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ENHANCED UNDERWATER ACOUSTIC COMMUNICATION USING F-SGM AND SPECTRAL COHERENCE BASED WAVELET TRANSFORM

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ABSTRACT

The acoustic channels beneath the sea are exceedingly complicated and active. Doppler shift, multi-path effect, phase noise, and temporal variation all affect underwater audio communication signals. Due to the features of the maritime environment, enacting UWA channels for reliable high data rate underwater wireless communication is extremely difficult. UWCs use the most common communication technologies, such as optical, magnetic induction, electromagnetic, and acoustic communications. In this work, entirely generalised spatial modulation in which one constant number and one multiple number of antennas are active to transmit data symbols in any time interval for underwater audio communication (UWAC). This work proposes the Spectral coherence based Wavelet Transform for adaptive channel estimation method over the underwater time-varying MIMO channel. Furthermore, maximum likelihood (ML) decoder is employed to detect the transmitted data and antennas indices from the received signal and the estimated UWA- MIMO channel.

KEYWORDS: *Massive MIMO, Statistical Channel State Information, Underwater Acoustic.*

INTRODUCTION

The main characteristics of optical communication, such as scattering, severe absorption, and LoS communication, limit its uses to pure water only. Ocean conductivity causes harsh attenuation of magnetic and electromagnetic waves, which is overcome by ultra-low frequency bands. Acoustic communication technology is a well-known physical layer technique that the UWC employs to accomplish extended communication distances, ranging from a few metres to ten kilometres for low-high transmission frequencies The acoustic wave has a narrow bandwidth, is affected by ambient noise, has a long propagation delay, has a large Doppler shift. Despite issues described previously, acoustic communication is the most reliable UWC technology [1]-[3]. Multi-path occurs when a transmitted signal collides with obstacles, resulting in reflected, diffracted, and scattered copies of the signal. Each of these duplicates is weaker in power, has a different phase, and has its own delay when viewed in direct line of sight (LOS).These copies of the transmitted signal are added together at the receiver, resulting in the total received signal. Multi-path can cause considerable performance deterioration due to inter symbol interference, which causes distortion of the received signal (ISI). The ISI makes communication less trustworthy, and removal is required to recover the original data symbols.

UNDERWATER ACOUSTIC MASSIVE MIMO MODEL

A beam-based Underwater acoustic massive MIMO channel model is used to evaluate the current architecture's properties. They demonstrate that using this model, the transmit design for rate maximisation can be done in a dimension-reduced space related to the channel taps. Furthermore, if the number of hydrophones likewise increases to infinity for the high signal-to-noise-ratio regime, the best power allocation may be discovered simply by utilising the water-filling algorithm, and the corresponding rate is positively associated with the number of channel taps.

Water filling algorithm does not always make the best use of the resources at hand. Because the classic OFDM system has additional power limits, the traditional water-filling technique cannot be used directly for power allocation in an acoustic system. As a result, the data rate will be reduced.

ACOUSTIC COMMUNICATION USING F-SGM AND SPECTRAL COHERENCE BASED WAVELET TRANSFORM

SMTs are appealing underwater acoustic (UWA) MIMO communication systems because of their high spectral and energy efficiency. As a result, this research focuses on SMTs for underwater audio communication, such as completely generalised spatial modulation, in which one constant number and one multiple number of antennas are active to broadcast data symbols at any time interval (UWAC). The Spectral coherence based Wavelet Transform is proposed in this paper as an adaptive channel estimate approach for underwater time-varying MIMO channels. Furthermore, from the received signal and the predicted UWA-MIMO channel, a maximum likelihood (ML) decoder is employed to detect the broadcast data and antenna indices. The data rate of the F-GSM increases linearly as the number of transmitting antennas increases.

This can be accomplished by transmitting data using a configurable number of transmit antenna configurations. Using a Spectral Coherence based Wavelet transform for channel estimation and a variable number of transmit antenna combinations for data transmission improves the wireless channel's reliability, makes it easier to distinguish between channel paths, improves decoding performance, and thus reduces BER degradation.

FGSM

The first two bits of the SM method are utilised as transmit antennas, while the remaining two bits are used for conventional modulation. The high rate of detection of the sent signal is a hurdle for GSM. The underlying idea of SM is to map a block of data bits to two data carrying units. One of the information carrying units is a symbol selected from a constellation diagram, while the other is a unique transmit antenna number selected from a group of transmit antennas.

Spectral Coherence based Wavelet Transform

The wavelet transform is based on the Fourier transform. Wavelet functions are spatially localised, but Fourier sine and cosine functions are not. The process of decomposing a signal into shifted and scaled versions of a particular wavelet is known as wavelet analysis. The wavelet transform is a signal filtering technique that combines low pass and high pass filtering. The high pass filter generates detail information at each level, while the low pass filter coupled with the scaling function generates coarse approximation information. The filtering and decimation process is repeated until the desired output level is achieved. The number of levels is determined by the length of the transmission. The architecture of the suggested system is depicted in Figure 1.

System Model

The spatial mapper converts a set of input bits A into a symbol Bei, where the i-th unit vector is a symbol. There is one non-zero entry in the i-th position of this i-th unit vector. Any real or complex valued symbol constellation is used to create the modulation symbol B. The number of bits sent per channel and the number of data symbols B determine a system's spectral efficiency. It is also affected by the signal point constellation used. The complex Gaussian noise vector of R receiving antenna is denoted by n. Yx+n denotes the received signal y for R receive antennas in one time slot (1) where x represents the transmitted vector and H represents the complex channel matrix hmn denotes the channel fading coefficients between T transmit antennas and R receive antennas. We'll suppose H is a Rayleigh flat fading channel that the receiver is aware of.

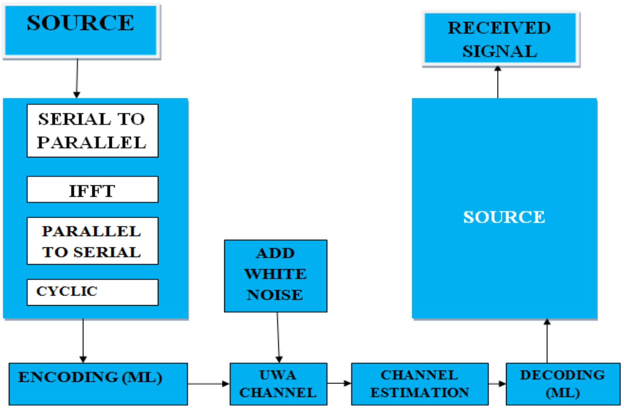

Figure 1: Proposed Block Diagram.

Assume that numerous outputs are positioned at the receiver's input and multiple inputs are located at the transmitter's input. Any real or complex valued symbol constellation can be used to create the modulation symbol B. The letter P stands for precoding matrix. In this, instead of a unit vector, there is a general beam forming vector B, which is made up of a codebook based on the first input bits. As a result, Bei provides the signal, and the symbol B is not necessarily delivered on a single antenna element. A precoding matrix P is multiplied with the output of a typical mapper. The codebook of accessible beam-forming vectors is represented by this precoding matrix.

ML Detection

Assume that the receiver's input has several outputs, whereas the transmitter's input has multiple inputs. Any real or complex valued symbol constellation is used to generate modulation symbol B. Precoding matrix is denoted by P. Instead of a unit vector, this has a generic beam forming vector B, which is made up of a codebook based on the first input bits. As a result, Bei transmits the signal, and the symbol B is not necessarily broadcast on only one antenna element. A precoding matrix P is multiplied by the output of a standard mapper. The codebook of available beam-forming vectors is represented in this precoding matrix.. Therefore, there is only one nonzero value in the vector, which is given as

$$X = [0, \ldots\ldots\ldots, 0, v, 0, \ldots\ldots\ldots 0]^T \quad (2)$$

Where v is a complex symbol from the signal set S with TS, and Y represents the received vector. The TR fading matrix H denotes the normalised complex fading gain from transmit antenna j to receive antenna I where n denotes the noise vector. We've already established that the receiver is aware of the SM channel's channel matrix H and the transmitted symbol vector I B,e as determined by the maximum likelihood detector.

$$[B, e_i] = \arg\min \| Y - Hx \|^2 \quad (3)$$

The Transmitter

The transmitter is the component of the system that generates and transfers the transmitted signal to the receiver. Figure 2 shows a schematic representation of the entire communication system.

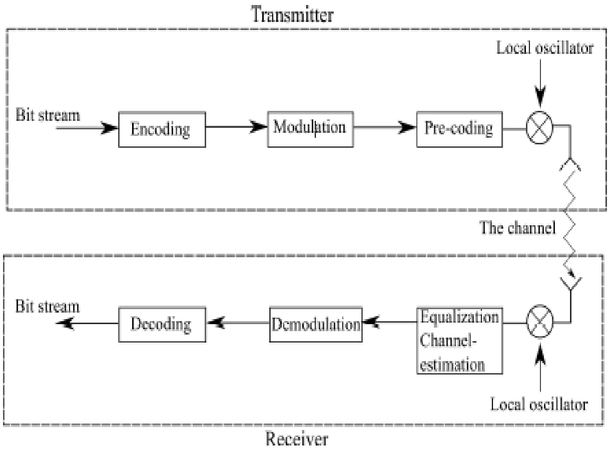

Figure 2: Transmitter and Receiver.

The Channel Model

The causes behind the channel effects present in the medium were stated earlier in the previous chapter. It is assumed that multi-path is present and ISI shall occur and that all paths experience fading, Doppler effects and are delayed. Many references about the UAC mention that these effects occur in acoustic underwater communications. It is assumed that there is multi-path, that ISI will occur, and that all paths will fade, have Doppler effects, and be delayed. These phenomena are mentioned in many UAC references as occurring in acoustic underwater communications.

$r(t) = p|\alpha|s(\alpha t)$ (4)

The Doppler effect is symbolised by a term α ,called the Doppler rate, as shown in (3.9). The Doppler rate is defined as

$\alpha = 1 + 2vc$

Where c is the underwater sound propagation speed and v is the overall speed of the transmitter and/or receiver. It assume that, there will be multi-path, ISI, and all paths will fade, have Doppler effects, and be delayed.

The receiver, which is the bottom element of the communication system, is introduced in this section. First, the carrier frequency is removed by converting to base-band. The receiver then performs equalisation, which eliminates any

ISI and channel estimation. The symbols are then deciphered and demodulated. The receiver then performs matched filtering, which is the same as 'sampling' the original received pulse after the conversion to baseband is completed. By collecting a sample of the received signal per symbol period T, where the sample represents the result of matched filtering. The results of matched filtering with dimensions 1 N are represented by the vector y, R is the channel matrix with dimensions N N, b is the vector containing the original symbols, and noise is represented by the noise vector n with dimensions N 1. The quantity of ISI present is determined by the number of non-zero entries. The ISI span extends to all symbols in a block if R does not contain any zero entries.

EXPERIMENTAL RESULTS

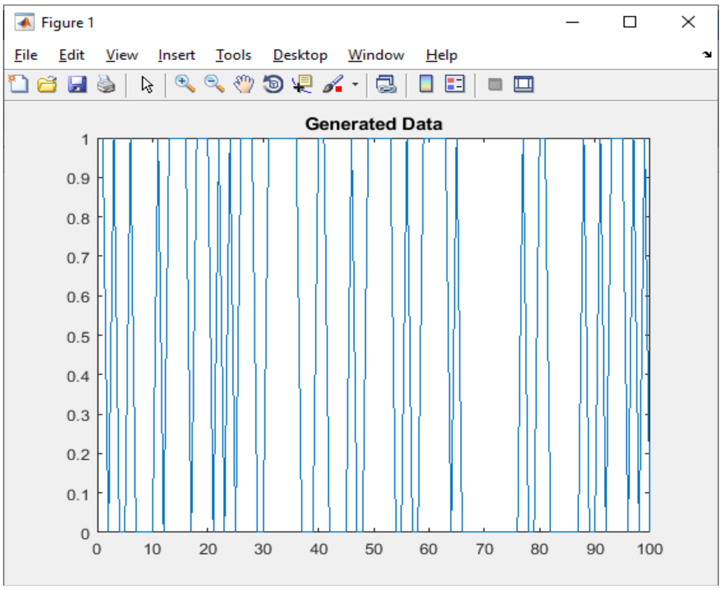

Figure 3: Generated Input Signal.

The generated data is the input data of communication as shown in Fig.3. This data is randomly generated.

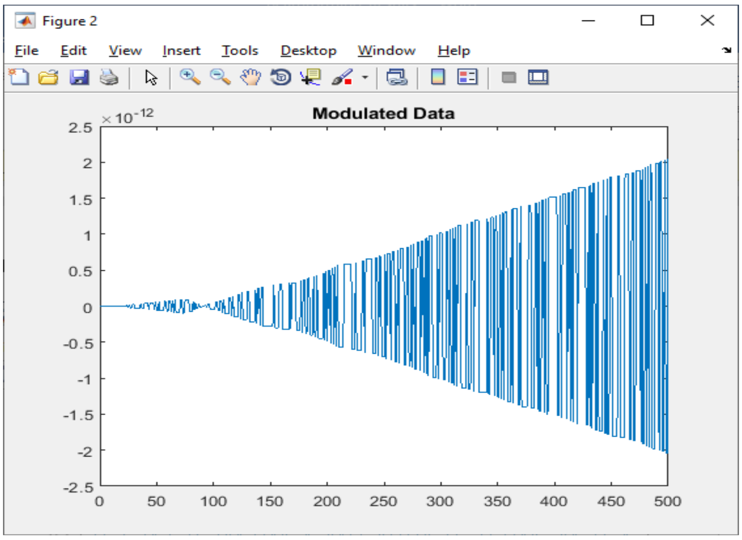

Figure 4: Modulated Data.

Fig.4 shows the generated signal which is the modulated data of the input generated signal. At the receiver side, apply the reverse process like parllel to serial, fourier transform and demodulation is applied, we get the original input signal. It is shown in Fig.5.

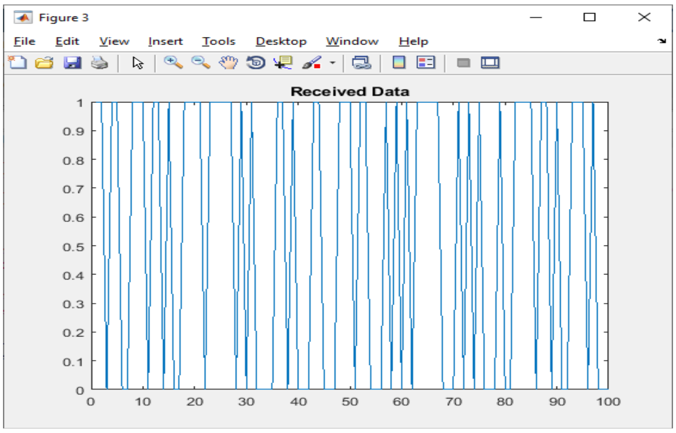

Figure 5: Received Data.

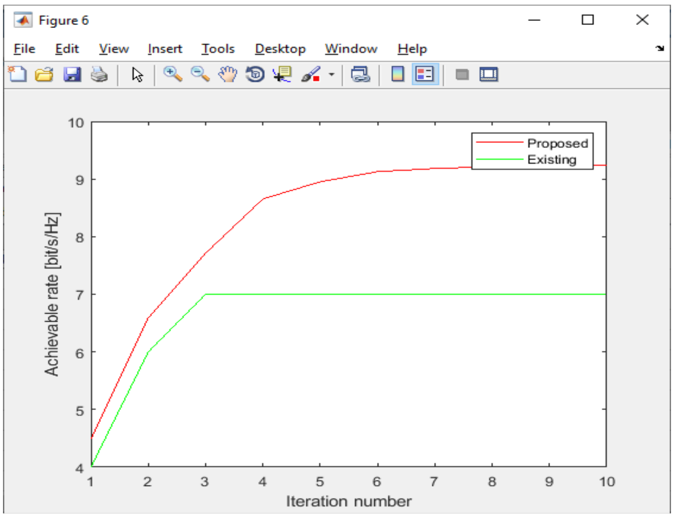

Figure 6: Performance Comparison.

The graph shows the performance comparison of existing and proposed. This is plot between number of iterations and achievable rate. Compared signal evaluates the performance metrics. The proposed method gives better performance rate as shown in Fig.6.

CONCLUSION

The UAC is widely regarded as one of the most difficult forms of communication now in use. The primary UAC phenomena were reviewed in this chapter, as well as the challenges that must be overcome if reliable communication is to be established. This is done in order to provide insight into future decisions, such as channel modelling. The remainder of the study will focus on how to construct a communication system that can cope with Doppler effects and eliminates the ISI in order to achieve reliable communication. In this work, We propose a spectral coherence based wavelet transform and FGSM system for UWA communications. The convolutional structure was used to formulate UWA channel estimation as a sparse recovery problem. We've also suggested a low-complexity sparse channel estimation technique that takes into account the fact that, in practise, each path's channel taps are frequently complex valued. The system achieves more accurate UWA channel estimate performance under the conditions of bandwidth, duration, data rate, and channel profile, according to simulation findings.

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