6

OFDM AND CDMA MIMO V-BLAST SYSTEM

6.1 INTRODUCTION

This chapter describes the system based on a MIMO OFDM and CDMA with V-BLAST receiver. It is a single-TDMA stream scheme (for multi-user operation) capable to handle rates ranging adaptively from 64 kbps to 100 Mbps according to the sub-carrier SNR and target BER. In that sense, the system can implement different modulation schemes (QPSK, 16-QAM, 64- QAM).

6.2 OFDM MIMO V-BLAST SYSTEM

The MIMO OFDM V-BLAST system operates in the 17 GHz unlicensed frequency band with an available bandwidth of 200 MHz (17.1–17.3 GHz) that is divided into four 50 MHz-width channels not simultaneously selectable. OFDM with L = 128 sub-carriers (frequency sub-channels) is designed for each of these 50 MHz wide channels. The indoor coverage ranges from 5 m for non line-of-sight to 20 m for line-of sight (LOS).

The indoor environment is the ideal rich-scattering environment necessary by the V - BLAST processing to get CCI cancellation at the receiver. V-BLAST algorithm with OSIC processing implements a non-linear detection technique based on Zero Forcing (ZF) filtering combined with symbol cancellation to improve the performance. The idea is to look at the signals from all the receive antennas simultaneously, first extracting the strongest sub-stream from the received signals, then proceeding with the remaining weaker signals, which are easier to recover once the strongest signals have been removed as a source of interference. Transmit space diversity techniques and V-BLAST receiver requires flat fading channel. The OFDM approach makes this assumption, for each frequency sub-channel, reasonable.

6.3 MIMO V-BLAST SYSTEM MODEL

Although various implementation architectures for Multiple - Input Multiple - Output (MIMO) systems have been introduced since the BLAST (**B**ell **L**aboratories **L**ayered **S**pace-**T**ime) system was proposed, a variation of such system, V-BLAST still emerges as a promising architecture due to lower receiver complexity (V-BLAST receiver algorithm) and higher data rates in the case of large number of antennas. In this project we consider a V-BLAST system with N transmit and M = N receives antennas. At the transmitter, a single bit stream (TDMA frame, for example) is horizontally encoded (HE) and de-multiplexed into N sub streams, and each sub stream is mapped to a symbol by the same constellation and sent to its respective transmit antenna. Since total transmit power E_S is preserved irrespective of the number of transmit antennas, there is no increase in the amount of interference caused to the other users or sub streams. Thus, at each symbol time t, a transmitted signal vector of size N, $\mathbf{a}^t$ = $[a\ 1^t,\ aNt]^T$, is sent to the receiver over a rich-scattering and quasi-static flat fading wireless channel. Each time sequence $\{a^t\}$ j, (j = 1, 2,..., N) is referred to as a layer. Transmitter needs no information about the channel, which eliminates the need for fast feedback links.

At the receiver, the signal ri^t received by antenna i at time t is a noisy superposition of the N transmitted signals respectively corrupted by noise ni^t,

$$r_i^t = \sum_{j=1}^{N} h_j^t a_j^t + n_j^t \quad (i = 1,2,\ldots,M) \tag{1}$$

Where, hij^t are the channel gains from transmit antenna j to receive antenna i at time t, which are complex Gaussian with zero mean and unit variance (ZMCSCG with unit variance), and ni^t are ZMCSCG with variance N_O. In matrix notation,

$$\mathbf{r} = \mathbf{Ha} + \mathbf{n} \tag{2}$$

Where

$$\mathbf{H}=\begin{bmatrix} h_{11} & \cdots & h_{1N} \\ \vdots & \ddots & \vdots \\ h_{M1} & \cdots & h_{MN} \end{bmatrix},\quad \mathbf{r}=\begin{bmatrix} r_1 \\ \cdots \\ r_N \end{bmatrix},\quad \mathbf{a}=\begin{bmatrix} a_1 \\ \cdots \\ a_N \end{bmatrix},\quad \mathbf{n}=\begin{bmatrix} n_1 \\ \cdots \\ n_N \end{bmatrix}$$

With the assumption of a quasi-static flat fading channel, that means the channel gain *hij* keeps constant over a block time, and then changes block by block in an independent random manner. Thus, the index t in the equation would be omitted. Another assumption on the channel is rich-scattering, which holds if antenna spacing is sufficient and if the scenario provides a large number of local scatters around transmitter or receiver, supports the channel gains are complex Gaussian and independent of one another.

6.3.1 Transmitter Model

The transmitter (Figure: 6.1) has an array of N-antennas and performs a MIMO vertical encoding (VE). The first step is the encoding of the bit stream from the information source (TDMA frame for multi-user operation). The coded bits are then mapped to some symbols. It has been established that OFDM is a spectrally efficient modulation technique, thus spectral efficiency depends mainly on the bandwidth of the symbol, B_S. This depends on the modulation technique used to modulate the individual sub-carriers. It is the mapping (over a constellation) that corresponds to the choice of modulation technique, which should minimize B_S.

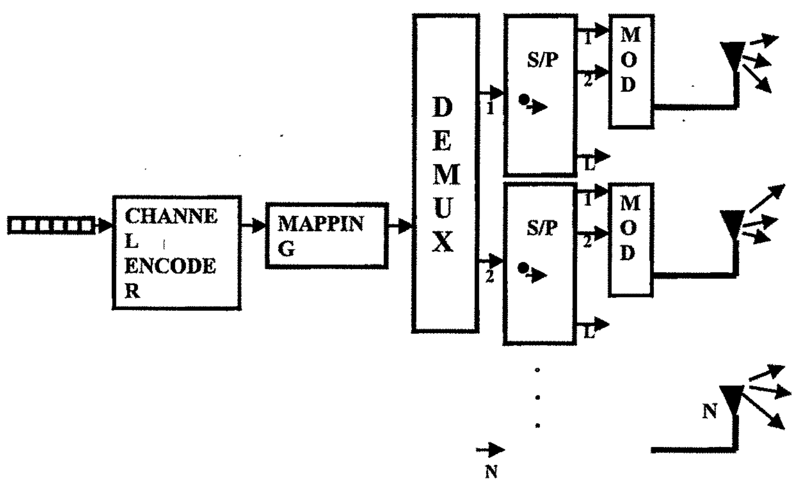

Figure: 6.1 OFDM MIMO V-BLAST Transmitter model

M-QAM is the most spectrally efficient system and it is most often used in OFDM systems. The use of the IFFT does not pose a problem as it can take in both real and imaginary inputs of the QAM symbol. Once the encoded bits are mapped to symbols, the symbol frame is passed through a de-multiplexer (1 to N) representing the space encoding. It maps symbols on the N space channels, which are sub streams of the original frame. Each symbol sub stream is then put through a serial-to-parallel (S/P) converter, which takes L of these symbols as input and produces L parallel output symbols corresponding to the OFDM sub-band channels. These symbols are put through the IFFT and then transmitted by the antenna n ($n = 1, 2, \ldots, N$). Because each input to IFFT corresponds to an OFDM sub-carrier, at the output we get a time -domain OFDM symbol that corresponds to the input symbols in the frequency domain.

In other words, the symbols constitute the frequency spectrum of the OFDM symbol. Once we have the OFDM symbol, a cyclic extension (with length depending on the channel) is performed. The final length of the extended OFDM signal will be the length of the original OFDM symbol plus the length of the channel response. As long as the guard interval, which is another name for the cyclic extension, is longer than the channel spread, the OFDM symbol will remain intact.

6.3.2 Receiver Model

After the channel, the cyclic extension is removed as it just contains the channel spread (assumed negligible in the simulation). Then the FFT is taken in each of the M receive antennas (V-BLAST requires $M \geq N$). Each antenna m receives a different noisy superimposition of the faded versions of the N transmitted signals (Figure: 6.2). If the transmit and receive antennas are sufficiently spatially separated, more than $\lambda/2$ (at 17 GHz it is about 0.9 cm) and there is a sufficiently rich scattering propagation environment, the transmitted signals arriving at different receive antennas undergo uncorrelated fading. Moreover, if the channel state is perfectly known at the receiver, V-BLAST receiver is able to detect the N transmitted sub-streams.

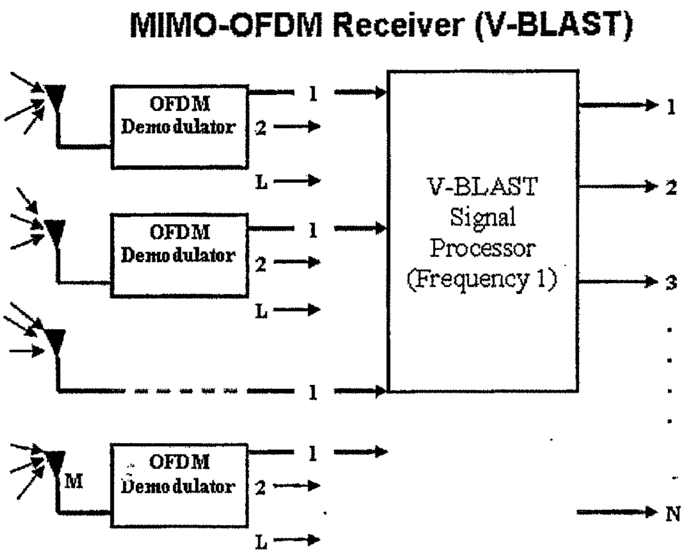

Figure: 6.2 OFDM MIMO V-BLAST Receiver model

The output of the OFDM demodulator, at the receive antenna M, is a set of L signals, one for each frequency sub-channel, described by

$$r_{m,l} = \sum_{n=1}^{N} \mathrm{h}_{m,n,l} \bullet \mathrm{C}_{n,l} + \eta_{m,l}, \quad \text{with } l = 1, \ldots, L \qquad (3)$$

where $\mathrm{h}_{m,n,l}$ is the flat fading coefficient representing the channel from the transmit antenna n to the receive antenna m at frequency l, and $\eta_{m,\ l}$ are independent samples of a Gaussian random variable with power spectral density N0 representing noise (where N0 is the power spectral density of the noise at the receiver input).The M outputs for the frequency l are the inputs to a V-BLAST signal processor l. This sub-system is able to detect the N different space channels once flat fading is assumed (true because OFDM). This processing is repeated for each of the L sub-bands. The output of the L different V- BLAST signal processors is passed through a parallel-to-serial converter (with a multiplexer $N=1$ is included) and the symbols are de-mapped and decoded to destination.

6.4 CDMA MIMO V-BLAST SYSTEM

In a Code Division Multiple Access (CDMA) system, several users transmit their signals simultaneously over a common channel. The receiver has knowledge of the codes of all the users. It is then required to demodulate the information symbol sequences of these users, upon reception of the sum of transmitted signals of all the users in the presence of additive noise This situation arises in a variety of communication systems such as wireless communication and other multipoint to multipoint multiple access networks. However, since multiple users share the same bandwidth to transmit data in a typical CDMA system, users signal may interfere with each other if orthogonality is not maintained and causes Multiple Access Interference (MAI). MAI degrades the performance of the system. Conventional CDMA detectors such as matched filter and RAKE combiner are optimized for detecting the signal of a single desired user. These conventional detectors are inefficient, because the interference is treated as noise and there is no utilization of the available knowledge of spreading sequences of the interferers. The efficiency of these detectors is dependent on the cross correlation between the spreading codes of all users.

The optimal multi-user detector, discovered by Verdu in early 1980s showed that a maximum likelihood receiver could be used to optimally decode multiple users in parallel, with dramatic gains. This receiver is unfortunately extremely complex, while in many practical applications such performance complexity prohibits implementation of the Verdu algorithm, its performance is still of very much of interest since it serves as a benchmark against which to compare other schemes with less implementation complexity such as those that employ interference cancellation to be discussed shortly.

One approach is to employ a suitable linear transformation on the matched filter outputs. Belonging to this family are the decorrelating receiver and Minimum Mean Square Error (MMSE) detector. In these methods, the different users are made uncorrelated by a linear transformation. This linear transformation is computed by measuring all cross correlations between pairs of user codes and then inverting the resulting huge matrix of cross-correlations. Since in practical systems each user is assigned a very long pseudo noise (PN) code, each bit has essentially a random code assigned to it. Thus, in this case, the above procedure would have to be repeated for each bit in succession.

Interference Cancellation (IC) schemes contribute another variant of multi-user detection and they can be broadly divided into two categories: successive cancellation and parallel cancellation. Interference cancellation should be interpreted to mean the class of techniques that demodulate and/or decode desired information, and then use this information along with channel estimates to cancel received interference from the received signal. Lower computation and hardware related structures are the main advantages of these methods beside the main advantage of lower BER or better capacity than linear multi-user detectors. With regard to former Patel and Holtzman suggested coordinated processing of the received signal with a successive cancellation scheme in which the interference caused by remaining users is removed from each user in succession. The approach successively cancels strongest users by re-encoding the decoded bits and after making an estimate of the channel, the interfering signal is recreated at the receiver and subtracted from the received waveform. In this manner successive user does not have to encounter MAI caused by initial users. One disadvantage of this scheme is the fact that a specific geometric power distribution must be assigned to the users in order that each see the same signal power to the background plus interference noise ratio. Another disadvantage of this scheme has to do with the required delay necessary to fully accomplish the IC for all the users in the system. Since the IC proceeds serially, a delay on the order of M computation stages is required to complete the job. This delay becomes intolerable for large number of users and SIC method looses its advantage.

Parallel processing of multi-user interference simultaneously removes from each user the interference produced by the remaining users accessing the channel. In this way, each user in the system receives equal treatment insofar as the attempt is made to cancel multiple user interference. As compared with the serial processing scheme, since the IC is performed in parallel for all the users, the delay required to complete the operation is at most a few bit times. Variance and Abashing proposed a multistage detector for an asynchronous system, where the outputs from a matched filter bank were fed into a detector that performed MAI cancellation using a multistage algorithm. At each stage in the detector, the estimates of all other users from the previous stage were used for reconstructing an estimate of the MAI and this estimate was then subtracted from the interfered signal representing the wanted bit.

The computational complexity of this detector was linear with respect to number of users and delay introduced was much less than serial method.

6.4.1 CDMA MIMO V-BLAST Transmitter Model

The figure 6.3 shown below is Model of Simple CDMA MIMO Transmitters. Here Data Bits from individual's users are first spreaded using their spreading code. After that each user's spreaded data is modulated using any convention modulation techniques. Vertical encoding is part of MIMO techniques here modulated signal is divided into a number of transmit antennas.

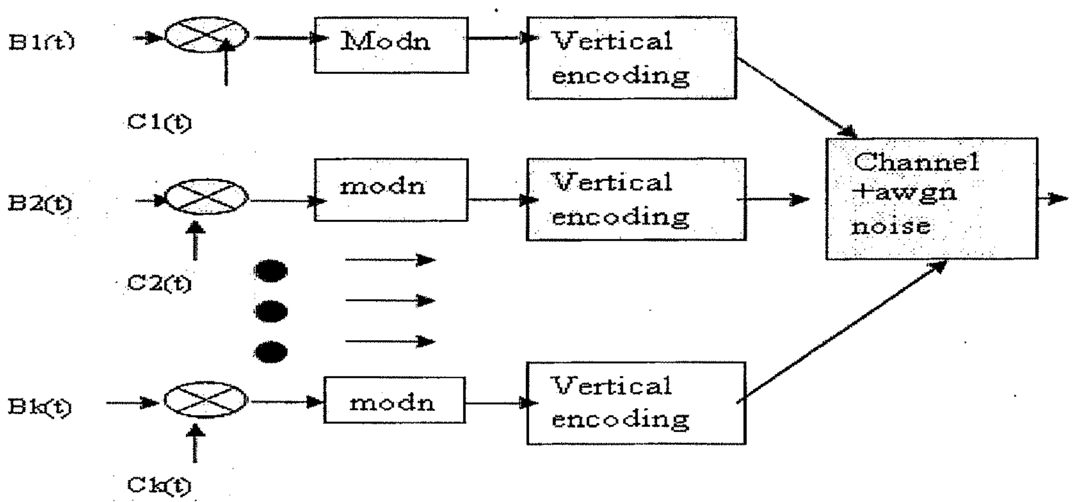

Figure 6.3 CDMA MIMO Transmitters

After vertical encoding all users signals is sent into Rayleigh channel and addition of AWGN (additive white Gaussian noise) noise is also considered.

6.4.2 CDMA MIMO V-BLAST Receiver Model

The figure 6.4 is a Model of Simple CDMA MIMO Receiver. Each receive antennas receives data from every transmit antennas. The correlator is optional. It is used for correlation for individual users. Then the signal is passed form any operator ZF or MMSE in Figure 6.4 we have indicated ZF. After Transformation of ZF signal is processed by V-BLAST decoding algorithms, it operates on channel matrix and all the steps of V-BLAST processing are performed to detect individual user signal.

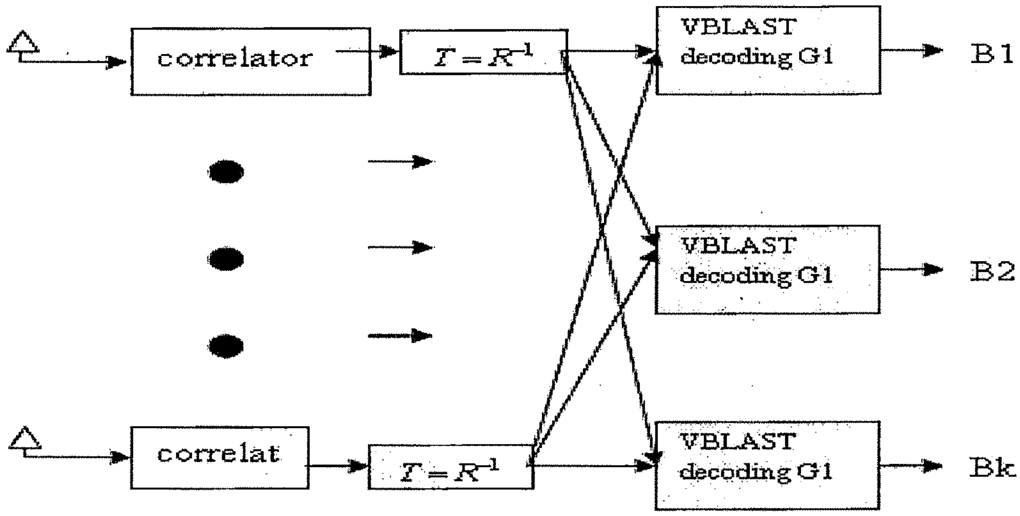

Figure 6.4 CDMA MIMO Receivers

6.5 SUMMARY

In this chapter we discuss OFDM MIMO V-BLAST and CDMA MIMO V-BLAST techniques. We discuss how OFDM and CDMA can be used in MIMO and how V-BLAST algorithm can be applied in the signal detection process. We discuss OFDM and CDMA MIMO V-BLAST transmitter and receiver model.