

Different approaches 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 different underwater acoustic communication approaches. Here in this paper it summarizes different estimation, equalization and transmission criteria of acoustic waves through underwater. This is a review paper to combine different approaches in UWAC as a summary work.

Key words: UWAC, Acoustic Waves, ICI, Sparse Recovery, Resampling, MIMO, Structured approach, MP, Estimation, 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 (UWA) 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. There are some familiar communications systems which is similar or which led to the development of a new system is given here as the literature papers. This paper follows with some literature paper works and 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. DIFFERENT UWAC APPROACHES

A criterion for unique recovery from blind deconvolution under sparsity[4] is explored priors. For key cases, it is possible to ensure unique recoverability given the regularized problem statement. The uniqueness results are informed by a matrix completion based viewpoint of blind deconvolution. Furthermore, this perspective enables characterization of why blind deconvolution[4] with two sparse inputs is an inherently hard problem. Two blind deconvolution algorithms are proposed which do not rely on alternating between the estimation of one input signal, while holding the other constant. The contributions of this work are, map the two hop cooperative communication problem to that of blind deconvolution. Then identify good regularizers for this problem and show that a matrix rank minimization approach towards blind deconvolution allows us to provide a clean answer to the unique recoverability question. Then argue using matrix completion ideas that a sparsity prior on both input signals leads to poor recovery performance and provides results on unique recoverability for both the well separated as well as the not well separated cases of blind deconvolution.

Underwater acoustic channels are wideband in nature due to the small ratio of the carrier frequency to the signal bandwidth, which introduces frequency dependent Doppler shifts. The channel is treated as having a common Doppler scaling factor on all propagation paths, and a two step approach to mitigating the Doppler effect[7], non-uniform Doppler compensation via resampling[9] that converts a wideband problem into a narrowband problem and high resolution uniform compensation of the residual Doppler is proposed. Zero padded OFDM is focused to minimize the transmission power. Null subcarriers are used to facilitate Doppler compensation, and pilot subcarriers[7] are used for channel estimation. The receiver is based on block by block processing, and does not rely on channel dependence across OFDM blocks, thus, it is suitable for fast varying UWA channels.

The time variation challenges[8] the use of orthogonal frequency division multiplexing destroying[8] carrier orthogonality and introducing significant inter carrier interference. Much of the current work on time varying channels assumes a single common Doppler shift for each path. As such, resampling is optimal preprocessing[8] in such cases. The current work examines the choice of resampling factor for the case of distinct Doppler shift on each path. The optimal resampling factor is selected to maximize the Fisher information[8] for the transmitted data. Fisher information is also used to evaluate the information loss due to resampling. The findings suggest that the optimal resampling factor is near that associated with the Doppler shift of the strongest path. It is also observed that the information loss is modest in many cases using this practical preprocessing. Data detection as an estimation problem and examine the associated Fisher Information Matrix under the assumption of resampling. As the FIM[8] is a function of the resampling parameter, the resampling factor is determined, which maximizes the information content after resampling. Also consider a channel estimation problem and determine the optimal resampling for that case. First examine sufficient statistics for data detection and then proceed to determine the optimal resampling rate for such communication environments.

Underwater acoustic communications features frequency dependent signal attenuation, long propagation delay, and doubly selective fading[5]. Thus, the design of reliable and efficient UAC protocols is very challenging. For cooperative relay communications[5], which can provide reliable data transmission, is a very attractive technology for UAC[5]. A practical asynchronous relaying protocol tailored for UAC asynchronous amplify and forward relaying with Precoded OFDM. This protocol resolves both the time synchronization difficulty and the frequency selective issue of UAC channels. However, the AsAP protocol[5] adopts fixed amplification and uniform power allocation among the source and the relays, which limits the system performance. Assuming statistical channel state information is available, we analyze the average SNR at the destination and perform the power optimization on the AsAP[5] system.

GLCP[5] consists of two steps grouping and precoding. After receiving the signal from the source, each relay amplifies the signal to compensate the S-R channel fading. Finally, the destination collects all the asynchronously arriving signals from the source and the relays and decodes them. Due to the reception and processing delay at relays, it can be shown that the direct link signal and relayed signals are separated temporally. The SR-AsAP[5] consists of three phases relay selection, relay notification, and AsAP transmission.

The design targets at improving bandwidth efficiency by reducing the amount of overheads typically associated with SIMO-OFDM UWAC. This design is composed of three major parts, the first part of the design targets at the overheads associated with initial channel parameter estimation. To reduce such overheads, proposed a preamble based parameter estimation scheme that exploits not only the structure of the preamble but also knowledge of training symbols in the preamble. This scheme is more bandwidth efficient in the sense that it is capable of acquiring initial estimates of more channel parameters with The second part of the design tackles the overhead due to the use of ZP.

To reduce such overhead, channel shortening by applying time reversal based SIMO-OFDM detection[2]. In TR-SIMO-OFDM detection, the TR operation[2] converts multiple time-dispersive fading channels associated with SIMO-OFDM into a single channel with generally smaller time dispersion and less fading. The same preamble.

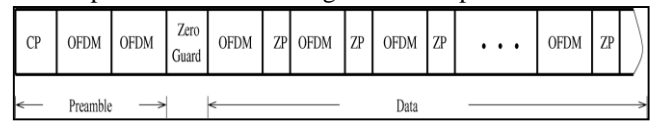


Fig. 1: Overall structure of the transmitted signal

Compared to conventional single carrier systems, for which complicated equalization schemes are usually required, OFDM systems are in general much simpler to implement as detection can be carried out symbol by symbol over time dispersive channels[6]. Cyclic prefixed OFDM over time varying UWA channels is focused. To cope with the ICI that arises at the receiver side because of the time variations in the channel, we consider two ICI mitigation[6] techniques. In the first scheme, the ICI coefficients are explicitly estimated, and minimum mean square error linear equalization based on such estimates is performed. In the second approach no explicit ICI estimation is performed, and detection is based on an adaptive decision feedback equalizer applied in the frequency domain across adjacent subcarriers.

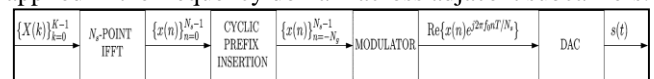


Fig. 2: Block diagram of a CP-OFDM transmitter.

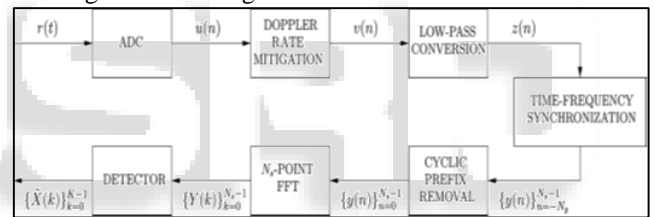


Fig. 3: Block diagram of the considered receiver.

The MUD based receiver adopts a frequency domain oversampling front end on each hydrophone, then performs joint channel estimation and multiuser data detection in an iterative fashion. The SUD based receiver adopts conventional single user processing modules, but adds a critical step of MUI cancellation. Since different users have different resampling operations, judicious amplitude[3], delay, and Doppler scale corrections need to be applied to the estimated multipath channels to reconstruct the MUI to other users. Compared the MUD and SUD based receivers in a system with two single transmitter users moving with different directions. Then presented the performance of the SUD based receiver in a two user system with one slowly moving single transmitter user and another stationary user having two or three data streams, as well as in a three user system with two mobile single transmitter users and one stationary user having two transmitters. The work has the distinctions[3] the system setting is expanded where different users could have different numbers of data streams, the receiver processing[3] and the signaling format are different and the performance results include different emulated settings[3] with up to four parallel data streams.

Multichannel approach [11] 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 CRB. The unstructured case assumed that, no presence of a multipath profile and estimates the channel directly from the received signal and training sequence. The objective was to develop a model which enables the exploitation of structure in channel estimation. The signal model is motivated by approximations made on the ray tracing model for the multipath profile. A single source communicates to a set of cooperating relays, then the relays transmit to a common destination node[11]. The channel estimation problem for the first hop is essentially a set of single channel estimation problems. Due to the many to one nature of the second hop, there was a multichannel estimation problem at the destination node. A pulse matched filtering and sampling at the destination node was assumed.

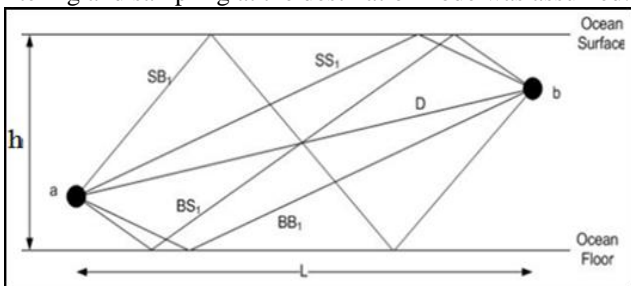


Fig. 4: Multipath reflections in a shallow water environment.

A recreation of the model is shown in Figure 4, with a and b are the transmitter and receiver heights, h is the ocean depth, L is the transmission distance and the reflection types. The multipath delays are determined by the speed of sound and the path lengths, and the multipath profile amplitudes are inversely proportional to path length and decay exponentially in the number of reflections. The channel estimation based on multipath profile and channel taps are done then the performance bound was considered with MSE and CRB. The main limitations of this model is it neglects some subtleties regarding underwater acoustic propagation, such as ray bending, surface scattering, and nonwhite ambient noise which are very important for reliability.

Multiple input multiple output (MIMO) [10] techniques have been actively pursued in UWAC mainly to increase the data rate over the bandwidth limited channels. In a MIMO system design, that spatial multiplexing is applied with OFDM signals is explained. 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.

This design has been tested using data recorded from three different experiments the AUV Fest, the RACE experiment and the VHF experiment. The Doppler estimation was carried out first. The channel Doppler Effect can be viewed as caused by carrier frequency offsets (CFO) among the transmitters and the receivers. The CFO estimation

algorithm is directly applicable, where the energy on the null subcarriers is used as the objective function to search for the best CFO estimate. After Doppler shift estimation and compensation, the average energy on the null subcarriers is used to compute the variance of the additive noise and residual ICI. This quantity is needed for the soft MMSE equalization. Then the channel estimation, after CFO compensation, pilot tones is used for channel estimation. Since each transmitter is assigned with an exclusive set of pilot subcarriers, channel estimation is carried out for each transmitter receiver pair separately and then iterative MIMO demodulation and decoding, the whole procedure is as shown in figure 5.

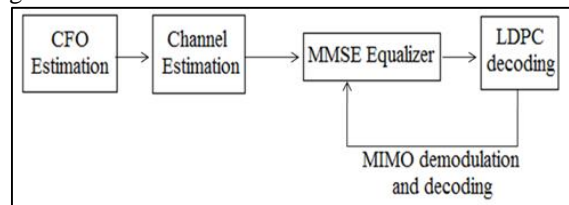


Fig. 5: Receiver block diagram

The AUV test [10] 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)[10] 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 [10] 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.

It is concerned with a challenging problem of channel estimation for amplify and forward cooperative relay based OFDM systems in the presence of sparse underwater acoustic channels and of the correlative non Gaussian noise. The sparse structure of the channel impulse response to improve the performance of the channel estimation algorithm, due to the reduced number of taps to be estimated was exploited. 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.

The main contribution in this work[12] is two folds means the sparse structure of the channel impulse response to improve the performance of the channel estimation algorithm, due to the reduced number of taps to be estimated. The resulting 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. Second, based on the Gaussian mixture model we develop an efficient and low complexity novel algorithm by combining the MP and the SAGE techniques, called the MP-SAGE algorithm which relies on the concept of the admissible hidden data, to improve the estimates of the channel taps and their location as well as the noise distribution parameters in an iterative way. Figure 6. Explains the block diagram of channel estimation in cooperative underwater communication in OFDM.

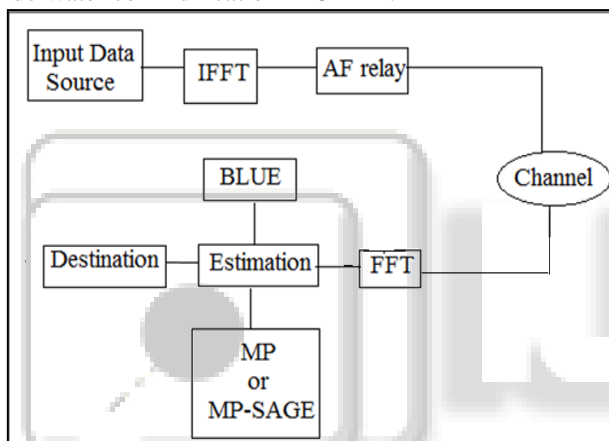


Fig. 6: Block diagram of channel estimation.

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. CONCLUSION

After a detailed survey among various underwater communication techniques and approaches for UWAC are analyzed. This paper deals with acoustic wave communication different approaches and applications. This also searches for the limitations in practical implementation of these systems. 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 summarize and identify different approaches many previous paper limitations are analyzed here.

This paper follows overhead reduction, iterative receiver approach, sparse recovery from convolved output, selective relaying, ICI mitigation, multicarrier UWAC, OFDM resampling, MIMO-OFDM, MP approach, multichannel structured approach are analyzed. Thus some future scopes are observed to implement in upcoming researches to overcome the limitations with this approaches.

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