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Pre-FFT Adaptive Antenna Using ISI Extraction for OFDM Systems

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1. Introduction

OFDM (orthogonal frequency division multiplexing) is known to be robust to multipath waves because the transmission rate per subcarrier is very low and a GI (guard interval) is inserted in each OFDM symbol. Therefore, the OFDM has been adopted as a standard in terrestrial digital broadcasting and wireless local area networks. However, when there are multiple paths with delays that exceed the GI length, the ISI (inter-symbol interference) occurs. As a result, the quality of communication rapidly deteriorates. To overcome this problem, adaptive array antennas have been investigated to suppress the multipath waves associated with a large delay.

In this paper, we propose a pre-FFT (fast Fourier transform) adaptive antenna using the guard interval, which is capable of performing the subcarrier diversity for the OFDM systems. The proposed method can achieve interference suppression before FFT and obtain multiple output signals after the suppression. Therefore, it is possible to perform the subcarrier diversity in the demodulator.

2. Proposed Method

2.1 Configuration

Figure 1 shows the system configuration, which consists of four antenna elements. For element #1, the ISI component is extracted by using other element signals. Subsequently, the ISI component of element #1 is eliminated from its received signal using the extracted ISI component. This process is carried out on each element and the signals obtained after interference suppression are outputted to the receiver (demodulator).

Figure 2 shows the signal model. $\mathbf{X}(t)$ is the received signal vector; $x_k^{S_h}$, the GI sample of the desired signal of the k-th element; and $x_k^{I_h}$, the GI sample of ISI of the k-th element. In the subsequent sections, the processing for element #1 is explained.

2.2 ISI extraction

The GI samples have the same waveform as the tail part of the effective symbol. Therefore, it is possible to use the GI sample as the reference signal for controlling the weights [2]. In the proposed method, ISI can be extracted by MMSE (minimum mean square error) criteria using the GI samples of ISI of each element except element #1. The signal vectors of the GI and the tail part of the effective symbol are defined as follows:

$$\mathbf{b}(m) = \begin{bmatrix} x_2^{I_h} & x_3^{I_h} & x_4^{I_h} \end{bmatrix}^T \quad (1)$$

$$\mathbf{b}'(m) = \begin{bmatrix} x_2^{I_t} & x_3^{I_t} & x_4^{I_t} \end{bmatrix}^T \quad (2)$$

The weight of SMI (sample matrix inversion) is given by:

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$$\mathbf{w}_{ISI}(m) = R_{bb}^{-1}(m)\mathbf{V}_{br}(m) \tag{3}$$

where

$$R_{bb}(m) = \frac{1}{N}\sum \mathbf{b}(m)\mathbf{b}^{H}(m) \tag{4}$$

$$\mathbf{V}_{br}(m) = \frac{1}{N}\sum \mathbf{b}(m)r^{*}(m) \tag{5}$$

$$r(m) = \mathbf{w}_{ISI}^{H}(m-1)\mathbf{b}'(m) \tag{6}$$

N is the averaging sample number.

2.3 ISI suppression

Next, the proposed method eliminates the ISI component of element #1 by using the extracted ISI component. This is easily performed by minimizing the output power because the output signals of the ISI extraction part only include the ISI component. Moreover, it is possible to use the arbitrary samples for this processing.

The abovementioned processing is performed for each element. Thus, after the ISI suppression, multiple outputs are sent to the demodulator and the diversity in the subcarrier domain (frequency domain) can be achieved.

3. Simulation Result

We evaluate the proposed method using a computer simulation. The modulation type is OFDM (16QAM) and the subcarrier number is 2808 (FFT size is 4096). The GI size is 256 samples. The channel model is 2-path Rayleigh fading. The inputs DUR (desired-to-undesired power ratio) and SNR (signal-to-noise ratio) of the input are 0 and 20 dB, respectively. The antenna configuration is 4-element linear array with half-wavelength spacing.

Figure 3 shows the BER (bit error rate) performance as a function of the input SNR. The result of MRC (maximal ratio combining) is shown in the form of a comparison. Since MRC does not suppress the ISI, it cannot improve the BER performance even when the input SNR is high. On the other hand, the proposed method achieves superior BER performance because it can suppress the ISI and combine the output signals in the subcarrier domain.

4. Conclusion

We have proposed a pre-FFT adaptive antenna using a GI that is capable of achieving the subcarrier diversity for OFDM systems. The proposed method can achieve interference suppression before FFT and obtain multiple output signals after the suppression. Therefore, the proposed method achieves a superior BER performance because it can suppress the ISI and combine the output signals in the subcarrier domain.

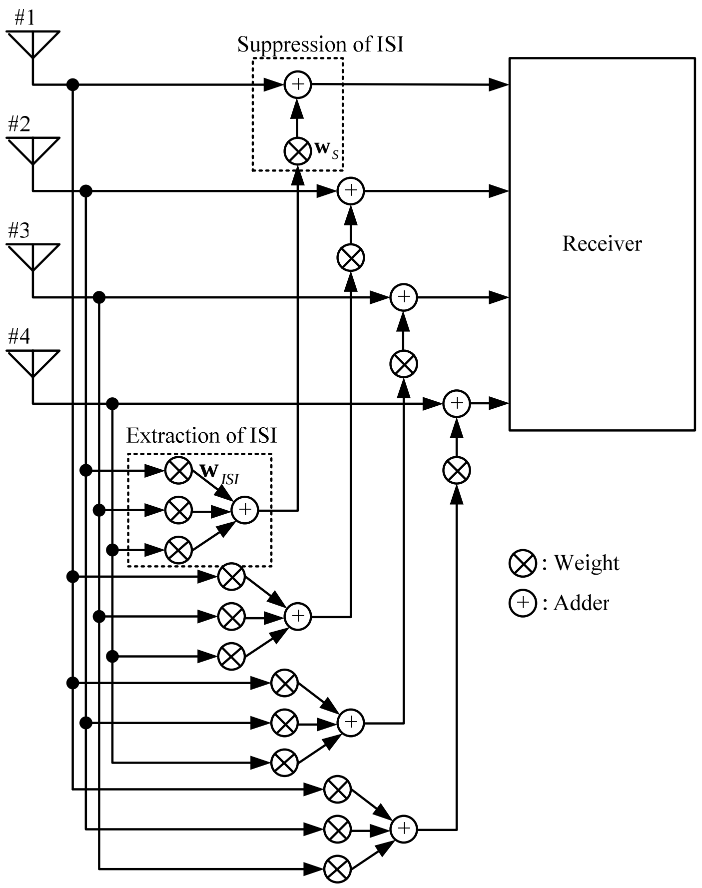

Figure 1: Configuration of proposed method

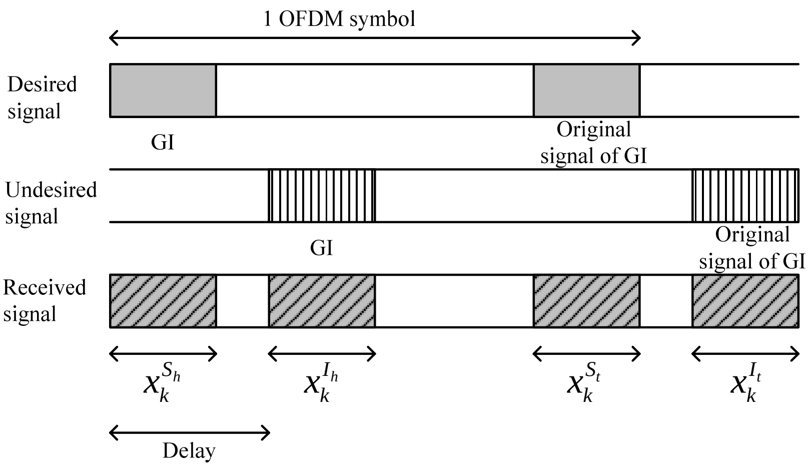

Figure 2: Signal model

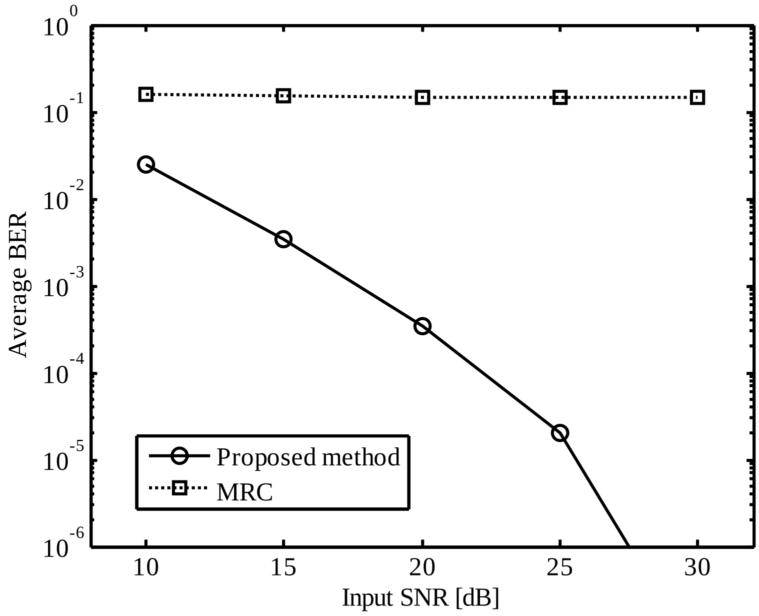

Figure3: BER as a function of input SNR

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