Comparison of BER Performance of a WCDMA System in Rayleigh fading and AWGN Channels at Different Data Rates

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Abstract—The Third Generation systems (3G) that have been implemented by mobile service providers have provided more benefits compared to the second generation systems. The 3G technology delivers services such as video streaming, internet, 3D games to the users at a very reliable rate. However, the signal encounters interference in the channel which can be Rayleigh fading or additive white Gaussian channel during transmission. The interference degrades the signal which gives rise to some bits being received in error. The performance of any given system is determined by its bit error rate (BER). When the BER is low the better the quality of the services offered by the system.

This paper has developed a wideband code division multiple access (WCDMA) system model which can transmit data from 64kbps to 2Mbps in a Rayleigh fading and AWGN channels. The BERs are calculated at the receiver section for each channel and a comparison done for the two channels with or without error correction. The computer simulation tool (MATLAB) was used to develop and evaluate the bit error rate (BER) performance of the system. The model is developed in Simulink which has blocks in the communication block set which have parameters for simulation of the system. The error rate is calculated at the receiver by comparing the number of bits received in error to the total number of bits that is transmitted.

The performance of the WCDMA is better in Rayleigh fading channel compared to the AWGN channel. The improvement of performance in a given system means an additional capacity in the channel and hence more users accessing the channel.

Keywords— AWGN, BER, Rayleigh fading, Third Generation, WCDMA

I. INTRODUCTION

The systems that are deployed currently should be able to support multimedia applications. As such the WCDMA is found to support higher capacity, has better limiting features of multipath propagating effects. The scheme can also offer higher flexibility in the provision of multimedia services under different user data rates and quality of service [1][2].

II. RAYLEIGH FADING

The radio signal transmitted from a fixed source will encounter multiple objects in an urban or indoor environment. This will create more signal paths through reflection, refraction and diffraction of the transmitted signal. These signal paths are the ones referred to as multiple signal components which can undergo attenuation of power, delay in time and phase or frequency offset from the line of sight of the signal from the receiver [1].

When these signal components reach the receiver, they are summed together and this can create distortion in the signal received and the transmitted signal. The distortion in the receiver is what causes an error in the bit stream of the transmitted signal. This is a common phenomenon in urban and suburban places where mobile phones are widely used, which causes rapid communication changes in the environment. This will introduce more complexities and uncertainties to the channel response as presented in [3]-[5].

III. AWGN CHANNEL

This noise is generated through the thermal motion of the electrons in all dissipative electrical elements. It is modeled as a zero-mean Gaussian random process where the random signal is the summation of the random noise variable and a d.c. signal as shown in Equation 1 [6]-[8].

\[ z = a + n \] (1)

The probability distribution function for this Gaussian noise can be represented as;

\[ p(z) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{1}{2}\frac{(z-a)^2}{\sigma^2}\right) \] (2)
IV. SYSTEM MODEL

The computer simulation tool, MATLAB, was used to develop and simulate the model that can transmit information at a data rate from 64kbps to 2Mbps as shown in figure 1. The system was developed using blocks from the communication block-set found in Simulink library. The parameters of each block were set on the block properties dialog box.

The Bernoulli binary generator was used to generate the user data at a rate of 64kbps to 2Mbps. It used the Bernoulli distribution to generate random binary numbers 0 and 1. The number zero (0) was generated when the probability is p and one (1) when the probability is 1-p. This distribution had a mean value of 1-p and the variance of p*(1-p). The user data rate was set in this block using its sampling time parameter which is given as:

\[ \text{Sampling time} = \frac{1}{R_b} \]

where \( R_b \) is the data rate

The differential encoder did the encoding of the binary input signal generated and the output is the logical difference between the present input and the previous output. In this block the initial condition was set at zero (0).

The modulation of the data signal was done by the QPSK modulator whose output was a baseband representation of the modulated signal. The QPSK demodulator was used in the receiver side to demodulate the signal that was modulated in the transmitter section using QPSK modulation. The input to the demodulator must be a discrete-time complex signal which can be either a scalar or a frame-based column vector.

The square root raised cosine filter was used in the transmitter part to up-sample and filter the input signal. The same filter was used in the receiver section so that the overall response resembles that of a raised cosine filter. The parameters which were set for the filter includes the roll off factor (\( \alpha \)), group delay (D), up-sampling factor (N), length of the filter's impulse response (2*N*D+1) and gain of the filter which was set as ‘normalized’ for automatic scaling to be done.

The communication channel was a multipath fading channel and an additive white Gaussian noise channel simulated separately.

The error rate calculator was used at the receiver section to compare the bits transmitted and the bits received to determine the bit error rate (BER). The error rate was calculated as a running statistic by dividing the total number of bits that were received in error by the total number of bits generated from the source. This block can also be used to determine the symbol error rate.

V. RESULTS

Tables 1 and 2 show the results of simulation with or without convolution coding which is a scheme added into the developed system model to detect and correct errors.

<table>
<thead>
<tr>
<th>User Data Rate</th>
<th>BER Without Convolution coding</th>
<th>BER with Convolution coding</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>64kbps</td>
<td>5.0505e-001</td>
<td>4.9554e-001</td>
<td>-1.88</td>
</tr>
<tr>
<td>144kbps</td>
<td>5.0105e-001</td>
<td>5.2081e-001</td>
<td>+3.94</td>
</tr>
<tr>
<td>384kbps</td>
<td>5.0302e-001</td>
<td>4.9850e-001</td>
<td>-1.99</td>
</tr>
<tr>
<td>2Mbps</td>
<td>5.0000e-001</td>
<td>4.8828e-001</td>
<td>-2.34</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>User Data Rate</th>
<th>BER Without Convolution coding</th>
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</tr>
</thead>
<tbody>
<tr>
<td>64kbps</td>
<td>5.1546e-001</td>
<td>5.0201e-001</td>
<td>-2.6</td>
</tr>
<tr>
<td>144kbps</td>
<td>5.1653e-001</td>
<td>5.0100e-001</td>
<td>-1.26</td>
</tr>
<tr>
<td>384kbps</td>
<td>5.1653e-001</td>
<td>4.9900e-001</td>
<td>-3.39</td>
</tr>
<tr>
<td>2Mbps</td>
<td>5.1758e-001</td>
<td>4.9900e-001</td>
<td>-3.39</td>
</tr>
</tbody>
</table>

A. Discussion of the Results

Figures 2 and 3 show the comparison between the theoretical and simulated error rates when the transmission is done through Rayleigh fading and AWGN channels respectively. Figures 4 and 5 show the comparison of the error rates in a Rayleigh fading and AWGN channels with or without error correction i.e. convolution coding. From the two curves it can be seen that the convolution coding performs well in a Rayleigh fading channel than in AWGN channel. It can also be observed that it works well in higher rate data transmission.
Since the BER is a function of the signal-to-noise ratio and the signal-to-noise ratio function of capacity in a channel, this implies the capacity of the channel depends on the BER in any given system. If the BER is improved, then the capacity of the system increases which can be used to accommodate more traffic.

VI. CONCLUSION

The performance of the WCDMA is better in Rayleigh fading channel compared to the AWGN channel as the data rate is increased from 64kbps to 2Mbps. In addition, the error correction scheme works well at higher data rates. The improvement of performance in a given system means an additional capacity in the channel and hence more users accessing the channel.
REFERENCES


