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A CROSS-LAYERED PILOT SCHEME FOR TIME- AND FREQUENCY-VARYING CHANNEL ESTIMATION AND ITS HARDWARE IMPLEMENTATION

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Abstract
The objective of this project is to carry out time domain PN sequence addition followed by frequency domain pilot insertion method. Hence the channel estimation accuracy has been improved with cross-layered pilot insertion for high mobility and selective fading channels. Furthermore, this hardware implementation reduces the receiver complexity. With this novel model, we can achieve good MSE performance in both static and mobile scenarios and can well support the FPGA implementation, especially when the maximum channel delay spread is fairly close to or even larger than the GI length.

Index terms: MSE, FPGA.

1. Introduction
Recently, a worldwide convergence has occurred for the use of Orthogonal Division Frequency Multiplexing as an emerging technology for high data rates. In particular, the wireless local network systems such as WiMax, WiBro, WiFi etc., and the emerging fourth-generation (or the so-called 3.9G) mobile systems are all OFDM based systems. OFDM is a digital multi-carrier modulation scheme, which uses a large number of closely-spaced orthogonal sub-carriers that is particularly suitable for frequency-selective channels and high data rates. This technique transforms a frequency selective wide-band channel into a group of non-selective narrow-band channels, which makes its robust against large delay spreads by preserving orthogonality in the frequency domain. Moreover, the introduction of a so-called cyclic prefix at the transmitter reduces the complexity at receiver to FFT processing and one tap scalar equalizer at the receiver. The simplified equalization at receiver, however, requires knowledge of the channel over which the signal is transmitted. To facilitate the estimation of the channel in an OFDM system (such as WiMax, WiBro, WiFi, and 3.9/4G), known signals or pilots could be inserted in the transmitted OFDM symbol.

There are several modulation methods which basically related to FDMA concept used in wireless communication Frequency domain equalization is used to remove the fading distortion in the signal for a frequency non-selective, time varying channel. Commonly employed modulation methods are as follows. In telecommunications, frequency division multiplexing (FDM) is a technique by which the total bandwidth available in a communication medium is divided into a series of non-overlapping frequency sub-bands, each of which is used to carry a separate signal. This allows a single transmission medium such as a cable or optical fiber to be shared by many signals. An example of a system using FDM is cable television, in which many television channels are carried simultaneously on a single cable. Where frequency-division multiplexing is used as to allow multiple users to share a physical communications channel, it is called frequency-division multiple access (FDMA).FDMA is the traditional way of separating radio signals from different transmitters.

FDMA (frequency division multiple access) is a channel access method used in multiple-access protocols as a channelization protocol. FDMA gives users an individual allocation of one or several frequency bands, or channels. It is particularly commonplace in satellite communication. FDMA, like other Multiple Access systems, coordinates access between multiple users. Frequency-Division Multiplexing (OFDM), essentially identical to coded OFDM (COFDM) and discrete multi-tone modulation (DMT), is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. Wired and wireless, fixed and mobile communications or networking technologies have chosen OFDM to achieve higher data rate (what is called broadband). Examples of such technologies are: ADSL, HomePlug AV, WiMedia UWB, Wi-Fi (802.11a/g), WiMAX. OFDM has developed into a popular scheme for wide band digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, wireless networking and broadband internet access. Channel equalization is simplified because OFDM may be viewed as using many slowly-modulated narrowband signals rather than one rapidly-modulated wide band signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to handle time-spreading and eliminate inter symbol interference (ISI).

2. Related Work
In the novel message passing based MIMO-OFDM data detector with a progressive parallel ICI canceller, Chao-Wang Huang, Pang-an Ting, and Chia-Chi Huang [1] proposed the ICI compression technique. ICI compression using correlative coding schemes can suppress the ICI component without reducing the spectral efficiency by a factor of two. However, this scheme usually cannot provide satisfactory performance in terms of the carrier - to-interference ratio (CIR) as it has a drawback that the detection errors generated at the receiver would be propagated through the OFDM symbols. An improved version of this method namely time domain windowing technique using correlative coding where the data samples of the tail subcarriers in an OFDM symbol are encoded with the data samples of the head ones in the subsequent OFDM symbol. For low complexity, the modified correlative coding scheme is realized using windowing function parameters.

Frequency domain equalization is used to remove the fading distortion in the OFDM signal for a frequency non-selective, time varying channel. Once the coefficients of the equalizer are found, linear or decision feedback equalizers are used in frequency domain. Since ICI is different for each OFDM symbol, the pattern of the ICI for each OFDM symbol needs to be calculated. ICI is estimated through the insertion of frequency domain pilot symbols in each symbol Correlative coding is another method used to suppress the ICI. This method does not reduce the bandwidth efficiency.

$$F(D) = (1 - D)$$

Without any loss in the bandwidth, 3.5dB improvement in CIR level is gained in this method using BPSK. A nonlinear adaptive filter is also used to reduce ICI. This method converges slowly as it uses higher order statistics.

In many cases frequency-domain channel matrix is no longer diagonal and the off-diagonal elements are interference gains among OFDM sub channels. Here Jun Ma, Philip V. Orlik and Geoffrey [2] estimated the interference gains and perform ICI cancellation accordingly. As an alternative to pilot-assisted ICI cancellation, various OFDM transmission schemes with inherent ICI mitigation capabilities have been developed. In reduced-rate OFDM transmission for inter-sub channel interference self-cancellation over high-mobility fading channels, they developed a general reduced-rate OFDM transmission scheme for ICI self-cancellation over high-mobility fading channels. By transmit and receive processing, we have transformed the original OFDM system into an equivalent one with fewer subcarriers and significantly reduced ICI.

In particular, general structure of transmit and receive processing matrices to guarantee a common average SIR over all equivalent sub channels in the transformed OFDM system. By reducing transmission rate, we are able to design a transmitted signal structure with inherent ICI self-cancellation capability without requiring the instantaneous channel state information. The general structure of transmit and receive processing matrices so that all equivalent sub channels in the transformed OFDM system have the same average signal-to-interference ratio (SIR). With transmit and receive processing, the original OFDM system is transformed into an equivalent one with fewer subcarriers. Schemes mostly consider channel model as a discrete-time multipath L-tap channel not a selective one. This method requires a large amount of pilots and decreases spectral efficiency significantly.

In performance analysis of multiple antenna multi-user detection, J. Kazemitabar and H. Jafarkhani [3] considered OFDM system with frequency selective time varying fading channel model and assume perfect channel state information is not available at the receiver. The channel frequency response ht k[n] and time domain impulse response hl t[n] are estimated at the receiver end by inserting pilots at some of the subcarriers and, thus, estimating the frequency response of the channel at selected frequencies. This paper is strongly motivated by the similarities between ICI distortion in OFDM systems and ISI distortion in single carrier systems, and considers an MMSE based detection technique to suppress ICI. By taking both ICI and additive noise into account, the MMSE-based OFDM detection technique is superior to the conventional OFDM detection scheme described above. By combat the ICI distortion caused by Doppler-spread of the time-varying fading channels, the MMSE-based OFDM receiver structure was used as a detection technique. The system performance is affected by the linear time variation of the channel. The channel estimations fully relies on unique detection techniques leads complexity.

Kazemitabar and H. Jafarkhani [4] proposed a novel technique called multiuser interference cancellation and detection for users with more than two transmit antennas technique transforms a frequency selective wide-band channel into a group of non-selective narrow-band channels, which makes its robust against large delay spreads by preserving orthogonality in the frequency domain. Moreover, the introduction of a so-called cyclic prefix at the transmitter reduces the complexity at receiver to space time coding processing and one tap scalar equalizer at the receiver. The simplified equalization at receiver, however, requires knowledge of the channel over which the signal is transmitted. To facilitate the estimation of the channel in an OFDM system (such as WiMax, WiBro, WiFi, and 3.9/4G), known signals or pilots could be inserted in the transmitted OFDM symbol.

3. Proposed Method

Since the early days of electronics, as advances in technology were taking place, the boundaries of both local and global communication began eroding, resulting in a world that is smaller and hence more easily accessible for the sharing of knowledge and information. The pioneering work by Bell and Marconi formed the cornerstone of the information age exists today and paved the way for the future of telecommunications. In wire-line communication, the data transmission is primarily corrupted by statistically independent Gaussian noise, as known as the classical additive white Gaussian noise (AWGN). In a typical wireless communications system, the transmitted signal typically undergoes refractions, shadowing and various reflections due to the presence of various objects (buildings, trees, etc.) in the channel. As a consequence the waves emitted by the receiver arrive at the receiver antenna over multiple paths, a phenomenon known as multipath propagation.

The complete set of propagation paths between transmitter and receiver forms the multipath channel. Each path can be characterized by three parameters: delay, attenuation and phase shift. The path delay depends on the path length and on the speed at which a wave is propagating in the different media along the path, while the attenuation and phase shift is caused by fading. In NLOS case, there is no direct line of sight between the transmitter and receiver, so all incoming waves have been reflected at least once. The multipath propagation scenario in NLOS case the envelope of the received signal can be best described by a Rayleigh distribution, and the fading is known as Rayleigh fading

In absence of interference, the primary source of performance degradation in such wire-line channels is thermal noise generated at the receiver. Reliable communication in wireless or radio channels, however, becomes a difficult task as the transmitted data is not only corrupted by AWGN, TFT-OFDM [5] has training information in both the time and frequency domains for every signal symbol, i.e., the time-

domain TS and the frequency-domain pilots scattered over the signal bandwidth are jointly used in TFT-OFDM.
The *i*th TFT-OFDM signal symbol **s***i* = si_0, si_1 .... si_{M+N-1} and *T* is composed of the known PN sequence **c** = *c*0, *c*1... , c_{M-1}. This figure1 presents by the use of CS and sparse channel nature, the pilot number *J* could be reduced significantly (far less than *L*, around 1% of *N*) and hence the spectral efficiency loss is negligible. The power of the pilots could be boosted for better CE performance, which is similar to that in the traditional pilot-aided CE method. The difference is that the pilots are equally spaced in conventional schemes, while the pilots are randomly located in the proposed scheme to ensure good CE performance based on CS. If the channel is exactly known at the receiver, the IBI of the PN sequence on the OFDM block can be completely removed. Then, by using the idea of the classical overlap and add (OLA) algorithm, the cyclicity reconstruction of the OFDM block can be obtained and hence the CP effect can be restored.

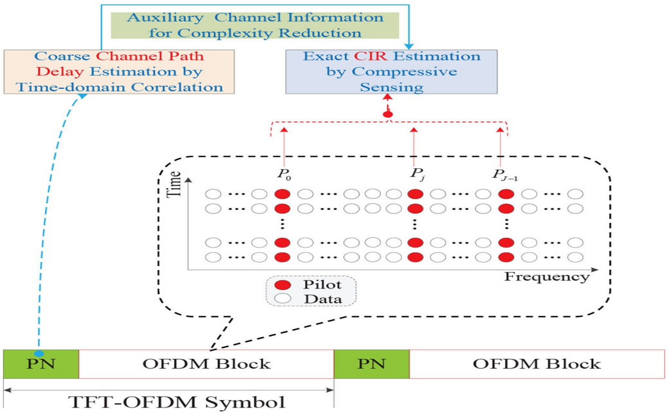

Figure 1: Proposed frame structure and the corresponding CS-based CE for the TFT-OFDM scheme.

4. Compressive Sensing Based Channel Estimation

CS theory has proved that the target signal **h***i* of large dimension *L* can be exactly recovered by a very small number of observations *J* if $\mathbf{h}_i$ is sparse, i.e., the number of nonzero entries of the target signal is much smaller than its dimension. Fortunately, numerous theoretical analysis and experimental results have verified that wireless channels are sparse in nature, i.e., in the CIR model, the dimension of the CIR *L* may be large, but the number of the active paths *S* with significant gains is usually small, i.e., *S* _ *L*, especially in the wireless wideband communications. This indicates that the sparse channel can be recovered by a very small amount of frequency-domain pilots based on CS.

Many efficient signal recovery algorithms have been developed for CS. Among them, the subspace pursuit (SP) algorithm is a widely used CS algorithm due to its robustness to noise, where the most significant *S* components of the original sparse signal are identified in an iterative manner. However, it requires the priori knowledge on the sparsity level of the signal, and has relatively high complexity.

In this section, by fully exploiting the joint time-frequency signal feature of TFT-OFDM, we propose a CS-based CE method with the auxiliary information based SP (A-SP) algorithm. Unlike the conventional TS-based or pilot-aided CE schemes which depend on either time- or frequency-domain information, the proposed CS-based CE method firstly utilizes the PN-based correlation in the time domain to acquire the auxiliary channel information, and then the frequency-domain pilots are used for the final exact CIR estimation based on CS. The specific procedure of this method can be divided into three steps: Under the approach proposed here, tests are generated using several assignments of weights. In this section, the selection of the weights is described. To derive weight assignments to be used in weighted pseudo-random test pattern generation, we use a known deterministic test set that provides the desired (in our case 100%) coverage of detectable faults. As in earlier work, a weight of **a,** 0 **I a I** 1, assigned to an input x of the circuit under test implies that the probability of input **x** being assigned the value 1 is **a.** The following example illustrates the basic idea behind our method for deriving the weight assignments to be used for weighted pseudorandom test pattern generation.

1) PN-based coarse path delay estimation;
2) Cyclicity reconstruction of the OFDM block;
3) Exact CIR estimation using A-SP.

A) PN-Based Coarse Path Delay Estimation
Based on the good auto-correlation property of the PN sequence, the received PN sequence di is directly correlated with the locally known PN sequence c to acquire the coarse channel estimate h –i

$$\bar{\mathbf{h}}^i = \frac{1}{M}\mathbf{c}\otimes\mathbf{d}^i = \mathbf{h}^i + \mathbf{v},$$

where v denotes the AWGN as well as the effect of interference caused by the preceding OFDM block. The ITU Vehicular B (ITU-VB) channel model with the signal-to-noise ratio (SNR) of 10 dB is considered, although the coarse path delay estimation is not accurate due to the existence of IBI, the good auto-correlation property of the PN sequence ensures that the auxiliary channel information necessary for the following A-SP algorithm could be obtained. Such information includes the locations of the most significant taps and the approximate channel sparsity level.

B) Cyclicity Reconstruction of the OFDM Block
The cyclicity reconstruction of the OFDM block is achieved by firstly subtracting the IBI caused by the PN sequence from the received OFDM block, then adding the received PN sequence and finally subtracting the first part of linear convolution outputs between the PN sequence and channel. This process is based on the idea of OLA algorithm and is briefly illustrated in Fig. 4. In this step, the IBI caused by the PN sequence is obtained by computing the linear convolution between the local PN sequence and the estimated CIR obtained in the preceding symbol.
Under the slow time-varying channels, which can be assumed in many wireless broadcasting systems, the estimated CIR obtained in the preceding symbol can be used for the IBI removal in the current symbol. In fact, the received PN sequence contains not only the useful part which is the IBI caused by the OFDM block, but also the useless part that is

the linear convolution between the PN sequence and channel. Hence, the useless part should be removed after the received PN sequence is added to achieve the cyclicity reconstruction.

C) Exact CIR Estimation Using A-SP

The pilots can be extracted from the OFDM block after cyclicity reconstruction for the final accurate CE. Based on the basic idea of classical SP algorithm, we propose the A-SP algorithm, whereby the auxiliary channel information obtained in exploited to improve the CE performance and lower the computational complexity.

5. Experimental Results

Combined with the highly time- and frequency-selective nature of vehicular channels makes robust channel estimation a challenging task. Several solutions have been proposed to address the problem of channel estimation in 802.11p systems. Channel estimation scheme called spectral temporal averaging (STA) is proposed in. The scheme uses decisions from data subcarriers in combination with averaging in time and frequency domains to compute updated channel estimates. Cyclone III is used as a family in the Quartus II tool. The MATLAB results for Cross layered pilot scheme has been differentiated as Channel estimation BER analyzes, BER performance analyzes of cross layered scheme, channel path gains with a longer path delay, BER performance of 802.11p transceiver over vehicular network. From the figure 2, the channel estimation BER analyzes a perfect CSI and LS channel estimator are compared to LS using cross pilot scheme is better than existing has been proved. This performance has been overcome by the LS channel estimator.

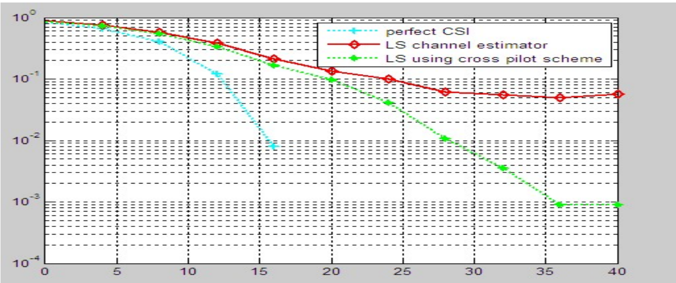

Figure 2: Channel estimation BER analyzes

The bit error rate performance as shown in figure 3, are existing level compare to proposed method can be reduced error with using cross layered scheme.

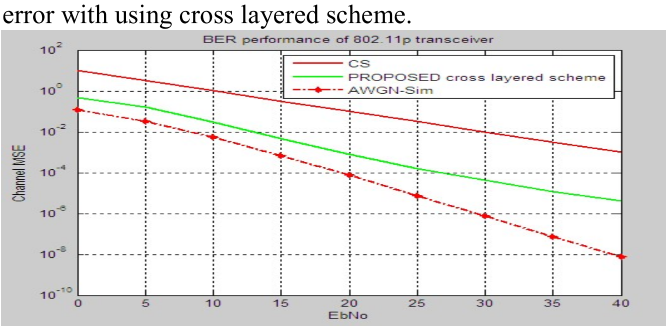

Figure 3: BER performance analyzes of cross layered scheme

Figure 4 shows the comparison to the path gain and mobility gain of time to time change gives the channel gain per path in channel estimation process.

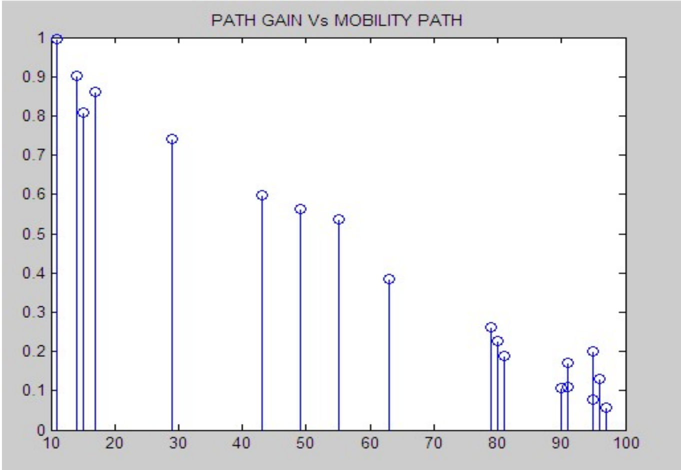

Figure 4: Channel path gains with a longer path delay

Figure 5: BER performance of 802.11p transceiver over vehicular network

The BER performance of 802.11p transceiver is used to a vehicular network can be seen from Figure 5. It is compared to CS and AWGN-sim higher to better performance for cross layered scheme. Table 1 shows the maximum speed of the slow corner in the channel estimation method. Speed is defined as how fast the device or hardware runs. The maximum speed of the slow corner is 455.79MHz.

From the Table 1, the experimental evaluations shows that the total thermal power dissipation in the existing system is 113.49mW and in the proposed system the total power dissipation is reduced to 57.31mW. The dynamic power dissipation is zero and the static and thermal power dissipation is reduced than the existing method. On comparing both the existing and proposed system the overall power dissipation is reduced.

Table 1: Cross-Layered Pilot Scheme Performance Report with QUARTUS II Hardware Synthesis Using CYCLONE II Family (EP2C35F672C6)

TYPE	SPEED	POWER DISSIPATION
Cross-Layered Pilot Scheme	455.79MHz	57.31mW
Existing method	149.56MHz	113.49mW

The signal time-spreading (signal dispersion) and time-variant nature of the channel may be examined in two domains, time and frequency, Large-scale fading is responsible or path-loss in wireless communications and large-scale fading models. The channel is said to experience frequency-selective fading when f0 < W, whereas frequency non-selective or flat fading occurs when the f0 > W.

5. Conclusion

In this project presented an introduction of 802.11p Cross-Layered Pilot Scheme in OFDM systems in high mobility channels, specifically, the topics of the channel, OFDM, ISI, and ICI over cyclic prefix. Mathematical descriptions of the channel, OFDM, and cyclic prefix and auxiliary information retrieval for estimations were given as well as MATLAB simulations to verify, illustrate concepts, or present a practical implementation. The MSE performance of this method outperforms the conventional schemes and is close to the theoretical simulation by simultaneously exploiting the time-domain PN sequence and frequency-domain pilots. Hardware implementation results show that the proposed scheme has a good MSE performance in both static and mobile scenarios and can well support the FPGA implementation, especially when the maximum channel delay spread is fairly close to or even larger than the GI length.

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