OFDM Based SER and MSE Analysis in Cooperative Underwater Acoustic Communication

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Abstract— Underwater communication is one of the unique and challenging fields in communication engineering in the case of both designing and communication. Previous papers explained about different views in acoustic based underwater communication. Communication with acoustic waves is suitable type of wireless transmission with sound waves underwater. This paper explains about SER and MSE analysis of AF relay based cooperative underwater communication based on CGM-MP-SAGE algorithm. Here in this paper it summarizes estimation and equalization with SAGE algorithm of acoustic waves through underwater. This is a review paper to analyze the error rate performance and reliability of UWAC with respect to the SNR for different signal parameters, mainly MP, perfect CSI and MP SAGE algorithms, Doppler rates, resolution factors, multipath with variable lengths and pilot spacing based on BPSK modulated OFDM signals.

Key words: UWAC, Acoustic waves, SAGE, SER, MSE, OFDM

I. INTRODUCTION

UNDERWATER exploration activities are mainly hampered by the lack of efficient means of real time based communication below water. The wide underwater environment is extremely rich with natural resources such as minerals and oil fields waiting to be explored. Although wire line systems through deployment of fiber optical links have been used to provide real time communication in some underwater applications, their high cost and operational disadvantages due to the lack of flexibility become restrictive for most practical cases. This triggers the growing demand for underwater wireless links. The transmission ranges of radio and optical underwater systems are limited to short distances. Due to the high attenuation of radio frequency signals in water, long range RF communication[1] is problematic and requires the use of extra low frequencies, which necessitate large antennas and high transmit powers. With relatively favorable propagation characteristics of acoustic waves, acoustic systems achieve longer transmission ranges. With the emerging bandwidth hungry underwater applications and the concept of underwater internet of things[1], demanding requirements are further imposed on underwater acoustic systems.

The underwater channel through which acoustic wave propagates has a high transmission loss, non uniform sound velocity, multi-path propagation, varying Doppler Effect, higher bit error rates and the omnipresent ambient noise contaminate the signal. Thus the underwater channel is the most challenging medium for communication. This first underwater acoustic telephone operated at 8.3 kHz and used single sideband suppressed carrier amplitude modulation. Until the 1980s, research efforts on UWAC were mainly dominated by military applications. Coupled with the limited bandwidth availability of the underwater channel, FSK became a bottleneck, limiting the operation of UWAC systems[1] to very low rates unacceptable for many modern applications. Emerging data heavy underwater applications impose further requirements on UWAC system design[1]. A wide variety under water communication system is available, but designers and engineers always search for a reliable and fast system when compare with all the previous systems. This paper follows as an analysis of SAGE algorithm and its limitations leading to a new system design. Also this paper covers and concluded with a summarized version of different technologies and approaches of underwater communication with acoustic waves.

II. LITERATURE ANALYSIS

A wide variety under water communication system is available, but we always search for a reliable and fast system when compare with all the previous systems. There are some familiar communications systems which is similar or which led to this system is given here as the literature papers. Multichannel approach was a simplified channel model using for the multichannel approach is a geometry based ray tracing model. An iterative scheme is derived for this approach from an approximation of the channels between the relays and the destination. The sparse nature of underwater acoustic channels were exploited in this method and performance over unstructured methods improved with this method. The efficacy of this method is evaluated with simulations, that is, comparing the mean square error of the estimated channel with its Cramer Rao bound. The unstructured case assumed that, no presence of a multipath profile and estimates the channel directly from the received signal and training sequence.

Multiple input multiple output (MIMO) techniques have been actively pursued in UWAC mainly to increase the data rate over the bandwidth limited channels. The receiver works on a block by block basis, where null subcarriers were used for Doppler compensation, pilot subcarriers were used for channel estimation, and a MIMO detector consisting of a hybrid use of successive interference cancellation and soft MMSE equalization was coupled with LDPC channel decoding for iterative detection on each subcarrier. The design has been tested using data recorded from three different experiments.

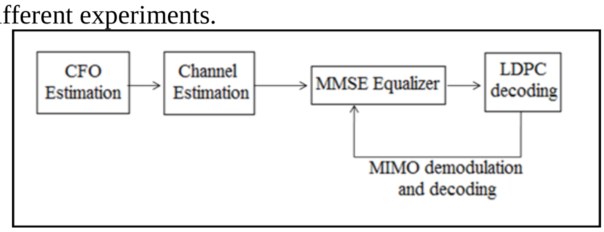

Fig. 1: Receiver block diagram

The AUV test was experimented with some specifications as the water depth was 20 meters. Two transmitters were deployed about 9 meters below a surface buoy. The receiving array was about 9 meters below a boat. The vertical array was 2 meters in aperture with 16 hydrophones, out of which we used four. Then the performance results for transmission distances of 500 and 1500 meters were reported. The Rescheduled Acoustic Communications Experiment (RACE) was done as the water depths in the area range from 9 to about 14 meters. The primary source of an ITC1007 transducer for acoustic transmissions was located approximately 4 meters above the bottom. A vertical source array consisting of three AT-12ET transducers with a spacing of 60 cm between each transducer was deployed below the primary source. The top of the source array was approximately 1 meter below the primary source.

Finally the third experiment VHF08 was conducted with the water depth was 12 meters. Two transmitters were about 6 meters below a surface buoy. The receiving array was about 6 meters below a boat. The array was 1 meter in aperture with 6 hydrophones. The transmission distance was 450 meters with a very high frequency (VHF) signal used. The test results were a spectral efficiency of 3.5 bits/sec/Hz for one experiment while a data rate of 125.7 kb/s over a bandwidth of 62.5 kHz for another. The limitations are this paper is very complex so it is difficult to implement and give importance to data rate with SE only but BER is not analyzed.

The resulting novel algorithm initially estimates the overall sparse channel taps from the source to the destination as well as their locations using the matching pursuit (MP) approach. The correlated non Gaussian effective noise is modeled as a Gaussian mixture. Based on the Gaussian mixture model, an efficient and low complexity algorithm is developed based on the combinations of the MP and the space alternating generalized expectation maximization (SAGE) technique, to improve the estimates of the channel taps and their location as well as the noise distribution parameters in an iterative way.

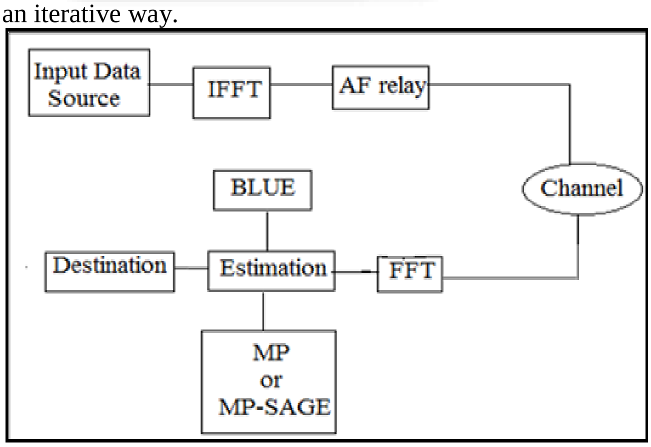

Fig. 2: Block diagram of channel estimation.

Fig. 2 explains the channel estimation with different algorithms. The MP algorithm is an iterative procedure which can sequentially identify the dominant channel taps and estimate the associated tap coefficients. Finally the MP algorithm at each SAGE iteration step by updating, all the dominant channel taps and the associated tap coefficients sequentially. MSE and SER performance curves of the MP, BLUE and MP-SAGE algorithms for BPSK and QPSK signaling format. Main limitations are SNR and equalization not considered, ISI and Doppler effect are not analyzed.

III. SER AND MSE PERFORMANCES

The channel estimation problem in a cooperative system with DF relaying involves the individual estimation of source-to-relay and relay-to-destination channels. This estimation problem is essentially the same as in point-to-point links and the existing results on channel estimation for point-to-point UWA links can be used for this purpose. On the other hand, for a cooperative system with AF relaying, the channel estimation problem involves the estimation of a cascaded channel consisting of source-to-relay and relay-to-destination links. In this model the prior probability density functions of the overall cascaded complex channel gains, from source-to-relay and relay-to-destination, as continuous Gaussian mixtures (CGMs) and show that an exponential type of mixing pdf admits this representation exactly.

The CGM model developed an efficient and low complexity novel channel estimation algorithm by combining the MP and the space alternating generalized expectation maximization (SAGE) techniques, called the CGM-MP-SAGE algorithm which relies on the concept of the admissible hidden data, to improve the estimates of the channel taps and their locations as well as the channel prior distribution parameters in an iterative manner. Then demonstrated that by suitably choosing the admissible hidden data on which the SAGE algorithm relies, a subset of parameters is updated for analytical tractability and the remaining parameters for faster convergence. A system model for an OFDM based underwater cooperative wireless communication system and descries the main parameters of the UWA channel.

Fig. 3, explains the block diagram of the designed system. Input data source is an acoustic wave generator, the waves are converted to binary symbols as OFDM is used. IFFT is performed in OFDM modulator and then it is amplified and forward using an AF relay. At destination FFT demodulates OFDM and then channel estimation and equalization is performed as a combination of MP algorithm and CGM-MP-SAGE.

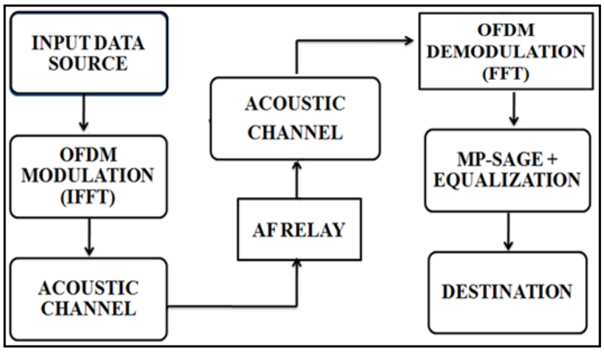

Fig. 3: Designed system block diagram

An iterative algorithm, called the CGM-MP-SAGE algorithm, based on the SAGE and MP techniques for channel estimation employing the signal model is used. The SAGE algorithm is a twofold generalization of the so called EM algorithm that provides updated estimates for a set of unknown parameters. First, rather than updating all parameters simultaneously at iteration, only a subset of indexed by is updated while keeping the parameters in the complement set fixed and second, the concept of the complete data is extended to that of the so called admissible hidden data to which the observed signal is related by means of a possibly non deterministic mapping. The convergence rate of the

SAGE algorithm is usually higher than that of the EM algorithm, because the conditional Fisher information matrix for each set of parameters is likely smaller than that of the complete data, given for the entire space. At the iteration, the expectation step of the SAGE algorithm is defined. In the maximization step, only is updated.

On the other hand, the MP algorithm is an iterative procedure that can sequentially identify the dominant channel taps and estimate the associated tap coefficients by choosing the column of that best align with the residual vector until all the taps are identified. This system CGM-MP-SAGE algorithm implements the MP algorithm at each SAGE iteration step by updating all the dominant channel taps and the associated tap coefficients sequentially. The initialization of the SAGE algorithm is a critical issue since the algorithm may not converge if the initial values of the parameters to be estimated are not chosen properly. Apply the matching pursuit algorithm to determine the initial considering. It is well known that as the MP algorithm can estimate the positions quite well, its estimation performance of the complex channel gains would not be sufficiently good. However, following the initialization step, the SAGE algorithm is able to compensate for this weakness by using those rough estimates, to enable the algorithm to converge to an optimal MAP solution. In first iteration the symbol with pilot sequence is estimated by CGM-MP-SAGE algorithm, if it converges then moved to next iteration, if it does not converge then estimated symbol is equalized and estimated again.

Before practical implementation a software simulation is to be done to analyze the reliability of the system designed and for finding the errors or limitations. Then only the limitations can be overcome and an effective system can design. For simulation of this work MATLAB is used. MATLAB is a powerful high level programming language for scientific computations developed by MathWorks. MATLAB is the abbreviated form of Matrix Laboratory. It is very easy to learn and use in solving numerically complex engineering problems mainly in signal processing. MATLAB consists of functions that are either built into the interpreter or available as M-files, with each containing a sequence of program statements that execute a certain algorithm.

IV. Simulation Results

Here a comb type pilot structure with equally spaced pilot subcarriers is considered. The performance of the system is measured in terms of the MSE of the channel estimator and the corresponding SER based on SNR values.

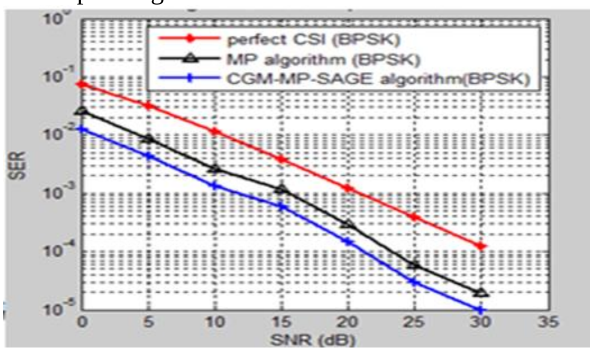

Fig. 4: SER vs SNR performance, BPSK comparison perfect CSI, MP and CGM-MP-SAGE algorithm

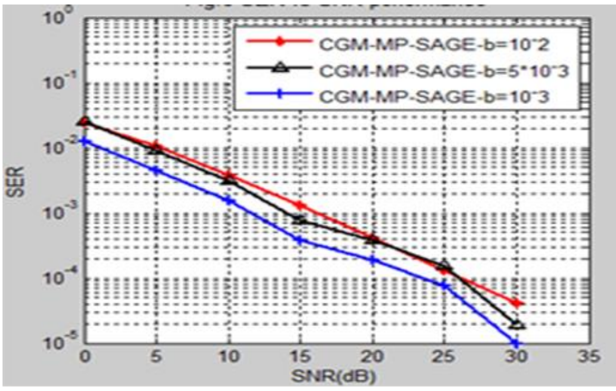

Fig. 5: SER vs SNR performance of the CGM-MP-SAGE algorithm for different Doppler rates.

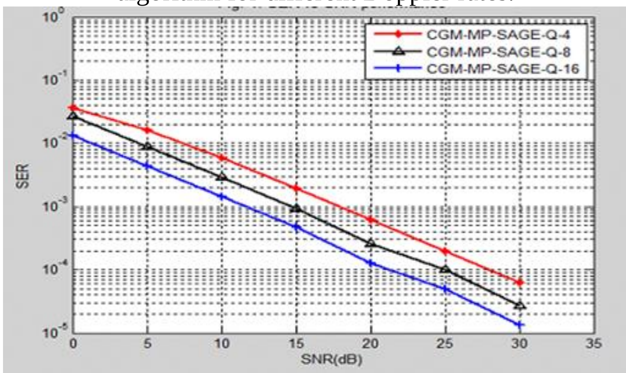

Fig. 6: SER vs SNR performance of CGM-MP-SAGE algorithm for different resolution factors.

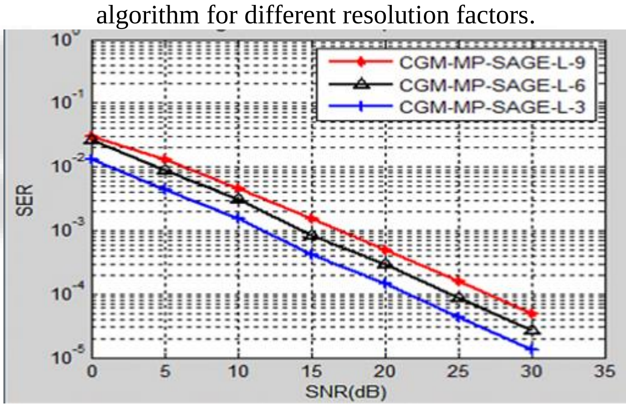

Fig. 7: SER vs SNR performance of CGM-MP-SAGE algorithm for multipath.

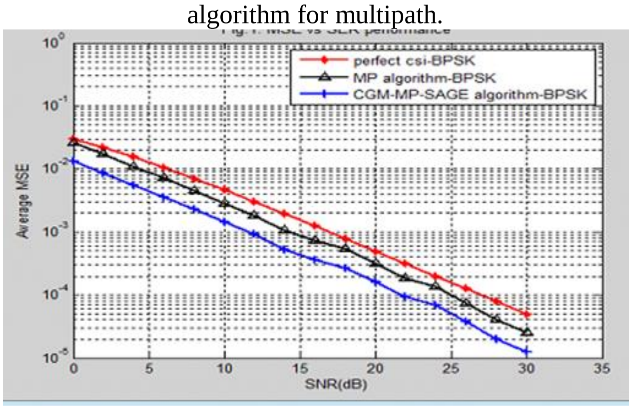

Fig. 8: MSE vs SNR performance, BPSK comparison perfect CSI, MP and CGM-MP-SAGE algorithm.

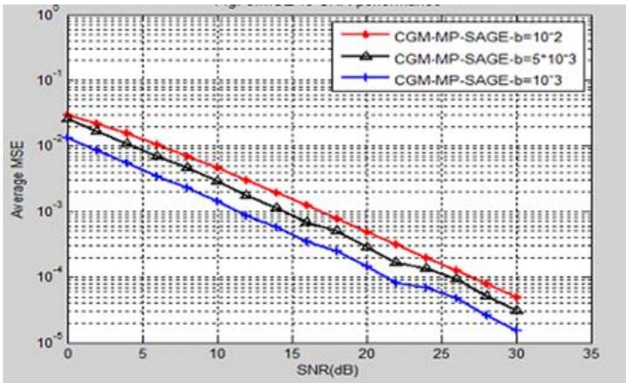

Fig. 9: MSE vs SNR performance of the CGM-MP-SAGE algorithm for different Doppler rates.

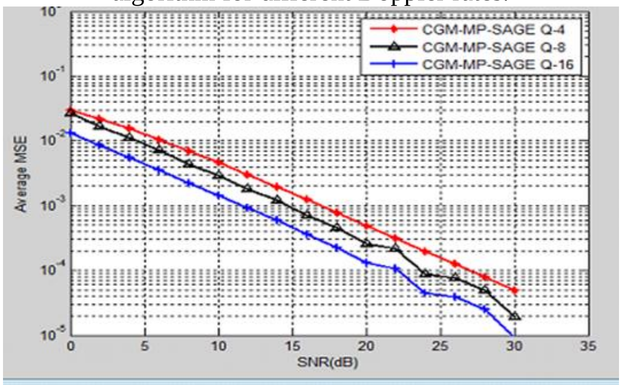

Fig. 10: MSE vs SER performance of CGM-MP-SAGE algorithm for different resolution factors.

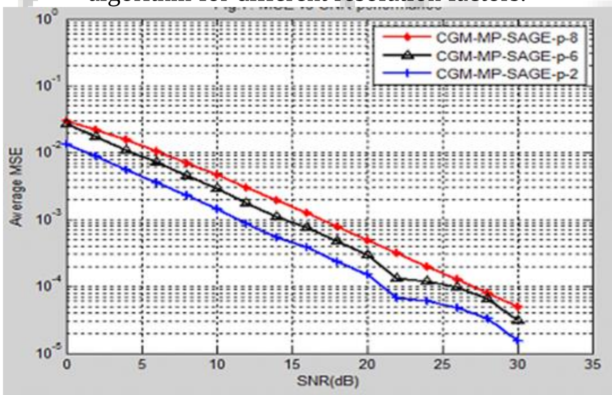

Fig. 11: MSE vs SNR performance of CGM-MP-SAGE algorithm for different pilot spacing

Fig. 4 simply compares SER performances of BPSK modulation of the perfect CSI, MP algorithm and CGM-MP-SAGE algorithm. Fig.5. explains SER performance of the CGM-MP-SAGE algorithm for different Doppler rates. Fig.6. measures the SER performance of CGM-MP-SAGE algorithm for different resolution factors. Analysis for different number of paths is expressed in Fig.7. as SER performance of CGM-MP-SAGE algorithm for multipath. As SER performances analyzed MSE should be analyzed based on SNR for each parameters in Fig.8. MSE performance based on BPSK modulation comparison for perfect CSI, MP algorithm and CGM-MP-SAGE algorithm. In fig.9.Doppler rates are analyzed with MSE performance of the CGM-MP-SAGE algorithm. Fig.10. defines MSE performance of CGM-MP-SAGE algorithm for different resolution factors and finally pilot spacing are computed based on MSE and SNR.

From this simulation results it is clear that SNR inversely proportional to SER and MSE. But the main limitations of this paper is time delay, which is not practically possible for underwater communication. One of the other limitation is complexity of the algorithm, so practical implementation is not well suitable.

V. Conclusion

After a detailed survey among various UWC techniques and approaches for UWAC are analyzed. This paper deals with acoustic wave communication for UWAC with SER and MSE analysis based on SNR. This system analyzed and measured variable parameters in underwater communication basically different algorithms with respect to BPSK modulation, Doppler rates and multipath which are the main limiting factors in underwater communication. This also searches for the limitations in practical implementation of this system. Thereby understood the advantages to incorporate with a system design and filtered out the limitations that should be avoided for a reliable system design. To develop a new underwater communication system, research and review should be a main factor, so this paper can be concluded wisely as it met both aspects. To summarizes and identify different approaches many previous paper limitations are analyzed here. Thus some future scopes are observed to implement in upcoming researches to overcome the limitations with this approaches. Researchers are going on to design a reliable approach for UWAC. Different ideas can be adoptable, with more applications and algorithms. For UWC reliable, long distance, less complex and fast responding is necessary, so as a future work this as to be researched.

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