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Alternate Time-Switched Space-Frequency Block Coding Technique for OFDM Systems

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Abstract

This paper proposes an alternate time-switched space-frequency block coding transmission technique for orthogonal frequency division modulation systems. There are two antennas in the transmitter but it still has only a baseband and RF and a switch that alternates between the antennas at every symbol timing. Alternating transmit symbols result in zeros that make maximal ratio receive combining possible in the receiver. Simulation results show that it provides better performance than the traditional algorithm at the expense of one additional antenna.

Key words: Diversity, MRC, OFDM, SFBC, Switch.

Ⅰ. Introduction

Orthogonal frequency division multiplexing (OFDM) system is known to be effective for wireless local area networks, and its combination of technologies, such as selection combining and maximum ratio receive combining (MRRC) [1], has been developed under the assumption of a single antenna receiver. The research to obtain maximal ratio combining effect in a situation where the number of transmit antennas increases, has resulted in Alamouti space-time block coding (STBC) [2], and Al-Dhahir suggests its application to single carrier system [3]. Repetition time-switched transmit diversity (R-TS-TD) [4], which derives additional spatial diversity by increasing only the transmit antenna number, suggests time-switching after the RF block and does not consider any multipath fading channel environments and OFDM systems. Recently paper [5] suggested an alternate time-switched space-time block coding technique for OFDM systems, and this paper applies it for space-frequency block coding technique for OFDM systems.

In this paper, we propose an alternate time-switched SFBC technique for OFDM systems with a guard period, simulate it in HiperLAN/2 channel A, and show the results. We use the simulation results to evaluate the performance of the proposed technique in comparison with the conventional 1x1 (SISO) SFBC OFDM system with twice repetitive transmission.

Ⅱ. Alternate Time-Switched Transmission and SFBC and Maximal Ratio Combining Technique

Transmitter and receiver block diagrams of the proposed algorithm are shown in Fig. 1. Let an $N/2$-sized data block be $\mathbf{X}^k$ in (1) which are user data. SFBC configuration block configures two $N/2$-sized data blocks at the k-th data block period for OFDM space-frequency block code in the frequency domain.

$$\begin{aligned}\mathbf{X}^k_{1^{st}half} &= [\ X(0)\ X(1)\quad X(2)\ X(3)\cdots X(N/2-1)]^T\\ \mathbf{X}^k_{2^{nd}half} &= [-\overline{X}(1)\ \overline{X}(0)\ -\overline{X}(3)\ \overline{X}(2)\cdots \overline{X}(N/2-2)]^T\end{aligned} \quad (1)$$

During the k-th data block period, user data $\mathbf{X}^k$ is configured as $\mathbf{X}^k_{1^{st}half}$ and $\mathbf{X}^k_{2^{nd}half}$, which are fed to two inputs of $N/2$-sized IFFT modules in (2), while user data $\mathbf{X}^k$ is fed to the input of $N/2$-sized IFFT module (1st half) directly and the input of $N/2$-sized IFFT module (2nd half) is modified from user data $\mathbf{X}^k$ by SFBC configuration. Two outputs of two IFFT modules in (2) are sequentially interleaved symbol by symbol with a multiplexer, starting from the output of the IFFT module (1st half), which are expressed in (3).

$$\mathbf{Q}^H\mathbf{X}^k_{1^{st}half} = \mathbf{x}^k_{1^{st}half},\ \mathbf{Q}^H\mathbf{X}^k_{2^{nd}half} = \mathbf{x}^k_{2^{nd}half} \quad (2)$$

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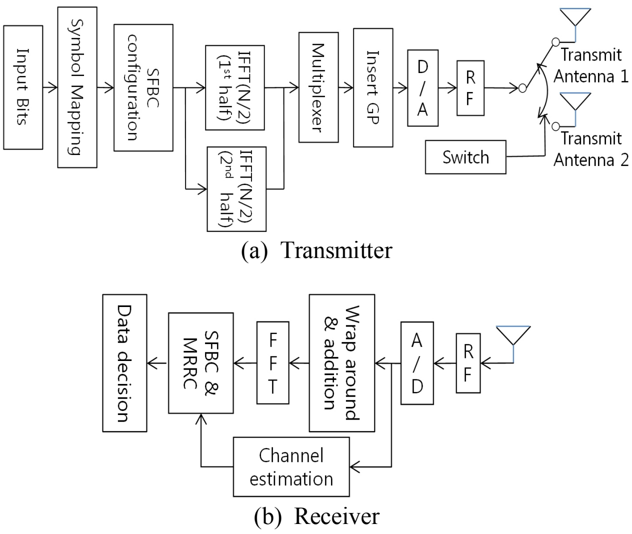


Fig. 1. Block diagram of the proposed algorithm.

where $\mathbf{Q}$, $(\cdot)_N$, $\overline{(\cdot)}$, $(\cdot)^T$, and $(\cdot)^H$ denote the orthonormal discrete Fourier transform matrix, modulo-N, complex-conjugation, transpose, and complex-conjugate transpose, respectively. This multiplexer output is fed to the transmit antennas controlled by the switch.

$$\begin{aligned}
\mathbf{x}^k_{1^{st}half} &= [x^k_1(0)\ \ x^k_1(1)\ \cdots\ x^k_1(N/2-1)]^T \\
\mathbf{x}^k_{2^{nd}half} &= [x^k_2(0)\ \ x^k_2(1)\ \cdots\ x^k_2(N/2-1)]^T \\
\mathbf{x}^k_{mux} &= [x^k_1(0)\ \ x^k_2(0)\ x^k_1(1)\ \ x^k_2(1)\cdots\ x^k_2(N/2-1)]^T
\end{aligned} \tag{3}$$

The switch operation after multiplexer causes insertion of zeros after every symbol of the N/2-sized IFFT module (1st half) output, and in addition circular rotation by one symbol is added to the N/2-sized IFFT module (2nd half) output.The transmit signals and the frequency domain expressions from transmit antennas after switch operation are expressed as follows:

$$\begin{aligned}
\mathbf{s}^k_1 &= \left[x^k_1(0)\ \ 0\ \ x^k_1(1)\ 0\ \cdots\ x^k_1(N/2-1)\ 0\right]^T \\
\mathbf{s}^k_2 &= \left[0\ \ x^k_2(0)\ \ 0\ \ x^k_2(1)\ 0\ \cdots\ x^k_2(N/2-1)\right]^T \\
\mathbf{Qs}^k_1 &= [(\mathbf{X}^k_{1^{st}half})^T\ \ (\mathbf{X}^k_{1^{st}half})^T]^T \\
\mathbf{Qs}^k_2 &= \mathbf{R}[(\mathbf{X}^k_{2^{nd}half})^T\ \ (\mathbf{X}^k_{2^{nd}half})^T]^T
\end{aligned} \tag{4}$$

where $\mathbf{R} = diag\{R(n,n)\},\ R(n,n) = \exp(-j2\pi n/N)$

We assume that the channels are fixed over two consecutive subcarriers in the frequency domain. The input output relationship in the time domain is as follows:

$$\mathbf{y}^k = \mathbf{hs}^k_1 + \mathbf{gs}^k_2 + \mathbf{n}^k \tag{5}$$

Hereafter subscript k is omittedfor simplicity.

$\mathbf{y}$ is a length-N block which the forepart symbols of the received data block are summed with the overflowed part of channel output beyond the size N of the data block for circular convolution. $\mathbf{s_1}$ and $\mathbf{s_2}$ are length-N blocks of input, and $\mathbf{n}$ is a length-N block of AWGN symbols. $\mathbf{h}$ and $\mathbf{g}$, $N\times N$ circulant matrices with first column equal to the channel impulse response (CIR) appended by $(N-v-1)$ zeros, are channels from transmitter 1 and 2 to receiver, respectively, and they have the eigen-decomposition $\mathbf{h} = \mathbf{Q}^H\mathbf{HQ}$ and $\mathbf{g} = \mathbf{Q}^H\mathbf{GQ}$. $\mathbf{H}$ and $\mathbf{G}$ are diagonal matrices whose (k, k) entry is equal to the k-th DFT coefficient of the CIR, respectively. The time domain block $\mathbf{y}$ is transformed to the frequency domain by applying the DFT.

$$\begin{aligned}
\mathbf{Y}^k &= \mathbf{Qy}^k = \mathbf{QQ}^H\mathbf{HQs}^k_1 + \mathbf{QQ}^H\mathbf{GQs}^k_2 + \mathbf{Qn}^k \\
&= \mathbf{H}[(\mathbf{X}^k_{1^{st}half})^T\ \ (\mathbf{X}^k_{1^{st}half})^T]^T + \\
&\quad + \mathbf{GR}[(\mathbf{X}^k_{2^{nd}half})^T\ \ (\mathbf{X}^k_{2^{nd}half})^T]^T + \mathbf{N}
\end{aligned} \tag{6}$$

In (6) $\mathbf{X}^k_{1^{st}half}$ and $\mathbf{X}^k_{2^{nd}half}$ consist of SFBC pairs and are repeated twice in a data block.

$$\begin{aligned}
Y(2k) &= H(2k)X_{1^{st}half}(2k) + G(2k)R(2k,2k)X_{2^{nd}half}(2k) \\
&\quad + N(2k) \\
Y(2k+1) &= H(2k+1)X_{1^{st}half}(2k+1) \\
&\quad + G(2k+1)R(2k+1,2k+1)X_{2^{nd}half}(2k+1) \\
&\quad + N(2k+1)
\end{aligned} \tag{7}$$

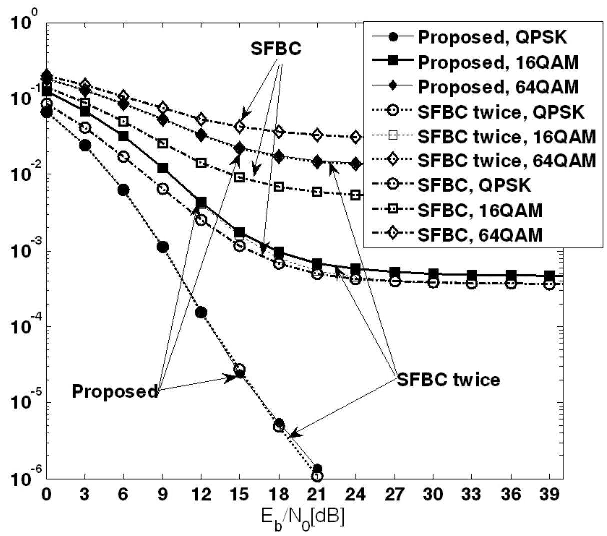
As $\mathbf{X}^k_{1^{st}half}$ and $\mathbf{X}^k_{2^{nd}half}$ are transmitted twice both in the first half and the second half of $\mathbf{Y}$, we can configure SF BC combining using 4 receive signals, $Y(2k)$, $Y(2k+1)$, $Y(N/2+2k)$, and $Y(N/2+2k+1)$, to detect $X(2k)$ and $X(2k+1)$ as follows:

$$\hat{X}(2k) \cong \frac{\sum_{i=0}^{1}\left(\begin{array}{l} Y\left(\frac{N}{2}i+2k\right)\overline{H}\left(\frac{N}{2}i+2k+1\right) \\ +Y\left(\frac{N}{2}i+2k+1\right)G\left(\frac{N}{2}i+2k\right)R\left(\frac{N}{2}i+2k,\frac{N}{2}i+2k\right)\end{array}\right)}{\sum_{i=0}^{1}\left(\begin{array}{l}\left|H\left(\frac{N}{2}i+2k\right)\right|^2 + \\ \left|G\left(\frac{N}{2}i+2k\right)\right|^2 R\left(\frac{N}{2}i+2k,\frac{N}{2}i+2k\right)\overline{R}\left(\frac{N}{2}i+2k+1,\frac{N}{2}i+2k+1\right)\end{array}\right)} \tag{8}$$

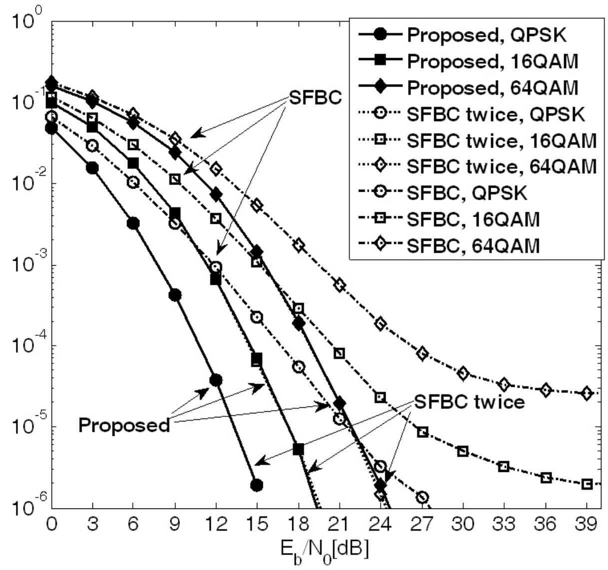
$$\hat{X}(2k+1) \cong \frac{\sum_{i=0}^{1}\left(\begin{array}{l} Y\left(\frac{N}{2}i+2k+1\right)\overline{H}\left(\frac{N}{2}i+2k\right) \\ -\overline{Y}\left(\frac{N}{2}i+2k\right)G\left(\frac{N}{2}i+2k+1\right)R\left(\frac{N}{2}i+2k+1,\frac{N}{2}i+2k+1\right)\end{array}\right)}{\sum_{i=0}^{1}\left(\begin{array}{l}\left|H\left(\frac{N}{2}i+2k\right)\right|^2 + \\ \left|G\left(\frac{N}{2}i+2k\right)\right|^2 \overline{R}\left(\frac{N}{2}i+2k,\frac{N}{2}i+2k\right)\end{array}\right)} \tag{9}$$

Ⅲ. Simulations

The parameters of the simulated OFDM system are set as follows. The entire bandwidth of 20 MHz is divided into N=64/512 subcarriers. The period of one OFDM symbol including effective symbol period (3.2 μs /25.6 μs) and guard period (0.8 μs), is 4 μs/26.4 μs. Every data block of 80/528 symbols (64/512 symbols of data payload and 16 symbols of GP) is grouped in the transmitter. HiperLAN/2 channel A is used for simulations, assuming perfect channel state information. The utilized data symbols are uncoded without channel codec. The diversity order of this algorithm is four, two for SFBC, and two for zero insertion effect simultaneously. Fig. 2 shows the performance of the proposed alternate time-switched OFDM SFBC algorithm (1 BB/RF and 2 TX ant., 1 RX) [Proposed] versus the traditional SFBC OFDM system (2 BB/RF and 2 TX ant., 1 RX) with twice repetitive transmission [SFBC twice] and versus the traditional OFDM SFBC system (2 BB/RF and 2 TX ant., 1 RX) [SFBC]. The proposed algorithm's performance is almost equal to the SFBC twice even though one BB/RF block is insufficient, and SFBC twice is an algorithm with MRC diversity order 2 rather than the SFBC OFDM system with no repetition [SFBC].



(a) N=64 case



(b) N=512 case

Fig. 2. Performance comparison between the proposed alternate time-switched SFBC OFDM and the conventional OFDM system with repetitive transmission (Proposed : 1BB/RF, N/2 symbols per OFDM symbol, SFBC twice : 2BB/RF, N/2 symbols per OFDM symbol, SFBC : 2BB/RF, N symbols per OFDM symbol).

Ⅳ. Conclusion

This paper proposed an alternate time-switched OFDM space-frequency block coding technique for OFDM system with a guard period. This scheme uses a transmit baseband and RF block and two transmit antennas and a time switch, which provides a method of obtaining maximal ratio combining gain of diversity order four. Significant performance gains over the conventional SFBC-OFDM system with repetitive transmission were demonstrated.

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