Wireless Channel Equalization in Troposcatter Communication Systems

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ABSTRACT: As tropo channel is a time varying channel, and distortion due to channel is also very high, to overcome these distortions Non Linear Equalizer (Decision Feedback Equalizer) is the most preferred approach. DFE consists of two filters that are forward and backward. Forward filter reduces the effects of precursor while backward filter reduces the effects of Post cursor. The main objective of the thesis is to evaluate the performance of channel with and without Forward filter. Forward filter is an adaptive filter, which is implemented using RLS filter. The performance of RLS filter is given in terms of BER plot. Tropo link analysis is presented and various parameters like scatter angle, delay, and losses are determined.

I. INTRODUCTION

The transmitted high power was the cause of concern about interference with other communication networks .To overcome this problem a new variety of troposcatter equipment were developed. These new equipment are smaller, lighter, and easy to use, operate and are capable of providing high data rate. Troposcatter communication is able to provide network multimedia services with attractive data rates. Due to worldwide use of tropo systems a need is felt to upgrade the existing tropolinks from analog to digital so as to meet various voice, data and multimedia requirements. Tropolinks are being used world over for civilian and defence communication. The important characteristics of troposcatter radio links is the great distance over which reliable communication can be obtained without need for intermediate repeaters. The troposphere is the lowest portion of the atmosphere. Most of our weather takes place in the troposphere. It contains 80% of the atmosphere's mass and 99% of its water vapor. The troposphere begins at ground level, and its height varies from about 20 km near the equator to 17 km in the mid-latitudes to 9 km near the poles in summer. Its height is greater in summer than in winter. The upper boundary of the troposphere is a temperature inversion called the tropo-pause, which separates the troposphere from the stratosphere.

The pressure of the atmosphere is greatest at the surface and decreases with height. Because the temperature of the troposphere also decreases with height (by approximately 6.5 degrees C per km) and saturation vapor pressure decreases with decreasing temperature, the water vapor content of the atmosphere decreases strongly with altitude. The troposphere has irregularities in temperature, pressure, and water vapor content due to stratification and turbulence, and it is believed that these irregularities, and their effects on electromagnetic wave refraction, are the basis for tropospheric scatter.

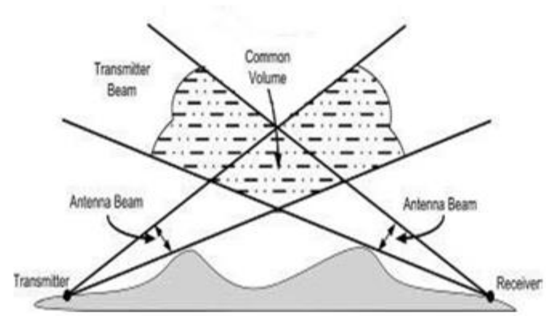

Fig.1: Profile of troposcatter path

Troposcatter communication systems are used to provide radio connectivity between network nodes, but in comparison to other type of radio communication techniques, troposcatter systems does not require line of sight path between transmitter and receiver. In Figure.1 A tropolink is established when terminals points toward common volume and energy transmitted from one terminal is scattered towards the other. Scattering is due to the variation in the refractive index of the troposphere which extends up to about 10 km from the earth surface resulting in beyond line of sight communication.

This results in a low received signal power that fluctuates randomly with time in the troposphere. Common volume is the common area that is formed at the intersection of transmitted and received beams on a troposcatter link.

II. RELATED STUDY

P.Varunkumar et al. (2017), suggested that the capacity gain of MIMO systems significantly depends on the fading correlation between antennas. A channel sounding experiments and One Ring model is a method to calculate correlation but cost of these methods are high due to use of high power amplifiers and large antennas. So using ring scatter model (RSM), to derive the fading correlation in the troposcatter systems as a function of space-frequency diversity or space-angle diversity to achieve the greater gain by decreasing the fading correlation. [1]

William F. Moler et al. (1960). Current scattering theory and the empirical findings of others to determine the gross meteorological
factors that influence changes in scattered fields. The two variables: the turbulent scattering coefficients, the scattering angle and the intensity of dielectricfluctuations at high wave numbers, are found to be dependent upon the refractive layeringand the thermal stability of the all mass. It has been shown elsewhere that refractivityand stability are principally functions of the vertical velocity in t he atmosphere. It is shown that the direction and relative magnitude of the vertical velocity can be inferred fromthe upper- tropospheric wind velocity divergence. Received scattered signals are found tobe well correlated with computed velocity divergence. [2]

Rosa Zheng ***et al (2014)*** *suggested that* a new frequency-domain channel estimation and equalization (FDE) scheme is proposed for single carrier (SC) underwater acoustic communications. The proposed SC-FDE employs a small training signal block for initial channel estimation in the frequency domain and converts the estimated transfer function to a desired DFT (discrete Fourier transform) size for channel equalization of the data blocks. The frequency domain equalizer is designed using the linear minimum mean square error criterion. A new phase coherent detection scheme is also proposed and deployed to combat the phase drift due to the instantaneous Doppler in the underwater channels. [3]

In year 2011, the author "**Anthony G. Stranges,"**found Algorithms for blind equalization and data recovery of orthogonal frequency-division multiplexed (OFDM) signals transmitted through fading channels are implemented and simulated in this thesis. The channel is estimated without knowledge of the transmitted sequence (i.e., blindly) using a least mean squares (LMS) adaptive filter and filter bank precoders. This method was used to estimate channel characteristics using both binary and quadrature phase-shift keying signals. Additionally, the method was analyzed for robustness with a poor initial estimate of channel characteristics, with the addition of white Gaussian noise to the signal, and with non-stationary channel conditions.

In addition, it is shown that the proposed method is particularly suited in situations with deep fading channels, where some of the subcarriers have a very low SNR. [4]

In the research study carried out by **Valeria Arlunno, (June 2013),** it wasaddressed that the design and performance evaluation of advanced Digital Signal Processing (DSP) algorithms for coherent optical fiber transmission systems. The research results showed transmission of highly spectrally efficient optical communication systems employing multiplexing techniques with polarization multiplexing and multi-level modulations format. Advanced digital signal processing techniques offer robustness and flexibility for next generation high capacity optical fiber networks and are therefore considered as key building blocks in next generation digital coherent receivers. [5]

Bhasker Gupta (2010) showed the BER performance improvement of IEEE 802.11a LAN based OFDM systems using these equalizers. Two categories of channels are considered, namely frequency flat channels and frequency selective channels. The presence of Multipath on troposcatter Channel causes Inter symbol Interference which ultimately limits the data rate. ISI imposes the main obstacle to achieve increased digital transmission rates. [6]

In [26], the author proposed a design process for Adaptive Equalization using Back Propagation Technique. It is shown that novel network structure and the inclusion of a nonlinear operator, the so called squashing function. A novel adaptive channel equalizer is presented based on the back propagation algorithm applied to an associative network. Simulations are made for linear and nonlinear channels. The performance is shown to be good and much better than with the LMS algorithm for the nonlinear channel.

In [16], **Martin et al.** have developed the Forced Redundancy with Optional Data Omission (FRODO) cost function which is a low-complexity, blind channel shortening algorithm for a multi-carrier MIMO system. FRODO works to restore the redundancy of the cyclic prefix, inducing a shortened channel. The FRODO algorithm is a generalization of the Multicarrier Equalization by Restoration of Redundancy (MERRY) algorithm that has been extended to work in a MIMO configuration with fractional spacing. In their paper, Martin et al. avoid the complication of an FEQ design by using differentially encoded binary phase shift keying. However, they mention that an adaptive FEQ can be designed without training when given a finite alphabet or constellation. In addition, they do not address how to spatially separate the two signals, noting only that the joint SNR is enhanced after channel shortening.

Space-time coding is a powerful way to leverage spatial diversity gain and improve reliability in multiple input multiple output (MIMO) communication systems. We consider a multi-carrier MIMO system model with additive noise and inter-symbol interference (ISI). Symbols sent at different times can arrive simultaneously at the receiver after traversing multiple reflective paths, causing ISI. Many spatial-temporal algorithms have been developed to suppress this interference, ranging from high-complexity maximum likelihood sequence estimators to simple minimum mean square error equalizers.**B.Sklar(1997)** [7].

The Recursive least squares (RLS) [13] adaptive filter is an algorithm which recursively finds the filter coefficients that minimize a weighted linear least squares cost function relating to the input signals. This in contrast to other algorithms such as the least mean squares (LMS) that aim to reduce the mean square error. In the derivation of the RLS, the input signals are considered deterministic, while for the LMS and similar algorithm they are considered stochastic.

In [15] authors present a low complexity turbo equalizer receiver for data transmission over time -varying frequency-selective fading channels by using extended Kalman filter (EKF). The resulting adaptive soft extended Kalman equalizer takes the soft decisions of data symbols from the SISO decoder as it's a priori information, and performs equalization iteratively. The proposed equalizer outperforms the other equalizers using conventional methods.

III. PROPOSED WORK

The first step of the methodology is Calculation of scatter angle and then calculates the path length and delay calculation. The calculation of losses and received signal strength is also performed.

In this section we represent the result of our simulation, based on the assumed parameters. Figure.2 represents the Simulink model with AWGN channel. The Model consists of Random Integer Generator which generates uniformly distributed random integer in the range [0 M-1], where M is the Mary number. Its output is converted into bits using Integer to bit converter and is modulated using Quaternary phase shift keying. Output of QPSK modulator is baseband representation of modulated signal is passed through AWGN channel and is finally demodulated using QPSK demodulator.

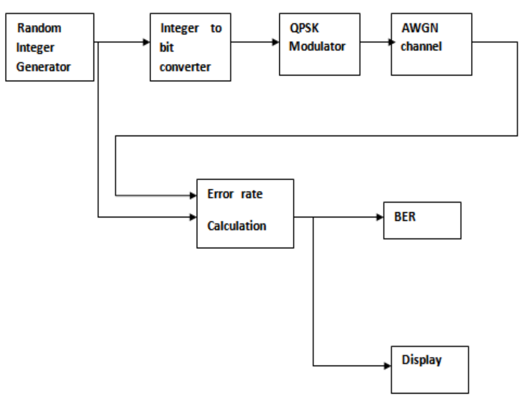

Fig.2: Simulink model with AWGN channel

Block Parameters

- Sample time-1/(20*10^6)s
- Number of bits per symbol-2
- Sample per frame-10000
- Doppler shift-10Hz
- Data rate-20Mb/s
- Symbol period-1/(10*10^6)

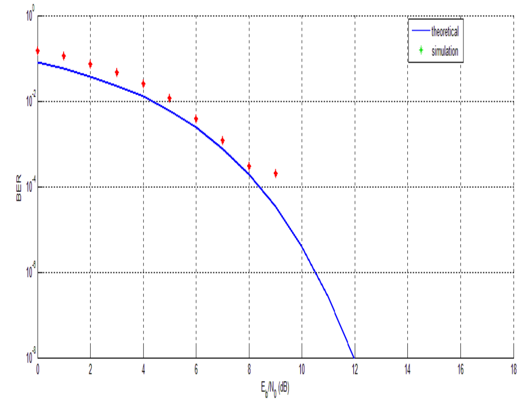

Fig.3: Theoretical and Simulated BER plot with AWGN channel

Figure.3 shows the BER plot with AWGN channel. Solid line represents theoretical result while green stars represent simulation result. From the above graph it is seen that our model for AWGN is correct as our simulation result are consistent with theoretical curves.

Simulink model of Tropo channel: Tropo channel is the combination of Rayleigh and AWGN channel .The Model consists of Random Integer Generator which generates uniformly distributed random integer in the range [0 M-1], where M is the Mary number. Its output is converted into bits using Integer to bit converter and is modulated using Quaternary phase shift keying. Output of QPSK modulator is baseband representation of modulated signal is passed through tropo channel and is finally demodulated using QPSK demodulator.

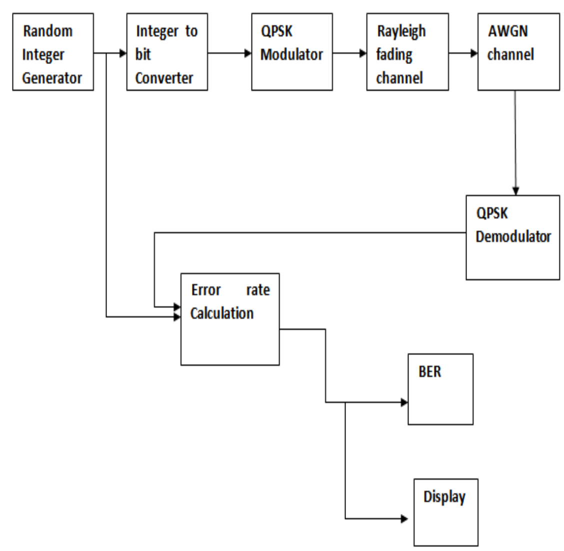

Fig.4: shows the Simulink model of Tropo channel. Tropo channel consists of Rayleigh and AWGN channel.

A. Analysis of channel performance with RLS filter for different values of forgetting factor

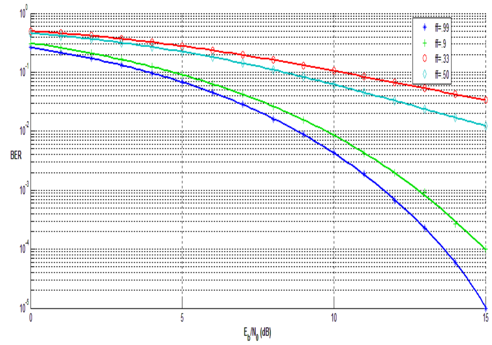

Figure.5: BER Plot for different values of forgetting factor (ff)

Figure.5 shows BER plot for different values of forgetting factor, here maximum Doppler shift is 10 Hz, path delay vector that is 50.0e-9*[0 1 2 3 4 5 6] s, and Average path gain vector that is [0 -3 -7 -12 -17- 23-29] dB. It is concluded form Figure 4.8 that optimum result for RLS filter are obtained with forgetting factor =0.99

B. Analysis of channel performance with RLS filter for different values of delays

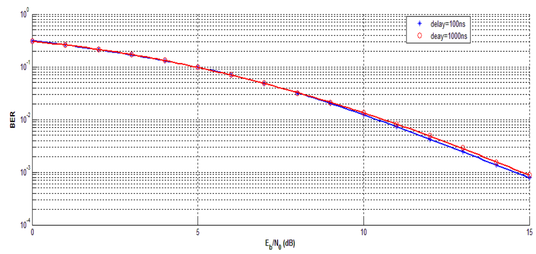

Fig.6: BER Plot for different values of delays

Figure.6 Analysis of channel performance with RLS filter for different values of Doppler shift (T=100ns)

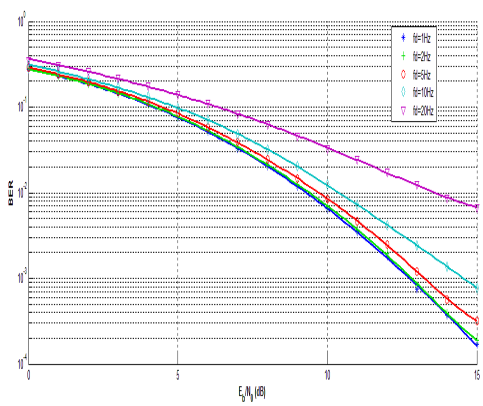

Fig.7: BER Plot for different values of Doppler shift

When Doppler shift is equal to 1Hz, 2Hz, 5Hz and 10Hz the influence on the BER performance for a fixed value of tap delay that is 100ns is shown in Figure.7 When Doppler shift increase it has inconspicuous influence on the BER performance.

C. Analysis of channel performance with RLS filter for different values of Doppler shift (T=1000ns)

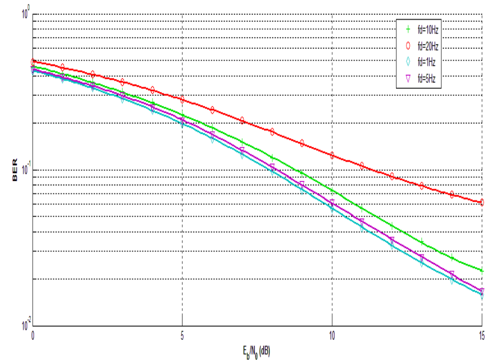

Fig.8: BER Plot for different values of Doppler shift

When T becomes larger, the BER curve becomes flat which can be seen from Figure 5.11,which implies that the ISI in the system is very small in condition of little T. With increase in T the BER performance of the system deteriorates continuously.

IV. CONCLUSION

From the above BER result it is concluded that when we are using Rayleigh channel with AWGN channel, the BER curve is flat. To improve BER result forward filter is used. Forward filter is an adaptive filter which updates its weight according to RLS algorithm. Among the different algorithms RLS is optimum for tropo channel as it is unaffected by channel characteristics, and its convergence rate is high in comparison to LMS algorithm which require training signal to adjust its coefficients initially. RLS filter is an optimum forward filter for single path. The best results are obtained with forgetting factor=0.99.Here we are doing the work for single path. We can also do it for multiple paths by employing forward filter in each path, and MRC (diversity Combining technique) is used to combine the result from the entire path.

- The BER is more sensitive to the combining techniquein uncorrelated channels than in time and frequencycorrelated channels.
- The throughput is sensitive to the combining techniquefor low and moderate SNRs, while the impact of thecombining technique is less evident when the SNR increases.
- PE technique is less sensitive to the number of interferersrather than classical MRC or suboptimum MMSE, providing a good solution for MC-CDMA systems.

V. REFERENCES

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