ISSN: 2321-8169
311 – 319

Simulation of Few Mode Fiber Communication System Using Adaptive Recursive least Square Algorithm

Aparna Tomar
Department of Electronics, MITS,
Gwalior, India
e-mail: aparnatomar92@gmail.com

Dr. Vandana Vikas Thakare
Assistant Professor, Department of Electronics,
MITS, Gwalior, India
e-mail: vandanavt_19@rediffmail.com

ABSTRACT- The constant demand of faster mode of communication has revolutionized the technology related to optical fiber communication system. The large member of global researchers are using space division multiplexing (SDM).The research is motivated by the urgent industrial requirement. This technology has sample of scope of improving the channel space. The few mode fiber (FMF) communication system improvement using adaptive algorithm has few issues which are posing the challenges like intermodal noise due to compiling in a random manner .It has some delay which needs to be taken care of is called as differential mode group delay (DMGD).In this work, Recursive Least Square (RLS) has been promised. This yield the convergence faster but at the cost of complex hardware. The FD-LMS algorithm has been considered as a reference. A step size controlled has been put to work. In the reference work the FD-LMS appears to better than LMS algorithm.

Keywords- *Optical channel, Transmission system, Adaptive algorithms, Space Division Multiplexing (SDM), Channel width, Few Mode Fiber (FMF) , Differential Mode Group Delay (DMGD)*

*****

I. INTRODUCTION

Transmission system involved with the development in the semiconductor technology . The laser led to the new era of communication at optical frequency is 5×1^{14}. It can carry 10 million TV channels.In1960 the atmospheric channels were tried. These system were very costly. The transmission was different due to atmospheric conditions. Initially the optical fiber had loss of the order 1000db/km.In1970 Karpon neck and manner fabricated a silica fiber with 20 db loss/km at 1550-nm wavelength. The information This system has many plus points. Little loss and wide bandwidth, small size, light weight, less prone to interference, electrical isolation, signal security, and abundance of silica in the nature are favorable characteristics of the such optical communication. This technology was first applied as TDM (Time Division Multiplexing) in telephone transmission. Communication systems are under going a revolutionary changes. The communication system can be modeled as in 1975 scientists discovered heavy metal theorize glass using ZrF4 and it has very low losses 0.01to 0.001 db/km. But it had the inherent problem of longer length manufacturing difficulties.

II.LITERATURE REVIEW

Xuen He and et.al have employed step size controller method to achieve an efficient solution in fiber communication system is to the communication system. This work makes the use of PSD directed adaptive FD-LMS algorithm. This algorithm nullifies the posterior derivation of each frequency being in the FMI system with AWGN channels. The proposed algorithm has been verified by simulation results. The three algorithms namely conventional adaptive FD-LMS, signal PSD dependent noise PSD directed FD-LMS is found to be minimum. The convergence speed is improved by 48-39%. It has also been established that the convergence is faster in longer transmission distance or larger differential mode group delay. The proposed algorithms are evaluated at different system MDL. The complexity comparison for three algorithms is done in terms of needed complex multiplication. The check is formed over long distance thus simulating transmission length varying between 1000and 3000 km. The power spectral density methodology requires in complex and needs of higher order. The hardware complexity of noise PSD directed method slowly decreases with the increase in the transmission distance. It has been found practically when the step size increased from 0.001 to 0.002 Frequency domain least mean square algorithm needs simple hardware and this tends to converge efficiently. The equalizer converges to higher MSE. The noise PSD directed method iterated over 3000 km transmission on all six modes and it tends to convergence at same MSE to get the standard -10 dB normalized MSE (NMSE).The noise PSD directed algorithms require 47 blocks and the conventional algorithm needs 48 blocks[1].

Sean O¨ Arık and et.al have proposed Long-haul mode-division multiplexing (MDM) for adaptive multi-input-multi-output (MIMO) equalization to reduce for modal crosstalk and modal dispersion. To minimize computational complexity**,** use MIMO frequency-domain equalization (FDE).Polarization division multiplexing (PDM) system use single mode fiber but its transmission effected by noise, fiber nonlinearity and dispersion In. multi-mode fiber (MMF) with multi-input-multi-output (MIMO) transmission Increasing per-fiber capacity can be achieved more readily by increasing spatial dimensionality the total number of dimensions available for multiplexing, including spatial and polarization degrees of freedom denoted by D. In first case two polarization modes of single mode fiber using D=2. This is made possible by equalization techniques goes on going up with the upward drift of D and higher group delay. In second case systems using mode division multiplexing (MDM) in MMFs (D>2) receiver, computational complexity increases because of an increase in *D* and because of the large group delay(GD) spread from the modal dispersion (MD). Two approaches for minimizing GD spread and controlling receiver complexity are optimization of the fiber index profile and the introduction of strong mode coupling. High group delay has been obtained in step index fiber and low group delay obtained in graded index fibers with large cores(D-).LMS algorithm and recursive version are used for MIMO FDE. It has been observed that RLS achieves faster convergence, higher throughput efficiency, lower output SER, and greater tolerance to mode-dependent loss, but gives higher complexity per FFT block. Therefore, RLS preferable for adapting to an unknown channel but LMS continuously might be preferable, depending on channel dynamics and system requirements[2].

Md. Saifuddin Faruk and et.al have been proposed a novel adaptive frequency-domain equalization (FDE) scheme in digital coherent optical receivers, which can work with rationally-oversampled input sequences using the constant modulus algorithm (*CMA).* Adaptive filters play an important role in digital coherent optical receivers because they can perform signal-processing functions such as equalization, polarization demultiplexing, and clock recovery all at once. the frequency-domain based equalization algorithm needs simple logic and computational expression. This requires lesser time the logic is to apply the processing in the blocks and fast implementation of the discrete Fourier transform (DFT) with the FFT algorithm. The proposed scheme is based on frequency-domain up sampling and down sampling the symbol-spaced error signal is obtained by the constant modulus algorithm (CMA).It has been obtained that comparison of previous scheme and proposed scheme. The equalization is done without dividing into groups. Thus, the required number of adaptive filters for dual-polarization (DP) systems is reduced from eight to four. The filter designed for the purpose is to initialize in such a way that the problem of singularity does not come on the way.The effectiveness of the proposed scheme is verified with 10-Gbaud dual-polarization QPSK transmission experiments[3].

Neng and et.al have propounded the normalized FDE over a thousand km. distance experiment. This work makes the use of master-slave phase estimation(MS-PE) can be used to reduce the complexity of carrier recovery with minimal Q2-penalty.To provide multiplicative capacity growth on a single fiber mode-division multiplexing (MDM) has been proposed. MDM transmission using few-mode fiber (FMF) in a long haul because of mode coupling it is difficult to reduce multimode interferences multiple-input-multiple-output (MIMO) equalization is required. Differential mode group delay (DMGD) is responsible for increase the algorithmic complexity of MIMO equalization. The collected DMGD grows the TDE becomes more complex, while FDE may be more feasible. The channel out consist of sharp spikes between the LP01 and LP11 modes. The MDM transmission for the first time based on NA-FDE TO increase the speed of convergence. The step size mew is responsible for the convergence speed for the specified frequency range. , Different frequencies have different rates of convergence. In NA-FDE, a normalized step size $\mu(k) = \alpha / P(k)$ is used for FDE. In both cases, an equalizer length of 1024 taps was used and same step size was used for fair Comparison. It has been observed that NA-FDE converges six times faster compared with CA-FDE at a mean square error (MSE) of 10-5.The application of NA –FDE for FMI transmission has been checked over loop over 1000 cm. In master-slave phase estimation (MS-PS) the LP01, X mode selected as master mode and LP01, X selected as phase noise. NA-FDE was found to give similar performance as a TDE but has 16.2 times reduced complexity[4]

An Li and et.al have demonstrated the use of mechanical grating based mode converters to achieve two forms of dual-spatial-mode transmission LP01and LP11 and dual LP11 modes. It has demonstrated mode- division multiplexing(MDM) of LP01 and LP11 modes to generate LP11 modes(LP11a+LP11b) and even all three modes(LP01+LP11a+LP11b)over few-mode fiber (FMF)The transmission system with mode multiplexing are a very crucial problem. The mode selective devices proposed in divided into two major categories: free-space based (FSB) and fiber based(FB).Free space components are bulky in size ex liquid-crystal-on-silicon (Lcos) spatial light modulator (SLM). But fiber based mode selective device have compact and easiness of integration. Firstly proposed 107-Gb/s coherent optical OFDM (CO-OFDM) transmission over a 4.5-km two-mode fiber using LP01 and LP11 modes. Secondly proposed 58.8-Gb/s CO-OFDM transmission using dual modes where the mode separation is achieved via 4* 4 electronic MIMO processing[5].

Sebastian Randel and et.al have been demonstrated the impulse response matrix of few-mode fiber links that support the propagation of LP01 and LP11 modes over up to 1,200-*km*.Results are obtained by by multiple-input multiple- output (MIMO) digital signal processing (DSP)in combination with differential group delay (DGD) compensated fiber spans. Equalizer is used to remove complexity in long haul transmission so two scheme must be remembered. first optical means to minimize the modal delay spread (MDS), i.e., the width of the impulse response, must be analyzed. second In a second step, the performance-complexity of efficient equalizer structures such as the frequency-domain equalizer (FDE) must be studied. it has been observed that MDS can be reduced to about 10 ns using a DGD compensated fiber span. Also observed that the system MDL is below 5 dB after 1,200 km. characterize the channel's model delay spread and mode-dependent loss[6]

Joseph M. Kahn and et.al have proposed a mode coupling scheme to overcoming major challenges incoherent mode-division-multiplexed systems. SMC (strong mode coupling) helps to bring down the delay done to the group and helps to optimize the complexity of MI (multiple inputs) multi-output signal processing. Strong mode coupling is responsible for creates frequency diversity dramatically reducing out stage probability. Transfer of energy from one ideal mode to another during propagation only due to mode coupling. I t has been observed that practically strong couple modes having equal or nearly equal propagation constant but weakly coupled modes having a highly unequal propagation constant. The separation between two modes results in modal dispersion increasing capacity through mode division multiplexing (MDM). SMF (single-mode fiber helps in the wave movement in two polarization conditions. Polarization-mode dispersion (PMD) and polarization-dependent loss (PDL) have long been described by field coupling models. It has been observed that strongly coupled modal group delay or gain depend only no. of modes and variance of accumulated delay or gain and can be derived from the Eigenvalue distributions of certain random variables[7].

SDM (space division multiplexing) has put forth by Savory.SDM is extremely challenging technology, of requiring developments in all areas of Photonics Technology. The optical communication systems are being upgraded every new system. There is a rapid development taking place in this field at the global level. The development of space division multiplexing. Space Division Multiplexing (SDM). While conceptually simple, SDM is extremely challenging technologically, requiring the development of new fibers, amplifiers, multiplexers, digital signal processing circuits, and other components. The multiplexing means the utilization of channel by the division of the space. It is telling that the SDM technology would be the cost of the operators provided the cost of the operators provided the cost of the technical operators is reduces, 1) lowers the cost per bit (i.e., SDM-based systems must be less costly than multiple independent systems), 2) provides there is a larger requirement of flexible photonic network .It most allows flexibility to an extent. 3) allows a reasonable transitional strategy from systems based on standard single-mode fibers[8].

Omid Zia-Chalabi and et.al have proposed a computationally efficient frequency-domain implementation of a fractionally spaced block-least-mean-square (LMS) equalization. Polarization division multiplexing (PDM) and digital signal processing have helpful to a paradigm shift in optical communication systems, by providing greater spectral efficiency than Intensity-Modulated. Digital equalization of chromatic dispersion (CD) and linear polarization-dependent effects usually preferred the dual-stage receiver architecture. A fractionally spaced equalizer (FSE) is mostly preferred for increase robustness of the receiver. Where the input signal

is sampled at twice or more the symbol rate 1/T. It has been proving more efficient for real-time processing to implement filtering in the frequency-domain (FD)as compared in the time-domain (TD). FD equalizers (FDE) could bring significant computational savings in the second stage, compared to TD equalizers (TDE). but requires the insertion of the block of the transmitter with a circular prefix. Another attractive solution is FD adaptive filtering based on the overlap-save technique (OS-FDE). Thus, the proposed equalizer architecture appears as a promising solution for 100 Gb/s and beyond real-time digital coherent receivers, which impose stringent constraints on algorithm complexity. Finally, the proposed FDE may be extended to weight update criteria other than LMS or CMA, by modifying accordingly[9]

Kun Shi and et.al have proposed frequency domain adaptive filters require very simple circulations hence simple circuitry to implement by using the overlap-and-save implementation method. FD algorithms may improve the convergence speed in comparison to the Time-domain algorithms. To optimize the convergence behavior of the adaptive filter a step size control scheme proposed for each frequency bin. A step-size control method is also proposed in to improve convergence behavior for systems working in a non-stationary environment. Discrete Fourier transform is proposed to improve the convergence rate. Step sizes that are inversely proportional to the signal power levels in the frequency bins of the discrete Fourier transform (DFT). A variable step-size algorithm is proposed for obtaining the low residual error. Therefore, overcome the compromise between fast convergence and low steady-state error in the

existing method the proposed method achieves faster convergence rate as well as smaller MSD and MSE[10].
Multiple input multiple outputs (MIMO) has been performed using stokes algorithm in a frequency domain (SSA).The unique work is the analysis of the convergence speed and frequency offset of the SSA .It is not compulsory to go for pre-compensation of frequency offset. There is tremendous growth in the transmission capacity of the optical fiber link. The hardware has improved which allows lower losses and longer distances of optical cable. The less line consuming algorithms can further increase the channel width. The research is going on in SDM [11]

III. WORKING OF OPTICAL FIBER COMMUNIOCATION SYSTEM

The optical fiber communication channel consists of a optical property installed cable between transmitter and receiver The cable is installed and then optical power is launched inside the core of the optical cable.LED and LASER diode are needed for this purpose. The light emitted by of these device can be modulated by changing the bias field. The transmitter converts these electrical signal to optical signal by varying the biasing of the photo device. It follows the square law.

The signal attenuates due to scattering , absorption and dispersion in the waveguide. The repeaters in the communication link simply amplify and reshape the distorted signals for the faster propagation in the waveguide.

A .Optical Fiber Modes

The waveguide which functions at the optical frequency is called fiber. The propagation of light can be expressed as guided electromagnetic waves. This is termed as the modes of a waveguide. Each mode displays a pattern of electrical and magnetic field.

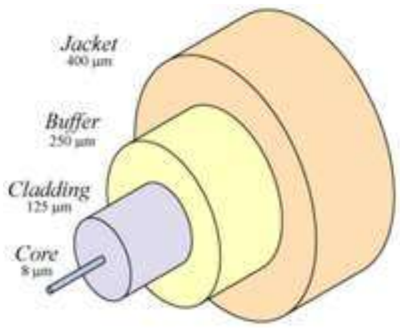

Figure 1. Schematic of a single fiber structure

Core= solid dielectric cylinder

Radius =a

Refractive index =n

Cladding is a covering with dialectical material refractive index n2 where n1>n2.The cladding reduces scattering loss and protects the core from getting contaminated. Step- index fiber uses uniform refractive index material and graded-index fiber has refractive index along the radius of core. These two types may have single mode or multimode class. The multimode fiber, has hundreds of modes. It is easy to launch power in the channel and LED can be used as a source. Where as in the single mode LASER diodes are used.

The disadvantage is that the multimode fibers have intermodal dispersion. This can be reduced by using a graded index profile in the fiber core This increases the bandwidth.

B. Attenuation

The attenuation or fiber loss is defined as

α =10/L log (Pin/Pout)

P_{in} =Optical power in

P_{out} =Optical power out

α =attenuation in decimal

C. Absorption

Absorption of radiation is due to atomic defects in the glass, extrinsic absorption by impurity atoms and intrinsic adsorption by basic constituent atoms of fiber material.0

D. Scattering losses

This loss is introduced due to certain manufacturing defects.

E. Bending loss

The radioactive losses due to bending at the turning point.

F. Mode coupling

The coupling of energy from one mode to another mode is due to some structural defects, varying diameter of fiber, varying refractive index and bends introduces propagation delays. This further increases the losses.

G. Cutoff wavelength

The cutoff wavelength (LP11) for first higher order mode. It separates the single mode from the multimode region cutoff wavelength is proportional to the fiber length

H. Optical Fiber Communication channel

The optical communication system technology is moving forward by leaps and bound. The remarkable point is that all the research experts are trying to increase the amount of information carrying capacity of the fiber link. There is a scope of research in developing the SDM. The ample of research is being conducted in expanding the signal carrying capacity of the optical link. This research is being driven by the need of the society. The communication system can be models as

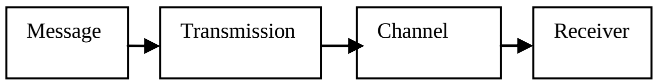

Figure 2 Optical fiber communication channel

IV. SPACE DIVISION MULTIPLEXING

The optical communication system technology is moving forward by leaps and bounds. The remarkable point is that all the research experts are trying to increase the amount of information carrying capacity of the fiber link. There is a scope of research in developing the SDM. The ample of research is being conducted in expanding the signal carrying capacity of the optical link. This research is being driven by the need of the society. It is a multiplexing technique that forms the multiple separate channels for the information and making it economical. The crosstalk reduction is also very important. The spacing between the cores reduces the crosstalk. Core to core coupling can be reduced by using trench-type core. Cross talk reduces by <-90 db for 4um spacing but the diameter of MCF is kept below 200um to avoid fractures. Hexagonal 7-cores cable are used commonly[12].

V.FEW MODE FIBER COMMUNICATION SYSTEM

The capacity crunch of the optical communication system can only be dealt with most modern and smart optical fiber technology unknown as a space division multiplexing (SMD). The SDM can be implemented over multi core fiber (MCF) and few mode fibers (FMF). The technology is moving fast with the achievements like fiber using 12 –core fiber. The single –mode multi-core fibers (SM-MCF) have specific core cross-sectional area (A_{eff}), crosstalk. The FMF (Few mode fiber) with differential mode delay (DMD) and few mode multimode fiber (FM-MCF) have very promising characteristics[13].

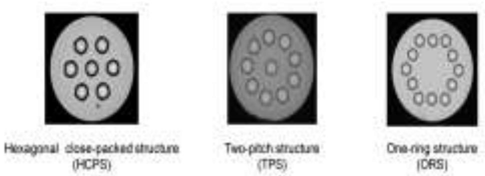

Figure 3 Cross sectional view of fabricated MCFs with various structures

VI. LMS ALGORITHM

FD-LMS

Adaptive frequency domain least mean square (FD-LMS) algorithm has been proposed as the most hardware efficient multi-input multi-output equalization method for compensating large differential mode group delay (DMGD). Except for hardware complexity, the convergence speed of the adaptive FD-LMS algorithm is another important consideration. In this paper, we propose a noise power spectral density (PSD) directed adaptive FD-LMS algorithm, which adopts variable step size to render the posterior error of each frequency bin convergent to the background noise in an additive white Gaussian noise (AWGN) channel.

The FDE techniques can reduce the algorithmic complexity significantly, in comparison with time-domain equalization (TDE) while maintaining comparable performance, amongst which the least mean squares (LMS) and recursive least squares (RLS) algorithms are most popular and hence widely investigated. While FD-LMS has lower complexity, it suffers from serious performance degradation and exhibits slower convergence whilst encountering on large number of parameters need to be simultaneously adapted in SDM channels. LMS is a stochastic gradient descent minimization using instantaneous estimates of the error. The convergence rate and performance of LMS depends on the scalar step size μ, which for convergence must satisfy

The adaptive filters find a wide application in variety of fields like speech reorganization system, surveillance system, seismology, biomedical engineering Least-mean square is most popular algorithms as it reduces the hardware complexity employs overlap and some implementation technique.FFT is used for block updating .The convolution is faster and improve the convergence speed. It has the time saving advantage over the time domain algorithms. The LMS uses approximation in decor relation of the excitation signals. The step size finds the balance between convergence speed and mean square error for frequency domain method. The step size reduces with increase in the power level in the frequency bins. The DFT and step size control is also used in the proposed methodology this is likely to reduce is the residual error for echo removal.

In FD-LMS adaptive domain least mean square is the most simple from hardware requirement side. It uses multi-input and multi-output equalization. It neutralizes the effect of DMGD (Differential mode group delay).We have proposed noise power spectral density PSD directed algorithm. FD-LMS algorithm uses variable step - size to render the posterior error of each frequency bin convergent to the environment noise in additive white Gaussian noise (AWGN) Channel[14].

VII. THE PROPOSED WORK RECURSIVE–LEAST SQUARE (RLS) ADAPTIVE ALGORITHM

The frequency domain equalizer can reduce the algorithms to a large extent as compared with (TDE) Time domain equalization. LMS and RLS algorithms find a very common

use and are therefore in investigation by world community at large. FD-LMS has lesser complexity but low speed. Alternatively faster convergence can be accomplished by applying FD-RLS with a more sophisticated algorithms struck but at the cost of complexity LMS and RLS are FIR of length M with coefficient tb_k, k= 1,2……M-1
The input{f(n)} passes through the filter and they output is generated {y(n)}.

The coefficient update by

Error e(n)=d(n)-y(n)

Where d(n) is expected response LMS filter uses a gradient descent method. While RLS filter calculates intermediate data at each time-step size to find the filter coefficients. The RLS filter responds to the varying input signal and convergence faster than LMS filter but yields higher mean square error

The output of this filter

y=H^Tx e=x-y

where H is the vector containing the tap coefficient and x is the vector with tap inputs .The target is to adjust to adjust H to minimum error

Alternatively, faster convergence can be accomplished by implementing FD-RLS with a more sophisticated algorithmic structure at the price of higher complexity. RLS involves iterative minimization of an exponentially weighted cost function, treating the minimization problem as deterministic [15]

$$W_{MD}\ [k] \leftarrow W_{MD}\ [k] + \left(\widetilde{X}\ [k] - W_{MD}\ [k]\tilde{y}[k]\tilde{y}[k]^H\ \ (R[k]k^{-1})\right)$$

$$\mathrm{R}[k] \leftarrow (R[k]k^{-1}) - \frac{(R[k]k^{-1})\ \tilde{y}[k]^H\ \ (R[k]k^{-1})}{1 + \tilde{y}[k]^H\ \ (R[k]k^{-1})\ \tilde{y}[k]}$$

VIII. MEAN SQUARE ERROR (MMSE)

LMS aims at minimizing mean square error (MSE) which is generated by the expected result. The cost function is as under[16].
J= E[$e(n)^2$]

Where E is the expects results the optimum tap coefficients in the terms of MSE

RH= D

Where R and D are auto and cross correlation matrices.

LMS algorithm is based on the steepest descent. The objective is to reduce MSE to minimum level. This is done by adapting tap weights and this is controlled by the slope of the surface. FIR filter are used as there is one minima.

The tap weights are recursively updated

H=H-$\mu\nabla$

Where μ is a constant that controls rate and stability

The LMS algorithms does not require R and D values instantaneous estimates refer to equation

∇ = -2P +2RH Steepest descent

∇ = -2X +2XX^TH LMS

= -2eX

IX. LEAST SQUARE ERROR

The idea of Least Squares (LS) filtering is to minimize the sum of all the estimation error squares, with the following cost function[16].

J =$\sum_{i=M}^{N} e^2$(i)

It can be shown that the optimal solution for the tap coefficients in the LSE sense is
RH=P

THE Recursive least square RLS algorithms uses intermediate values of the tap vector based on least square error(LSE).This is a type of kalman filter.

Let us think of equation for self correcting correlation matrix.

$R_N = R_{n-1} + X_n X_n^T$

The above equation can be modified as

A=B- B C(D+ (C^HBC) $^{-1}C^H$B

Where A =R_n, B =R_{n-1}^{-1}, C=X_n and D=1

The update equation (5) can be modified as

$H_N = H_{N-1} + R^{-1}$Xe

X. DATA FLOW

- Initialize the parameters (input data, number of FFT-blocks, Convergence parameter, EbN0(energy per bit to noise power spectral density ratio)))
- Apply the base and proposed algorithm
- Plot the graph (number of DFT vs number of mismatches) for various convergence factors (1 to 2.5e-5) and for various EbN0 (1 to 10).
- Compute the run time by applying tic and toc in MATLAB

ISSN: 2321-8169
311 – 319

- Plot the graph between samples (time) and the number of mismatches (Mismatch between the original and the equalizer output).

XI. SIMULATION AND RESULTS

The optical communication system is simulated in MATLAB version 11

I. RUN TIME COMPLEXITIES

TABLE I

Step size	1.00E-05	1.50E-05	2.0 e-5	2.50E-05
RLS(in sec)	0.6494	0.634	0.6881	0.6964
LMS(in sec)	1.5305	1.5207	1.5219	1.5348

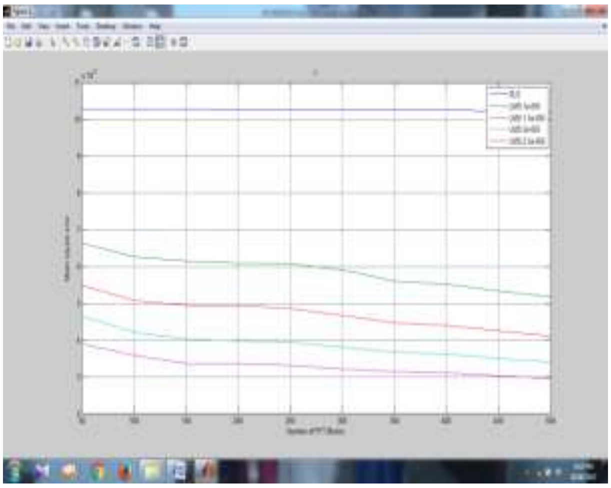

Fig 1. Number of FFT Blocks vs MSE (SNR=1)

The simulation result of mean square error vs FFT (Fast Fourier Transform) attach at signal to noise ratio (SNR=1).The propose RLS is independent of the step size. The other three lines in the graphs are showing the result of LMS at different step size ranging 1.0e-5 to 2.5e-5.It is clear that the convergence is better for higher block size.

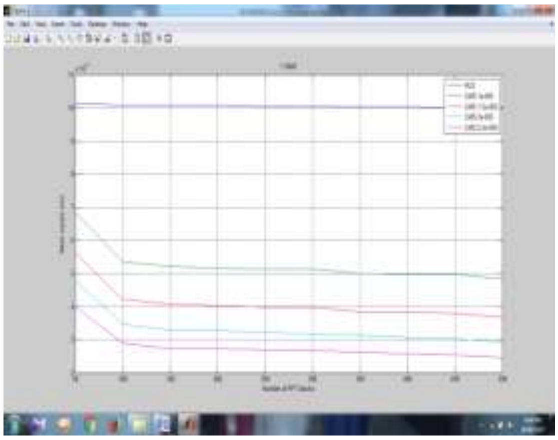

Fig 2. Number of FFT Blocks vs MSE (SNR=1.5849)

The simulation result of mean square error vs FFT (Fast Fourier Transform) attach at signal to noise ratio (SNR=1.5849).The propose RLS is independent of the step size. The other three lines in the graphs are showing the result of LMS at different step size ranging 1.0e-5 to 2.5e-5.It is clear that the convergence is better for higher block size.

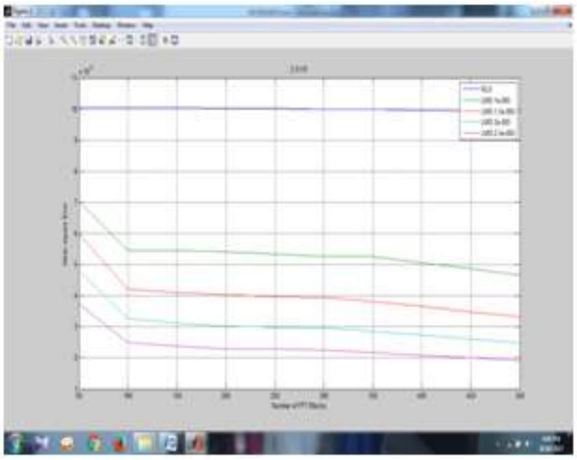

Fig 3. Number of FFT Blocks vs MSE (SNR=2.5119)

The simulation result of mean square error vs FFT (Fast Fourier Transform) attach at signal to noise ratio (SNR=2.5119).The propose RLS is independent of the step size. The other three lines in the graphs are showing the result of LMS at different step size ranging 1.0e-5 to 2.5e-5.It is clear that the convergence is better for higher block size.

ISSN: 2321-8169
311 – 319

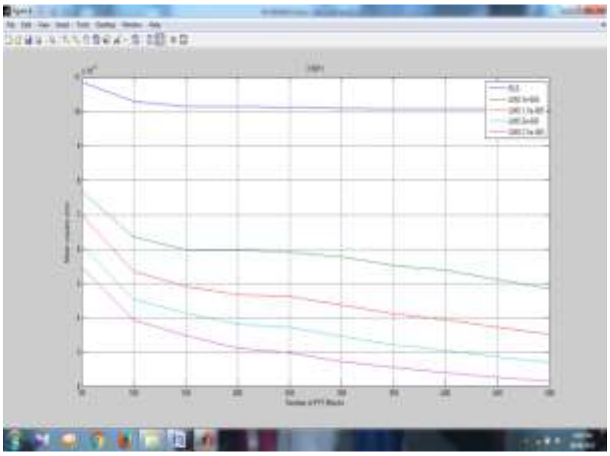

Fig 4. Number of FFT Blocks vs MSE (SNR= 3.9811)

The simulation result of mean square error vs FFT (Fast Fourier Transform) attach at signal to noise ratio (SNR=3.9811).The propose RLS is independent of the step size. The other three lines in the graphs are showing the result of LMS at different step size ranging 1.0e-5 to 2.5e-5.It is clear that the convergence is better for higher block size.

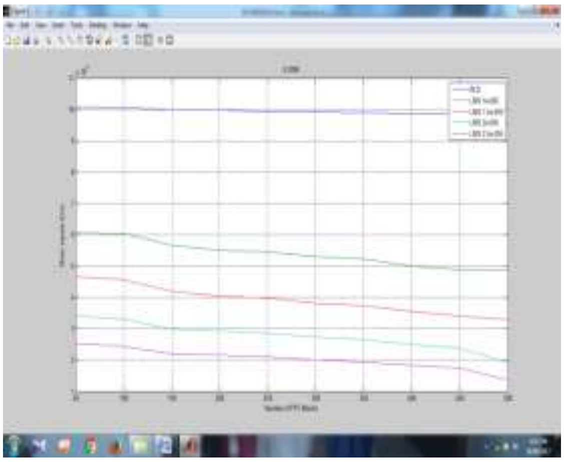

Fig 5. Number of FFT Blocks vs MSE (SNR= 6.3096)

The simulation result of mean square error vs FFT (Fast Fourier Transform) attach at signal to noise ratio (SNR=6.3096).The propose RLS is independent of the step size. The other three lines in the graphs are showing the result of LMS at different step size ranging 1.0e-5 to 2.5e-5.It is clear that the convergence is better for higher block size.

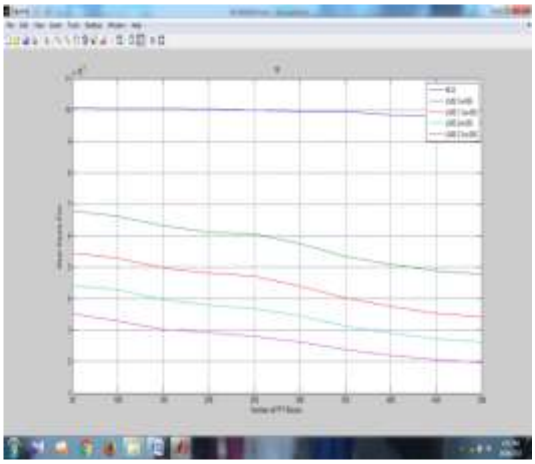

Fig 6. Number of FFT Blocks vs MSE (SNR=10)

The simulation result of mean square error vs FFT (Fast Fourier Transform) attach at signal to noise ratio (SNR=10).The propose RLS is independent of the step size. The other three lines in the graphs are showing the result of LMS at different step size ranging 1.0e-5 to 2.5e-5.It is clear that the convergence is better for higher block size.

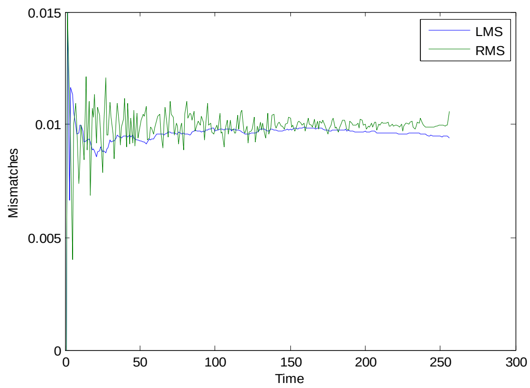

Fig 7. Convergence Graph plot between Mismatches and Time

The above graph shows that RLS mismatches over the period become minimum as compared to FD-LMS algorithm. This shows that the quality of RLS output is better.

CONCLUSION

In this we implemented two algorithms (FD LMS and FD RLS). We compared the proposed FD- RLS with the FD-LMS in terms of run time, number of DFT vs number of mismatches for various convergence factors and for various EbN0. We also compared the convergence between the FD LMS and FD RLS. The simulation results shows that than

RLS convergence faster but at the cost of hardware complexities.

REFRENSES

[1] Xuan He ,Yi Weng, "A Step-Size Controlled Method for Fast Convergent Adaptive FD-LMS Algorithm in a Few-Mode fiber communication system", journal of lightwave technology, vol. 32, no. 22, november 15, 2014.

[2] SercanO¨.Arık, Daulet Askarov, and Joseph M. Kahn," Adaptive Frequency-Domain Equalization in Mode-Division Multiplexing Systems ", journal of lightwave technology, vol. 32, no. 10, may 15, 2014.

[3] Md. Saifuddin Faruk and Kazuro Kikuchi, "Frequency-Domain Adaptive Equalizer with Rational Oversampling Rates in Coherent Optical Receive", ECOC 2014, Cannes – France P.3.22.

[4] Neng Bai, Ezra Ip, Ming-Jun Li, Ting Wang and Guifang li, " Long-Distance Mode-Division Multiplexed Transmission using Normalized Adaptive Frequency-Domain Equalization", 978-1-4673-50600/$31.00 ©2013 IEEE.

[5] An Li, Abdullah Al Amin, "Reception of Dual-Spatial-Mode CO-OFDM in optical fiber", journal of lightwave technology, vol. 30, no. 4, february 15, 2012.

[6] Sebastian Randel, Miquel A. Mestre, Roland Ryf, and Peter J. Winze "Digital Signal Processing in Spatially Multiplexed Coherent Communications", ECOC Technical Digest © 2012 OSA

[7] Joseph M. Kahn and Keang-Po H02, "Mode Coupling in Coherent Mode-Division Multiplexed Systems Impact on Capacity and Signal Processing Complexity", 978-1-4673-5051-8/12/$31.00 © 20 12 ieee

[8] SEB J. SAVORY, "Editorial Special Issue on Photonics Technology for Space Division Multiplexing", ieee photonics technology letters, vol. 24, no. 21, november 1, 2012.

[9] Omid Zia-Chah "Efficient Frequency-Domain Implementation of Block-LMS/CMA Fractionally Spaced Equalization for Coherent Optical Communication", ieeephotonics technology letters, vol. 23, no. 22, november 15, 2011.

[10] Kun Shi, "A Frequency Domain Step-Size Control A method for LMS Algorithms", ieee signal processing letters, vol. 17, no. 2, february 2010

[11] D. J. Richardson1, J. M. Fini2 and L E. Nelson3 "Space Division Multiplexing in Optical Fibres" ,Optoelectronics Research Centre, University of Southampton, Highfield, Southampton, SO17 1BJ, UK. 2OFS Laboratories,19 Schoolhouse Road, Somerset, New Jersey 08873, USA.3AT&T Labs - Research, 200 S. Laurel Avenue, Middletown, New Jersey 07747, USA

[12] D. J. Richardson, J. M. Fini and L E. Nelson Space Division Multiplexing in Optical Fibre**s***1*Optoelectronics Research Centre, University of Southampton, Highfield, Southampton, SO17 1BJ, UK.2OFS Laboratories,19 Schoolhouse Road, Somerset, New Jersey 08873, USA. 3AT&T Labs - Research, 200 S. Laurel Avenue, Middletown, New Jersey 07747, USA

[13] S. Matsuo, Y. Sasaki1, I. Ishida, K. Takenaga, K. Saitoh and M. Koshiba "Recent Progress on Multi-Core Fiber and Few-Mode Fiber" OFC/NFOEC Technical Digest © 2013 OS

[14] Kun Shi, *Member, IEEE*, and Xiaoli Ma, *Senior Member, IEEE*A " Frequency Domain Step-Size Control Method for LMS Algorithms" IEEE SIGNAL PROCESSING LETTERS, VOL. 17, NO. 2, FEBRUARY 2010

[15] Introduction to Recursive-Least-Squares Adaptive Filters Massachusetts Instituteof Technology Department Of Mechanical Engineering Mit OpenCourseWare 2.161 Signal Processing -Continuous and Discrete 2008

[16] N. Dahnoun, M. Hart and F. Umbarila, "Software optimisation techniques for real-time applied adaptive filtering using the TMS320C6201 Digital Signal Processor" University of Bristol