A New Scheme of Pilot Arrangement in OFDM Systems by using a feedback Branch

Babak Sabooniha[1], Hamidreza Bakhshi[2], Farbod Razzazi[3]

1, 3. Department of Electrical Engineering, Science and Research Branch of Islamic Azad University, Tehran, Iran

2. Department of Electrical Engineering, Shahed University, Tehran, Iran

Abstract* — Channel estimation techniques for Orthogonal Frequency Division Multiplex (OFDM) systems based on a pilot arrangement are investigated. Training based Channel estimation with a block type pilot arrangement is studied through an algorithm for determination of efficient number of pilot symbols in an OFDM symbol by adding a feedback branch. Channel estimation at pilot frequencies is based on Least Square (LS) method while channel interpolation is done using linear interpolation. At the end the influence of the new algorithm on three different Stanford University Interim (SUI) channels are simulated. It will be shown that with this technique a dramatic amount of assigned bandwidth for channel estimation can be saved for data transmission. Also, the Bit Error Rate (BER) performance in the proposed system remains approximately constant in comparison with the state that the maximum numbers of pilot symbols are sent.

***Keywords* — Channel estimation, OFDM, CP, Delay spread, Pilot symbols.**

I. INTRODUCTION

Nowadays OFDM is known as the most popular and high data rate technique for various types of wireless communication systems. These systems are also capable of working in different ranges of frequencies and different medium conditions. OFDM is a particular form of Multi-Carrier and it is suited for frequency selective channels. In particular, many wireless standards such as Wi-Fi [1], Wimax [2], LTE and DVB have adopted OFDM technology.

Up to now, several techniques have been introduced for the estimation of channel parameters in such wireless systems, such as [3-4]. There are two main group of channel estimation, which are called blind and training based channel estimation. The focus of this paper is on the pilot based channel estimation techniques. In OFDM systems the distance between the pilot symbols in frequency domain is related to a parameter of the wireless channel which is named delay spread. As a consequence, obtaining of the time dispersion has a vital role in the determination of pilot spacing in an OFDM symbol. Moreover, several researches on proposing an effective and reliable arrangement of pilot symbols have been done until now.

Adaptive filtering is one of the possible techniques for the estimation of channel parameters. In [3], a two-dimensional wiener filter, which is implemented as a cascade of two one-dimensional wiener filters, is used for the estimation of channel. Pilot arrangements are chosen adaptively by using a prediction of the channel estimation error at the receiver in [5]. The number of pilots and their frequency distance are also determined depending on the knowledge of delay spread in [6]. Time dispersion of the channel and its related parameters can be estimated by using the channel impulse response (CIR) estimates too. In [5] and [8], the CIR is acquired by using the inverse discrete furrier transform (IDFT) of channel frequency response estimation, which is calculated at pilot locations. In [7], time dispersion is calculated by using of the power delay profile (PDP) estimation. RMS delay spread of the channel is obtained using the channel frequency correlation (CFC) in [8]. At the end, in [6] and [10], techniques using the CP are proposed for the estimation of delay spread. The change of correlation gradient between the CP and the last part of the OFDM symbol is used as a strategy to determine the time dispersion parameters in [9]. In [10], the magnitude of each arriving tap and the corresponding delay are estimated from the obtained correlation.

There are also some papers which focus on the optimal distance between the pilot symbols in an OFDM symbol or frame. In [11], optimal pilot sequences and optimal placement of the pilot tones are driven with regard to the mean square error (MSE) which is computed in this paper.

A new hexagonal method is proposed for the arranging of pilots in [12]. A technique which has demonstrated, under a particular situation, is the most efficient way of two dimensional sampling, the authors of this paper claimed. In [13], developed versions of Sine algorithm, Shift algorithm and Sine and Shift algorithm, in order to increase the accuracy of the symbol time offset estimator are presented. A method of pilot design by means of virtual subcarriers, with the expected MSE performance is presented in [14]. It is also claimed that the total number of pilots, which are used for channel estimation, is almost two times smaller than the conventional systems.

In this paper, first the model of system is introduced in section II. The new algorithm is presented in this section and it is explained how it can be possible to use a feedback branch in the structure of an OFDM system. At the next section the conditions of simulation are explained, and simulation results are presented. In these simulations, SUI channel models [15] are chosen to be used for acquiring acceptable results. At the end, section IV is for conclusion and discussing the results.

II. SYSTEM MODEL

In the OFDM technique a serial data stream which is contained N data and pilot symbols, and with a period of T seconds, is converted into N parallel sub-streams, each with the same period as the prior data stream. There are several choices for pilot arrangement, like block type, comb type or scatter type of pilot insertion. In this paper block type arrangement is elected. Then these parallel sub-streams are entered into an IDFT block.

$$x_m(n) = IDFT\{X_m(k)\}$$

$$= \sum_{k=0}^{N-1} X_k(k) e^{j2\pi nk/N} \quad 0 \le n \le N-1 \quad (1)$$

After a P/S conversion, cyclic prefix (CP) is added to the obtained time domain signal, because of two reasons. The first one is reduction of inter symbol interference (ISI) between OFDM symbols. CP insertion also lets us use circular convolution in the structure of an OFDM system. Therefore, the use of IFFT and FFT is can be possible in OFDM systems.

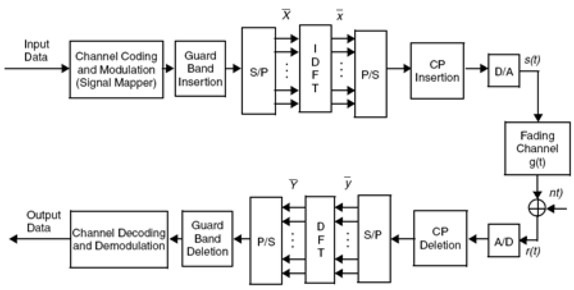

Fig.1: The block diagram of an OFDM system

After the CP insertion, the signal is passed through a D/A convertor, and then it travels through the medium. Here there are AWGN and different kinds of fading and channel distortions. The OFDM symbols are affected by them and arrive from the receiver. The receiving signal can be written as:

$$y_m(n) = \sum_{l=0}^{L-1} x_m(n-1) h_m(l) + w_m(n) \quad (2)$$

where L is the number of taps, $w_m(n)$ is zero mean AWGN with the variance of ${\sigma_m}^2$, and $h_m(l)$ is the impulse response of the *m*th tap. By using a Discrete Fourier Transform (DFT), the frequency domain of received stream can be written as:

$$Y_m(k) = DFT\{y_m(n)\}$$

$$= X_m(k) H_m(k) + W_m(k) \quad 0 \le k \le N-1 \quad (3)$$

where H_m, X_m and W_m are the frequency domain equivalents of h_m, x_m and w_m respectively. By using Least Square (LS) estimation, the estimation of Channel Frequency Response can be obtained as:

$$\widehat{H}_m(k) = \frac{Y_m(k)}{X_m(k)} \quad (4)$$

Finally with a reliable interpolation algorithm the CFR for all of sub-carriers can be calculated. There are several Interpolation techniques in both time and frequency domains, such as Linear Interpolation, Second-order, Low-pass, spline cubic and etc. in this paper Linear Interpolation is used that for $mL < k < (m+1)L$ given by:

$$H_I(k) = H_I(mL + l) \quad 0 \le l \le L-1$$

$$= \frac{l}{L}\left[H_p(m+1) - H_p(m)\right] + H_p(m) \quad (5)$$

where L, H_I and H_p are the distance between pilots, the interpolated symbols between them, and estimation of transmitted pilots respectively.

Now, it is time of discuss about the proper distances between the pilots which are related to the parameters of the channel -such as delay spread and Doppler spread- and the bandwidth of the transmitting signal. In this paper, the block type of pilot arrangement is used, and because of this, the distance between pilots in frequency domain plays an important role in reducing of error rate. The optimal pilot space in frequency is obtained as:

$$N_p^f = \frac{1}{\Delta f . \sigma_\tau} \quad (6)$$

where N_p^f, Δf and σ_τ are the distance between pilots in frequency domain, the bandwidth of a sub-carrier and delay spread respectively.

In this paper the method of [7] is accepted for the estimation of time dispersion. In this technique, first the power delay profile (PDP) is estimated from the channel frequency correlation (CFC) which is calculated by the estimated symbols at the receiver. Then by means of PDP, RMS delay spread can be obtained as:

$$\sigma_\tau = \sqrt{\overline{\tau^2} - \bar{\tau}^2} \quad (7)$$

Which it is calculated by the mean excess delay:

$$\bar{\tau} = \frac{\sum_k P(\tau_k)\tau_k}{\sum_k P(\tau_k)} \quad (8)$$

And

$$\overline{\tau^2} = \frac{\sum_k P(\tau_k){\tau_k}^2}{\sum_k P(\tau_k)} \quad (9)$$

where τ_k and $P(\tau_k)$ are the amount of delay for the *k*th tap, and *k*th tap of the channel PDP. These delays are measured relative to the first detectable signal arriving at the receiver at $\tau_0 = 0$.

As it is explained the amount of pilot distance in frequency is related to RMS delay spread which is a parameter of the wireless channel. Several channel models are proposed for fixed wireless OFDM systems. SUI channel models are the most popular ones in this area. Almost all the algorithms that argue about the optimal distance between the pilots have assumed that the number of them is fixed and it cannot be changeable during the time. Therefore the results are for the hardest condition that may be happened in the channel. But in practice the amount of RMS delay spread is changing during the time and sometimes it is equal to the maximum amount that is predicted in SUI channels. So it may be possible that the lower number of pilots use for the procedure of channel estimation.

Fortunately it is possible by adding a feedback branch to the prior system. It just remains a point. In what times the receiver send out its information about the channel information. This period of time which the receiver has this permission for broadcasting the channel information in it is called feedback time.

The channel which is the aim of this paper is a channel that has almost fixed time dispersion. In other words, if a statistic distribution is defined for the variation of the channel delay spread, the period of its changing was almost fixed. A distribution with an arbitrary mean and a very low variance satisfies this condition. In this situation, because of low complexity of the system, it is better to determine a fixed feedback time. So after a fixed period of time receiver aware the transmitter that changed the number of the pilots for the next period of data transmitting. It is known that, SUI channel models can be good channel models for fixed wireless channels. Each SUI channel is consists of three separate paths, with three different path delays. Changing of these path delays by using of a random variable can generate the needs of this paper accurately. As a consequence, in comparison with the situation that maximum numbers of pilots are used for the channel estimation, the amount of pilot symbols have a slight decrease during the time. Beside, the feature of BER is remained approximately near to the condition which maximum pilot numbers are sent. At the next stage, it will be shown that what advantages are gained with this algorithm.

III. SIMULATION RESULTS

An OFDM system, with 1024 numbers of sub-carriers, which 960 of them are used for the transition of data and pilot symbols is used for these simulations. The total bandwidth of the system is 100 KHz and the amount of delay spread is variable between zero and 200 microsecond. 3 types of SUI channels are selected. In each

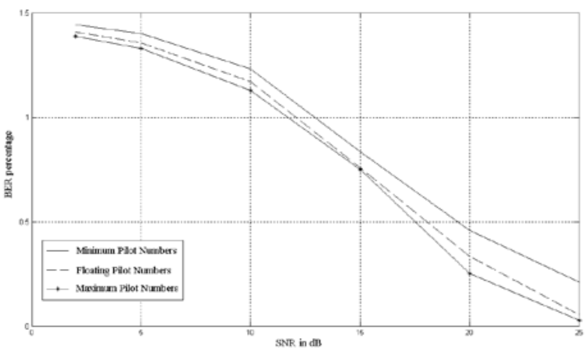

Fig. 2. BER percentage for SUI-I channel

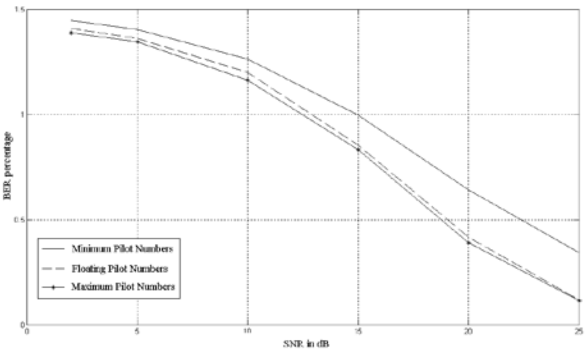

Fig. 3. BER percentage for SUI-III channel

channel 3 conditions are studied. The maximum number of pilots, minimum number of them and the floating amount of them based on the new algorithm which is introduced in this paper. At the presented technique, the amount of pilots is varied between 4 and 40 symbols which are known as the minimum and maximum numbers of pilot symbols. Therefore, it is clear that when the maximum numbers of pilots are sent out, 4% of total bandwidth is occupied for them.

For changing of path delays of each channel model a random variable with a uniform distribution is defined. For the satisfaction of this paper's aims the variance of this uniform random variable is chosen small enough and its average is equal with the approximate period of 10 OFDM symbols. After each period of 10 OFDM symbols, with the typical assumption that path delays cannot be varying suddenly, the receiver which determines the later amount of pilot symbols in each OFDM symbol, send out the new information of pilot symbols numbers, by using of the feedback branch which is added to the proposed system in this paper. This procedure will be continued until all the information received by the receiver.

It can be easily seen that the BER performance of the proposed technique is approximately close to the BER performance, related to sending out the maximum number of pilot symbols. On the other hand, the results of simulations show that there is a reduction by 1.5 %, from 4% to about 2.5%, of total bandwidth in the proportion of pilot symbols in this system. If the larger numbers of pilots are sent from the transmitter, then the reduction of pilot symbols will be shown more dramatically.

IV. CONCLUSION

Channel estimation is one of the crucial stages for the recovery of transmitted data streams. In this paper, an efficient and sensible technique is proposed for reducing of pilot symbols which are needed for a certain estimation of channel parameters in training based channel estimation techniques, by adding a feedback branch. Simulations on SUI channel types I, III and V, are performed for the evaluation of the effects of the new introduced scheme on BER performance of an OFDM system. Although by using of this technique, the BER performance remains very close in comparison with the state which the maximum numbers of pilot symbols are sent, it can be seemed a significant

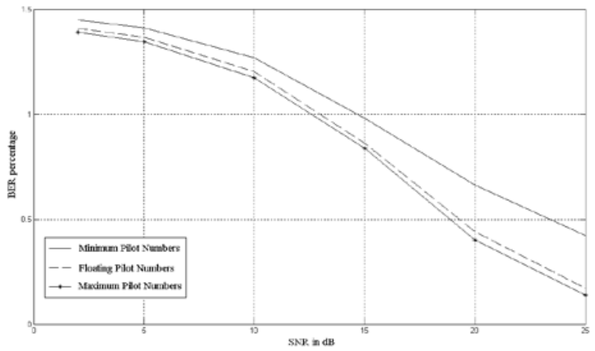

Fig. 4. BER percentage for SUI-V channel

reduction in the specified amount of pilot symbols in each OFDM symbol.

REFERENCES

[1] IEEE802.11-a/b/g/n,"IEEE Standard for Wireless Local and Metropolitan Area Networks."

[2] IEEE 802.16-2004,"IEEE Standard for Wireless Local and Metropolitan Area Networks", October 2004.

[3] F. Sanzi and J. Speidel, "An adaptive two-dimensional channel estimator for wireless OFDM with application to mobile DVB-T," *IEEE Trans. Broadcast.*, vol. 46, no. 2, pp. 128–133, June 2000.

[4] P. Fertel and G. Matz, "Multi-User Channel Estimation in OFDMA Uplink Systems Based on Irregular Sampling and Reduced Pilot Overhead," *in ICASSP IEEE conf.,* pp.297-300, April 2007.

[5] O. Simeone and U. Spagnolini, "Adaptive pilot pattern for OFDM systems," in *Proc. IEEE Int. Conf. Commun.*, vol. 2, pp. 978–982, June 2004.

[6] A. Dowler, A. Doufexi and A. Nix, "Performance evaluation of channel estimation techniques for a mobile fourth generation wide area OFDM system," in *Proc. IEEE Veh. Technol. Conf.*, Vancouver, Canada, vol. 4, pp. 2036–2040, Sept. 2002.

[7] T. Yucek and H. Arsalan, "Delay spread and time dispersion estimation for adaptive OFDM systems," *IEEE wireless communication and networking conf.,* pp. 1433-1438, 2006.

[8] H. Schober and F. Jondral, "Delay spread estimation for OFDM based mobile communication systems," in *Proc. European Wireless Conf.*, Florence, Italy, pp. 625–628, Feb. 2002.

[9] C. Athaudage and A. Jayalath, "Delay-spread estimation using cyclicprefix in wireless OFDM systems," *IEE Proc. Com.*, vol. 151, no. 6, pp. 559–566, Dec. 2004.

[10] K. Ramasubramanian and K. Baum, "An OFDM timing recovery scheme with inherent delay-spread estimation," in *Proc. IEEE Global Telecommunications Conf. (Globecom)*, San Antonio, TX, vol. 5, pp. 3111–3115 Nov. 2001.

[11] I. Bahrami, G. Leus and M. Moonen, "Optimal training design for MIMO OFDM systems in mobile wireless channels," *IEEE Trans. On Signal processing,* Vol. 51, no. 6, pp. 1615-1624, 2003.

[12] M. J. Ferniindez-Getino Garcia, S. Zazo and J.M. Piez-Uorrallo," Pilot patterns for channel estimation in OFDM," ETSI Telecommunication, Univ. Politecnica de Madrid, Vol. 36, pp. 1049 – 1050, June 2000.

[13] S. B. Hong, H. M. Kim, "Pilot signal design algorithm for efficient symbol time offset estimation in an OFDM system," Signal Processing, Vol. 87, pp. 489-498, March 2007.

[14] Jun-Young Son, Jihyung Kim *and* D. S. Kwon, "The pilot design for channel estimation in a practical MIMO OFDM system," *International Conf. on Computing, Engineering and Information,* Fullerton, CA, pp. 325 - 328, April 2009.

[15] IEEE 802.16 broadband wireless access working group, "channel models for fixed wireless applications", IEEE pres., June 2003.