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BER Improvement using MIMO : 2 x 2

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ABSTRACT

Wireless channel usually suffers from fading and interference from other users. Adaptive modulation may combat deep fading and ISI may be reduced by the use of OFDM. But with the use of spatial diversity better link performance can be obtained. In mobile wireless applications, where it is difficult to deploy multiple antennas in the handset for spatial diversity, the use of multiple antennas on the transmit side combined with signal processing and special coding technique called space-time coding, gives a unbeatable performance improvement.

1. INTRODUCTION

Demand for higher data rates in future wireless communications system design requires increased spectral efficiency and improved link reliability. Challenge for wireless broadband access lies in providing a comparable quality of service (QoS) for similar cost as competing wire line technologies. The challenges for wireless communication designs come from the detrimental characteristics of wireless environments, such as multipath fading, Doppler effect, co-channel interference, and intentional jamming in military communications. Multipath fading of wireless channels leads to inter-symbol interference (ISI), which limits the transmission rate of single-carrier systems. In conventional single carrier communication systems, the ISI is usually dealt with by a time domain channel equalizer [1]. When the data rate increases, the symbol duration reduces and the equalizer becomes very complex.

OFDM is a special form of multicarrier modulation [4], which was originally used in high frequency military radio. An efficient way to implement OFDM by means of a Discrete-time Fourier Transform (DFT) was found by Weinstein in 1971 [2]. The computational complexity could be further reduced by a Fast Fourier Transform (FFT). In the 1990s, OFDM was adopted in the standards of digital audio broadcasting (DAB), digital video broadcasting (DVB), asymmetric digital subscriber line (ADSL), and IEEE802.11a. OFDM is also considered in the new fixed broadband wireless access system specifications. In OFDM systems, the entire channel is divided into N narrow sub channels and the high-rate data are transmitted in parallel through the sub channels at the same time. Therefore, the symbol duration is N times longer than that of single-carrier systems and the ISI is reduced by N times.

In this paper we are going to analyze the performance of 2×1, 2×2 and 3×1 antenna systems.

2. MODULATION SYSTEM

The Multiple antenna technologies enable high capacities suited for Internet and multimedia services, and also dramatically increase range and reliability. The key objectives of the system are to provide good coverage in a non-line-of-sight (LOS) environment, reliable transmission, high peak data rates (>1 Mb/s), and high spectrum efficiency. These system requirements can be met by the combination of two powerful technologies in the physical layer design: multi-input and multi-output (MIMO) antennas and orthogonal frequency division multiplexing (OFDM) modulation. Henceforth, the system is referred to as Airburst.

Single-Carrier Modulation System

A single carrier system modulates information onto one carrier using frequency, phase, or amplitude adjustment of the carrier. For digital signals, the information is in the form of bits, or collections of bits called symbols, that are modulated onto the carrier. When higher data rates are used, the duration of one bit or symbol of information becomes smaller. The system becomes more susceptible to loss of information from impulse noise, signal reflections and other impairments. These impairments can impede the ability to recover the information sent. In addition, as the bandwidth used by a single carrier system increases, the susceptibility to interference from other continuous signal sources becomes greater. This type of interference is commonly labeled as carrier wave (CW) or frequency interference.

Multi Carrier Modulation System

Frequency division multiplexing (FDM) extends the concept of single carrier modulation by using multiple subcarriers [6] within the same single channel. The total data rate to be sent in the channel is divided between the various subcarriers. FDM systems usually require a guard band between modulated subcarriers to prevent the spectrum of one subcarrier from interfering with another. These guard bands lower the system's effective information rate when compared to a single carrier system with similar modulation.

If the FDM system above had been able to use a set of subcarriers that were orthogonal to each other, a higher level of spectral efficiency could have been achieved. The guard bands that were necessary to allow individual demodulation of subcarriers in an FDM system would no longer be necessary. The use of orthogonal subcarriers would allow the subcarriers' spectra to overlap, thus increasing the spectral efficiency. As long as orthogonality is maintained, it is still possible to recover the individual subcarriers' signals despite of their overlapping spectrums. Orthogonality can also be viewed from the standpoint of stochastic processes. If two random processes are uncorrelated, then they are orthogonal.

OFDM [3] is a special form of multicarrier modulation especially suitable for high-speed communication due to its resistance to ISI. As communication systems increase their information transfer speed, the time for each transmission necessarily becomes shorter. Since the delay time caused by multipath remains constant, ISI becomes a limitation in high-data-rate communication. OFDM avoids this problem by sending many low speed transmissions simultaneously. For example, Figure 1 shows two ways to transmit the same four pieces of binary data.

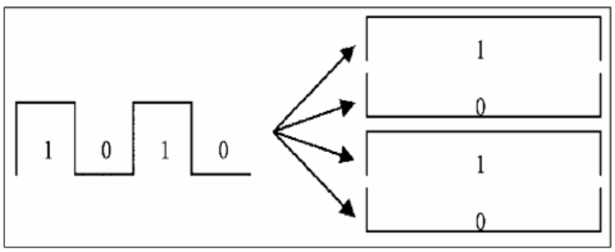

Fig 1: Two Ways to Transmit Binary Data

Suppose that this transmission takes four seconds. Then, each piece of data in the left picture has duration of one second. On the other hand, OFDM would send the four pieces simultaneously as shown on the right. In this case, each piece of data has duration of four seconds. This longer duration leads to fewer problems with ISI. Another reason to consider OFDM is low-complexity implementation for high-speed systems compared to traditional single carrier techniques. By adding a cyclic prefix (CP) ahead of each OFDM symbol, the ISI can be totally suppressed as long as the length of CP Tg is longer than the maximum channel delay ômax.

OFDM modulation and demodulation can be efficiently implemented by an IFFT and FFT.

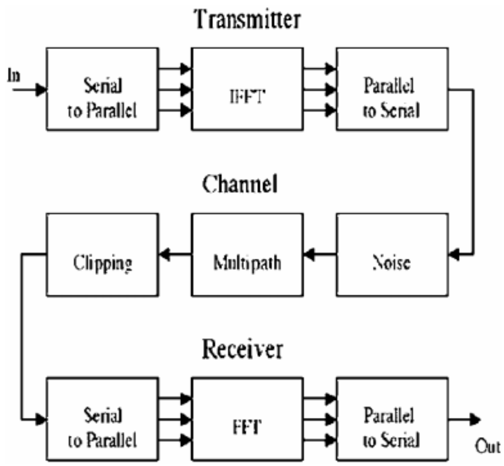

Fig 2: OFDM Simulation Flow Chart

The transmitter first converts the input data from a serial stream to parallel sets. Each set of data contains one symbol, Si, for each subcarrier. For example, a set of four data would be [S0 S1 S2 S3]. Before performing the Inverse Fast Fourier Transform (IFFT), this example data set is arranged on the horizontal axis in the frequency domain as shown in Figure 3.

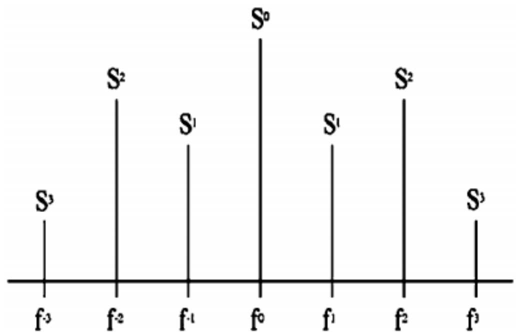

Fig 3: Frequency Domain Representation of [S0 S1 S2 S3].

This symmetrical arrangement about the vertical axis is necessary for using the IFFT to manipulate this data. An inverse Fourier transform converts the frequency domain data set into samples of the corresponding time domain representation of this data. Specifically, the IFFT is useful for OFDM because it generates samples of a waveform with frequency components satisfying orthogonality conditions. Then, the parallel to serial block creates the OFDM signal by sequentially outputting the time domain samples.

3. SIMULATION

The channel simulation allows examination of common wireless channel characteristics such as noise, multipath, and clipping. By adding random data to the transmitted signal, simple noise is simulated. Multipath simulation involves adding attenuated and delayed copies of the transmitted signal to the original. This simulates the problem in wireless communication when the signal propagates on many paths.

Although OFDM successfully prevents the ISI, it does not suppress channel fading. By using coding and interleaving across the frequency and time domain, the transmitted data can be effectively protected. Further improvement can be achieved through other advanced techniques, such as power allocation and adaptive modulation. For adaptive modulation, the constellation size of modulation for each sub channel is adjusted according to the sub channel quality such that a low bit error rate is preserved. The figures 4, 5 & 6 show the simulation result of different systems with significant improvement in bit error.

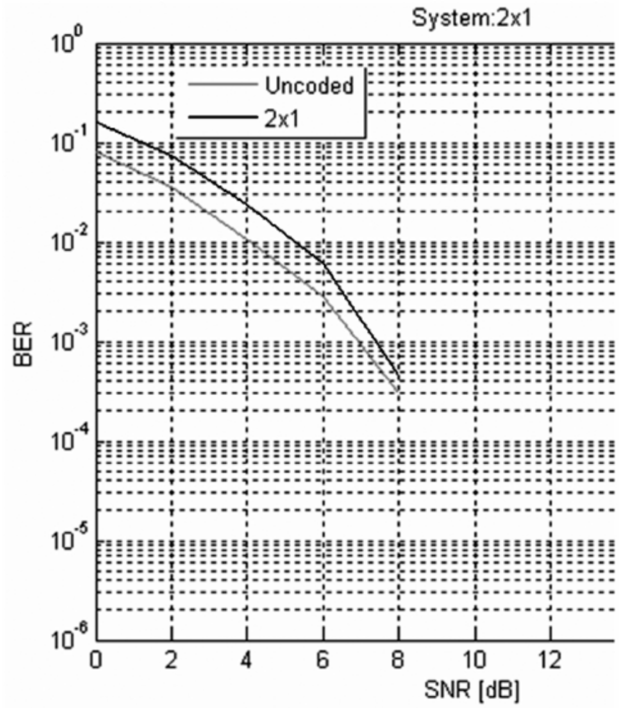

Fig 4: BER Vs SNR for 2 × 1 Antenna System

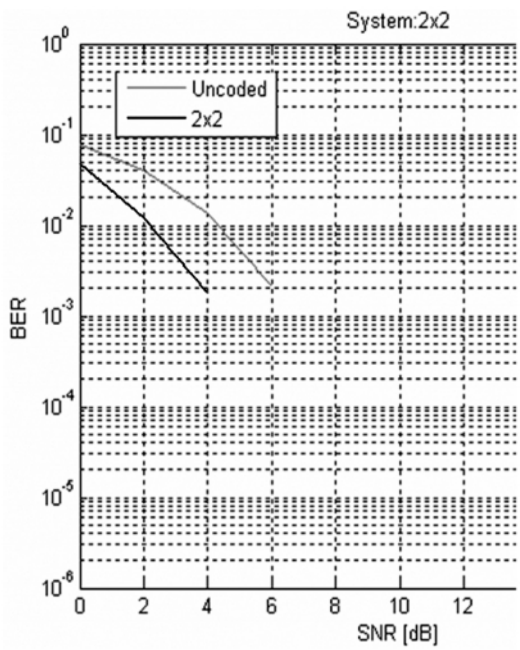

Fig 5: BER Vs SNR for 2 x 2 Antenna System

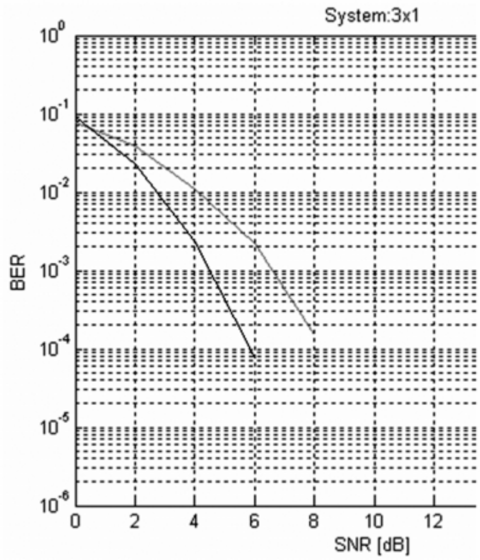

Fig 6: BER Vs SNR for 3 × 1 Antenna System

4. FUTURE SCOPE

In mobile wireless applications, where it is difficult to deploy multiple antennas in the handset, the use of multiple antennas on the transmit side combined with signal processing and coding [1] has become known under the name of space-time coding and is currently an active area of research The use of multiple antennas at both ends of a wireless link (multiple-input multiple-output (MIMO) technology) has recently been demonstrated to have the potential of achieving extraordinary data rates. Orthogonal frequency division multiplexing (OFDM) significantly reduces receiver complexity in wireless broadband systems. The use of MIMO technology in combination with OFDM, i.e., MIMO-OFDM [8] therefore seems to be an attractive solution for future broadband wireless systems.

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