Performance Enhancement of OFDM System using Hybrid Channel Estimation with Pseudo Pilot

Mamta Arora, Paras Chawla

Abstract*: For high spectral efficiency and robustness against intersymbol interference (ISI), orthogonal frequency division multiplexing (OFDM) is the best suited technology for many applications such as digital audio broadcasting (DAB), wireless networks, digital video broadcasting (DVB) and LAN. For efficient recovery of the original transmitted signal we require the coherent demodulator as the frequency selective fading channels affects the transmitted signal in OFDM. At the receiver end for coherent demodulation we require channel state information (CSI), which is done by channel estimation. To find the channel characteristics which varies with time and frequency, a reference signal is transmitted with payload signal know as pilot or training sequence and technique or process is known as channel estimation. The use of pilots in the OFDM system leads to pilots overhead. So we propose a new technique which will reduces the transmission delay, reduce pilot overhead, increases transmission rate and improves the BER performance without any computational complexity, which is implemented using the Hybrid algorithm for channel based OFDM system. In this proposed technique, for the channel estimation in OFDM system over AWGN fading channel pseudo-pilots are used. At the transmitter end, pseudo-pilots are employed to breed bank of pseudo random symbol (PRS). In this OFDM system with pseudo-pilot the channel estimation is done by the Hybrid (LS + RLS) estimation approach to recover the original transmitted information. The performance of the proposed techniques and the weighted scheme are compared and verified using computerized simulation carried out using Matrix Laboratory (MATLAB) software.

***Index Terms*: OFDM, Pseudo-pilots, Least Square (LS), Recursive Least Square (RLS).**

I. INTRODUCTION

When high bit rate data is transmitted through channel the channel impulse response extents over various symbol periods. This increased symbol period of channel response leads to ISI [1]. To overcome this ISI in transmission, OFDM is the most suitable technique and moreover it is capable to handle high data rate [4]. In OFDM system data the whole bandwidth is divided into small sub-bands and each band of bandwidth has its own carrier known as sub-carriers. The Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT) operations are performed to convert parallel low rate frequency domain signal to time domain at transmitter end and time domain signals to frequency domain at the receiver respectively. Before the use of IFFT at transmitter end, pilots are added and to remove the channel effects from the received signal the information of the channel impulse response (CIR) is essential which is delivered by channel estimation done by channel estimator after FFT at the receiver end [3].

In this paper, to obtain channel estimation and synchronization we insert pilots with payload symbol. As the number of pilot transmitted each independently pilot burst, affecting the range of state in time domain and this cause overhead problem in OFDM system. To restrict the performance of the system we need to overcome the pilot overhead problem [2]. It is done by employing Pseudo-pilot and using Hybrid (LS+RLS) estimator. In OFDM system in place of pilot we transmitted the pseudo-pilot in order to overcome overhead in it. Pseudo-pilot reduced or even provides zero overhead with identical performance as conventional pilot system. Pseudo-pilot with hybrid of LS and RLS estimator is used as it mitigate overhead and improve OFDM performance with low complexity, delay time and high transmission rate.

1. System Model

The typical block diagram of an OFDM system with channel estimation model is figure1.

In OFDM model, data stream is first encoded by the channel encoder this operation of coding is known as forward error correction coding. Encoded data bits from the FEC act as input to interleaver in order to protect against the bursts errors. The main operation of interleaving is to randomize the burst errors which can be solve at receiver side by using decoding operation. In this system model we are use the block interleaver. Serial-to-parallel converter is used to put the encoded data bits into N parallel carriers by applying binary sequence of data at input of converter. The data obtained from S/P acts as a modulator which is then applied to bit-to-symbol mapping operation. There are many modulation techniques depending upon the data rates implemented into OFDM system including: QAM, PSK, QPSK, DQPSK [6].We use 16 Quadrature Amplitude Modulation (QAM) in this paper. The frequency domain data is converted to time domain sample with help of Inverse Fast Fourier Transform (IFFT). The signal value obtained from the IFFT operation is given by:

$$Xm(k)=(Xm(0),\ Xm(1),\ Xm(2)\ldots\ldots\ldots\ldots\ Xm(N-1)) \quad \ldots.(1.5)$$

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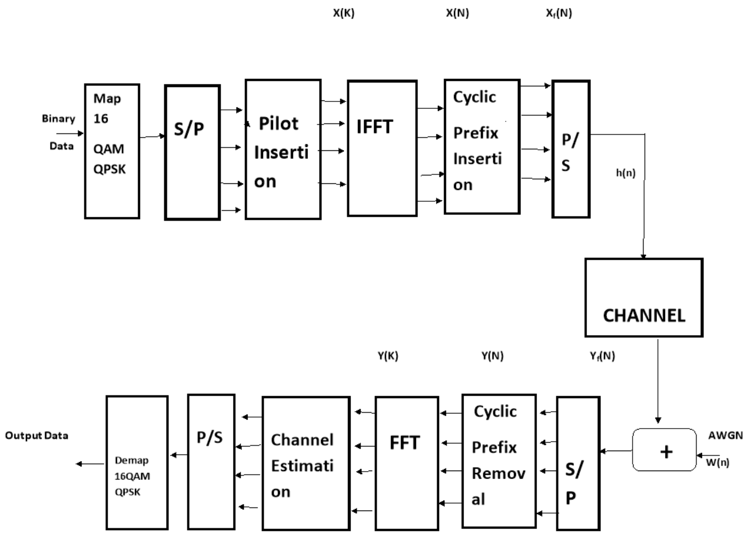

Fig.1: OFDM Model Design [6]

Where, Xm is the data vector with N number of modulated symbols.

After getting data from IFFT we add cyclic prefix (CP) into payload symbol. Cyclic prefix also known as zero symbol or known symbol is added into these serial stream. In CP end portion of the OFDM symbol is added at the beginning of the payload symbol.

CP is joined with data symbol to combat Intersymbol Interference (ISI) and Intercarrier Interference (ICI). After adding CP, the signal goes for the parallel-to-serial converter which is then ready for the signal transmission. During transmission these serial stream is goes through wireless channel [2].

At receiver side, the signal is received from the free space in which some unwanted signal or noise is added into the transmitted signal. Firstly, the received signal data is converted to parallel then fed to guard removal block where cyclic prefix is removed. At receiver side FFT is used to convert the time-domain sequence back into frequency-domain and get the received symbol data. After getting symbols from FFT they are demodulated and we get the received signal in frequency domain.

In wireless transmission due to noise, attenuation, multipath fading and phase shift, Doppler Effect etc. signal get distorted. To recuperate original transmitted signal at receiver end we need to find channel response which can be obtain by using channel estimation techniques like [5] Least Square estimation (LS), and Minimum Mean Square estimation (MMSE). In wireless communication system when signal is transmitted through the channel, at receiver end we receive only small amount of signal which is very low in term of power. When signal pass through free space channel some of the original transmitted signal lost due to noise or unwanted signal. The signal loss can be recovered by inserting some known signal before transmission at receiver side, these are known as pilot or reference signal [7]. So after inserting known signal, channel allowing our data to pass

through it and consists some kind of barriers that degrades the original payload signal. To decode signal at receiver without much error are to remove we need to find out the characteristics of the channel through which signal has gone. The process or technique use to find out characterize of channel is called as "Channel Estimation". In wireless, transmission through free medium effect the original signal and to figure out the properties of channel or estimate the channel in order to channel estimation is illustrate as following: 1. We employing the set of predefine or known signal called as reference signal. These reference signal transmitted with payload symbol and get distorted when go through free space i.e. noise, attenuation, phase shift effect the original signal. 2. We receive the some part of the original signal and decode the reference signal at receiver [8]. Compare the transmitted and received reference signal and find the correlation between them. In OFDM system, channel transfer function appears unequal at different subcarriers for wideband radio channel in time and frequency domain. So their required a dynamic estimation of channel. To estimate the channel properties and received signal pilot based approaches are used. The main objective of this paper is to analyze the channel estimation using hybrid algorithm in Pseudo-pilot channel based OFDM system.

II. INTRODUCTION TO PROPOSED SYSTEM MODEL

In most of the wireless communication system pilots are inserted in order to obtain the channel estimation. In OFDM system we have different techniques to find the channel response, pilot type arrangement is widely used in the communication system. But pilot type arrangement count as overhead in time domain. In simple OFDM system we transmitted the pilot signal also known as reference signal with payload symbols, where they are transmitted over free wireless channel. Wireless channel introduced the noise or unwanted signal into original signal. At receiver block every signal has a particular execution time but noise effect the length of the burst due to which the execution time is violated and there is large number of burst come in their time period and act as overhead in system. So in OFDM system to maximize the transmission rate of data symbol pilot should be less. In propagation environment with both high frequency and temporal fading the channel estimation can be improved by increasing pilot symbols.

But if we raise the pilot symbol in system the spectral competence of the data transmission is declines. In the communication system, channel varies with time and frequency. If channel changes its state slowly with time and frequency in OFDM system, pilot inserted cyclically and if channel is highly frequency dependent then plot inserted periodically at all the frequency simultaneously. If channel change its state very quickly with time the time intervals between symbols must be reduced in order to allow an accurate estimation of the channel through interpolation. This will increase the overhead in signal.

To overcome the overhead in OFDM system we need a new pilot insertion approach which overcome the overhead and follow highly predictable estimator. Pseudo-pilot is a novel paradigm of channel estimation in which we use the non-pilot assisted approach for channel estimation. Our main idea is to generate the pseudo random symbols (PRS) by using interleavers where we transfer the numbers of payload symbols by employing the banks of interleavers at the transmitter side. The symbols transmitted through the uncertainty, serves as pseudo-pilots for the receiver to perform channel estimation. Basic idea is to introduce pseudo random symbol interleavers also known as interleaver bank. At interleaver sample of signal is consider after shuffling of sample signal. The interleaver signal is rearrange in such a way that one of the arrangement of system is consider as reference and selected by selector which match one of the sub-lock before transmission of the signal. Interleaver rearranges the payload symbols block in numbers of ways so that at least one of the arrangement is contains a sub-block. Symbols within the sub-block are known as pseudo-pilot and these symbols are already known at receiver.Now these pseudo-pilot generated by interleaver is used for the channel estimation process in OFDM system. In the conventional OFDM system pilot are transmitted with the payload symbols which used to find channel impulse response but here bank of interleavers used to generate PRS those are served for channel estimation process. In the OFDM system there are many estimator used for channel estimation purpose we applied the Hybrid (LS + RLS) estimation approach to recover the original transmitted information.

III. WORKING

The OFDM system with Pseudo-pilot and hybrid channel estimation technique shown in Figure 2. The information signal in the form of binary data is act as input to mapping block where we map the signal in different modulation like BPSK, QPSK and QAM. In our proposed technique we map signal with 16-QAM modulation technique where each symbol is consist of 4 bits. OFDM is a multicarrier transmission technique where entire bandwidth dividing into small subcarriers and data transmission in parallel form, so serial to parallel converter is used to convert signal into parallel signal. Parallel data transmission allows the symbols containing the data to be large duration which reduced the multipath fading. Then parallel signal is act as input to bank of interleavers where pseudo random symbols (PRS) are generated. At banks of interleavers output we get symbols in parallel series which represent as:

$$[\ X(0), X(1), X(2), X(3)\ldots.X(L)] \qquad (1)$$

Where X(L) is the last symbol and loaded onto the L^{th} subcarriers

Inverse Fast Fourier Transform is use to overcome the complexity in system due to number of modulators and it convert the discrete frequency domain symbol X(k) into discrete time domain x(n). IFFT is perform on N number of symbols and given by

$$\text{IFFT} = x(k) = \frac{1}{N}\sum_{L=0}^{N-1} X(L)e^{j2\pi\frac{kL}{N}} (2)$$

Where x(k) is k^{th}sample and X(L) is symbols. After the IFFT operation we have symbols in time domain and represented as

$$[\ x(1), x(2), x(3), x(4)\ldots..\ x(k-1)] \qquad (3)$$

Cyclic prefix is used in system to avoid the inter-symbol interference. For that purpose we add the pre-fix the last or tail of the block and after prefix we have samples like

$$[\ x(k-1), x(1), x(2), x(3)\ldots x(k-1)\ ] \qquad (4)$$

By adding cyclic prefix we have convert the output of a channel i.e. linear channel or convolution into circular convolution which use to overcome the ISI in system. At the end of transmitter before transmission of the signal, parallel signal is convert back into serial and composite signal is transmitted using wireless channel.

In transmitter N numbers of subcarriers so there is N numbers of data stream so composite signal at transmitter is

$$S(t) = \sum_i S_i(t) (5)$$

WhereS(t) is composite signal and $s_i(t)$ is i^{th} data stream modulation onto the i^{th} subcarrier

$$S(t) = \sum_i X_i e^{j2\Pi f_i t} \qquad (6)$$

Where f_i is central frequency and equal to $i\,\frac{B}{N}$, so now

$$S(t)= \sum_i Xi\ e^{j2\Pi i\frac{B}{N}t} \qquad (7)$$

This is the required composite signal transmitted from the transmitter end with X_i as information signal and $i\,\frac{B}{N}$ as symbol rate of i^{th}subcarrier. Then composite signal is transmitted through an AWGN channel which introduced some distortion in the original signal.

At receiver side we use the coherent demodulator which is use to coherently demodulate each stream with corresponding subcarrier. When signal transmitted through free channel it experience noise and multipath fading which affect the original signal. The composite signal is transmitted over the channel due to which ISI is experienced by symbols. But addition of the CP we convert the channel output into circular convolution which overcomes ISI. At channel we have

y(k) = h(0) x(k) + h(1) x(k-1) + n (k) (8)

Wherey(k) received symbol across channel and h(k) is channel coefficient and n(k) is noise coefficient.

So here is circular shift of channel filter or taps over the samples [x(0), x(1), x(3) ….   x(k-1)]. It is circular convolution and represented as

y = h ʘ x + n   (9)

Where ʘ is circular convolution and circularly shift the channel due to CP and overcome ISI. So at demodulation process first of all composite signal is converting back to parallel form and after it cyclic prefix remove. Fast Fourier transform (FFT) convert discrete time domain signal into discrete frequency domain. So here we take FFT of the received signal which is given by

$y(l) = \frac{1}{N}\sum_{k=0}^{N-1} x(k)e^{-j2\pi\frac{kL}{N}}$ …   (10)

FFT (y) = FFT(h ʘ x + n)   (11)

= FFT (h ʘ x) + FFT (n)

= FFT (h) * FFT(x) + FFT (n)

So here * is the product and circular convolution in the FFT domain i.e. frequency domain. For channel estimation pseudo random symbols (PRS) are employed to Hybrid (LS + RLS) estimator. The detector has characteristics to ensure successful equalization i.e. removal of ISI. After successfully equalization signal get back into original position by rearranging by de-interleaver and after demodulation of the rearranged signal we get the recovered original information signal.

In reception process of signal we use the coherent demodulator where we get the signal through different subcarrier$\frac{B}{N}\int_0^{N/B} y(t)(e^{j2\pi f_i t})dt$(12)

Where y(t) is received signal and f_i is central frequency so the signal we get at receiver end with composite signal is $\frac{B}{N}\int_0^{N/B} Xi\, e^{j2\pi i\frac{B}{N}t}(e^{-j2\pi\frac{LB}{N}t})dt$

$\frac{B}{N}\sum_i\int_0^{N/B} Xi\, e^{j2\pi(i-l)\frac{B}{N}t}\, dt$ (13)

So we know that the central frequency of system is $F_0 = \frac{B}{N}$ and symbol time is

$T_0 = \frac{1}{F_0} = \frac{N}{B}$when i = l then we get from

$\int_0^{N/B} dt = \frac{N}{B}$(14)

So here all subcarriers except the l^{th} subcarrier are orthogonal to the l^{th} subcarrier.

IV. Algorithms

STEP 1: the signal constellation value (16).
STEP 2: Enter length of the input bits to process (1000).
STEP 3: Define the number of bits per sample ($\log_2(16)$).
STEP 4: In this step we will define number of sample per symbol which is equal to one.
STEP 5: Data generation randomly in zero's and one's form with vector of binary data.
STEP 6: QAM modulation is used
STEP 7: For convolutional encoding data constellation length define (Length of encoder =7) with code generated polynomial [171 133]. After get round of value QAM data is convert from decimal to binary and we will get binary encoded data.
STEP 8: Pilot are inserted into payload data, total 4 numbers of pilot inserted with pilot data size = 52
STEP 9: Bank of interleavers are inserted in transmitter side to generate the pseudo random symbol (PRS) with equal probability.
STEP 10: Inverse Fast Fourier Transform (IFFT) is use to convert discrete frequency domain into discrete time domain. In IFFT input each input control signal at one frequency complex value representing data, where at output samples of modulated and multiplexed signals.
STEP 11: Add Cyclic prefix to the data.
STEP 12: Noise AWGN is generated.
STEP 13: Add noise AWGN to the signal at the channel output.
STEP 14: At receiver side firstly, remove the cylic Prefix.
STEP 15: At receiver side Fast Fourier Transform use to convert discrete time domain into discrete frequency domain i.e. fft_sig=fft(cext_data)
STEP 16: Total numbers of OFDM sub carriers are 128.
STEP 17: Transmitted signal power cab be calculated using following equation:
powerDB = 10*log10(var(fft_sig))
STEP 18: Noise variance calculated by using: noiseVar = 10.^(0.1*(powerDB-snr)) where signal pass through noisy channel.
STEP 19: Dispreading of data occurs by detector.
STEP 20: For least square we define the finite impulse response with step size equal to 0.08 and length =32 and calculate the bit error rate using equation:
data_lms=abs(e/sum(out_sig))
STEP 21: Output of LS estimator provide to RLS estimator by defining correlation matrix inverse as{ p0=10*eye(32)}and RLS forgetting factor as 0.99
STEP 22: Calculate the bit error rate (BER) by using Hybrid (LS+RLS) estimators
So we find that estimation by using Hybrid (LS+RLS) is better than simple LS estimator by using pseudo-pilot.

V.SIMULATION AND RESULT

In this section, we will analyses and observe the result of the proposed technique. This analysis will be carried out with respect to various parameters of evaluation. The result of the proposed Hybrid (LS+RLS) technique is the observed with the conventional Least Square (LS) technique as LS technique is absolutely one of the various techniques for BER reduction in channel estimation. All the simulation results are carried out in MATLAB.In figure 3, the binary data is encoded; symbols which act as training sequences are inserted as the length of the encoded data define. Symbol sequences are inserted into real and imaginary term as 3+3j. In the payload symbol, size of the sequence defined as 52 and upsizing up to 64 bits.

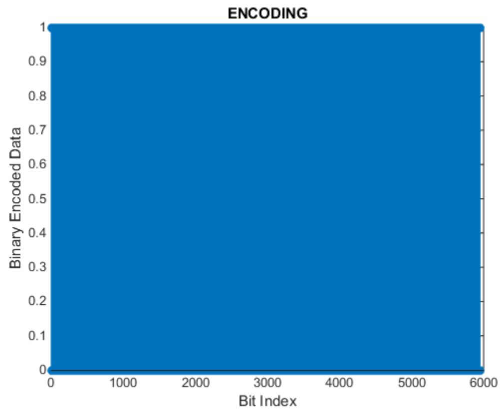

Figure 3:Encoding of binary data

Interleavers are used in to generate the pseudo random signal according to the length of the signal provide as input to interleavers. Interleavers rearrange the symbol sequence and one of the rearranged sequences is match with the reference sequence of block and that block of sequence is act as pseudo random sequence used for channel estimation. QAM modulation technique is used with modulation size 16. During transmission of signal through free space AWGN noise is added into the original signal.

In the proposed technique we used total 128 OFDM subcarriers. E_b/N_o in the system defined in the range (0 to 20). At receiver side we calculate transmitter signal power side and noise variance.

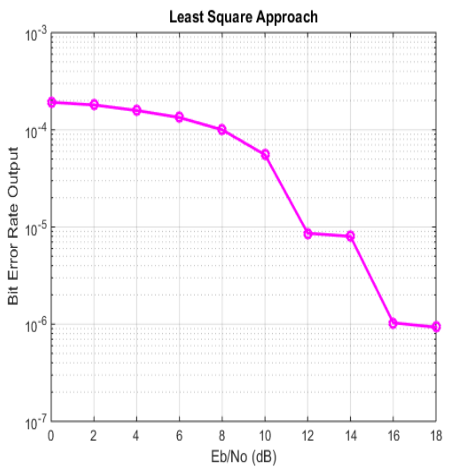

Figure 4: BER performance for LS Estimator

Figure 4, shows the effect of SNR on Least Square (LS) approach by employing pseudo-pilot for channel estimation purpose. It is observe that with the increase of SNR, QAM symbol is more distinguishable and bit error rate (BER) decreases.

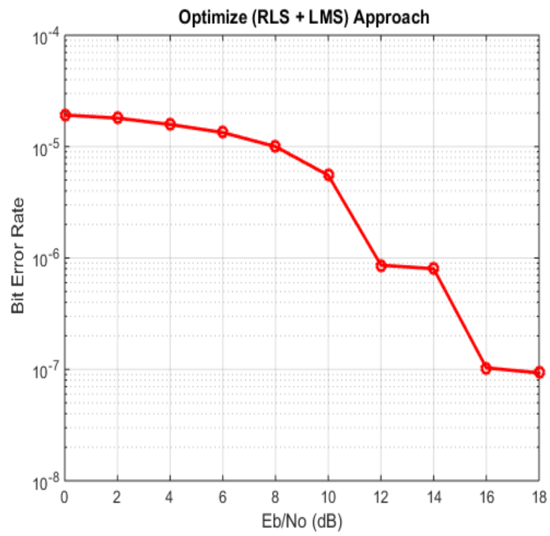

Figure 5: BER performance for Hybrid (LS+ RLS) Estimator

We have already observed the effect of fading channel on the BER for QAM modulation in LS approach. Now we will observe the performance of Hybrid (LS+RLS) Least Square and Recursive Least Square with pseudo-pilot approach is shown in figure 5.

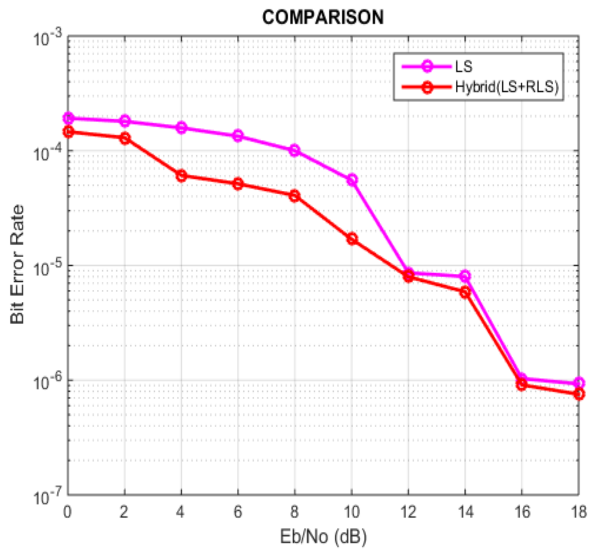

Figure 6: Comparison of LS estimator and proposed Hybrid technique

Figure 6, shows the effect of SNR on Hybrid approach. It is observed that with increase of SNR, bit error rate (BER) decreases as compare to LS approach. In the graph 6, the performance of OFDM system is evaluated on the basis of BER w.r.t SNR (E_b/N_0) ratio. AWGN channel is used for both techniques proposed as well as conventional for SNR ranging between 1 and 20. According to the graph 6, the performance evaluation shows that BER performance of the hybrid (LS+RLS) technique is better than Conventional (LS) techniques. In other words, the proposed technique provides greater transmission rate and low execution time delay while slightly improving the BER performance.

VI. CONCLUSION

In this paper, we have investigated channel estimation based on Hybrid (LS+RLS) algorithm in OFDM system. Performance of this algorithm is also analyzed for pseudopilot aided system. Further the estimation technique is also investigated for pseudo pilot with LS and AWGN fading channel. Graphical results show that channel estimation based on pseudo-pilot with hybridalgorithm gives optimum results. It has also been observed that system execution time and overhead reduced, transmission rate increases and BER performance is better than conventional LS pseudo-pilot based channel estimation technique. Hybrid (LS+RLS) algorithm using Pseudo-pilot channel based OFDM system could also be investigated for other model of multipath fading channels.

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