 symbols per period results in a higher bit error rate than BPSK or 2-QAM. This occurs as the bits shared axis: with QPSK, each bit could be thought of as being transmitted on it's own wave, independent of the other. As such, even if the symbol received does not match the one transmitted, not all of the bits will necessarily be lost. However, with the implementation of n-PSK, more than two bits of information are being transmitted on only two axis at any given point of time. For this reason, increased error can be expected, though it can be mitigated through the use of Gray code. In essence, it is possible to construct a constellation diagram in such a manner that each symbol differs from its neighbor by only one bit. This type of ordering is called Gray code. The series

*000, 001, 011, 010, 110, 111, 101, 100*

is the sequence of Gray code for three bits. Note that the leading and trailing bits only differ by one bit as well. This is important, as the constellation diagram is constructed in a circle, as seen below and to the right.

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