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Comparison between the Superimposed Training Sequence and Conventional Training Sequence on OFDM System

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Abstract **— Many universities are involved in projects related to the design, assembly and operation of fast fading channel to increase the experience level of researchers and students. For high speed data communication, the recovering data operation from the noisy data corrupted with inter-symbol interference (ISI), the equalizers are necessary components of the receiver architecture. Fading is one of main problems which affect on the transmitted signal through medium have many obstacles. In this medium the signal suffers from three phenomena: reflection, refraction and scattering. The fading come from these phenomena's defined as multipath fading. The fast fading is used to describe channels when the coherence time of the channel < transmission symbol time. The superimposed training sequence is one modern technical employed to decrease the effect of multipath fading channel. The aim of this paper is to investigate and compare the effect of using superimposed training sequence technique instead of the conventional training sequence (CTS) in OFDM systems for three kinds of modulation schema (BPSK,QPSK and 16QAM) to meet the fast fading Rayleigh channel, caused by multipath, requirements, based on the use of RLS adaptive equalizer.**

Keywords **— Fast Fading Channel, Recursive Least Square Equalizer, Superimposed Training Sequence STS.**

I. INTRODUCTION

Channel is a medium, which transfer data or information from transmitter to receiver. Channels include the physical medium like free space, fiber, waveguides etc. The features of any physical medium is that, the transmitted signal is corrupted in various way by frequency and phase distortion, inter symbol interference, thermal noise etc and the receiver receives the corrupted signal [1].

Estimation means prediction, detection or approx calculation. Channel estimation is simply defined as the process of characterizing the effect of the physical channel on the input sequence. We can say a channel is well estimated when its error minimization criteria is satisfied [1]. Channel estimation gives the basic idea of the effect of the physical channel on the input sequence of the receiver [2]. The error can be minimized by equalization technique. Channel estimation algorithms explain the behavior of the channel and allow the receiver to approximate the impulse response of the channel. In this paper, RLS algorithm is implemented for OFDM fast fading channel equalization. The work study presents a comparison between the performance of the use of the conventional training sequence and superimposed training sequence in equalizing OFDM system channel.

In the previous works, December 1999, Hoeher P and Tufvesson F [2], performed a superimposed pilot training sequence technique based on the Viterbi algorithm, for purpose of channel estimation in receiver.

.January 2005 Mounir Ghogho, Des McLernon, Enrique Alameda-Hernandez, and Ananthram Swami [3], showed that best estimation can be got when the training sequence is arithmetically added to the OFDM transmitted data instead of putting in an empty part of time slot. November 2007 Yang, Q. and Kwak, KS [4]: in "Optimal superimposed training for estimation of OFDM channels", introduce an optimal method for using superimposed pilots in channel estimation for OFDM system using Wiener filter. This algorithm is a device to find set of the optimal rectangular of time-frequency samples for the complex channel estimation.

Rest of the paper is organized as follows: a general background is presented in section II. Comparison between STS & CTS based on OFDM system is presented section III. Simulation and results is implementing in section IV. Finally, in section V concludes the paper.

II. GENERAL BACKGROUND

1. Conventional training sequence

Conventional training sequence used Matrix Concatenate to add the training sequence, the benefit for this method is to isolation the data frame form the affecting area during the transmutation time and make the insulator between the data frames. CTS consider as one technique for channel estimation and equalization by add random data to the OFDM frame in the transmitter and used equalizer like LMS, RLS, LS to remove this training from the OFDM frame, the main benefit of training sequence to support the channel estimation and estimate the channel coefficients by stored the same training sequence in the receiver. The mobile communication (GSM) set the standardize to add the training sequence like other parameters such as frequency hopping, TDM and time slot, especially for GSM like GSM synchronization burst which used 26 bit from transmitted frame to employed the training sequence as shown in figure (1).

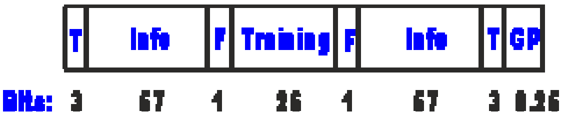


Fig.1: GSM Normal Burst

In figure (2) showing the conventional training sequence receiver, the channel impulse response was estimated by the known training sequence stored at the receiver [7].

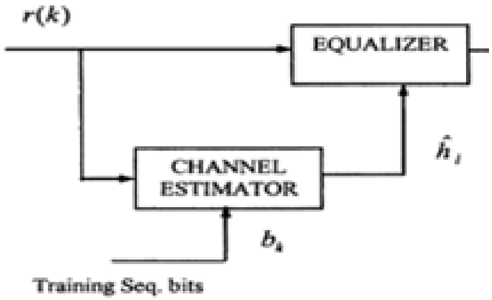


Fig.2: Conventional GSM receiver [1]

The complexity is evaluated by the total operation needed in receiving one GSM block. The interleaving and de-interleaving processes are ignored in this complexity calculation. Channel sounding is used as channel estimation algorithm for both training sequence estimation and iterative channel estimation. The operation needed for one GSM burst is shown in Table 1. For soft decision feedback, a look up table used to convert the log likelihood ration (LLR) of each transmitted data into soft values [6].
Equalization is performed burst by burst and the decoding is taken when it receives the whole speech block. So the equalization and decoding complexity are estimated in term of the number of operation needed for equalizing one burst and decoding one speech block.

Operation	Channel Sounding		
	Training Sequence Estimation	Iterative Channel Estimation	
		Hard Decision Feedback	Soft Decision Feedback
Multiplication	$M_{CIR}L_t$	$M_{CIR}(L_B - M_{CIR})$	$M_{CIR}(L_B - M_{CIR})$
Addition	$M_{CIR}(L_t - 1)$	$M_{CIR}(L_B - M_{CIR} - 1)$	$M_{CIR}(L_B - M_{CIR} - 1)$
Look-ups			$L_B - M_{CIR} - 26$

Table 1. The Complexity of channel sounding [3]

M_{CIR}: Number of estimated channel impulse response taps.
L_t : Number of training sequence bits used in channel estimation.
L_B : Length of a GSM normal burst excludes guard bits.

2. Superimposed training sequence

We specific the issue of fast fading channel estimation by using the superimposed training sequence, the superimposed training sequence included of algebraic sum of known and unknown sequence , Researchers were identified this known sequence like pilots sequence which used in communication system to reliable transmission channel wireless [8].
Researches performed to a method decrease the BER during channel estimation. This method included comprises for the training sequence in the transmitter and receiver for channel estimation steps to bring the superimposed received data together with the input data. The cross-correlation role to take the received data with to an estimate time delay defines by the rms delay spread of the channel. The superimposed training sequence stored in a register on the receiver and it is the same training e sequence which is added to the OFDM frame in the transmitter. At the receiver end, the cross-correlated data being proceed over a length custom of samples that can be make long to used and compared the coherence time of the channel and operate along with the stored values in the register of the inverse of auto-correlation of STS so as to get a better channel estimate.
In this work and for best performance the OFDM system need to bandwidth efficient channel estimation. The training symbols, being known and stored in the receiver end are algebraic addition to the data. this method for adding that avoiding using additional time slots for training sequence, at the receiver the noise and unknown data used for channel estimation as shown in fig. (4)[5].

$$X_k = S_k + C_k \quad (1)$$

The X_k is the summation of the input data and C_k is the training sequence hen is pass through OFDM system this data will modulated and occupies all sub band of OFDM system by components of matrix as writing in equation (2) to protect from inter symbol interference.

$$c_k(m) = e^{j\frac{2km}{N}}\left(\frac{m}{2} + 1\right) \quad (2)$$

m th is the row of the vector. This sequence will sum with guard band which are specified according to standard of OFDM system.

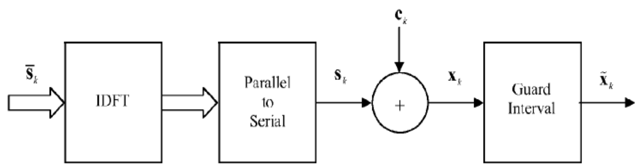


Fig.3: the block of the transmitter of a STS based OFDM system. [3]

Figure 3 show the method and location for adding the training sequence to the OFDM system. Binary data is collected into symbols depending on the level of modulation schema used. $\bar{S}_k$ Vectors of such symbols are formed after those are passed to the IDFT. Here k represent for the OFDM symbol index. some of values which entries are zero to meet the requirements of the spectral mask of the OFDM system. The output of the IDFT is $s_k = F^H \bar{s}_k$, Where F is the normalized N×N DFT matrix with $F(m,n) = \frac{1}{\sqrt{N}\, e^{-\frac{2j\pi mn}{N}}}$ and F^H is the complex conjugate transpose. Here (m,n) is the m th row and nth column of the matrix. A multiplexing add to the end of transmitter to convert from parallel to serial after exit from

IDFT. A training sequence c_k is then algebraic addition to this IDFT output `with a specific low training to data power ratio.

In this case the training sequence is given by

$$c_k(m) = IDFT_N\left\{DFT_N\left[e^{j\frac{2km}{N}}\left(\frac{m}{2}+1\right)\right] \times W_{(k)}\right\} \quad (3)$$

W (k) is the frequency domain window function used to meet the requirements of the spectral mask of the OFDM system. Here w_k can be any spectral mask including a rectangular function defined for $0 \le k \le N-1$ The DFTN[x (n)] and IDFTN[X(k)] are defined as,[9]

$$DFT_N[x(k)] = X(k) = \int_{N=0}^{N-1} X(n) e^{-j\left(\frac{2\pi nk}{N}\right)} \quad k=0,1,...N-1 \quad (4)$$

$$IDFT_N[x(k)] = X(n) = \frac{1}{N}\int_{k=0}^{N-1} X(k) e^{j\left(\frac{2\pi nk}{N}\right)}, n=0,1,...N-1 \quad (5)$$

III. Comparison Between Sts & Cts Based On Ofdm System.

The main work in the paper is two make comparison between the conventional training sequence and superimposed training sequence and show the addition method(as shown in section **II**), and the effecting on the signal output resolution when we compare the signal constellation , power spectrum and BER value between the received signal from Rayleigh multipath channel before equalizer and after equalizer and channel estimation process.

The type of the training sequence is random date with normalized average power. In the case of superimposed the training is algebraic sum with the input data to cover all the transmitted frame before pass through multipath channel. In the conventional training sequence the training date is add by use Matrix Concatenate after the input data.

All the OFDM symbol passed on the transmission channel after exit from the guard band, the situation will work on it for transmission channel types is the fast varying time channel that caused by multipath of three path with different power gain and time Daley and consider the OFDM symbol passed through adaptive white Gaussian noise AWGN after delivered from Rayleigh fading channel.

IV. Simulation And Results

This simulation and evaluation tests for the effect of superimposed training sequence and conventional training sequence in OFDM systems. The adaptive algorithm of a Recursive least sequences estimation is implemented here using MATLAB environment. Because the parameter estimation depend on structures of the received signals (such as, conventional training sequence), this technique is applicable to a wide range of present and future OFDM based communications standards. The accuracy of the OFDM parameter estimation and consequently the performance of the compensation is arbitrarily scalable, allowing for a flexible trade off between performance, computational effort and measurement time. The performance of the simulated systems is evaluated for three modulation techniques BPSK, QPSK and 16QAM. The simulation results are performed using MATLAB (R14). The results are documented for two scenarios; the first is the conventional training sequence with adaptive equalizer, and the second superimposed training sequence with adaptive equalizer.

By using a simulation program in MATLAB 2014b (R14), the effect of the superimposed training sequence and conventional training sequence parameters will be discussed by employing the signal constellation diagrams, Bit Error Rate (BER) characteristics and the power spectrum for the transmitted and received signals.

Table 2 Parameters values used in the simulation IEEE 802.11a

Parameter	Specifications
FFT Size	64
Number of subcarriers	52
Conventional Training sequence	52
Superimposed Training sequence	52
Guard Length	25% (16 samples)
Guard Type	Cyclic Extension
Wireless Channel	Rayleigh fading channel + AWGN
Signal Constellation	BPSK,QPSK and 16-QAM
Equalizer types	Adaptive equalizer (RLS)

The Table (2) is shows the parameters values which used in OFDM system according to IEEE 802.11a standards. The model supports all of data rates. The model implements adaptive modulation and coding over dispersive multipath fading channels. Note that the model uses an artificially high channels fading rate to make the data rate change further rapidly and thus make the imagining more animated and useful.

The model included components that model the important features of the WLAN 802.11a standard the right side row of blocks comprises the transmitter components though the left side comprises the receiver components. The communication system in this model performs these tasks: Generation of random data at a bit rate that varies during the simulation [6]. The varying data rate is complete by enabling a source block periodically for a period that depends on the favourite data rate. Coding and modulation using one of numerous systems specified in the standard.BPSK, QPSK,and16-QAM modulation. OFDM transmission using 52 data subcarriers, training sequence, 64-point FFTs, and a 16-sample and cyclic prefixes, dispersive multipath fading channels and receiver equalization and Viterbi decoding.

1. Conventional training sequence with OFDM system by using RLS equalizer.

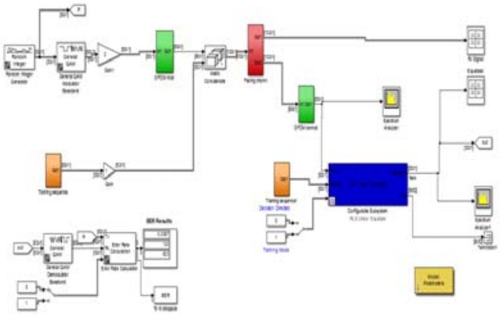
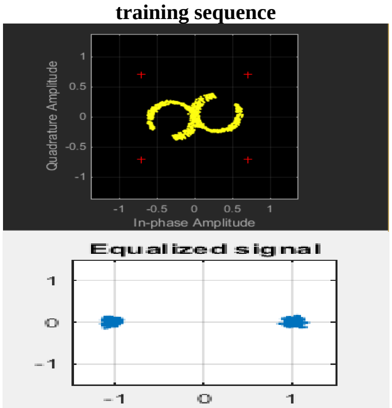


Fig. 4: the OFDM system with RLS equalizer and conventional training sequence



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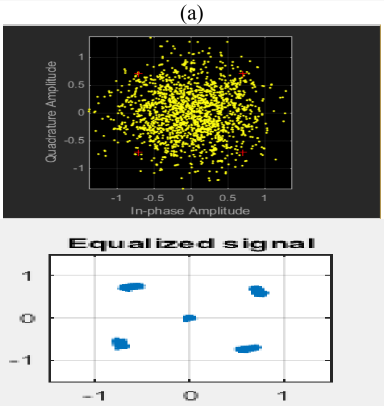

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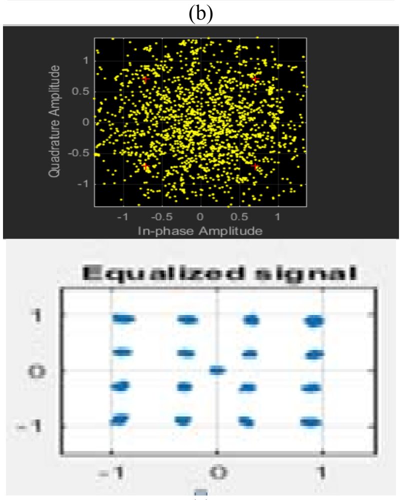
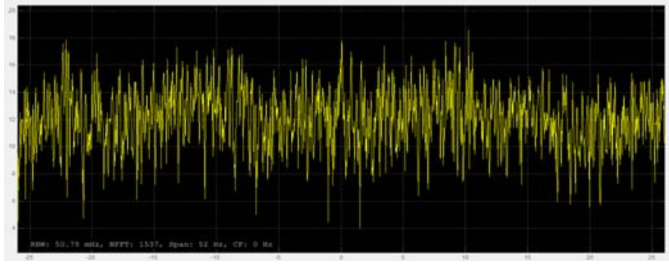


(c)

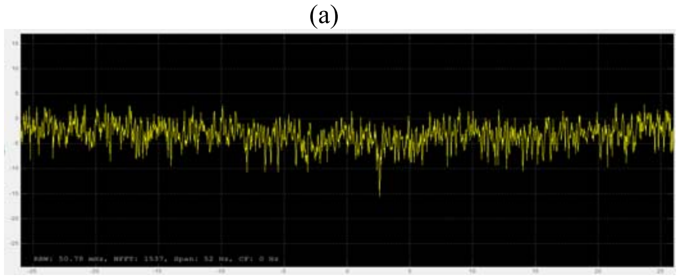
Fig.5: OFDM system with RLS equalization Conventional TS signal constellation before and after equalizer. (a) BPSK (b) QPSK (c) 16 QAM

Fig.5 Shows the difference in signal constellation between the received signals before equalizer and after equalized. The equalized constellation show clearly the role that equalizer played to improve the received signal by two clear amplitude in phase amplitude.

The figures below are showing the power spectrum for the transmitted and received signal for three modulation techniques.



(a)



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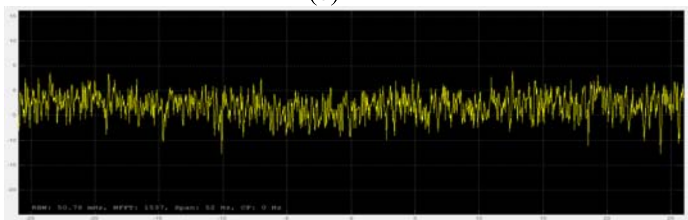

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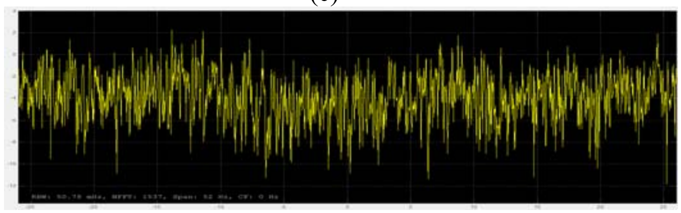


(d)

Fig.6 OFDM system with RLS equalizer and Conventional TS power spectrum for three modulation techniques. (a) Transmitted (b) received BPSK (c) received QPSK (d) received 16QAM

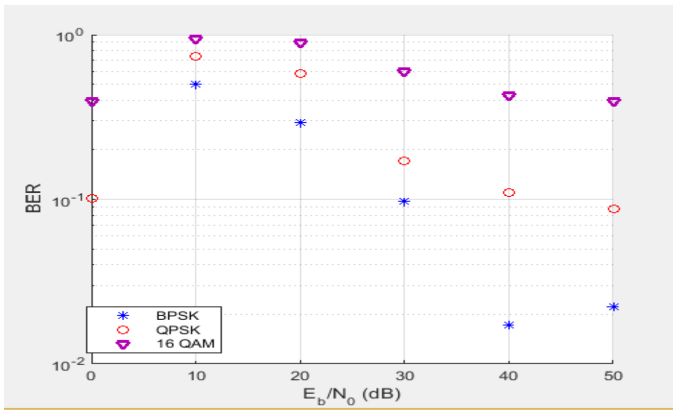


Fig.7: BER for OFDM system with RLS equalizer by using CTS

2. **Superimposed training sequence with OFDM system by using RLS equalizer**.

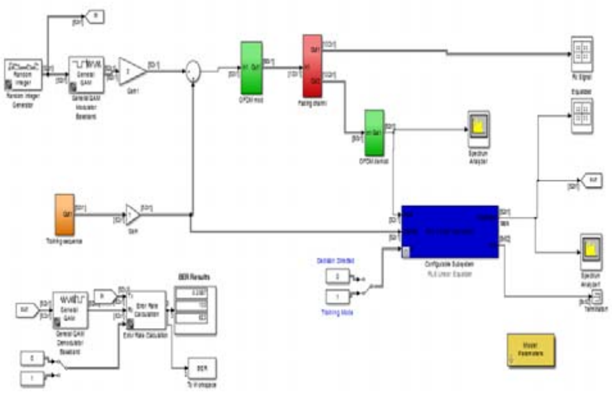
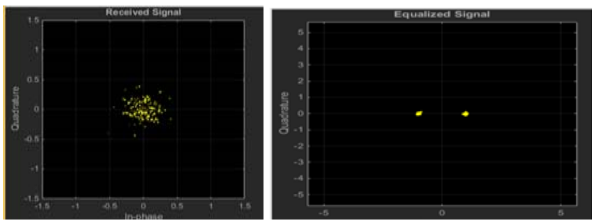


Fig.8: The OFDM system with RLS equalizer and STS

Superimposed training sequence can be used with OFDM system to prevent the inter symbol interference ISI which appeared in fading channels as a resulted from multipath fading. This sequence is a random sequence not has any information which added to the frame of data after passed through modulation mapped.

The addition of training sequence the is the direct sum with the input data (algebraic summation) after added process completed. The compacted signal enters the OFDM modulation and transfer into channel. At receiving end we used the equalizer to remove the effect of fast fading channel by training sequence which is used as the desired input to equalize the received signal, where the superimposed training sequence being a reference input.

The training sequence is stored in register on receiver end and the proposed for this store is make good synchronisation between the transmitter and receiver when the integer data generation start generate the input data , it data. This synchronisation can be considered as an essential additional work to be ensured for training sequence. The figures below are showing the signal constellation for the transmitted and received signal for three modulation techniques.



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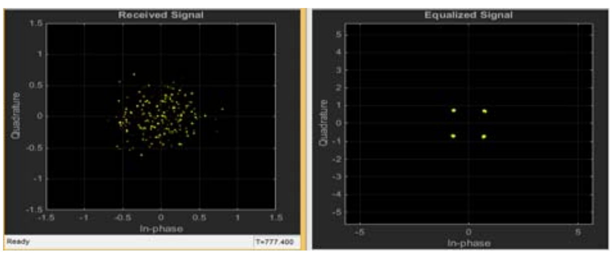

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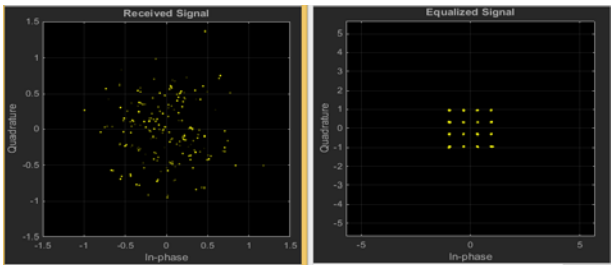
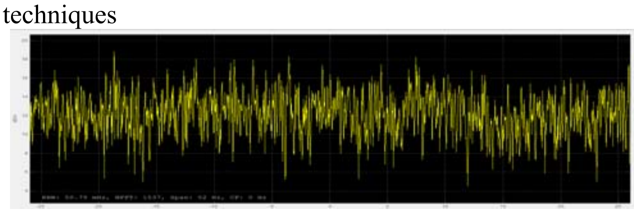


(c)

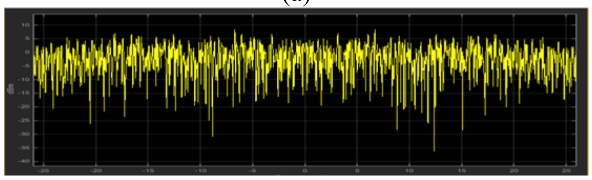
Fig.9: OFDM system with RLS equalization and STS signal constellation Before and after equalizer. (a) BPSK (b) QPSK (c) 16 QAM

Figure 9 show the difference in signal constellation between the received signals before and after equalized. the equalized constellation show more clearly the role that equalizer played to improve the received signal.

The figures below are showing the power spectrum for the transmitted and received signal for three modulation techniques



(a)



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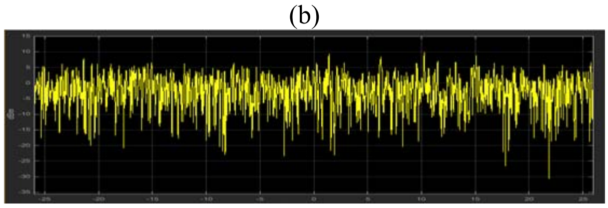

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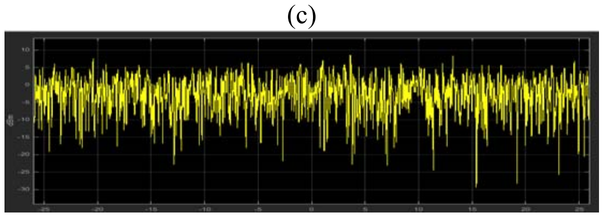

(d)

Fig.10: OFDM system with RLS equalizer and STS power spectrum for three modulation techniques. (a) Transmitted (b) received BPSK (c) received QPSK (d) received 16QAM

The above figures are showing the power spectrum for the transmitted and received signal when using superimposed training sequence for three modulation techniques. Fig. 10(a) shows the received signal power spectrum before passing into the RLS equalizer. The equalized received signal power spectrum after the equalizer for the three modulation techniques are shown in Figs. 10(b), (c), and (d) for the range on dB axis between -10 to 5 dB, where the decrease in spectrum fluctuations can be noticed. The spectrum is showing approximately satiable on zero values.

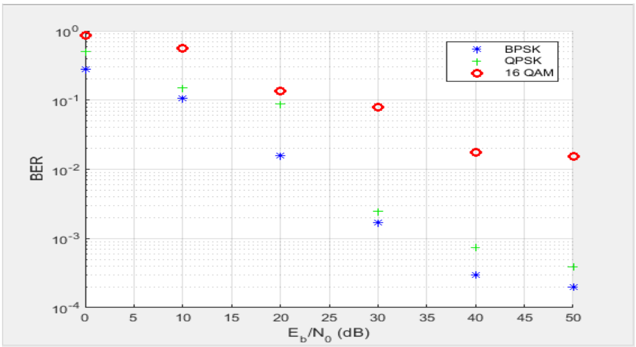

Fig.11: BER for OFDM system with RLS equalizer by using superimposed training sequence.

In the Fig. 11, the Bit error rates (BER) of the various BPSK, QPSK and 16-QAM modulation techniques are compared for RLS adaptive block equalizers. The simulation is performed on MATLAB software. The various input parameters used for the simulation are given in the Table 1. In the research the channel is modeled with normalized Channel Impulse Response (CIR).

It is found that using superimposed training sequence improves the performance of equalizers significantly. It is found that RLS equalizers can achieve minimum BER order of 10^{-4}. Channel Normalization produces the smooth BER curves and also reduces the error probability. The BER performance of the different M-PSK with M = 4, 16, are, compared for RLS equalizer under the frequency selective fading channels respectively It can be observed that up to around 16 dB the proposed system with normalized CIR performs approximately similar for all PSK sizes.

V. Conclusions

In this work, the objective was to present the superimposed training sequence compared with the conventional training sequence which applied on OFDM system to resolve the fast fading channel difficulties to provide better BER performance and reduce the effect of inter symbol interference (ISI). This job was accomplished in three types of modulation techniques: BPSK, QPSK and 16 QAM and with adaptive equalizer recursive least square (RLS) on the multipath channel consist Rayleigh fading channel and AWGN. It was found that the best results are obtained for the case when BPSK modulation is used compared to QPSK or 16QAM modulation techniques. The best BER level was found when using superimposed training sequence with RLS adaptive equalizer, it about 10^{-4} starting from 50 E_b / N_0 values.

From the signal constellation figures found that the accurate and clear constellation obtained when using superimposed training sequence with RLS equalizer especially in BPSK modulation technique. The power spectrum figures showed the stability of the frequency spectrum along the Zero value in dB axis with small fluctuations with values between -5 to Zero appear when using superimposed training sequence with RLS equalizer and the second rating it when using LMS equalizer with superimposed training sequence , it's about -7 to 5 dB.

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