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Reduction of Impulsive Noise in OFDM System Using Adaptive Algorithm

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Abstract**—**The Orthogonal Frequency Division Multiplexing (OFDM) with high data rate, high spectral efficiency and its ability to mitigate the effects of multipath makes them most suitable in wireless application. Impulsive noise distorts the OFDM transmission and therefore methods must be investigated to suppress this noise. In this paper, a State Space Recursive Least Square (SSRLS) algorithm based adaptive impulsive noise suppressor for OFDM communication system is proposed. And a comparison with another adaptive algorithm is conducted. The state space model-dependent recursive parameters of proposed scheme enables to achieve steady state mean squared error (MSE), low bit error rate (BER), and faster convergence than that of some of existing algorithm.

Keywords**—**OFDM, Impulsive Noise, SSRLS, BER.

I. Introduction

THE Orthogonal Frequency Division Multiplexing is a variant of signal modulation that splits the modulated high data rate stream into many slow modulated narrowband close-spaced subcarriers and is less sensitive to frequency selective fading. Therefore OFDM has attracted much attention in past decades and is successfully implemented in the cellular communication standards like LTE / LTE-A and WiMAX. Digital Audio/Video broadcasting standards have also adopted OFDM making it suitable for high data throughput [1].

OFDM is normally corrupted by the impulsive noise, which is non-Gaussian in nature and has disastrous effects in OFDM transmission. The performance of OFDM system is degraded by the multiple impulsive noise existence in received OFDM signal because of its wide frequency component. Researchers are inspecting solutions for mitigating this type of noise, and therefore improving systems performance in terms of mean square error and bit error rate.

Various techniques are reported in literature which attempt to suppress the impulsive noise from the original transmitted signal. Researchers are inspecting solutions for mitigating this type of noise, and therefore improving systems performance in terms of mean square error and bit error rate. Various techniques are reported in literature which attempt to suppress the impulsive noise from the original transmitted signal.

The conventional method for removal of impulsive noise is the median filter with some signal degradation [2]. The impulsive noise suppressing techniques of clipping and nulling are proposed in [3], [4]. The bit error rate performance metric in OFDM systems is improved by combination of clipping and nulling [5]. The sample replacement [6] algorithm was proposed to cater for removing multiple impulsive noises in received OFDM signal. However the replica signal subtraction method [7] was proposed to solve the problem when impulsive noise arises between the OFDM samples in time domain. In [8], the replica of impulsive noise is generated and subtracted from the received OFDM signal in an iterative manner for impulsive noise reduction.

In [9], the Periodic impulsive noise from OFDM based power line communication systems was suppressed by notch and Least Mean Square algorithms. The NLMS, RLS, VSNLMS adaptive filters based receiver technique for removing impulsive noise from the MIMO-OFDM system was designed in [10].An impulsive noise canceller of sinusoidal and ECG signal based on SSRLS filter [11], [12] in time domain is proposed. In addition comparison of SSRLS with RLS and NLMS adaptive algorithm was carried out. Another new technique based on Clipping and Adaptive Filters in AWGN Channel for impulsive noise reduction is proposed in [13]. In this paper, an impulsive noise suppressor for OFDM system is implemented by motivational results obtained in [11]-[13].

This paper is organized as: Section II briefly explain the principle of OFDM, Section III gives the review of different adaptive filters which is followed by comparative analysis supported with the simulation results in section-IV. In the end, section V then concludes the paper and is then followed by the references.

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II. OFDM

The Orthogonal Frequency Division Multiplexing is a multicarrier modulation in which transmission over a dispersive channel is carried out. The basic block diagram of OFDM system is shown in Fig. 1. In OFDM the high data rate streams are split into low data rate streams in parallel and modulated separately on different orthogonal sub-carriers. The introduction of pilot insertion and cyclic redundancy at the transmitter reduces the complexity to only Fast Fourier Transform FFT processing on the receiver side. These subcarriers are multiplexed and passed through the channel, which is responsible for adding impulsive noise and white Gaussian noise in the transmitted OFDM signal. At the receiver side, the signal is demodulated and passed through the adaptive filter block for impulsive noise reduction in the OFDM signal.

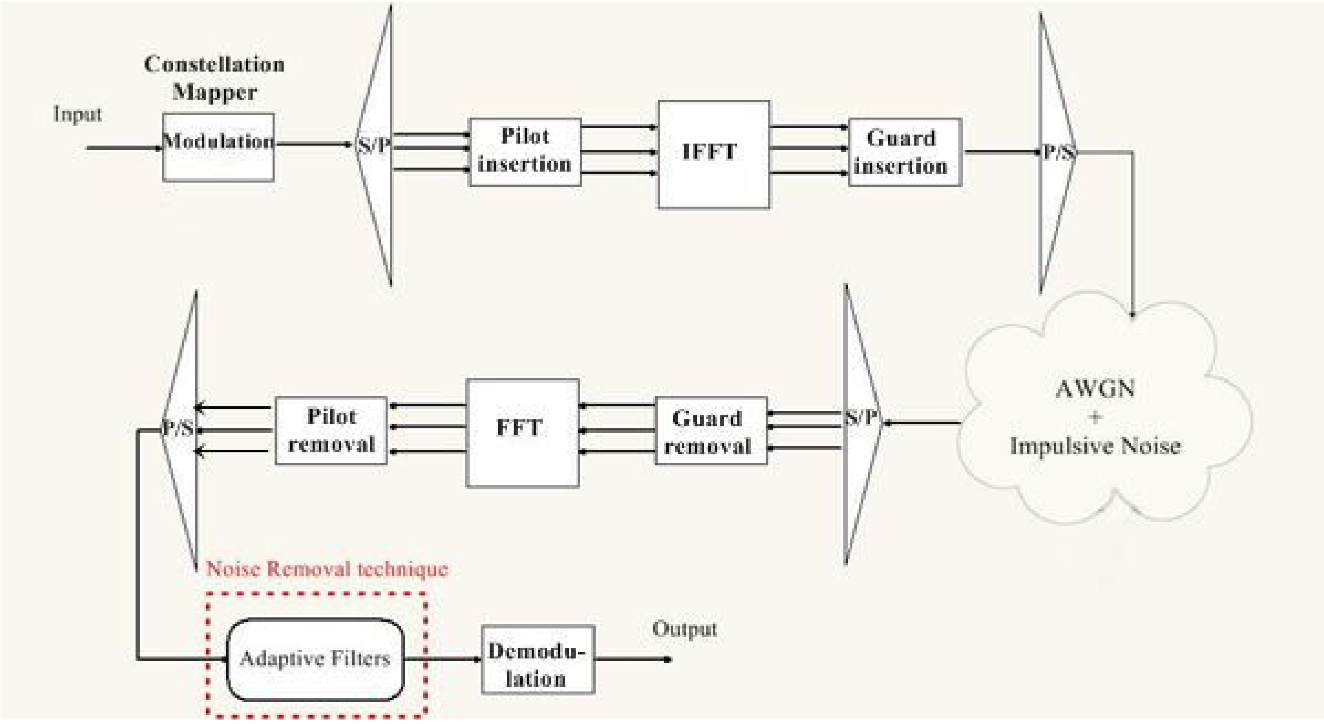

Fig. 1 Block Diagram of Proposed Scheme for OFDM system

III. Impulsive Noise

Impulsive noise is a human made noise consisting of relative short duration 'on/off' noise caused by variety of sources such as car ignition, power line, switching transients' etc. It has high power density and binary-state sequence of impulses with random amplitudes and random positions of occurrence. An impulsive noise sequence can be modeled as Bernoulli Gaussian model, where amplitude is modeled by Gaussian distribution and rate of occurrence of impulses will be modeled by Bernoulli distribution and expressed as

$$n_i(\mathrm{m}) = n(m)b(m) \quad (1)$$

In (1), a binary Bernoulli process of random sequence of ones and zeros is denoted by b(m) and n(m) is a random noise process. The probability density function of impulsive noise is given by

$$f_N{}^{BG}\,(n_i(\mathrm{m})) = (1-\alpha)\delta(n_i(\mathrm{m})) + \alpha\, f_N\,(n_i(\mathrm{m})) \quad (2)$$

A zero-mean Gaussian probability density function model of the random amplitudes of impulsive noise is given by

$$f_N\,(n(\mathrm{m})) = \frac{1}{\sqrt{2\pi}\sigma}\exp[\frac{-n^2(\mathrm{m})}{2\sigma^2} \quad (3)$$

$\alpha(1-\alpha)$ is the variance and α is the mean of Bernoulli process. The autocorrelation of impulsive noise is represented by binary-state process:

$$r_{nn}(k,m) = E[n_i(m)n_i(m+k)] = \sigma_n{}^2\,\delta(k)b(m) \quad (4)$$

The Kronecker delta parameter is denoted by δ (k) in (4). Considering the uncorrelated noise process, the autocorrelation r_{nn} and the power spectrum $P_{N_I N_I}$ of impulsive noise are given by following equations:

$$r_{nn}(0,m) = \sigma_n{}^2\,b(m) \quad (5)$$

$$P_{N_I N_I}(f,m) = \sigma_n{}^2\,b(m) \quad (6)$$

IV. Adaptive Algorithms

The two adaptive filters basic algorithm used in this research are summarized as follow.

A. Bhagyashri Proposed Filter

This filter has different cost function which assumes that the error produced in adaptive systems is non-Gaussian [14]. The weight update equation of Bhagyashri proposed algorithm is

$$w_{\mathrm{n+1}} = w_{\mathrm{n}} + \mu.\ \tanh\,[\beta.\,\mathrm{e}(n)] \quad (7)$$

$$\tanh\,[\beta.e(n)] = \begin{cases} \mathrm{sign}(\mathrm{e}(n)) & \text{if } |\mathrm{e}(n)| > 1/\beta \\ -\mathrm{e}(n).|\mathrm{e}(n)|\beta^2 + 2\beta.\mathrm{e}(n), & \text{if } |\mathrm{e}(n)| \le 1/\beta \end{cases} \quad (8)$$

$$w_{n+1} = \begin{cases} w_n + \mu.\ \mathrm{sign}\,[\mathrm{e}(n)].\,x_n & \text{if } |e(n)| > 1/\beta \\ w_n + \mu[2\beta - \beta^2.\,|e(n)|]\,e(n)x_{n,} & \text{if } |e(n)| \le 1/\beta \end{cases} \quad (9)$$

The function β control the concavity in the cost function and sensitivity to large outliers in the value of $e(n)$and is defined as

$$\beta = \frac{3}{m+3\sigma} \quad (10)$$

The m and σ are the mean and standard deviation of error signal.

B. State space Recursive Least Square (SSRLS) Filter

State Space Recursive Least Squares or SSRLS algorithm is state space representation of an extension of RLS algorithm. It is used to remove noise and its performance can be evaluated in a non-stationary environment(impulsive noise).The steps of SSRLS form II filter along with sinusoidal model for implementation are given in [15].

$$\hat{x}[n] = \bar{x}[n] + K[n]\varepsilon[n] \quad (11)$$

$$\hat{x}[n] = A\bar{x}[n-1] \quad 12)$$

$$\varepsilon[n] = y[n] - \bar{y}[n] \quad (13)$$

$$\bar{y}[n] = Cx[n] \quad (14)$$

$$\Phi[n] = \lambda(A^{-T}\Phi[n-1])A^{-1} + C^T C \quad (15)$$

$$K[n] = \Phi^{-1}(n)C^T \quad (16)$$

where $\hat{x}[n]$ is the input state, $\varepsilon[n]$ is the prediction error, $K(n)$ is observer gain, n is predicted input state, $\hat{n}$ is estimated state, $\bar{y}[n]$ is the predicted output state and $\Phi[n]$ is the correlation matrix.

III. Simulation Results

The performance of proposed scheme is evaluated in AWGN channel with the Bhagyashri algorithm. The simulation platform selected for research was MATLAB version 12.The parameters used in simulating the OFDM system are represented in the Table I.

TABLE I
PARAMETER SET OF OFDM SYSTEM SIMULATION

Parameters	Values
Modulation technique	BPSK
Number of subcarriers	52
Size of cyclic prefix	16
FFT-length	64
Number of bits generated	52000

The impulsive noise is generated by following algorithm mentioned in [16]. The parameters used for simulating impulsive noise are mentioned in Table II and it is illustrated in Fig. 2.

The impulsive noise generated distorts the binary data, while passing through the channel responsible for adding impulsive noise and white Gaussian noise are depicted in Fig. 3.

TABLE II
PARAMETER SET FOR IMPULSIVE NOISE SIMULATION

Parameters	Symbol	Value
Sampling Frequency	F	10
Total time	T	8000
Average Time between samples	β	1s
Mean of log amplitude	A	10dB
Standard deviation of log amplitude	B	5dB
Mean of Additive Gaussian Noise	M	0
Standard deviation of Gaussian Noise	σ	0.3

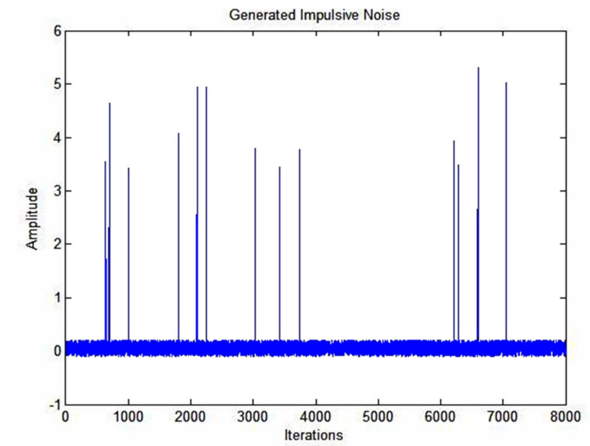

Fig. 2 Impulsive Noise Signal

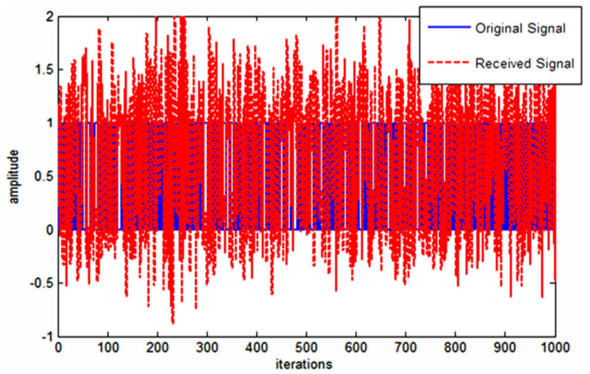

Fig. 3 Original and received signal

The system output error signal $e(n)$ should contain the original signal $s(n)$ in an optimum sense. The length of all the three adaptive filters is fixed to 10. The step size parameter for Bhagyashri proposed Algorithm is chosen to be equal to 0.0002 and forgetting factor for SSRLS is 0.99. The error signals obtained by above mentioned adaptive filters are compared with one another in Fig. 4.

Fig. 4 represents the comparison of SSRLS and Bhagyashri algorithm error plots, while cancelling impulsive noise from the OFDM signal. SSRLS exhibit better performance in cancelling the largest peaks of impulsive noise from the OFDM signal, while other investigated algorithms fail to remove the noise with large amplitudes.

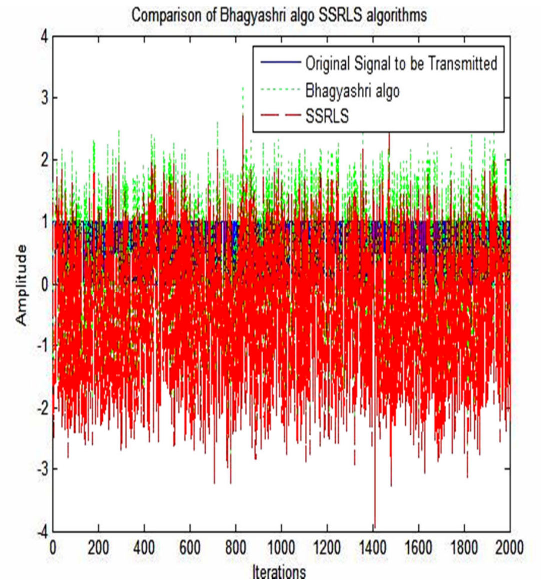

Fig. 4 Comparison of original data, received data and recovered data using SSRLS and Bhagyashri Filters

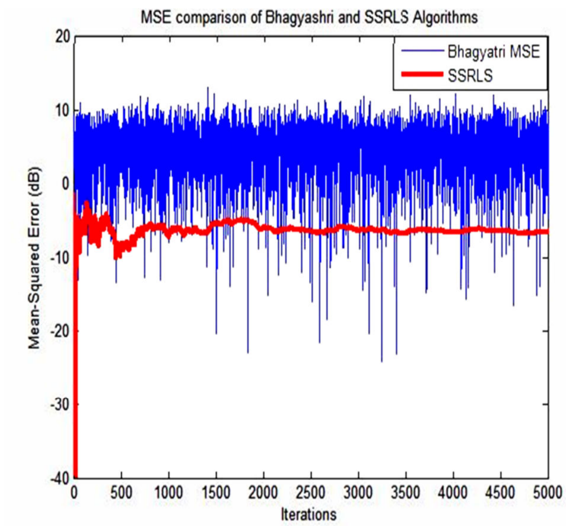

Fig. 5 Comparison of MSE (dB) of adaptive filters

The mean square error in terms of decibel simulation results also confirms that SSRLS give lowest MSE and fastest convergence while cancelling impulsive noise as depicted in Fig. 5. It can be seen that the mean square error of the SSRLS based technique is less than -5dB whereas the Bhagyashri based impulsive noise canceller mean square error is below 10dB.

The comparative analysis of SSRLS and Bhagyashri based Noise canceller in terms of bit error rate (BER) is depicted in Fig. 6.the BER plot indicate that SSRLS filter outperforms the Bhagyashri filter in impulsive noise cancellation of OFDM signal by giving minimum BER. The constellation used for the OFDM in this research is BPSK.

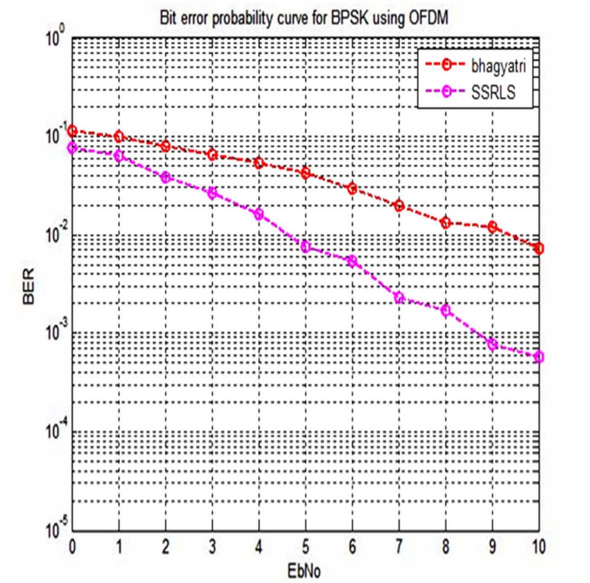

Fig. 6 Comparison of Bit Error Rate of adaptive filters

IV. Conclusion

In this paper, an adaptive impulsive noise suppressor for orthogonal frequency division multiplexing OFDM system has been proposed that is based on state space recursive least square (SSRLS) algorithm. Due to the state space dependent model, the proposed technique exhibit better impulsive noise cancellation in OFDM signal when compared to Bhagyashri algorithm. The simulation results obtained by proposed enhanced impulsive noise suppressor guarantees the superior performance of SSRLS in terms of convergence speed, lowest MSE and BER. In the future work, SSRLS based proposed noise canceller can be tested on different constellation schemes in OFDM systems.

References

[1] Wen Zhou, B. Xie, S. Jun-de, "Link level simulation and performance estimation of WIMAX IEEE 802.16e", in *2nd Int. Conf. Pervasive Computing and Applications*, pp.667– 671, 2007.

[2] S. V. Vaseghi, "*Advanced Digital signal processing and noise reduction*," 4th ed. John Wiley & Sons Ltd, 2000, pp.355.

[3] Z H. A. Suraweera, C. Chai, J. Shentu, J. Armstrong, "Analysis of Impulse Noise Mitigation Techniques for Digital Television Systems", *in Proc. 8th Int. OFDM workshop, 2003,* pp.172-176.

[4] Sergey, et al, "Analysis and Comparison of Several Simple Impulsive Noise Mitigation Schemes for OFDM Receivers", *IEEE Trans. Communications*, vol. 56, ED-1, pp.5-9, 2008.

[5] A. Mengi and A. J. H. Vinck, "Successive Impulsive Noise Suppression in OFDM," *IEEE. Int. symp. Power line communications and its Applications*, pp. 33-37, 2010.

[6] T. Hirakawa et al, "Improving Influence of Impulse Noise to OFDM Signal by Recovering Time Domain Samples," *14th Int. Conf. computers in Education*, 2006, pp.327-328.

[7] T. Umatani, K. Ohno and M. Itami, "A study on scheme of reducing influence of impulse noise in OFDM under multi-path channel", [*Dig. Tech. papers Int. Conf. Consumer Electronics*, 2010, pp.119-120].

[8] Takuya Kitamura, Kohei Ohno and Makoto Itami, "Impulsive noise reduction using it`s replica signal under class-A impulsive channel," *15th Int. symp. wireless personal multimedia communications*, 2012, pp.463-467.

[9] S. Mathew, et al, “Periodic Impulsive Noise Reduction in OFDM based Power line Communication”, *Int. J., Research in Engineering and Technology*, vol.3,pp. 517 – 522, 2014.
[10] A. Hakam, N. A. Aly, M. Khalid, S. A. Jimaa, S. R. Al-Araji, “Impulsive Noise Reduction in MIMO-OFDM Systems using Adaptive Receiver Structures”, *11th Int. Conf. Signal Processing*, Abu Dhabi, UAE, 2012.
[11] A. Mirza, S. M. Kabir, S. Ayub, M. Arsalan, S. A. Amin, “Impulsive Noise Cancellation of ECG signal based on SSRLS,” *Int. Conf. Soft Computing and Software Engineering, 2015,* USA.
[12] A. Mirza, S. M. Kabir, S. A. Amin, “Enhanced Impulsive Noise Cancellation based on SSRLS”, *2nd Int. Conf. Computer, Communication, and Control Tech.,* kuching, Sarawak, Malaysia, 2015, April 21-23.
[13] S. M Kabir, A. Mirza, S. A. Amin,” Impulsive Noise Reduction Method based on Clipping and Adaptive Filters in AWGN Channel,” *5th Int. Conf. Computer Communication and Management*, 18-19 May, 2015, Rome, Italy.
[14] Bhagyashri B. Sawant* and Dr. S. M. Deokar, “Adaptive Filter for Removal of Impulsive Noise and Its Comparison with LMS Algorithm,” *Int. Conf. Industrial Automation and Computing, 2014,* pp.12-14.
[15] M. B. Malik, “State-space recursive least-squares: part I & II”, *Signal Processing J.,* vol. 84, pp. 1709 – 1728, 2004.
[16] P. Torio, M.G Sanchez, and I. Cuinas, "An algorithm to simulate impulsive noise,”*19th Int. Conf. Software, Telecommunications and Computer Networks, 2011,* pp.1-4.