Adaptive Digital Video Transmission with STBC over Rayleigh Fading Channels

Jia-Chyi Wu[1,*], *Chi-Ming Li*[1] *and Kuo-Hsiang Chen*[2]

[1]*Department of Communications, Control and Navigation Engineering, National Taiwan Ocean University*
[2]*Data Communications group, Chunghwa Telecom Co.,*

Abstract--In this study, we have proposed an algorithm assigned rates to MPEG2 video code and convolutional channel code, combined with space-time block coding (STBC) schemes, associated with BPSK/QPSK modulation method, based upon the feedback information from Performance Control Unit (PCU) over Rayleigh fading channel. The proposed scheme investigates a combined video source and channel coding together providing a uniform video transmission rate to achieve better system performance in wireless systems.

Index Terms--Performance Control Unit (PCU); MPEG2; STBC; Convolutional Code

I. Introduction

UNDER channel condition limitation assumption, we have investigated a performance controlled video transmission system of a joint MPEG-2 coding scheme with convolutional channel coding and space time block coding (STBC) techniques, associated with suitable modulation method (BPSK or QPSK), for video data transmission over a wireless system with Rayleigh fading noises. Rates assigned to MPEG-2 source code and convolutional channel code as well as space-time block code schemes are based on the feedback information from Performance Control Unit (PCU) under channel condition limitation, which ensures the given system achieved the best performance compared to conventional systems. In general, the design concept simply connecting the best source coding scheme with the best channel coding scheme together barely promise an optimum performance. Therefore, this study employs a joint source-channel coding scheme and STBC concept to reach a better performance in the system design over wireless Rayleigh fading channel.

Information source coding is concerned with the efficient representation of a signal. While bit errors in the uncompressed signal can cause minimal distortion, in its compressed format a single bit error can lead to significantly large errors. For data, channel coding is necessary to overcome the errors from noisy channel. Furthermore, STBC algorithm was introduced [1, 2] as an effective transmitting diversity technique to resist multipath fading effect. For a fixed number of transmit antennas, its decoding complexity increases exponentially with the transmission rate. The STBC algorithm is suitable for MIMO-based system with varying coding rates and modulation schemes. Hafeez *et al.* [10] investigated the impact of video characteristics and design a criterion to switch between spatial multiplexing and STBC configurations for a cross-layer motion adaptive MIMO video communication design. Jansher *et al.* [11] proposed an application-aware MIMO video rate adaption method by modeling video distortion processes. In our study, we employs joint source-channel coding scheme with STBC algorithm to reach an improved performance in wireless video transmission system design.

When processing a given video data stream, we apply the MPEG2 scheme [9] to the input video frames, with convolutional channel coding and space-time block coding techniques. The coded video is then transmitted over a wireless multipath fading channel. The transmission medium is modeled as a Rayleigh fading channel and BPSK/QPSK modulation is adopted in the study. Convolutional channel coding space-time block coding algorithms are applied to improve the system transmission performance while at high bit error rate (BER) fading channel condition. In this paper, Section 2 describes the system configuration adopted in this study. Experimental results for performance of the overall adaptive video transmission system compared with the conventional scheme over Rayleigh fading channel are shown in Section 3. Finally, a summary and conclusions are presented in Section 4.

II. System Configuration

We are interested in the joint source-channel coding with modulation scheme design under the channel capacity constraint consideration over wireless Rayleigh fading channels. We have applied the integrated transmission system design method [12] to adaptive transmitting digital video signals over noisy channels. To transmit a given video bit stream efficiently, the proposed joint source-channel coding system is shown in Fig. 1.

The video sequence is first source coded by a MPEG2 algorithm. After the source coding stage, convolutional channel coding is performed to protect the bit stream by the error correction encoder. The source code is MPEG2 format with 160x120 pixels in every frame. In order to reduce the

*Corresponding author: jcwu@mail.ntou.edu.tw

complexity of decoding, we use convolutional code and STBC in channel coding. The interleaver is effected resisting burst error in wireless channel. There are two modulation schemes provided to be selected, BPSK or QPSK. The channel capacity limitation is assumed to be 1 bit/transmission, which is served as an upper bound for the joint source-channel coding rate assignment (Table I).

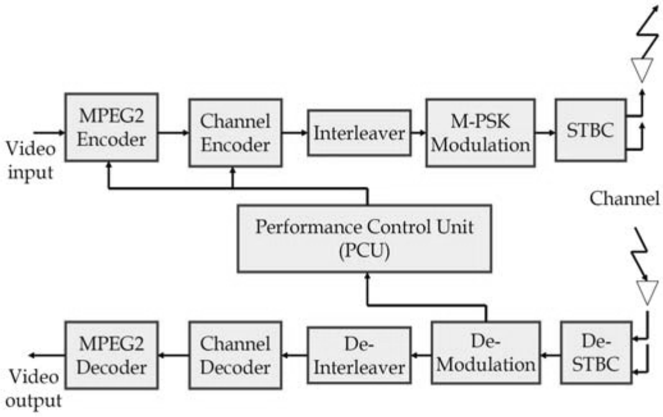

Fig. 1. System Block diagram

TABLE I
CORRESPONDING SOURCE-CHANNEL CODING RATE TO ACHIEVE TRANSMISSION RATE, $R \approx 1$ BIT.

State Type	Transmission rate ($R = K/N$)	Channel coding rate, N (Convolutional)	Source coding rate, K (MPEG2)	Modulation type
A	0.9965 bit	2/5	0.3986 bpp	BPSK/QPSK
B	0.9988 bit	1/2	0.4994 bpp	BPSK/QPSK
C	0.9989 bit	2/3	0.6659 bpp	BPSK/QPSK

To simplify the analysis, we consider the simple Alamouti [1] STBC G_2 encoder (Fig. 2) with space diversity applied in this study: the two transmitter antennas (2TX) and two receiver antennas (2RX) system – 2x2, the two transmitter antennas and one receiver antennas system – 2x1, and the one transmitter antennas and two receiver antennas system – 1x2. The input symbol vector of the STBC encoder is denoted as S = $[S(0), S(1), \ldots, S(2N-1)]^T$, where N is the number of the subcarriers. Let $S_1 = [S(0), S(1), \ldots, S(N-1)]^T$ and $S_2 = [S(N), S(N+1), \ldots, S(2N-1)]^T$, after the STBC encoder, the generated STBC G_2 coded data symbols are:

$$G_2^{STBC} = \begin{bmatrix} S_1 & S_2 \\ -S_2^* & S_1^* \end{bmatrix} \qquad (1)$$

Rates assigned to MPEG2 source coding and convolutional channel coding schemes as well as STBC space diversity selection are based on the feedback information from Performance Control Unit (PCU) under system channel capacity limitation, which ensures the given system achieved the best performance compared to conventional systems. PCU is the key components in the adaptive system design, where we have assign three PCU states to report the changeable overall transmission status as shown in Table II.

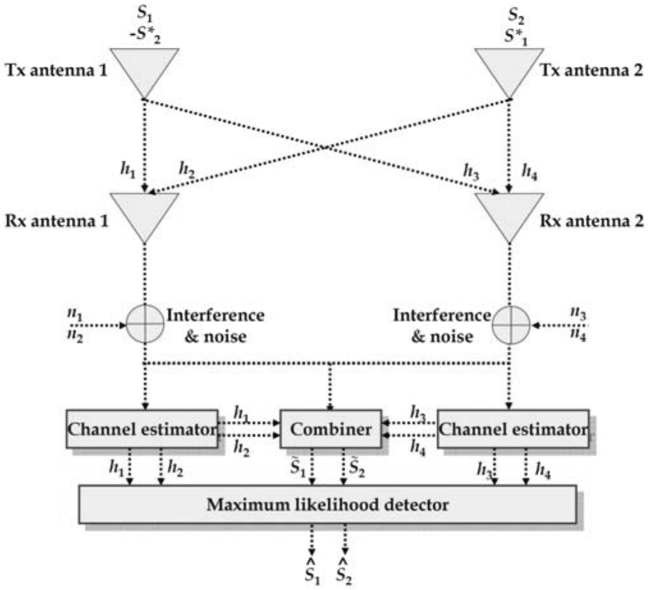

Fig. 2. Alamouti 2x2 STBC G_2 coded diversity transmission diagram

TABLE II
THE CONDITION OF PCU

PCU state	The BER after feedback	Convolutional code rate	No. of Receiver antenna
H = 1	BER ≤ 20%	2/3	2
H = 0	BER = 0 %	1/2	2
H = -1	20% < BER	2/5	1

We adopt first-order Markov chain to describe the system states transfer [12]. The present state is associated with the one-step adjacent states as shown in Fig. 3. We have set-up a simply three states to collaborate with the variable Rayleigh fading channel conditions. The three states is arranged to form a circular situation where the state transition is made according to Table I, the system state assignment of PCU. In Fig. 3, H is the output status index of the PCU, where the assignment rules are given as, $H = 0$ is the "state A" index, system with good channel condition and a fast channel coding rate (n = 2/3) is assigned; H = 1 is the "state B" index, the channel is in an "OK" condition and the transmission data need more protection (channel coding rate n = 1/2); $H = -1$ is the "state C" index, channel condition has degraded and the channel code with good protection has to be utilized (n = 2/5).

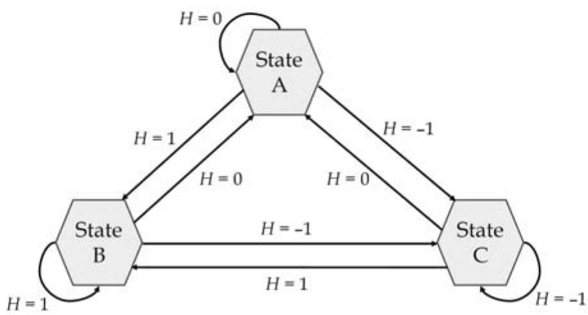

Fig. 3. System state transition diagram with PCU conditions

III. System Performance Analysis

It is assumed that the amplitudes of fading from each transmit antenna to each receiver antenna are mutually uncorrelated Rayleigh distributed and that the average signal power at each receiver antenna from each transmitter antenna is the same. Furthermore, we assume that the receiver has perfect knowledge of the channel.

To realize the channel coding rate effect under wireless Rayleigh fading channel with AWGN noise conditions, we have performed the experiment for 2x2 system antenna structure with three convolutional coding rates: 2/5, 1/2 and 2/3, respectively. The resulted system performance is shown in Fig. 4. The system performance is improved with lower channel coding rate in the experiment. It can be found from Fig. 3, rate 2/3 convolutional coded system has the worst bit error rate (BER) performance, where rate 2/5 convolutional coded system shown the best BER performance at the same SNR conditions. On the other side, system with lower channel coding rate (2/5 in this case) resulted in slower overall transmission rate. Therefore, if we may alternate the source coding rate corresponding to the channel coding rate, we are able to remain a consistent transmission rate which achieves channel capacity with considerable system BER performance.

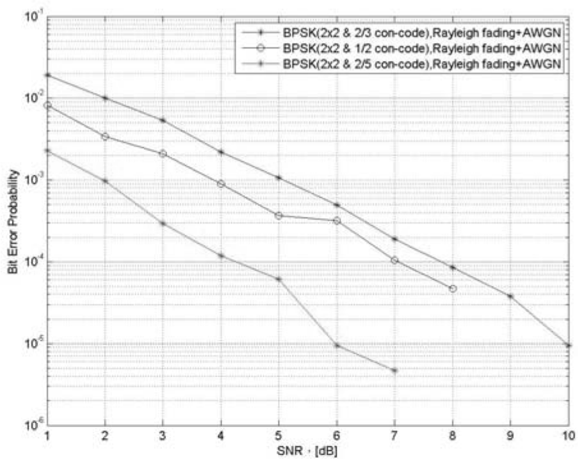

Fig. 4. Bit error rate (BER) performance of three concolutional channel coding rates under Rayleigh fading and AWGN noise in a 2x2 system.

The BER performance versus SNR for different space diversity schemes over Rayleigh fading and AWGN channel is shown in Fig. 5. It is assumed that the amplitudes of fading noise from each transmitter antenna to each receiver antenna are mutually uncorrelated Rayleigh distributed and that the average signal power at each receiver antenna from each transmitter antenna is the same. Furthermore, we assumed that the receiver has perfect knowledge of the channel conditions. The simulation results of (2TX, 2RX) 2x2 STBC coded system shows the best BER performance at higher SNR values (> 10dB), while the worst performance goes to the 2x1 STBC coded system. The proposed adaptive coding system with 2x1 (in this case, number of antenna is fixed) space diversity can improve the system performance especially in lower SNR (< 10dB) situation, and with close performance as the 2x2 STBC coded system in SNR > 10 dB environment.

The BER system performance can be improved more with adaptive receiver antenna numbers (as given in Table II). From the results shown in Fig. 6, we have noticed that, with the fading channel parameters been fully estimated, the proposed PCU adaptive system gained a better BER performance than STBC (2x2, 2x1, 1x2) coded systems. The SNR performance of the proposed PCU based adaptive system at BER = 10^{-4}, is at least 2.5dB better than the other STBC coded systems.

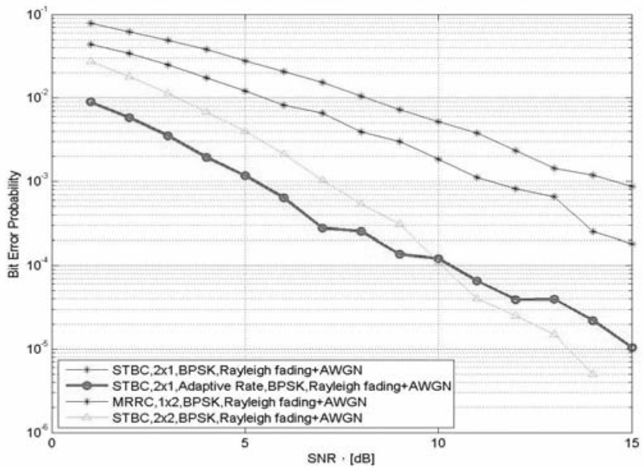

Fig. 5. The BER performance comparison of STBC systems (2/3 convolutional coded) and the proposed adaptive system (with 2x1 antennas structure) over Rayleigh fading channel.

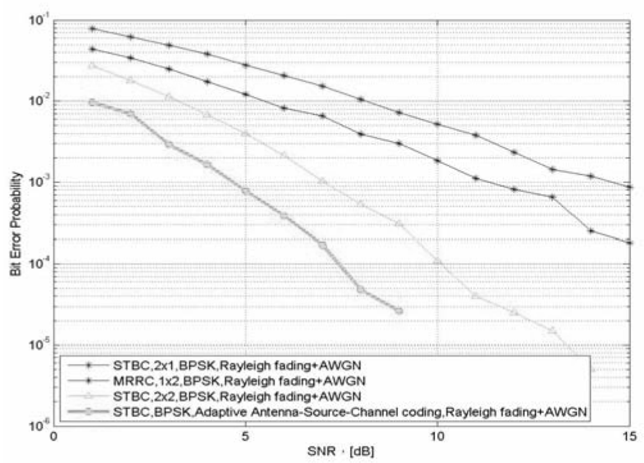

Fig. 6. The BER performance comparison of STBC systems and the proposed adaptive system over Rayleigh fading channel (the number of receiver antenna is adaptive).

In Fig.s 5 and 6, we have assumed that the channel fading conditions can be best estimated, while in Fig.s 7 and 8, the fading channel parameters are unknown. Obviously we obtain the worst system performance for the proposed scheme as shown in Fig. 7, where the transmitted video is unable to be effectively decoded. To overcome this kind of situation, we adjusted the convolutional channel coding rate to be 2/5, simulation performance improved from BER = 6×10^{-2} to BER = 8.9×10^{-3} for the proposed scheme at SNR = 5dB as shown in Fig. 8. The quality of reconstructed video at the received end is improved.

Under burst error interference in the transmitted channel, the BER performance for the proposed adaptive system is 3.5×10^{-4} (for SNR = 5dB) shown in Fig. 9. If we adopt rate 2/5 convolutional channel coding, the BER is reduced to 8.9×10^{-5} shown in Fig. 10. It has shown that the usage of interleaver in the given system may efficiently reduce the effects resulted from burst errors.

IV. Conclusions

In this study, we applied joint source-channel coding and modulation with STBC scheme to design an adaptive video transmission system over wireless Rayleigh fading channels. The compression bit rate of MPEG2 can be adaptive to associated with the convolutional channel codes and space-time block code (STBC). In this study, there are three rate combination states of the joint source-channel coding algorithm to approach the assumed channel capacity limitation about 1 bit/transmission. From the simulation results, increase the transmitter antenna number and reduce the channel code rate can get better video frame quality at lower SNR values.

In this study, the proposed adaptive system can choose an adequate transmission rate and the number of receiver antennas based on the channel condition. With the feedback bit error rate (BER) information provided by the performance control unit (PCU), the proposed system is able to choose an appropriate transmit rate to transmit video. Therefore, the transmitted video quality can be maintained at almost uniformly performance.

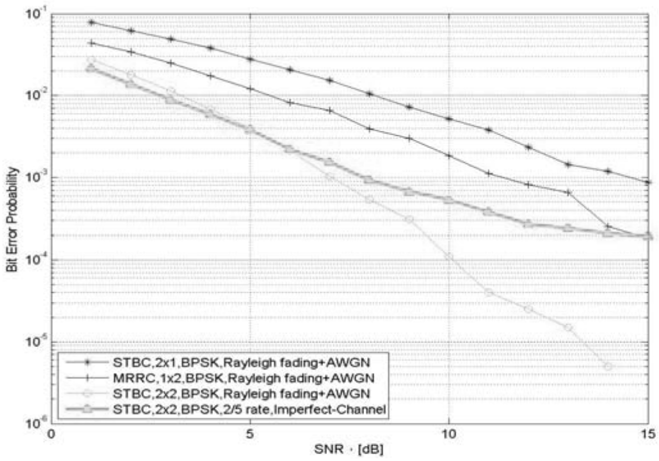

Fig. 8. The BER performance comparison of STBC systems and the proposed system with fixed coding rate (convolutional coding rate = 2/5) over Rayleigh fading and AWGN channel (unknown channel fading parameters).

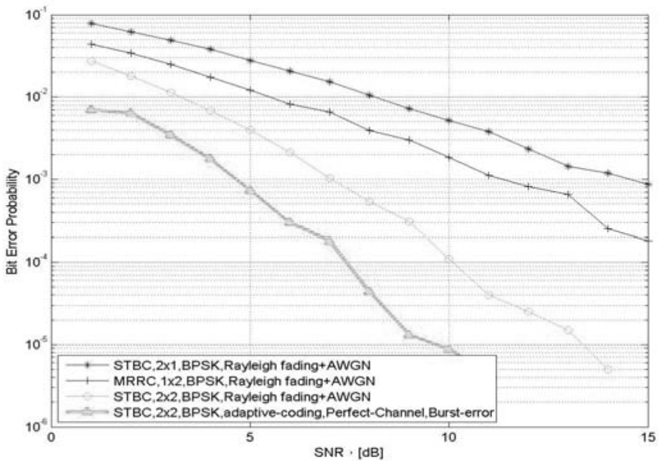

Fig. 9. The BER performance comparison of STBC systems and the proposed PCU adaptive system over Rayleigh fading and AWGN channel with burst errors.

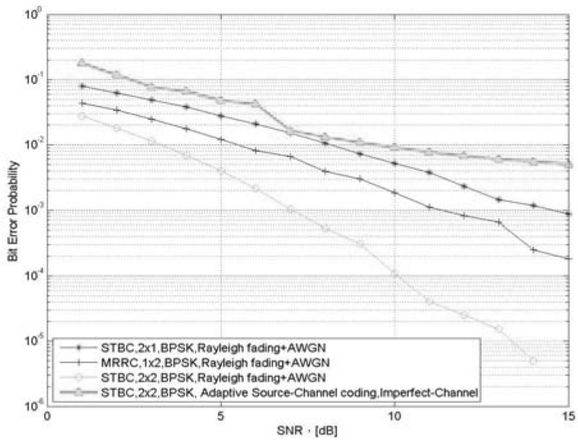

Fig. 7. The BER performance comparison of STBC systems and the proposed PCU adaptive system over Rayleigh fading and AWGN channel (unknown channel fading parameters).

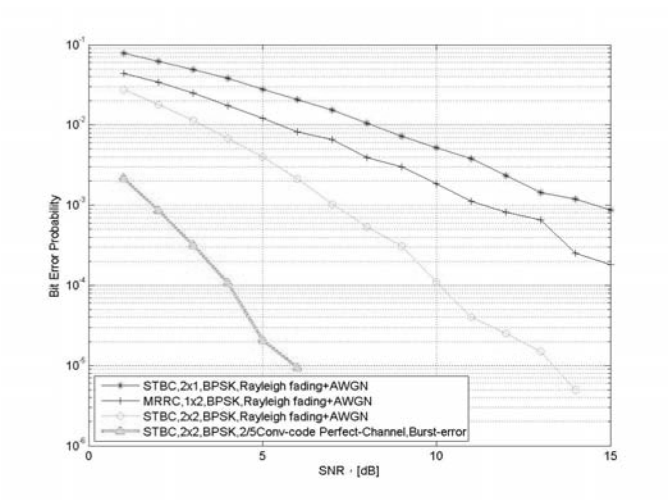

Fig. 10. The BER performance comparison of STBC systems and the proposed system with fixed coding rate (convolutional coding rate = 2/5) over Rayleigh fading and AWGN channel with burst errors.

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BIOGRAPHIES

Jia-Chyi Wu received the Ph.D. degree from Rutgers, the State University of New Jersey, USA in 1998. He is currently an assistant professor in the Department of Communications, Navigation and Control Engineering, National Taiwan Ocean University, Keelung, Taiwan. His current research interests include digital communications, joint source-channel rate allocation, information and coding theory, and digital image transmission.

Chi-Min Li received the Ph.D. degree from the Graduate Institute of Communication Engineering, National Taiwan University, Taipei, Taiwan, in 2004. He is currently an assistant professor in the Department of Communications, Navigation, and Control Engineering, National Taiwan Ocean University, Keelung, Taiwan. His research interests include wireless communications, spread spectrum communications and smart antenna.

Kuo-Hsiang Chen received the M.S. degree from the Department of Communications, Navigation, and Control Engineering, National Taiwan Ocean University, Taiwan. His research interests include Space-Time coding, video signal transmission, MIMO system and OFDM technology.