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Decision Feedback Channel Equalization for a Wireless Access inVehicular Environment System

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Abstract
In this paper, a Decision Feedback Channel Equalization (DFCE) method for the transmission of Orthogonal Frequency Division Multiplexing (OFDM) that complies with the Wireless Access in Vehicular Environment (WAVE) standards over a fast mobile environment is proposed. In the proposed DFCE, channel estimation uses the least squares (LS) estimation. During the long training sequence (LTS) section, channel estimation is performed using a pre-known LTS and then after the payload section, channel estimation is performed using the regenerated signal obtained through the decision feedback path. The estimated channel value recovers distorted payloads. Our experiment result showed the proposed DFCE method revealed a bit error rate (BER) performance of 10^{-4} at E_b/N_0 = 20dB in Binary Phase Shift Keying (BPSK).

Keywords: WAVE, Decision feedback, LS, OFDM, LTS.

1.Introduction

The Wireless Access in Vehicular Environment (WAVE) technology is a medium-to-short distance wireless data communication service that supports public safety and private communication through Vehicle-to-Infra (V2I) Communication or Vehicle-to-Vehicle (V2V) Communication and it has been standardized in the Institute of Electrical and Electronics Engineers (IEEE) standard 802.11p [1].

The IEEE 802.11a standard Wireless Local Area Network (WLAN), which is the physical layer of the WAVE, is based on Orthogonal Frequency Division Multiplexing (OFDM). This technology was designed based on a static environment originally, rather than a mobile environment. To perform channel equalization, it is widely acknowledged that long training sequence (LTS) is used by means of a least squares (LS) method, and channel recovery is performed up to the end of the frame with the same channel value, regardless of the changes to channel values with respect to payloads after LTS [1]. However, the above method is not appropriate for very fast mobile channel environments (normally above 120 km per hour), such as the WAVE channel [1]. Changes can be traced in WAVE channels through the pilot subcarrier, but it is not enough to improve its performance [2].

In this paper, a Decision Feedback Channel Equalization (DFCE) method for the transmission of OFDM that complies with the WAVE standards over fast mobile environments is proposed. As it is not possible to modify the frame format to comply with the WAVE standards, the best alternative is to use the decision feedback method. In the proposed DFCE, channel estimation uses the LS estimation, which is widely employed in OFDM. During the LTS section, channel estimation is performed using a pre-known LTS and then after the payload section, channel estimation is performed using the regenerated signal obtained through the decision feedback path. Furthermore, a simple low pass filter (LPF) is used to adjust a speed that traces the change in the channel. The estimated channel value recovers distorted payloads.

2.WAVE Standard and Channel Modeling

2.1.WAVE Standard

The structure of the WAVE frame is shown in Fig. 1. First, a short training sequence (STS) is transferred, and 160 samples (one sample = 0.1μs) are transferred as a 16-sample-long sequence, which is iterated 10 times for the STS. Following the STS, an LTS is transferred. The LTS is transferred as a 64-sample-long sequence, which is iterated twice. The number of total samples in the LTS can be 160 if Guard Interval (GI) is included. The LTS is converted into a time domain via the Fast Fourier Transform (FFT) and employed as a sequence for channel equalization. Following this, the SIGNAL field containing transmission information and the PAYLOAD (or DATA) field are transferred. In the PAYLOAD field, channel recovery and decoding are done using estimated channel values from the LTS.

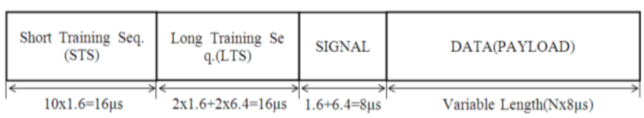

Fig.1. WAVE Frame

In Table 1, some modulation parameters applied to the WAVE are listed. Not all modulation methods are listed here due to space limitations. Eight modulation methods can be found and each is notated with RATEn(1≤n≤8). RATE1 uses the Binary Phase Shift Keying (BPSK) method and the coding rate of the convolutional encoder is 1/2. As the number of bits in a single OFDM symbol is 24 and the symbol frequency is 8μs, the data rate becomes 3 Mbps. Using the above method, up to a 27-Mbps data rate can be provided if the modulation dimension is raised to 64 Quadrature Amplitude Modulation (QAM) of Rate8.

Table 1. Modulation Parameters for WAVE

Modulation	Coding Rate	Coded Bits per Subcarrier	Coded Bits per OFDM Symbol	Data Bits per OFDM Symbol	Data Rate (Mb/s)
RATE1 (BPSK)	1/2	1	48	24	3
…	…	…	…	…	…
RATE8 (64QAM)	3/4	6	288	216	27

2.2. Channel Modeling

Table 2 shows the simplified fading channel profile proposed in the WAVE [3]. For convenience, we call this channel the Georgia Channel. The Georgia Channel is about objects that can move at a speed of 140 km/h and the distance between sending and receiving objects is 300 to 400 m. In this paper, the Georgia Channel was developed based on Jake Fading.

Table 2. Approximated Georgia WAVE Fading Channel

	Path Loss(dB)	Delay Value(ns)	Fad. Doppler(Hz)
1	0.0	0	60
2	-6.3	100	655
3	-25.1	200	823
4	-22.7	300	110

3.Channel Equalization in WAVE

3.1. Conventional LS Equalization

The first task that must be performed after receiving signals are converted into the frequency domain via the FFT at the OFDM receiver is channel equalization. As channels experienced while the subcarrier is transmitted due to general characteristics of OFDM can be modeled as Frequency Nonselective Fading Channels, the LS estimator for OFDM can be expressed simply using the below equation (1) [4-6].

$$\widehat{H}_k^{-1} = \frac{X_k Y_k^*}{Y_k Y_k^*} = \frac{X_k Y_k^*}{|Y_k|^2} \qquad (1)$$

In the above equation, X is the pre-known LTS and Y is a received signal of LTS passed through the channel. The below subscript k refers to the subcarrier number. If the above equation (1) is depicted by a figure 2, it can be implemented easily by a single-tap LS equalizer (LSE).In the LSE, no considerations of changes to the channel bythe mobility of receivers are included. In the WAVE standards, the LTS is placed in front of the frame, thereby estimating channel values in the front frame by the LSE, followed by channel recovery in the later frame. Thus, if a channel changes in the middle of frame reception, the accuracy of the channel values estimated at the LTS may degrade, which is a problem.

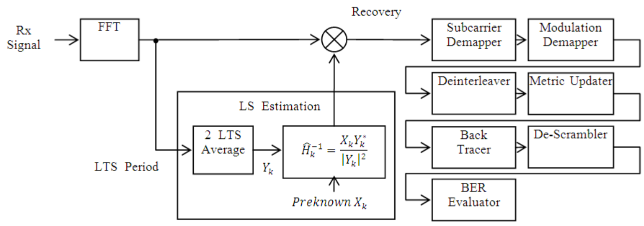

Fig.2. Basic LSE Structure

3.2. Proposed DFCE

The overall structure of the proposed DFCE-applied receiver is shown in Fig. 3. In the LTS period after FFT, channel distortion is estimated using an average of two LTS values received to recover the signals in the payload period. In the proposed DFCE, distorted channel values can be found through the LS estimation in Equation (1). To do so, LTS Y received through the channel and pre-known LTS X should be received as inputs.

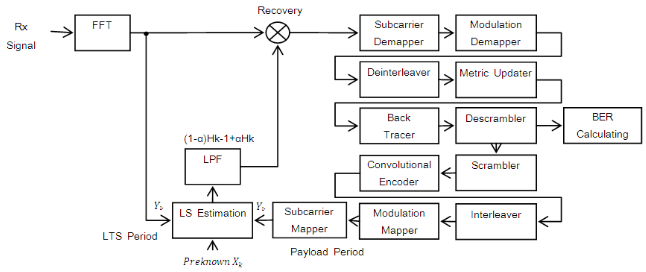

Fig.3. Proposed DFCE Structure

However, as symbols after the LTS period cannot be known in advance, regenerated signals should be received as inputs using the decoding bits. To achieve this, a decision feedback path is needed. In the decision feedback path, bits are decoded via a Subcarrier Demapper, Modulation Demapper, Deinterleaver, Viterbi Decoder, and Descrambler. On the contrary, regenerated signals are obtained via a Scrambler, Convolutional Encoder, Interleaver, Modulation Mapper, and Subcarrier Mapper.

Changes to the channels are dependent on the travel speed of the receiver. When the speed of the receiver changes quickly, changes to the channel can also be fast, so the update speed in the equalizer should also be fast. In the proposed DFCE channel equalizer, the following simple LPF was used to adjust the speed that chased the speed of the change in the channels.

$$\widehat{H}_{DF} = (1-\alpha)\widehat{H}_{k-1} + \alpha\widehat{H}_k \qquad (2)$$

Changes in fading are chased according to the α value in Equation (2). That is, if α is large, the estimated value of the current channel is reflected more proportionally, whereas an estimated value of the past channel is reflected more if α is small.

4. Simulation Results and Conclusions

Fig. 4 shows the performance of DFCE for RATE1, where α in the LPF was set to 1 or 0.5. The simulation result showed it would be advantageous to have a large α because changes to the Georgia Fading Channel were very fast.Moreover, if the payload length is long, its performance was slightly degraded but it can be accepted to some extent. Overall, the performance of the equalizer was very high and a noticeable performance improvement was found compared to using the general LSE (note the performance of using the general LSE is not displayed due to its poor performance).Overall, the performance showed a BER within a range ofE_b/N_0=20 dB to 10^{-4}.Fig. 5 shows the DFCE performance for RATE8, which also showed a substantial performance improvement compared to using the general LSE.

In this paper, a DFCE method for the transmission of OFDM that complies with the WAVE standards over a fast mobile environment is proposed. As it is not possible to modify the frame format to comply with the WAVE standards, the best alternative is to use the decision feedback method.

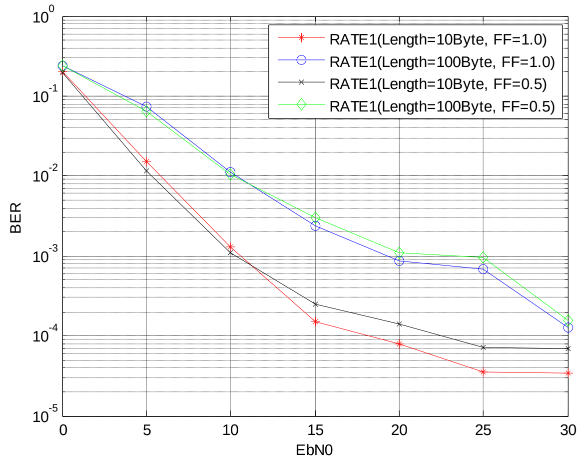

Fig.4. DFCE Performance for RATE1 Transmission

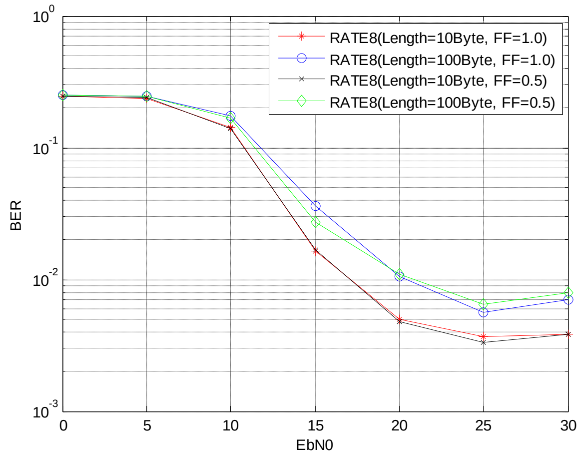

Fig.5. DFCE Performance for RATE8 Transmission

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