OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

Study of Space–Frequency Block Coding for Underwater Communications

Supriya A Londhe[1], P. N. Kota[2]

[1]*Department Of Electronics And Telecommunication Engineering, Modern Education Society's College Of Engineering, Pune, India*

[2]*Sinhagad College Of Engineering Research Student,*
Modern Education Society's College Of Engineering, Savitribai Phule Pune Unversity, Pune, India

ABSTRACT: *Underwater acoustic signals propagation is quite slower speed of propagation compared to Electromagnetic wave in atmosphere. The slow speed of the propagating wave leads to time-varying multipath phenomenon that imposes severe limitations on the performance of the MIMO OFDM system. For such a noisy Under water communication It is necessary to design the space frequency block code (SFBC) Detection system at the receiver to achieve reliable communication. In this paper,some detection algorithms has been discussed and on Maximum Likelihood Decoding (MLD) and minimum mean square error (MMSE)are focused and designed for SFBC-MIMO system by using Simulink simulation. This paper also simulates and discusses about different configuration of MIMO - Orthogonal Frequency Division Multiplexing (OFDM) system, which allows the system to transmit the high-speed data rate and to robust against the underwater acoustic(UWA) channel.*

Keyword: *multiple-input–multiple-output (MIMO), orthogonal frequency-divisionmultiplexing (OFDM), space–frequency block coding(SFBC),Minimum mean square error(MMSE),Maximum likelihood detection (MLD).*

I. INTRODUCTION

The earth is surrounded by 70.8% of water that is in the form of oceans. Nowadays, for Constantly growing underwater development need to be establish effective communication system. But conductivity of salty water and many other hurdles available technologies like Wi-Fi, Bluetooth, GPRS is not possible to communicate under water effectively. By designing wireless transmission system In dynamic and harsh environment will enhance many different under water applications like natural disasters (Tsunamis,earthquakes),security. So, scientists and researchers are motivated to design the reliable wireless communication system to explore the less unexplored ocean to benefit mankind. This has paved the way for them to develop Underwater Wireless Communication Networks (UWCNs). Due to the acoustic propagation characteristics such as multipath propagation,transmission loss,multipath fading, time-dependent channel variations, Doppler spreading, ambient noise, and variable delays in Underwater acoustic communication channel, there are various challenges in many aspects which are quite different from the terrestrial radio communication channel.

By using space frequency diversity with Multiple-input multiple-output (MIMO) we can achieve the reliable Bit Error Rate (BER)as compaired to traditional MIMO OFDM system. It is necessary to design the system having suitable detection technique for under water acoustic channel with low complexity structure and high performance at the receiver.As UWA channel is a nonideal linear filter for a low bitrate single-carrier modulations transmission over an UWA channel, would lead to severe inter-symbol interference (ISI).So it requires complex equalizer.With the help of orthogonal frequency division multiplexing (OFDM)we can achive reliable system having high data rate with simple equalizer in UWA channel.

Over UWA channels The feasibility of MIMO OFDM has been shown in recent experimental studies. These systems have been considered for spatial multiplexing , as well as for different diversity through Alamouti coding. Research says that space-frequency block coding (SFBC) diversity technique outperforms space-time block coding (STBC) in time varying channel. Due to the time-varying nature of the UWA channels, SFBCs are deemed better suited.SFBC as a means of obtaining spatial and frequency diversity over UWA channel.

There are various detection techniques which have been investigated in many papers. Different detection techniques includ linear detections, Ordered Successive Interference Cancellation (OSIC) detections and Maximum Likelihood Decoding (MLD). Most of the study carried out in a flat fading environment . In addition, every subcarrier is assumed to be flat non-frequency selective channel if the number of subcarriers is large enough in MIMO-OFDM architecture. In our work, we firstly introduce the main conventional detection algorithms such as linear detection techniques (ZF, MMSE), Ordered successive interference cancellation (ZF,MMSE), and Maximum likelihood detection. By using Matlab Simulation,we evaluate the error performance comparisons of these detection algorithms of SFBC MIMO-OFDM systems in UWA channel.

This paper is divided into six Sections.Section I contains introduction of challenges of Under water communication System. In Section II we introduce the basic SFBC system model.section III contains detailed discussion of acoustic channel. Section IV contains study of detection technique for SFBC system. Section V and VI contains result analysis and conclusion.

II. SYSTEM MODEL

We consider a MIMO system with MT = 2 transmitters and M_R receivers. OFDM is used with K subcarriers, equally spaced within the system bandwidth B at $\Delta F = B/K$. The OFDM symbol duration is $T = 1/\Delta F$, and a guard interval (cyclic prefix) of duration Tg, sufficient to accommodate the multipath spread Tmp, is added for the total block duration of T′ = T + Tg .The symbols are encoded using the Alamouti SFBC scheme, i.e. if k is the carrier pair index (k = 0 . . .K/2 − 1), during the n^{th} block, the simultaneously transmitted symbols on carriers 2k and 2k+1 are, respectively, $d_{2k(n)}, d_{2k+1(n)}$ from the first transmitter,and

$-d^{*}_{2k+1}, d^{*}_{2k}$ (n) from the second transmitter. The channel transfer function observed on the carrier k′ between transmitter t and receiver r during the n-th OFDM block is denoted by $H_{k}^{t,r}$ (n), k′ = 0 . . k− 1. The received signal,corresponding to the k-th coded carrier pair and the r-th receiving element after OFDM-FFTdemodulation, is given by

$$\tilde{y}_k^{r,A}(n) = \begin{bmatrix} H_{2k}^{1,r}(n) & H_{2k}^{2,r}(n) \\ H_{2k+1}^{2,r*}(n) & -H_{2k+1}^{1,r*}(n) \end{bmatrix} d_k^{A}(n) + z_k^{r,A}(n)$$

Where $y_k^{r,A}(n) = \begin{bmatrix} y_{2k}^{r}(n) \\ -y_{2k+1}^{r*}(n) \end{bmatrix}$, $d_k^{A}(n) = \begin{bmatrix} d_{2k}(n) \\ -d_{2k+1}^{*}(n) \end{bmatrix}$

And

$$z_k^{rA} = \begin{bmatrix} z_{2k}^{r}(n) \\ -z_{2k+1}^{r*}(n) \end{bmatrix}$$

represents zero-mean additive noise components. If MR > 1 receiving elements are used, their signals can be arranged into a single vector, so that the system is fully described by

$$\begin{bmatrix}\hat{y}_k^{1} \\ \vdots \\ \hat{y}_k^{M}(n)\end{bmatrix} = \begin{bmatrix}G_k^{1}(n) \\ \vdots \\ G_k^{M}(n)\end{bmatrix} \hat{d}_k(n) + \begin{bmatrix}z_k^{1}(n) \\ \vdots \\ z_k^{M}(n)\end{bmatrix}$$

Based on this model, least squares (LS) data estimates are obtained as

$$\hat{d}_k(n) = \left[\sum_r G_k^{rH}(n) G_k^{r}(n)\right]^{-1} \sum_r G_k^{rH}(n)\, \hat{y}_k^{r}(n)$$

A. Alamouti Assumption[2]

The Alamouti assumption, expressed for space–frequency coding, states that the channel does not change much over two consecutive carriers

$$H_{2k}^{tr}(n) \approx H_{2k+1}^{tr}(n)$$

When this assumption holds, the channel matrix satisfies the Property

$$G_k^{rH}(n) G_k^{r}(n) = \underbrace{\left|H_{2k}^{1r}(n)\right|^2 + \left|H_{2k}^{2r}(n)\right|^2}_{H_k^{r}(n)} I_2$$

Where I_2 is the 2×2 identity matrix. The LS data estimate above equation then reduces to

$$\hat{d}_k(n) = \frac{1}{\sum_r H_k^{r}(n)} \sum_r G_k^{rH}(n)\, \hat{y}_k^{r}(n)$$

Extraction of the transmit diversity gain through summation Of individual channel's energies , and simplicity of data detection without matrix inversion, form the essence of Alamouti processing.

III. ACOUSTIC CHANNEL

In underwater acoustic communication which exhibit many challenges to deal with due to the time varying multipath and Doppler Effect and multipath propagation.Acoustic communication channel capacity determines the maximum data rate that can be supported (theoretically) by an acoustic channel for a given source power and source/receiver configuration. The acoustic channels impose many constraints that affect the design of UW communication systems. These are characterized by a path loss,absorption loss,eventually imposing a limit on the available bandwidth.

Underwater Signal-to-Noise Ratio

Since the transmission loss in a UW channel depends both on frequency as well as the transmission distance, let it be represented by $A(l, f)$.Using $A(l,f)$and noise PSD $N(f)$,the signal to noise ratio (SNR) at the receiver at a distance l and frequency f for a transmitted power of P and receiver noise bandwidth Df is given by

$$\gamma(l,f) = \frac{P/A(l,f)}{N(f)\Delta f}$$

Considering absorption and spreading loss alone, the frequency dependent factor in the SNR $1/[A(l, f)N(f)]$ is plotted in Figure 3 for different propagation loss models. It may be noted that the optimum transmission band depends on link distance. Further, for each l, there exists an optimal frequency $f_0(l)$ for which maximum SNR is obtained. This is the frequency for which the term $1/A(l, f)N(f)$ becomes maximum.The optimal frequency is shown in Figure 4
for various loss models.

Channel Characteristics

When underwater acoustic signals propagation compared with electromagnetic propagation that flow all the way through the underwater acoustic signals propagation, environment is distinguished significantly by frequency causing disturbances and relatively quite slower velocity of propagation. Mandate factors that find out the efficient point of a MIMO underwater communication system, though the slow speed of the propagating wave which causes time-varying multipath phenomenon that as well has a say in the system plan and usually imposes severe limits the performance of system with input of transmission loss and noise.

Transmission loss

The sum of these three terms that effects attenuation mechanisms: the absorption loss, spreading loss and also the reflection loss can be viewed primarily as underwater acoustic signal. Due to the flow and therefore the development of the fixed amount of transmitted energy over a larger area as the signal gradually propagates away from its source the scattering losses are occurred. It is already proved that energy dicreases at the rate of *l^(−k)* in which *l* is the sepration and *k* is the spreading factor depending upon the geometry of propagation (its frequently used values are for spherical spreading $k = 2$, for cylindrical spreading $k = 1$ and $k = 1.5$ for all spreading).

Noises

There exists various ways of natural sources of ambient noise. Considered four sources are: shipping waves, turbulence and also thermal noise.Power spectral density (p.s.d.) given in dB, μ per Hz as a function of frequency modeled given with Colored Gaussian noise.

Multi-paths propagation

There exist different paths of multiple propagation which are derived from technique source to the receiver under majority of environments in which frequency of communication signal can be identified. Multi-paths spread affected by the transmission link configuration calculated as vertical or horizontal. A relatively long delay spread While vertical links have less time spreading , multi paths are formed by a mechanism of ray bending which causes the sound waves to reach the area of poor propagation speed, multi-paths are formed by ray bending which occurs as the sound waves tend to reach region of lower propagation speed where in case of shallow water environment, multi-path method we find results due to reflections on surface bottom bounce reflections or a through a possible direct path. The description of deep and shallow water is floppy one, but that assumed shallow water considered for water depth not as much of than 100 m Moreover we have assumed a steady water temperature in the entire water deepness which is of importance since a stable temperature gives a invariable sound speed (is velocity).

Time-variation

The dispersion on the moving sea-surface (waves or bubbles) characterizes each and every propagation path which results in random varying component. Movement of reflection surfaces effects in Doppler spreading of the reflected signal sliding to a transient channel impulse response. Which is time varying. Time-varying product is omnipresent inside the submarine channel in spite of of an ultimate motion of transmitter or receiver.

IV. DETECTION TECHNIQUE

Detection algorithms description[1]

A) Linear Detection algorithms

1) Zero-Forcing (ZF)

By using Pseudo Inverse matrix denoted by, the effect of the matrix channel can be reversed. is defined as follows:-

$$W = \left(H^H H\right)^{-1} H^H$$

The detected signal is

$$\hat{x} = W_{ZF} y = x + W_{ZF} z$$

The effect of gaussian noise still exist in detected signal and is amplified by the factor which reduces the performance of detection algorithm.

2) Minimum mean square error(MMSE)

MMSE signal detection will be studied as the linear signal detection algorithms. This is another linear detection which obtains the higher performance than ZF detection because the filter matrix,which considers the effects of both matrix channel and Gaussian noise, is used to detect the signal. $WMMSE$ is defined as [6]:

$$W_{MMSE} = \left(H^H H + \sigma_z^2 I\right)^{-1} H^H$$

Where σ^2 is the variance of Gaussian noise. The detected signal can be calculated as

$$\hat{x} = W_{MMSE} y = W_{MMSE} H x + W_{MMSE} z$$

These both are linear type detection which normally have low performance when gaussian noise is large. In order to increase performance OSIC detections is used. MMSE detectors balances the noise enhancement and multi-stream interference by minimizing the total error. Its BER performance is superior to ZF detection due to mitigating the noise enhancement.

B) OSIC detections

The idea of these techniques is using each row vector of the filter WZF or $WMMSE$ matrices to cancel one by one the interference from different transmitter antennas and this can be described in fig. 1.

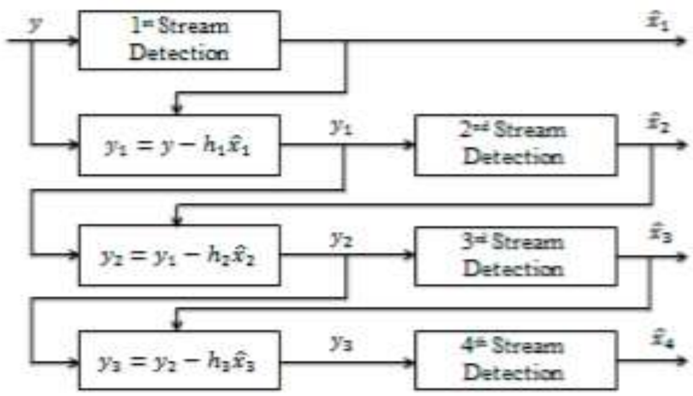


Figure 1. OSIC detection for 4 sub-streams [1]

Firstly, after one sub-stream is $\hat{x}_1$ detected, it will be feedback and excluded from the received signal y. Hence, one element caused the interference no longer exists and this procedure continues repeating again until there is only one sub-stream x_4 remaining in received signal. When using sub-stream cancellation, the order in which sub-streams are detected plays an important role of the SDM system. When sub-streams are detected in different orders, the different BERs are obtained respectively.

1) ZF OSIC

Let the ordered set $K = \{k_1, k_2, \ldots, k_M\}$ be a permutation of the integer 1, 2,M which defines the order in which sub- streams are extracted. Finding this order is similar with finding the largest

$$SINR_i = \frac{E_x}{\sigma_z^2 \|w_i\|^2}$$

Where E_x is the energy of the transmitted signals and w_i is the i^{th} row of the filter matrix W_{ZF} .

Step 1:- Detect the first sub-stream

Step 2:- Feedback to cancel substream.

Step 3:-repeat step1 and step2 for other substreams.

2) Mmse Osic

The idea of MMSE OSIC method is using the filter matrix combining with SINR-Based optimal order.

$$SINR_i = \frac{E_x |w_{i,MMSE} h_i|^2}{E_x \sum_{l \neq i} |w_{i,MMSE} h_l|^2 + \sigma_z^2 \|w_{i,MMSE}\|^2}$$

Step 1:- Detect the first sub-stream

Step 2:- feedback to cancel the interference

Step 3:-repeat step1 and step2 for other substreams.

C) Maximum likelihood detector:-

ML detection calculates the Euclidean distance between the received signal vector and the product of all possible transmitted signal vectors with the given channel **H**, and finds the one with the minimum distance [6]. Let and denote a set of signal constellation symbol points and a number of transmit antennas, respectively. Then, ML detection determines the estimate of the transmitted signal vector x.

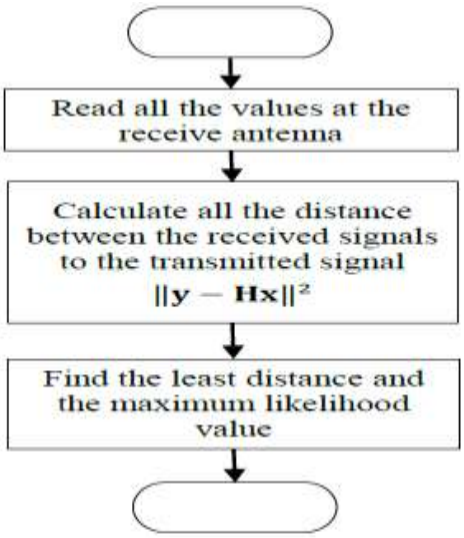


Figure 1. MLD detection

$$\hat{x}_{ML} = \arg\min_{x \in C^{N_T}} \|y - Hx\|^2$$

Assuming that all the sub-streams passed through the same modulator which has M points on the constellation and SDM system uses two transmit antennas. At the receiver , y = (y1,y2) are denoted as the received signals which actually two symbols.To find the original transmitted symbols, from the constellation, the MLD chooses a pair of symbols which have the minimum Euclidian distance with y. Obviously, to find the minimum Euclidian distance, MLD has to exhaustedly search all of positive conditions which are totally conditions, where is the number of transmit antenna. That is why MLD will become so complicated when increasing the number of point in constellation or transmit antenna.

QRM-MLD algorithm and SD algorithm are the algorithms reduce the complexity of ML algorithm.

V. RESULT

In this Section, we provide numerical results based on Matlab simulation. The performance of systems is demonstrated in wideband fading channel. The number of multipath paths in TGn channel model B and ITU-R channel model A are 9 and 4 respectively. In the modulation, the FFT size is 256 and the cyclic prefix length is ¼. The QPSK and 16-QAM modulations are used in this simulation. The performance of 4-QAM 2x2 MIMO-OFDM SDM system in multipath environment is showed in Fig. 7 and 8. Simulation result implies that multipath effects can be mitigated well by OFDM technique.

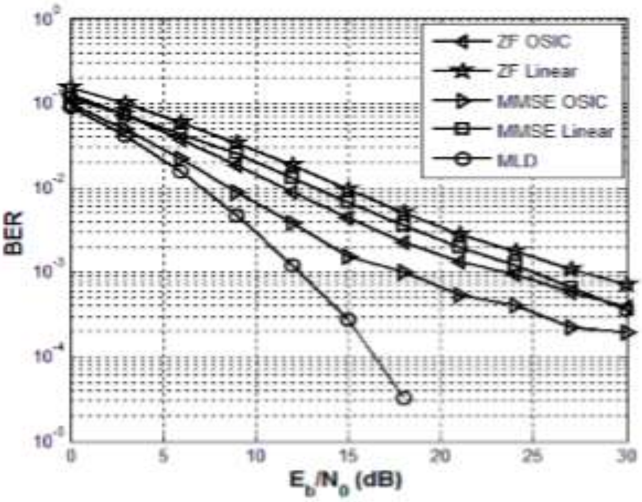
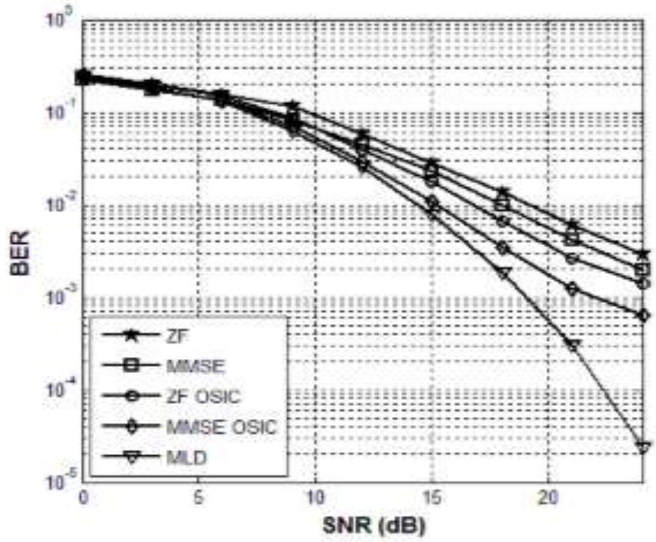


Figure 4.MIMO SDM using linear and OSIC detection[1]

Simulation result implies that multipath effects can be mitigated well by OFDM technique.



  RESULTS

Figure 5. MIMO OFDM SDM[1]

The Fig 5 illustrates the BER performance of MIMO OFDM SDM system that MLD is still the best. However, it now is close to MMSE OSIC case. For that reason, MMSE OSIC is a good choice instead of MLD. will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

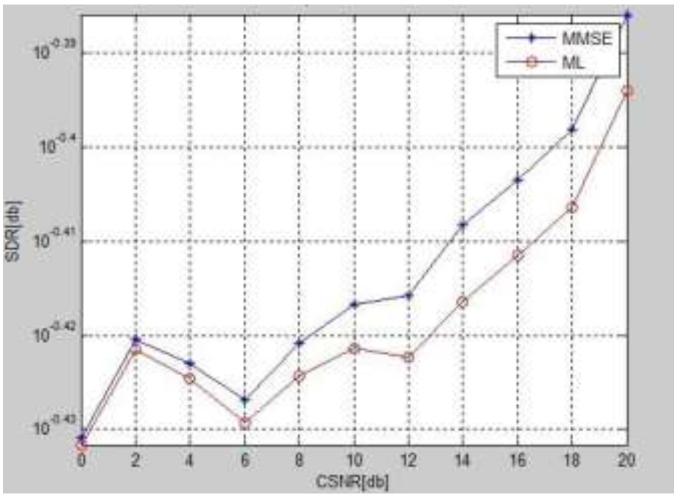


Fig -6. Performance comparison in cooperative scenario[7]

The performance of MMSE is predominant in cooperative communication scenario as ML decoder aims at improving the estimation error thus providing optimal performance but lesser performance compared to MMSE. In a cooperative scenario, mean square error minimization technique improves system performance compared to likelihood technique as it involves decreasing the estimation error for a given value of CSNR.The performance of protocols under various bandwidth reduction systems are depicted and analyzed in figure.6.

VI. CONCLUSION

Generally, the performance (BER) of the MIMO SDM and MIMO-OFDM SDM by using different SDM detections, namely: linear detections, OSIC detections and especially MLD are studied.Results showed that MLD obtained the best BER among SDM detections.The performance of these algorithms in MIMO-OFDM systems is studied by applying for two kinds of frequency selective fading environments.Based on a new pilot arrangement and LS method, the channel estimation could be done well in the high SNR. MIMO spatial diversity was investigated for underwater

acoustic communications through the use of Alamouti space –frequency coding coupled with OFDM. The use of space–frequency coding, as opposed to space–time coding, is motivated by the fact that frequency coherence naturally exists between the carriers of a properly designed (ICI-free) OFDM system. While it is needed to support FFT-based OFDM channel equalization, frequency coherence simultaneously supports Alamouti detection, which accomplishes MIMO crosstalk elimination without the need for matrix inversion.

MMSE OSIC is a good choice instead of MLD. From the theory of the signal detection algorithms of the five detectors studied in this study, ZF detection and MMSE detection have advantages of simple and low complexity but the performance is not ideal. ML detection has the optimal Comparison of different MIMO-OFDM signal detectors for LTE detection performance.

REFERENCES

[1]. Performance Comparisons of Detector Algorithms for High Data Rate MIMO OFDM Systems in Frequency Selective Fading Channel Tu T. Nguyen1, Viet T. Nguyen2, Tuan A. Hoang1, Tri M. Nguyen1, and Khoa L. Dang1

[2]. University of Science HoChiMinh City, Vietnam,

[3]. Email: 1{nttu, hatuan, nmtri, dlkhoa}@fetel.hcmus.edu.vn, 2ntviet2409@yahoo.com

[4]. Space–Frequency Block Coding for Underwater Acoustic Communications Eduard Valera Zorita and Milica Stojanovic , Fellow, IEEE

[5]. B. Li and M. Stojanovic, "A simple design for joint channel estimation and data detection in an Alamouti OFDM system," in Proc. OCEANS Conf., Sep. 2010, DOI: 10.1109/OCEANS.2010.5663867.

[6]. M. Stojanovic, "MIMO OFDM over underwater acoustic channels," in Conf. Record 43rd Asilomar Conf. Signals Syst. Comput., Nov. 2009,pp. 605–609.

[7]. M. Nordenvaad and T. Oberg, "Iterative reception for acoustic underwater MIMOcommunications," in Proc. OCEANS Conf., 2006, DOI:10.1109/OCEANS.2006.307060.
[8]. S. Roy, T. Duman, V. McDonald, and J. Proakis, "High-rate communication for underwater acoustic channels using multiple transmitters and space time coding: Receiver structures and experimental results," IEEE J. Ocean. Eng., vol. 32, no. 3, pp. 663–688, Jul. 2007
[9]. Performance analysis of ml and mmse decoding using gradient based algorithm k.mahalakshmi1, s.palanivelrajan2 1PG Scholar, Communication systems, M.Kumarasamy College of Engineering Karur, India 2Assistant Professor, Electronics and Communication Engineering, M.Kumarasamy College of Engineering, Karur, India
[10]. [8] Differential Decoding for SFBC OFDM Systems in
[11]. Underwater MIMO Channels H. Eghbali∗ , Milica Stojanovic∗ ∗ and S. Muhaidat‡Simon Fraser University, Burnaby, BC, Canada, V5A 1S6 Northeastern University, Boston, MA 02115 USA
[12]. ‡UniversityofSurrey,Guildford,UnitedKingdomEmail:hea7@sfu.ca,∗ ∗ militsa@ece.neu.edu,and ‡sami.muhaidat@kustar.ac.ae