Throughput Improvement of Adaptive Modulation System with an Efficient Turbo−Coded V−BLAST Technique in each MIMO Channel

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ABSTRACT

In this paper, an Adaptive Modulation (AM) system with an efficient turbo−coded Vertical−Bell−lab Layered Space−Time (V−BLAST) technique is proposed. The proposed decoding algorithm adopts iteratively the extrinsic information from a Maximum a Posteriori (MAP) decoder as a priori probability in the two decoding procedures of the V−BLAST scheme of ordering and slicing. In this analysis, each MIMO channel is assumed to be a part of the system of performance improvement.

Keyword
V−BLAST, MAP decoder, AMC, STD, turbo code

Ⅰ. Introduction

To improve the throughput performance together with the development of the MIMO scheme, the Adaptive Modulation and Coding (AMC) scheme has attracted considerable attention as the forerunner of next−generation mobile communication systems. Consequently, the combination of a MIMO scheme and an AMC scheme can potentially improve the throughput performance.

V−BLAST [1] was selected as the MIMO multiplexing scheme and the turbo−coding was chosen as the channel coding scheme of the AMC due to the complexity of the aforementioned combined system. The turbo−coding scheme is iteratively decoded with a posteriori probabilities (APP) algorithms for the constituent codes [2].

A performance analysis is offered here of AM systems with several turbo−coded V−BLAST techniques including the turbo decoding algorithm used with MIMO. For greater performance improvement, the proposed system utilizes a 2x2 MIMO channel using two transmitter antennas and two receiver antennas, a 4−2x2 MIMO channel applying a Selection Transmit Diversity (STD) scheme that selects two antennas from four transmitter antennas, a 4x4 MIMO channel using four transmitter antennas and four receiver antennas, and a 8x8 MIMO channel using eight transmitter antennas and eight receiver antennas.

Ⅱ. Improved V−BLAST decoding algorithm

Fig. 1 shows the structure of the system used with the proposed decoding algorithm. The proposed decoding algorithm is defined as "efficient", considering the improvement of performance and the practicable degree of complexity. The difference between this algorithm and the conventional V−BLAST decoding algorithm is that the extrinsic information from a MAP decoder is used as an a priori probability in the ordering and slicing decoding procedures of the V−BLAST scheme [3]. That is, the ordering and slicing of the V−BLAST decoding procedure are modified using the extrinsic information. This scheme operates iteratively and is defined as the main MAP iteration. Moreover, whenever it operates internally, iterative decoding of the MAP decoder is performed, and this method is defined as the sub MAP iteration. Here, an iterative decoding algorithm that shows superior performance and lower complexity is proposed for application to a practical system.

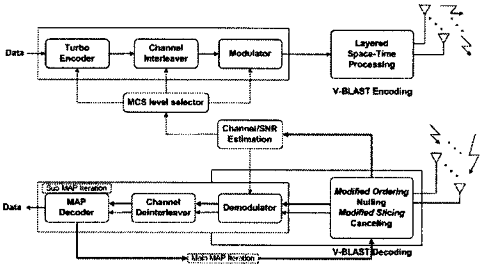

Fig. 1 Transmitter−receiver structure of the AM system with the efficient turbo−coded V−BLAST technique

In the system used with the proposed decoding algorithm, it is assumed that the system is equipped with M transmit antennas and N receive antennas. Furthermore, each transmission channel is assumed to be modeled as a flat Rayleigh fading channel. The received signal in the V−BLAST receiver is denoted by

$$X = Hs + n \quad (1)$$

where $X = [x_1, \cdots, x_N]^T$ denotes the received signal vector, $s = [s_1, \cdots, s_M]^T$ is the transmitted symbol vector, H is the $N \times M$ channel matrix and $n = [n_1, \cdots, n_N]^T$ is the noise vector. The superscript T signifies the transpose matrix. The noise vector, n, is modeled as a complex gaussian random process. s_m is the 2Q−ary modulated symbol, specifically $s_m = f(d_1^m, \cdots, d_Q^m) \in \Phi = \{\phi_1, \cdots, \phi_{2^Q}\}$, where Q denotes the bit number per symbol, $f(\cdot)$ denotes the symbol modulation function, $\{d_q^m\}_{q=1,\cdots,Q}$ represents the q−th information bits corresponding to sm, and $\{\Phi_i\}_{i=1,\cdots,2^Q}$ represents the i−th symbol.

The proposed slicing algorithm does not make a hard decision with the received signal but it makes a decision with the extrinsic information from the MAP decoder [4]. This extrinsic information from the MAP decoder is the log−likelihood ratio (LLR) function. It can be described as

$$L_{m,q} = \log\frac{p(d_q^m = 1)}{p(d_q^m = 0)} \quad (2)$$

where $L_{m,q}$ denotes the extrinsic information corresponding to d_q^m. That is, $\{d_q^m\}_{q=1,\cdots,Q}$ is respectively decided by $\{L_{m,q}\}_{q=1,\cdots,Q}$. (e.g., if $L_{m,q}$ is more than 0, d_q^m is determined to be 1. Otherwise, d_q^m is determined to be 0.) The proposed slicing algorithm then performs the quantization operation appropriate to the constellation in use corresponding to $\{d_q^m\}_{q=1,\cdots,Q}$.

In the conventional V−BLAST ordering procedure, the decoding order is determined by the SNR of the corresponding layer. The conventional V−BLAST ordering is described as

$$l_k = \arg\min_m \| (H_k^\dagger)_m \|^2 \quad (3)$$

where k represents the decoding stage and the superscript † denotes the pseudo−inverse matrix. The SNR is a function of the channel power, and the layer with the largest channel power is the first layer that is decoded. A high SNR signifies a low symbol error rate. Thus, it follows that the maximum SNR criterion can be considered to be a specific version of the minimum symbol error criterion.

The proposed ordering algorithm is a function, not only of the SNR, but also of the extrinsic information. Accordingly it can be modified to

$$l_k = \arg\min_m P_m(e|X_k, H_k, L_m^{(i)}) \quad (4)$$

where $P_m(e|X_k, H_k, L_m^{(i)})$ is the symbol error probability of the m−th layer and $L_m^{(i)} = [L_{m,1}^{(i)}, \cdots, L_{m,Q}^{(i)}]^T$ is the extrinsic information vector of the l_k−th layer at the i−th main MAP iteration. The symbol error probability, P_m, can be calculated from

$$P_m(e|X_k, H_k, L_m^{(i)}) = \frac{1}{2^Q}\sum_{q=1}^{2^Q}\sum_{p=1, p\neq q}^{2^Q} P(\phi_q|L_m^{(i)}) P\{\phi_q \rightarrow \phi_p | X_k, H_k, L_m^{(i)}\} \quad (5)$$

where ϕ_q denotes the original transmitted symbol, ϕ_p is the possible symbol except for ϕ_q, and $P\{\phi_q \rightarrow \phi_p | X_k, H_k, L_m^{(i)}\}$ is the pair−wise symbol error probability, which can be obtained from

$$\begin{aligned} &P\{\phi_q \to \phi_p | X_k, H_k, L_m^{(i)}\} \\ &= P\{p(\phi_q|y_m) < p(\phi_p|y_m)\} \\ &= P\{\log p(\phi_q|y_m) < \log p(\phi_p|y_m)\} \end{aligned} \tag{6}$$

Here, y_m is the desired symbol deleted from the interference of other symbols after the nulling process of the V-BLAST decoding in the received symbol of the m-th layer, x_m. Assuming that the variance of the noise corresponding to the m-th layer is $\sigma_m^2/2$, in (6), the log posteriori function of ϕ_p is described by

$$\begin{aligned} &\log p(\phi_j|y_m) \\ &= \log \frac{p(\phi_j|L_m^{(i)})p(y_m|\phi_j)}{p(y_m)} \\ &= \log p(\phi_j|L_m^{(i)}) + \frac{Re\{(\phi_j-\phi)(2y_m-(\phi_j+\phi))^*\}}{2\sigma_m^2} \end{aligned} \tag{7}$$

where the superscript * signifies a complex conjugate.

Ⅲ. Simulation results

Table 1 shows the MCS level selection thresholds and the simulation parameters. In this table, the detailed parameters are established based on the 1X EV-DO Standards [5].

One frame is set up with one transmission slot, and the frame length is 2,048 symbols. If one bit error occurs in one frame, it is considered as a frame error. When a frame error does not occur, the transmission rate is calculated in accordance with V-BLAST technique by the order of (bit length × data rate × number of transmit antenna). The performance of the transmission rate closely corresponds to the capacity of the FER. Hence, in accordance with the transmission rate, the performance analysis is obtained by the error probability.

Table 1 MCS levels and parameters for simulation

MCS level	Data rate (Kbps)	Number of bits per frame	Code rate	Modulation
1	614.4	1,024	1/3	QPSK
2	1,228.8	2,048	2/3	QPSK
3	1,843.2	3,072	2/3	8PSK
4	2,457.6	2,096	2/3	16QAM

Fig. 2 shows the throughputs of each decoding algorithm in the AM systems with several turbo-coded V-BLAST techniques in a 2x2 MIMO channel. Here, the proposed decoding algorithm achieves a better throughput performance than the conventional the conventional V-BLAST decoding algorithm over the entire SNR range. Furthermore, the proposed decoding algorithm is close to the existing ML decoding algorithm in terms of the throughput performance.

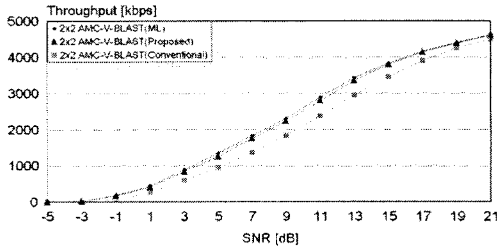

Fig. 2 Throughputs of the AMC systems with several V-BLAST decoding algorithms in a 2×2 MIMO scheme

Fig. 3 shows the throughputs of the AM systems with several turbo-coded V-BLAST techniques in a 2x2 and 4-2x2 MIMO channel. It is demonstrated that the systems in a 4-2x2 MIMO channel achieve superior throughput performance relative to the others. The systems in the 4-2x2 MIMO channel that utilize a STD scheme show improvements in the SNR through the selection diversity gain. These improvements lead to a reduced error rate and an increase in the probability of selecting the MCS level with a higher data rate.

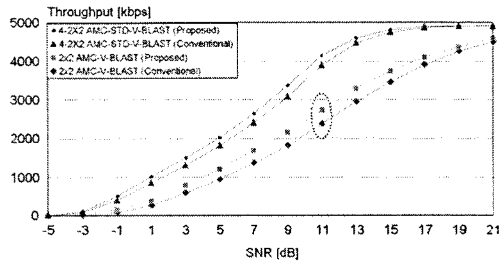

Fig. 3 Throughputs of the AM systems with several turbo-coded V-BLAST techniques in a 2x2 and 4-2x2 MIMO channel

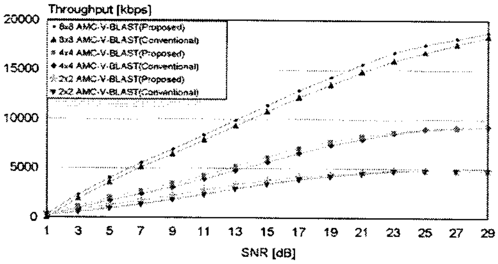

Fig. 4 Throughputs of the AM systems with several turbo-coded V-BLAST techniques in a 2x2, 4x4, and 8x8 MIMO channel

Fig. 4 shows the throughputs of AM systems with several turbo-coded V-BLAST techniques in a 2x2, 4x4, and 8x8 MIMO channel. Here, the proposed decoding algorithm is shown to be more effective as the number of system antenna increases. In addition, when the MIMO diversity scheme or a higher MIMO channel is applied, its performance can be enhanced significantly.

Ⅳ. Conclusions

The proposed decoding algorithm achieves a better throughput performance than the conventional V-BLAST decoding algorithm over the entire SNR range. For the example of $M=N=4$ and QPSK, it was demonstrated that the proposed decoding algorithm has nearly 24 % lower complexity than the existing ML decoding algorithm while it provides an approximate increase of 8.3 % in capacity compared to the conventional V-BLAST decoding algorithm. In addition, the simulation results show that the maximum throughput improvement in each MIMO channel is nearly 421 kbps (a 17.7 % increase in capacity) for a 2x2 MIMO, 545 kbps (an 8.3 % increase in capacity) for a 4x4 MIMO, and 880 kbps (a 5.5 % increase in capacity) for an 8x8 MIMO. Thus, the effect of the proposed decoding algorithm increases as the number of system antennas increases. Accordingly, if the MIMO schemes can be applied in each case for a higher throughput performance, the proposed decoding algorithm will then be a practical candidate for next-generation mobile communication systems.

References

[1] Bhargave, A., and DeFegueiredo, R.J.P, "A new MIMO detector for iterative decoding with multiple antenna systems," Military Communications Conference, MILCOM 2005. IEEE, vol. 3, Oct. 2005, pp. 1428-1432.

[2] Qifan Chen, Haifeng Wang, Ming Chen, and Shixin Cheng, "An Improved Turbo-BLAST System for Quasi-static Channel," Personal, Indoor and Mobile Radio Communications, 2004. PIMRC 2004. 15th IEEE International Symposium on vol. 3, Issue, 5-8, Sept. 2004, pp. 1588-1591.

[3] Z. W. Catherine, H. Sweatman, J. S. Thompson, B. Mulgrew, and P. M. Grant, "Comparison of Detection Algorithm including BLAST for Wireless Communication using Multiple Antennas," PIMRC'00, vol. 1, 2000, pp. 698-703.

[4] Elkhazin, A., Plataniotis, K.N., and Pasupathy, S., "Reduced-Dimension MAP Turbo-BLAST Detection," Communications, IEEE Transactions on vol. 54, Issue 1, Jan. 2006, pp. 108-118.

[5] 3GPP2 C.P9010, "Draft baseline text for the physical layer portion of the 1X EV specification," Aug. 2000, pp. 9-78.

[6] Hozun Sung, Jee Woong Kang, Kwang Bok Lee, "A Simplified Maximum Likehood Detection for MIMO Systems," IEICE TRANS. COMMUN., vol.E89-B, no. 8, Aug. 2006, pp. 2241-2244.