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Cyclic Prefix Based Channel Estimation of Single Carrier - Frequency Domain Equalization

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Abstract: *For the mobile communication, single carrier cyclic prefixed (SC-CP) with frequency domain equalizer (FDE) is favourable and robust channel estimation. Conventional SC-CP wireless system uses training sequences that put in every packet to get the channel information. Channel State Information (CSI) is the crucial parameter that should be available at the receiver. Correct channel estimation is very important to the implementation of any communication system. In wireless communication system, data is often transmitted through unknown channel. This state of information is generally obtained at the receiver by sending training sequence from transmitter to receiver repeatedly and a training algorithm is performed by the receiver on the observed channel output and the known input to the channel. Since, training sequence is sent with the data frame, these solution results in loss of net throughput. A different way of obtaining CSI has been explored in this paper, making use of the transmitted information i.e. cyclic prefix itself and without adding any training symbols. This obviates the need for*
training sequences and results in overall increase in throughput.

Keywords: *Channel estimation, cyclic prefix, frequency domain equalization, single carrier, wireless.*

1. INTRODUCTION

The wireless communication channels are generally multipath fading channels which cause Inter Symbol Interference (ISI) in the received signal. To compensate for this channel induced ISI, various equalizer are in use. However, the information about the channel is highly desirable for proper functioning of equalizer. General Method of obtaining Channel information in Fig 2 shows a generic communication system which exploits channel estimation and signal detection operations in equalization. The digital source is usually protected by channel coding and interleaved against fading phenomenon, after which the binary signal is modulated and transmitted over multipath fading channel. Additive noise is added and the sum signal is received. Due to the multipath channel there is some inter symbol interference (ISI) in the received signal. For successful equalization, channel state information need to be known. Traditionally, the channel estimation is based on the known sequence of bits, which is unique for a certain transmitter and which is repeated in every transmission burst. Thus, the channel estimator is able to estimate CSI for each burst separately by exploiting the known transmitted bits at the receiver and the corresponding received samples. These known sequences are called training sequences or training symbols. Every time a frame is transmitted, these training symbols are transmitted and form the preamble part of the frame.

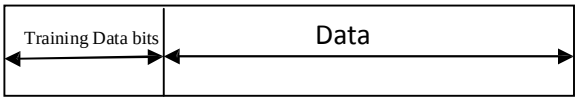


Figure 1 Training Sequences and data block

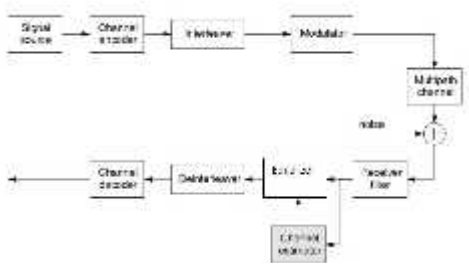


Figure.2 *Generic* wireless system with Channel Estimator

Fig 2 shows that data bits from signal source are encoded, interleaved and modulated. After modulation, it passes through the Multipath channel. Due to the multipath channel there is some inter- symbol interference (ISI) in the received signal. Here CSI is estimated based on the known training sequence, which is transmitted in every transmission

burst as Fig.1. The receiver can utilize the known training bits CSI typically for each burst separately.

However, there in one drawback of above system that it consumes bandwidth with every frame transmitted.
Every time a frame is transmitted, a large space is occupied by the training symbols and hence the overall throughput reduces.

2. PROPOSED WORK

2.1 Proposed Model for CSI in SC-FDE

In case of SC-FDE, a frame has the structure as shown in fig 3 with every frame transmitted, a cyclic prefix is appended with every frame to maintain the periodicity in the signal which has advantage.

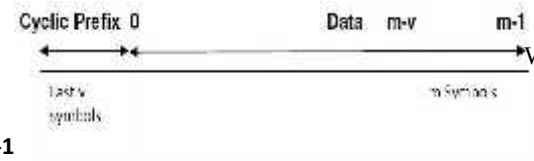


Figure 3. cyclic prefix is of length v

to -1.The last v symbols (from m-v to m-1) has been prefixed in the frame. The input to the receiver of SC- FDE can be expressed in the form of equation given by

$$y = Hx + V_n \quad (1)$$

Where x is the transmitted vector and y is the received vector and H is the Channel matrix. Now if we consider only the cyclic prefix part of the frame then

$$y_{cp} = Hx_{cp} + V_n \quad (2)$$

The above equation can also be expressed as

$$y_{cp} = X_0 h + V_n \quad (3)$$

Which is another way of expanding convolution, where h is of length l and X_o is matrix containing cyclic prefix symbols. X_o has dimensions of [v x l] where v is the cyclic prefix length and represented as

$$X_0 = \begin{bmatrix} x_v & x_{(v-1)} & x_{(v-2)} & \cdots & x_1 \\ 0 & x_v & x_{(v-1)} & \cdots & x_2 \\ 0 & 0 & x_{(v-2)} & \cdots & x_3 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & x_{l-1} \end{bmatrix} \quad (4)$$

Now estimation of channel h can be described through equation

$$\hat{h} = X^{-1} y_{cp} \quad (5)$$

Where $\hat{h}$ is the estimate of channel h and X^{-1} can be given as

$$X^{-1} = (X_0^T X_0)^{-1} X_0^T \quad (6)$$

In fig 3, the Cyclic Prefix (CP) is of length v from –v

This is the pseudo inverse matrix of Xo. In equation5, y_{cp} is available to us at the receiver. Now in order to estimate the channel through equation 5,

we need to know the entries in the matrix X^{-1} or basically the cyclic prefix symbols transmitted. Here, we will make use of equation 2 the estimate of x is

given by

$$\hat{x} \quad \underline{x} \quad H \quad {}^{1}V \qquad {}_{n} \qquad (7)$$

2.2 Block Diagram of Proposed System

Here, we make use of the fact that the last v symbols of the frame are equal to the cyclic prefix part. That is true also since the last part of the frame has been prefixed at the input. In the received vector also, the last v symbols must be equal to first v symbols.

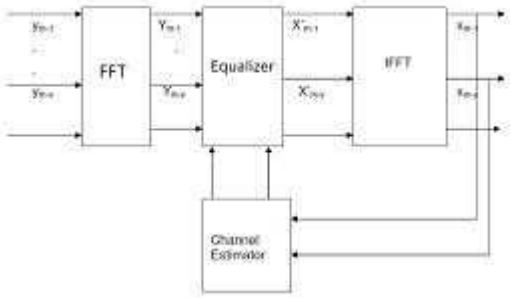


Figure 4 Block diagram of channel estimator in SC- FDE

Initially, assumption is made that channel coefficients are available to us. Based on this, the received symbols are equalized. Once these symbols are equalized, the first v symbols are extracted and put in equation and channel is estimated. Now based on the new channel estimated, again the received symbols are equalized; the first v symbols are extracted and compared with cyclic prefix part. The last symbols of data block and prefixed symbols, both of these should be equal or the difference of them should be equal to zero. This process is repeated again and again until we get those values of h coefficients for which the first and last part of the frame are equal or their difference is minimum. Once we reach that stage, that will be the correct estimate of h and the frame can be equalized with these coefficients. In the next operation, when new frame arrives at the receiver, the recent value of h is updated.

This way, it is possible to obtain channel state information. We have made use of the fact that there is duplicity in the initial and last symbols of the frame which is the only information available to us here.

3. SIMULATION RESULT

3.1 Flow Diagram

Channel estimation take palce when the last symbols of data block and prefixed symbols, both of these should be equal or the difference of them should be

equal to zero. This process is repeated again and again until we get those values of h coefficients for which the first and last part of the frame are equal or their difference is minimum. Once we reach that stage, that will be the correct estimate of h and the frame can be equalized with these coefficients. In the next operation, when new frame arrives at the receiver, the recent value of h is updated

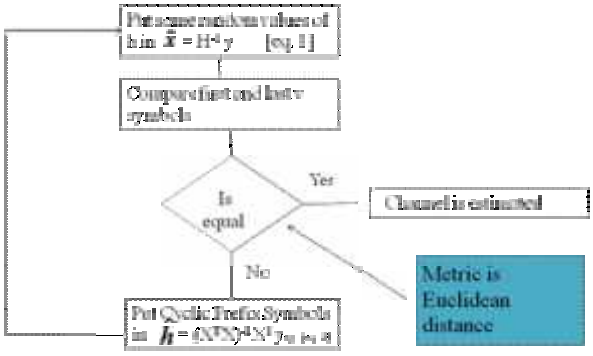


Figure-5 Simulation Flow Diagram

3.2 Simulation Result

Here are results of the above explained algorithm for estimating the channel matrix. First column have the exact value of channel coefficient and other column have the estimated value of channel for repeating the loop different number of times.

Table 1

Real h values	Estimated h values	Estimated h values	Estimated h values	Estimated h values	Estimated h values
1	1	1	1	1	1
2	1.998	1.997	2	2.0003	2.007
1	1	1	1	1	1
3	2.99	2.95	2.98	2.954	2.95
3	2.91	2.996	2.992	3.001	2.992
4	3.880	4	4	4	4
4	3.99	3.95	4	3.98	3.90
5	5	5	5	5	5
2	1.99	1.99	2.01	2.002	2
3	3	3	3	3	3

3.3 Advantage of proposed System

The proposed system does not require any additional bits in the form of training sequences to be sent with each frame. Therefore, high throughput can be expected here compared to the system when training symbols are sent along with the main frame.

3.4 Drawback of proposed system

The drawback of the proposed system can be in the form of delay in decoding a frame. However, today highly computational devices are available that can be used for fast processing.

4. CONCLUSIONS & FUTURE SCOPE

In CSI using cyclic prefix in SC-FDE: one system has been proposed for estimating the channel in SC- FDE that does not require any training symbols to obtain channel coefficients. Therefore, high throughput can be expected here compared to the traditional system like in GSM where training symbols are sent along with the main frame Some of the points regarding the future scope of the paper that can be expected, Includes:

A basic strategy to obtain Channel state information using cyclic prefix has been proposed here in this paper. However, there is scope for using better algorithm while using the same basic principle proposed in this paper.

Simulation for large frame size, different cyclic prefix length and long channel impulse response (v>L) can be explored further.

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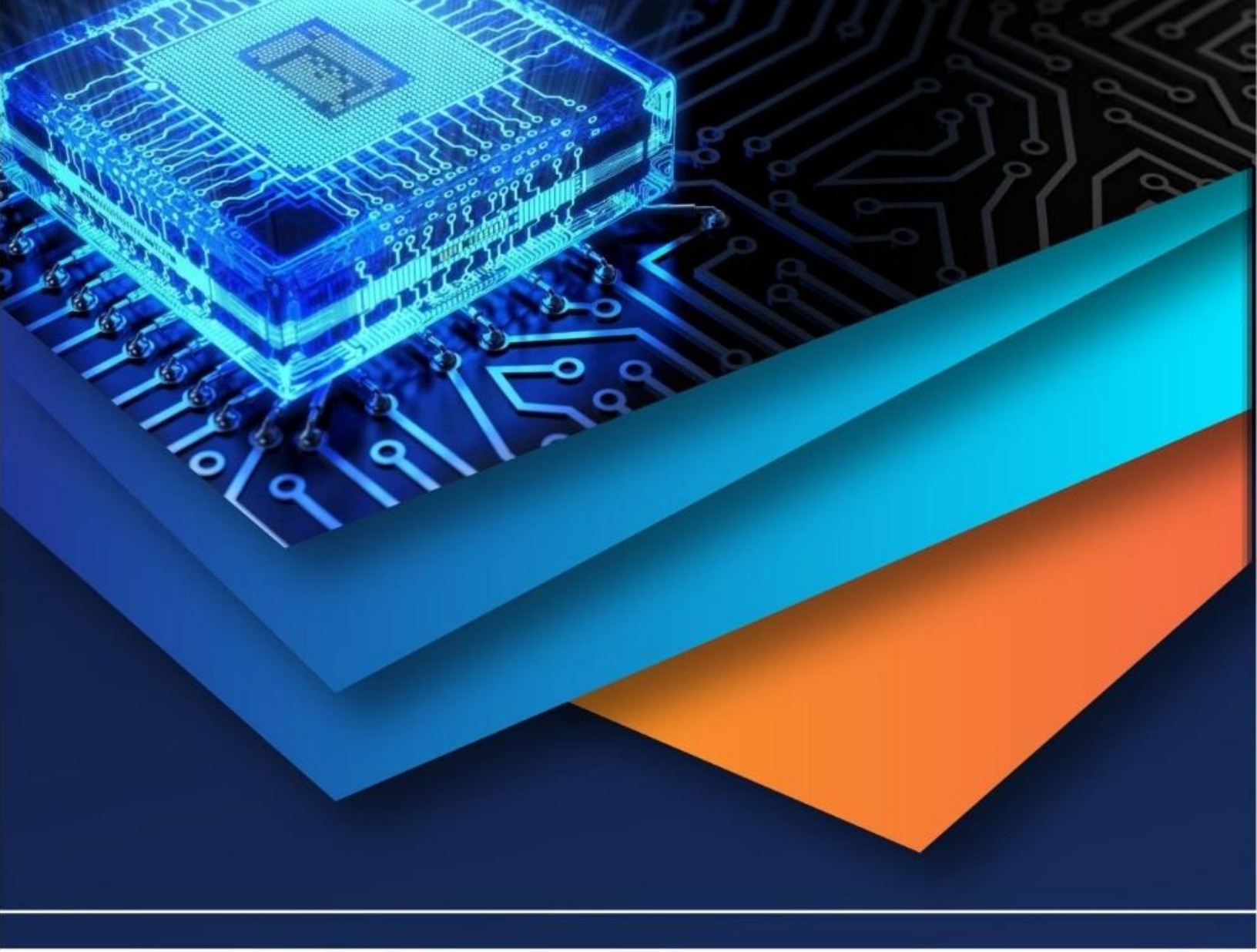
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