An efficient Channel Estimation Technique of OFDM-Base Space-Time Coded Wireless LAN Systems

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Abstract**—**This paper presents a way to maximize transmission efficiency and reception ability through transmission diversity technology, which can be adapted to wireless multimedia Wireless LAN system. The presented method is a comparative analysis between a case where parameter a for time average is 0.3.1 with consideration of channel presumption with two types of rms delayed spread, which is 50nsec. 150nsec, for the performance analysis of STTC (Space-Time Trellis Code) adopting time-space ciphering method appropriate for MIMO channel, and performance in the case where presumed channel value from long training column section is applied to according frame in a single frame.

The result showed that BER brought SNR improvement of 1.0dB in 10^{-3} when a was 0.3 than adopting only the long training column, and showed increase of general performance improvement for the sake of time average rather than the case without.

Keywords**—**CDMA, adaptive transmission, MIMO, OFDM, WLAN.

I. INTRODUCTION

Various technologies are needed for reliable communication against physical constraint of wireless communication channel. In general, wireless channel consists time varying aspects like noise, interference and multipath. Also, terminal size and power limitation are needed to be considered. Most personal communication service and wireless mobile terminals demand power, miniaturization and light-weight. Development of VLSI and ASIC offers partial solution of previous demands. From engineering side, more signal processing at a base station with more electrical power, is encouraged against signal processing at a terminal.

Information capacity of wireless communication system exceeds by adopting multiplex commun-ication antenna. For higher data transfer rate, apply proper coding technique to multiplex communication antenna is essential. The most proper technique is STC (Space-time coding) [1],[2]. STC is a coding technique adopting multiplex communication ante-nna. STC technique applies the relation between time and space of the signals those are transmitted to other antennas for code gain with absolute diversity effect and no bandwidth loss.

This paper presents a way to maximize transmit-ssion efficiency and reception ability through transmission diversity technology, which can be adapted to wireless multimedia OFDM system. First, MIMO channel suitable transmission diversity technique adopting space-time coding technique will be present. Based on previous technique, the way suitable for IEEE 802.11a system will be presented.

II. TRANSMISSION DIVERSITY ADOPTING STTC AT IEEE 802.11a

A. The Way of Structuring the System

Let us look at the way of applying STTC coding technique at IEEE 802.11a system. Figure1. shows the block diagram when STTC coding technique is applied at IEEE 802.11a.

Quantity of sending antenna is 2 and that of receiving antenna can be assumed as 1 or 2 based on size and expense. In general, one of the essential aspects of receiving antenna that uses space-time code is detecting the channel condition. Signal delivered to the receiver is an accompanying signal, sent from several sending antennas.

Accurate channel state presumption based on accompanying signal is the key of performance improvement. Therefore, the most important aspect in adopting transmission diversity is the training column structuring.

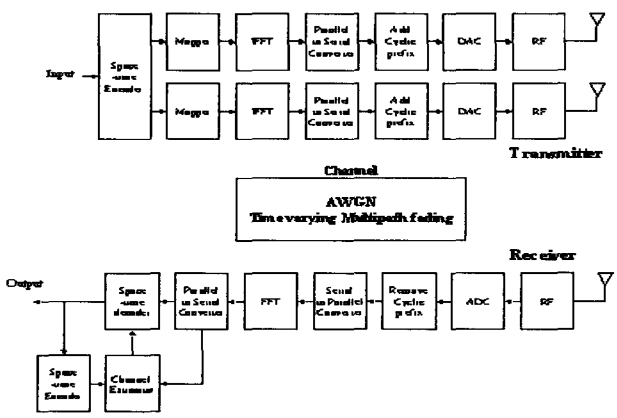

Fig. 1 STTC using for OFDM System

As in Figure 2 IEEE 802.11a system consists of 8sec short training symbols and long training symbols. For the primary channel state presumption, separate each channel from the long training symbol is needed. This paper presents two ways in adopting STTC and each characteristic.

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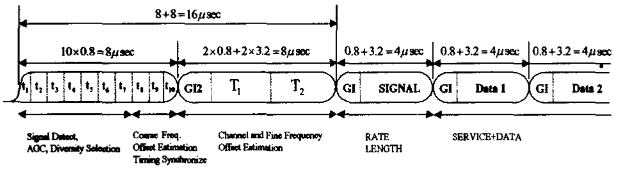

Fig. 2 frame structures of IEEE 802.11a's

First way is, adopting the short training symbol as it is and designing the new long training symbol possible to STTC. In other words, adopting the signal portion as it is and applying STTC to the data portion. Because, adopting IEEE 802.11a's long training symbol as it is, makes receiver channel separation difficult.

Following aspects are needed to be considered when designing training signal. They are frequency off-set presumption, channel presumption of time varying MIMO and PAPR(Peak to Average Power Ratio). PAPR guideline is generally 3dB and IEEE 802.11a long training symbol PAPR is 3.1658 dB.

Second way is, adopting all the training signal of IEEE 802.11a as it is. For the presumption of each channel state, applying STBC concept only to the long training symbols. In other words, from the number 1 sending antenna, transmitting IEEE 802.11a long training symbol and from the number 2 sending antenna transmitting STBC transmitting matrix applied by formula (1).

$$G_2 = \begin{bmatrix} T_1 & -T_2^* \\ T_2 & T_1^* \end{bmatrix} \qquad (1)$$

In Formula(1), T_1 indicates the first signal of the long training symbol and T_2 indicates the second signal. During the first transmitting section, T_1 is transmitted from the sending antenna#1 and T^*_2 from the sending antenna#2. And during the second transmitting section, T_1 is transmitted from the sending antenna#1 and T^*_1 is transmitted from the sending antenna#2. Also at the data section, STTC coding is in process.

Based on previous points, Figure 3 and Figure 4 shows the frame and transmitter structures of STTC applied IEEE 802.11a system.

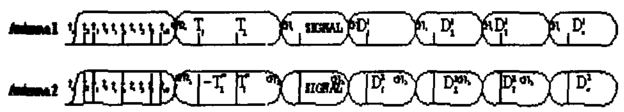

Fig. 3 The frame structures for STTC applied IEEE 802.11a system

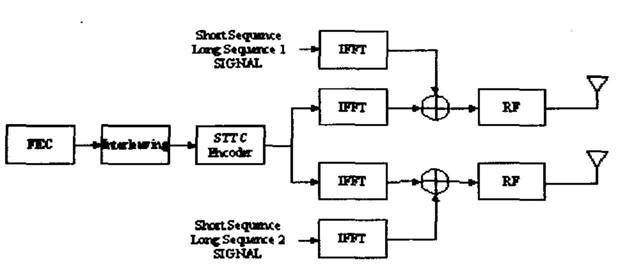

Fig. 4 The transmitter structures for STTC applied IEEE 802.11 a system

B. System Model & Channel Presumption

Figure 5 shows Space-time coding method applied OFDM system structure. The assumed quantity of each sending & receiving antennas are two. First, imputing binary data blocks are coded into two different signals by space-time encoder. These two signals form OFDM blocks by IFFR(Inverse Fast Fourier Transform) and transmitted via two sending antennas. During the ℓ^{th} symbol cycle, OFDM signal transmitted via ℓ^{th}antenna can be expressed as [3].

N indicates the quantity of additional channel. $X_I[\ell,k]$, and $X_I[\ell,n]$ indicates each coded symbol at k^{th} additional channel, and time area sample value at n^{th} moment. Also WN = exp(-j(2 /N).

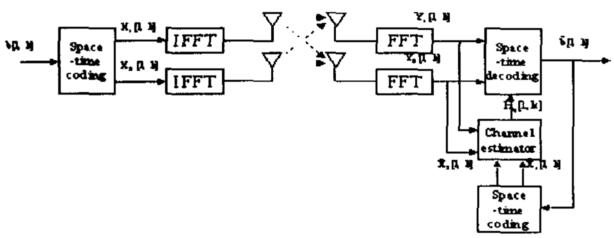

Fig. 5 Transmission diversity run FODM System of form

Cycle prefix adding and deleting process is omitted at Figure. 5. j^{th}sending antenna transmitted signals are accompanying signals from two sending antennas. These signals changed into discrete signals by AD transducer. I f muntipath channel is longer than the longest delay spre ad, TFT output can be expressed as following.

$$Y_j[l,k] = \sum_{t=1}^{2} H_{ij}[l,k]X_j[l,k] + \Omega_j[l,k], k = o,..N-1, \qquad (2)$$

$H_{ij}[l,k]$indicates channel frequency response of multipath channel between j^{th} sending antenna k^{th} for additional channel and j^{th}receiving antenna within j^{th} symbol section. Average j $[l,k]$ is 0(zero) and means FFT output of AWGN when distribution is $\delta^2\Omega$ Demodulation signal descrambling is done by space-time decoder and can be calculated by metric applied Viterbi algorithm similar to Formula(3).

$$IIY[l,k] - \hat{H}[l,k]\hat{X}[l,k]II^2 \qquad (3)$$

ll*ll indicates Euclidean norm, $Y[l,k]$is receiving signal vector and $H[l,k]$is estimated signal vector. $Y[l,k]$ and $H[l,k]$can be expressed as following.

$$Y[l,k] \triangleq \begin{pmatrix} Y_1 & [l,k] \\ Y_2 & [l,k] \end{pmatrix} \qquad (4)$$

$$\hat{H}[l,k] \triangleq \begin{pmatrix} \hat{H}_{11}[l,k] & \hat{H}_{21}[l,k] \\ \hat{H}_{12}[l,k] & \hat{H}_{22}[l,k] \end{pmatrix} \qquad (5)$$

$$\hat{X}[l,k] \triangleq \begin{pmatrix} \hat{X}_1 & [l,k] \\ \hat{X}_2 & [l,k] \end{pmatrix} \qquad (6)$$

Formula(3) shows space-time code decoding is channel frequency response and $H[l,k]$ presumption is essential. Channel frequency response of OFMD can be expressed as following.

$$H[l,k] \triangleq H(nT_f, k\Delta f) = \sum_{l=0}^{k-1} h[n,l]W_k^{kl} \quad (7)$$

$h[n,l] \triangleq h(nTf, kt_s:$
$W_k = \exp(-j(2\pi / k)$

K : Number of OFDM block tones
f : Tone spacing of OFDM system
t_s : Sample interval of f related system ($t_s = 1/f$)

$h[n,l]$ and index $K_0(<<k)$ depends on delay spread profile and dispersion of wireless channel. rms delay spread d can be expressed as following.

$$\tau_d \triangleq \sqrt{\sum_k \frac{\delta_k^2}{\sum_l \delta_l^2}\tau_k^2 - \left(\sum_k \frac{\delta_k^2}{\sum_l \delta_l^2}\tau_k\right)} \quad (8)$$

As from formula(7), frequency response at i^{th} ith sending antenna corresponding n^{th} block's k^{th} subcarrier can be expressed as following.

$$H_i[n,k] = \sum_{l=0}^{k_0=0} h_i[n,l]W_k^{kl} \quad (9)$$

To get $Hi[n,k]$, presumption of $hi[n,l]$ is essential. Receiving signal received from each antenna can be expressed as following.

$$\gamma[n,k] = \sum_{l=1}^{2} H_i[n,k]t_i[n,k] + \Omega[n,k] \quad (10)$$

$(note) = k = k-1,,,$

Fig. 6 shows 2 dimensional description of OFMD channel characteristic. Time zone depends on Doppler frequency and Frequency zone depends on multipath.

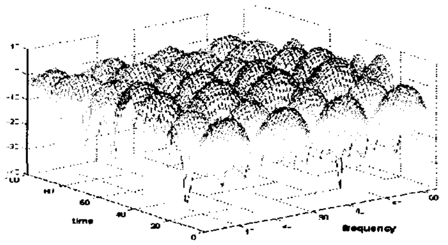

Fig. 6 OFMD System channel characteristic

1) Channel Presumption possible to apply at STTC

Channel presumption method of training column is as same as the method applied to STBC. Data zone's channel presumption uses channel presumption value, which is calculated from training block, and by adopting decoded data, channel presumption can be done. If training column block calculated frequency response is $H[-1,k]$ current data block's channel parameter can be calculated by adopting following factors. The data, decoded by Viterbi algorithm that uses current channel response, reuses space-time encoder coded value. The data can be expressed as following.

$$\hat{H}_1[l,k] = \frac{Y[l,k] - \hat{H}_2[l-1,\hat{X}_2[l,k]}{\hat{X}_1[l,k]} \quad (11)$$

$$\hat{H}_2[l,k] = \frac{Y[l,k] - \hat{H}_1[l-1,\hat{X}_1[l,k]}{\hat{X}_2[l,k]} \quad (12)$$

Channel presumption can be done by applying formula (11) and (12). Presumed Channel characteristic can be applied to the next block.

III. SIMULATION & PERFORMANCE ANALYSIS

In order to analyze Space-time trellis code performance two rms delay spreads (50 $n$sec and 150 $n$sec) and two Doppler frequency (40Hz and 100Hz) was considered. Basically, channel presumption, that was used for decoding, applies previous data block channel presumption value. Performance analysis is for knowing the diversity effect regard to quantity of receiving antennas. If channel presumption value is accurate, do the performance analysis first, then do the channel presumption method performance next. Accurate channel presumption means channel presumption of previous OFDM block channel is accurate. Data loss should be considered when apply space-time trell is code to IEEE 802.11a standard. Because, termination is demanded when decoding space-time trellis code at the receiver. This termination varies regard to space-time code state number. In case of QPSK modulation 4, symbol quantity 1 is needed for the termination and in case of modulation 8 or 16, symbol quantity 2 is needed.

Let us analyze channel presumption method performance in case of applying STTC to IEEE 802.11a system. Basically channel presumption method uses the method that was applied to STBC. Comparing case 1, which parameter a for time average is 0.3, with the case that presumed channel value from long training column, that is in one frame, is all applied to the related frame. Both receiving antenna and sending antenna quantities are two.

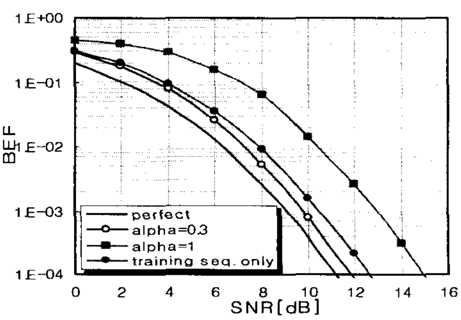

Fig. 7 BER performance(fd=40Hz, rms delay spread=50 $n$sec)

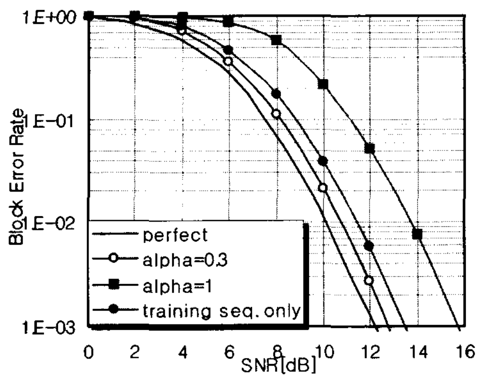

Fig. 8 Block Error Rate performance(fd=40Hz, rms dela y spread=50$n$sec)

Fig. 7 and Fig. 8 shows BER performance and Block Error Rate when Doppler frequency is 40 Hz, and rms delay spread is 50 $n$sec . Fig. 7 shows that SNR, which is essential to get $BER = 10^{-2}$, is 6.3dB at accurate channel presumption, and 7.0dB when a = 0.3. Also, 10.2dB when a = 1 and 8.0dB when adopting only long training column. Therefore, a= 0.3 shows 1.0dB SNR improvement compare to adopting only long training column. SNR, which is essential to get $BER = 10^{-3}$, is 9.1dB at accurate channel presumption, 9.8dB when a = 0.3. Also, 13dB when a = 1 and 10.5dB when adopting only long training column. In general, considering time average shows performance improvement compare to other cases without time average considering. Fig.8 shows Block Error Rate that its phase is similar to that of Fig. 7. From above, in case when a = 1 (without time average consideration) degradation is bigger than adopting only long training column. As a result, in order to obtain performance improvement, adopting time average is needed.

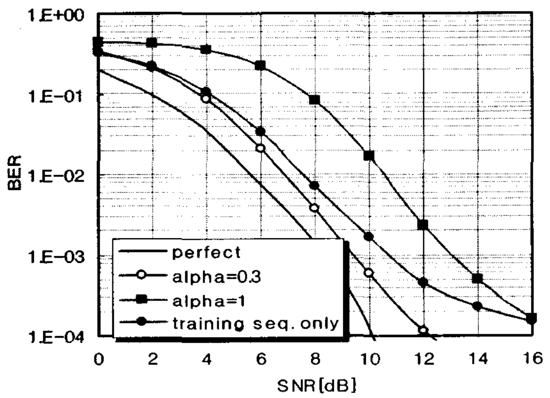

Fig. 9 BER performance(fd=40Hz, rms delay spread = 150$n$sec)

Fig. 9 and Fig. 10 show BER performance and Block Error Rate when Doppler frequency is 40Hz and rms delay spread is 150 $n$sec . Fig. 9 shows SNR, which is essential to get $BER = 10^{-2}$, 6.8dB when a = 0.3, 10.5dB when a = 1 and 5.6dB at accurate channel presumption. This shows when a= 0.3, 0.7dB SNR performance improvement can be achieved compare to adopting only long column. SNR, which

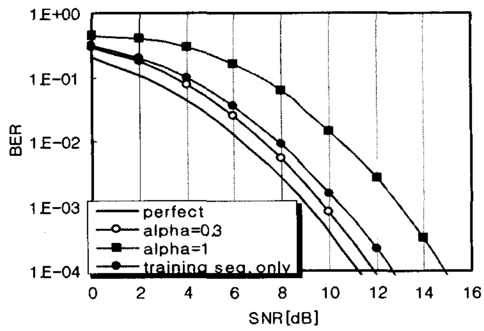

Fig. 10 Block Error Rate performance (fd=40, rms delay spread=150$n$sec)

is essential to get $BER = 10^{-3}$, is 8.4dB at accurate channel presumption and 9.3dB when a = 0.3. Also 13dB when a = 1 and 11.7dB when adopting only long training column. Fig.10 shows Block Error Rate that its phase is similar to that of Fig. 9.

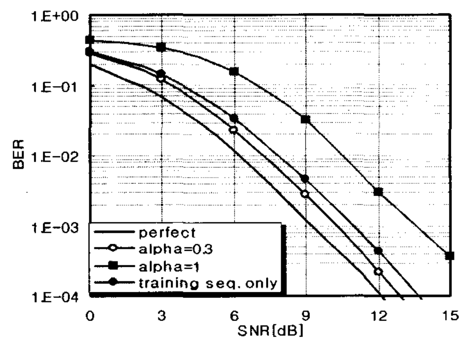

Fig. 11 BER performance(fd=100Hz, rms delay spread = 50$n$sec)

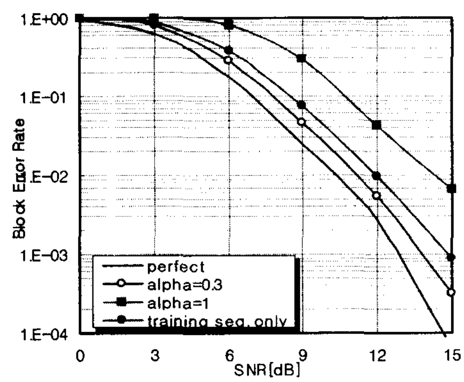

Fig. 12 Block Error Rate performance (fd=100Hz, rms delay spread = 50$n$sec)

Fig.11 and Fig.12 show BER performance and Block Error Rate when Doppler frequency is 100Hz and rms delay spread is 50nsec. If comparing these figures with Fig. 7, which its Doppler frequency is 40Hz, we can know that when Doppler frequency exceeds, performance is degrading. Especially, Doppler frequency sensitively effect channel presumption performance. Fig. 11 shows SNR, which is essential to get $BER = 10^{-2}$, 6.3dB at accurate channel presumption, 7.3dB when a = 0.3. Also, 10.5dB when a= 0.1 and 7.8dB when adopting only long training column. 0.5dB SNR improvement can be achieved when a = 0.3 compare to adopting only long training column. Also, SNR, which is essential to get $BER = 10^{-3}$, is 9.3dB at accurate channel assumption and 10.3dB when a = 0.3. Also, 13.5dB when a = 1 and 10.8dB when adopting only long training column. Fig.12 shows Block Error Rate that general performance improvement phase is similar to that of Fig. 16.

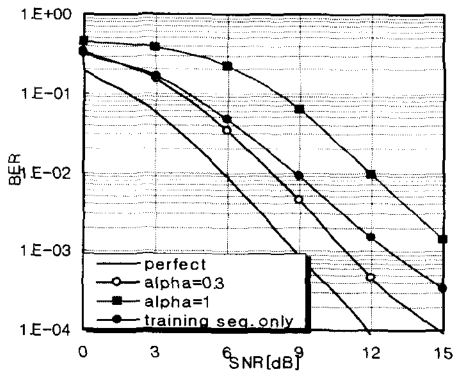

Fig. 13 BER performance(fd=100Hz, rms delay spread = 150$n$sec)

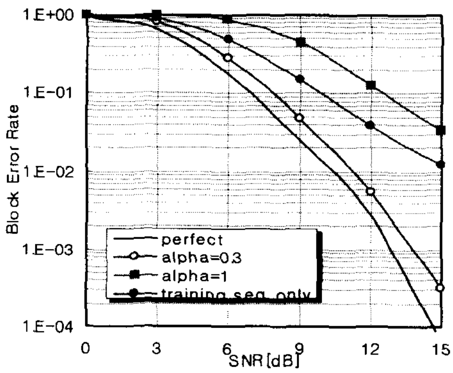

Fig. 14 Block Error Rate performance(fd=100Hz, rms delay spread=150$n$sec)

Fig. 13 and Fig. 14 show BER performance and Block Error Rate when Doppler frequency is 100Hz and rms delay spread is 150nsec. If comparing these figures with Fig. 9, which its Doppler frequency is 40Hz, we can know that when Doppler frequency exceeds, performance is degrading. Doppler frequency sensitively effect channel presumption performance. Also, performance degrading is deeper than in case of 50nsec rms delay spread. Fig. 13 shows SNR, which is essential to get $BER = 10^{-2}$, is 5.8dB when accurate channel presumption and 7.8dB at a = 0.3. Also, 12dB at a = 1 and 8.8dB when only adopting long training column. Therefore, when a = 0.3, we can obtain 10dB SNR improvement comparing when adopting only long training column. Fig. 14 shows Block Error Rate that its general performance phase is similar to that of Fig. 13.

IV. CONCLUSION

For the performance analysis of channel presumption method, which applies STTC to IEEE902.11a system, channel presumption of this thesis's training column is as same as the method that was applied to STBC, and channel presumption of data section was done based on decoded data that used channel presumption value the training block.

This paper shows that SNR, essential to get $BER = 10^{-2}$, is 9.0dB at accurate channel presumption and 10dB when a = 0.3. Also, 13.2dB when a = 1 and 11dB when adopting only long training column. This means there is 10dB SNR improvement.

Also, channel presumption method shows that in case Doppler frequency exceeds, performance is degrading, based on the values of delay spread and Doppler frequency related BER performance and Block Error Rate of general simulation performance. Especially, Doppler frequency sensitively effect channel presumption performance. The simulation shows degrading of performance is deeper in case when do not adopt time average than adopting only the long training column. As a result, for the performance improvement, considering time average is profitable.

The method that is proposed at this thesis can be adopted at communication system that demands more reliability at wireless internet OFDM multimedia system in the near future.

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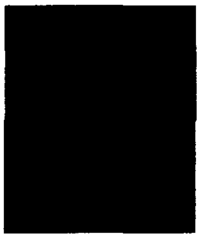

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