UP GRADED CONVOLUTION ERROR DIMINUTION CODE PERFORMANCE IN SEA WATER COMMUNICATION

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Abstract:

Quality assurance of an image is an important task in underwater transmission systems. Underwater channel is characterized by speckle noise and multipath currents which lead to variations in Doppler frequency and also changes the distance between the nodes. As the reliability of an image in an acoustic channel can be judged in terms of Peak Signal to Noise Ratio (PSNR) and low Mean Square Error (MSE),Structural Similarity Index(SSIM),channel, Signal to Noise Ratio requirement, Band width efficiency can be obtained by employing suitable modulation techniques or efficient fault reduction coding techniques. While considering design and implementation fault reduction coding techniques are more prominent. This paper proposes a new channel coding technique that ensures secrecy , comparatively good PSNR low MSE, high SSIM . This paper addresses the comparison of proposed Upgraded Convolution code with convolution code, Reed Solomon(RS)code , Turbo code, Low Density Parity Check code (LDPC) for transmission of JPEG image through underwater acoustic channel by using frequency hopped M-ary FSK modulation (FH M-ary FSK).

Keywords: Fault reduction coding techniques, PSNR, MSE, SSIM, frequency hopped M-ary FSK modulation, Convolution code, Reed Solomon code, Turbo code, LDPC code.

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1. Introduction

In present scenario Underwater communication is a challenging technique of sending and receiving message below water due to complication of ocean environment [1]. There are several modes of employing such communication but most common one is by acoustic waves. Under water signal propagation is difficult because of so many factors like multi-path propagation, time variations of the channel, small available bandwidth and strong signal attenuation especially over long ranges which badly affect the underwater channel [2]. underwater acoustic communication suffers from low data rates compared to terrestrial communication since underwater acoustic communication uses acoustic waves instead of electromagnetic waves. The signal frequency determines the absorption loss, this loss increases with increase in frequency and distance as well [3], eventually imposing a limit on the available bandwidth. So the carrier frequencies for underwater communication lie in the low frequency range of the order tens of KHz range. The noise generated in the water by reverberations (by the rough ocean boundaries, both at the ocean surface and the bottom sediment) also lie in the frequency range of carrier frequencies ,hence The problem of transmission and reception is not a difficult task but ensuring the reliability of data reception, optimal power consumption, and spectral efficiency is far more challenging task now a days. Under this circumstances low noise error diminution code and suitable modulation technique must be required. As per the design point, optimum power point of view error diminution code is cheaper compared to efficient modulation technique.

There are two most popular error detection and correction techniques [4, 5], first one is Automatic Repeat Request (ARQ) and second one is Forward Error Correction codes (FEC). ARQ performs well for adequate packet delivery ratio by providing well stop and wait protocols but it provides low latency due to retransmission. Some systems may not possible to allow full-duplex transmission leads to retransmission may not allow. Hence Forward Error Correction codes (FEC) are powerful codes that provide low Bit Error Rate (BER) but reduces throughput due to adding extra bits.

Reed solo men codes are not suitable for burst errors [6], Checksum techniques which have disadvantages that probability of hidden error may occur because of non uniform data[7,8]. AN-VE code performs well with little BER for transmission of text data through Gaussian channel [9, 10]. Proposed Upgraded Convolution code performs well with little BER compared to convolution code for transmission of text data through Gaussian channel ,Rayleigh faded channel and Rician faded channel have done by using frequency hopped M-ary FSK modulation with variation in Doppler shifts (fd) effect[11] .

PSNR, MSE, SSIM are quantitative metrics for determining the quality of a distorted image. PSNR is the ratio of maximum power of a signal to maximum power of a noisy distorted signal. MSE is averaging over the squares of the difference between original image to the distorted image. SSIM gives structural data considering luminance as well as contrast in the visual scene. Received image with high PSNR(ideal value 'infinity'),high SSIM(ideal value 'one ') and low MSE(ideal value 'zero') resembles the original transmitted image. High band width efficiency near to Shannon limit is the figure of merit of any communication system.

This paper addresses performance comparison of proposed Upgraded Convolution code with convolution code ,RS code, turbo code, LDPC code for transmission of an image using the parameters PSNR ,MSE, SSIM, visual quality, spectral efficiency through underwater channel by using frequency hopped M-ary FSK modulation(18).

2. System Design Model

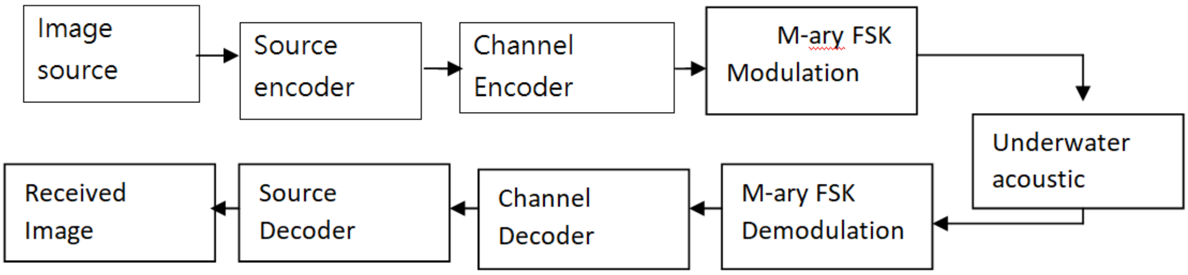


Figure1. Shows Underwater communication System design model .The detailed explanation of each block in section 2 is as follows.

2.1. Upgraded convolution encoder

Algorithmic Steps to be followed for encoder design in sequential order:

- The image can be entered through keyboard. JPEG image first converted into binary image [12].
- Security is provided to image by transformed into encrypted coded integer symbols [13].
- This Upgraded convolution code is encoded as a coded set of symbols (integers) and these combined set of symbols (integers) are used to represent Text data and image.
- Each text data is encoded using convolution code with code rate of 0.75 and then this code again converted into a fixed number integer symbols ranging from 0 to 7.
- Each encrypted symbol undergoes channel coded fixed number of symbols ranging from 0 to 15.
- Image first converted into binary image and then to octal symbols ranging from 0 to 7.
- Each octal symbol undergoes channel coded fixed number of symbols ranging from 0 to 15 maintains minimum hamming distance between symbols.

2.2. Frequency Hopped M -ary FSK Modulation

The encoded symbols are now interfaced to the processor by using MATLAB software. They are converted into corresponding carrier frequencies(f_1,f_2,f_3,.f_M -1)using Frequency Hopped M –ary FSK modulation[9].Multi-carrier modulation offers an alternative to a broadband single-carrier communication Owing to multipath fading characteristics , the sea channel can be modeled using the non-Gaussian model such as Rayleigh-faded distributions with absorbtion losses [14]. The complete transmitted signal waveform Z (t) as inequation-(1)

$$z(t) = \Sigma y(t - kt)\exp(j2\pi(\mathrm{fc} + \mathrm{k}\delta\mathrm{f})\mathrm{t} \quad (1)$$

Where signal waveforms are delayed by T seconds and are transmitted in a time division manner with k ranging from 0 to M-1, δf is frequency bin, f_c is the main carrier frequency. The carrier frequencies in each symbol in this modulation are orthogonal to neighboring frequencies causes inter symbol interference (ISI) will be reduced. The range of carrier frequencies is 10-18

KHz in Frequency Hopped M –ary FSK scheme of modulation with frequency bin of 0.5 KHz [16,17].

2.3. Underwater acoustic channel model

Practically time variant and reverberations (by the rough ocean boundaries, both at the ocean surface and the bottom sediment) nature of the channel leads to shift (Doppler frequency shift) in carrier frequency. In order to lessen the shift in Doppler frequency, the ambiguity in the Doppler frequency shift estimation should be less than frequency variation. Doppler frequency shift ω_d can be expressed in equation-(2)

$$\omega\mathrm{d} = \mathrm{fc} * \mathrm{T} * (\frac{c}{v-c}) \qquad (2)$$

Where v is sound velocity in sea, c as relative velocity and symbol rate is 1/T. These multi carrier modulated [15] frequencies are passed through under water channel. Hence the channel Ch (τ, t) can be modeled using equation-(3) by considering path gains, multipath effects along with Doppler shifts , transmission loss and Ambient noise(N_f).

$$ch(\tau,t) = \sum_{k=1}^{\mathrm{qk}} \mathrm{A_k}\,\delta(\tau - [\tau_k - \alpha_k\, t] + \text{Transmission loss} + \text{Ambient noise}(N_f). \qquad (3)$$

Path amplitude A_k, path delay τ_k, path amplitude gain α_k, in a kth path.

The acoustic transmission loss in under water channel is a combination of absorption loss, spreading loss, loss due to different paths of propagation of acoustic signal. This paper uses three paths with path delays [0 1.5e-4 2.5e-4]with path gains [0 -1 -9].

Based on Thorp approximation for the absorption loss (Yang and Liu, 2009)

Absorption loss can be expressed by equation-(4).

$$10logA(l,f) = l * 10loga(f) \qquad (4)$$

$$where \qquad 10loga(f) = 0.11\frac{f2}{1+f2} + 44\frac{f2}{4100+f2} + 2.75 * 10e - 4f^2 + 0.003$$

$$Spreading\ loss = klogl \qquad (5)$$

Equation-(5) gives Spreading loss where the spreading constant k=1.5 for practical spreading (Uric,1983), l is the distance between transmitter and receiver in km and f is the carrier frequency in kHz . .

Ambient noise(N_f) is the noise power spectral density(PSD) and is a combination of turbulence noise (N_t) expressed by equation-(6), shipping noise(N_s) by equation-(7), wind noise(N_w) canbe modeled by equation-(8),and thermal noise(Nth) can be expressed by equation-(9).

$$10l0gN_t(f) = 17 - 30\log(f) \qquad (6)$$

$$10logN_s(f) = 40 + 20(s - 0.5) + 26\log(f) - 60\log(f + 0.03) \qquad (7)$$

$$10logNw(f) = 50 + 7.5w^{0.5} + 20\log(f) - 40\log(f + 0.4) \qquad (8)$$

$$10logN_{th}(f) = 15 + 20\log(f) \qquad (9)$$

Where w is wind speed is in 10m/s, s is shipping factor is in 0.5, f is in kHz.

Signal to Noise Ratio (SNR) of a received signal is expressed by (Yang and B. Liu, 2009;) equation-(10)

$$SNR = Source\ Level - total\ transmission\ path\ losses - \overset{\mu Pa}{Noise}\ PSD - DI \qquad (10)$$

Where Source Level is 20log I , intensity of a signal indicated by I and is expressed as $P_t/2\pi H$

Directivity index (DI) is assumed to be zero(omni directional antenna). P_t transmitted power and H is Ocean depth in meters equals to 500m(assumption).

2.4. Upgraded convolution Decoder

Algorithmic Steps to be followed for decoder design in sequential order:

- The first stage of the receiver section is a set of sixteen narrowband pass filters.
- The 16 carrier frequencies (frequencies belong to integer symbols of 0-15) are center frequencies for 16 narrowband pass filters respectively.
- After the filter bank next stage is envelop detector that provides threshold (DC) on each received signal and is maximum at the centre frequencies of corresponding narrow band pass filters[19].
- Output of the narrow band pass filters pass through priority encoder and all the 16 channels outputs are converted to a 3 bit data and then this data is decoded into text data using viterbi decoder
- This text data in a sequence is converted as a binary image and then converted into received image

3. Simulations and Discussions

Section 3 illustrates simulations carried by MATLAB software package for upgraded Convolution code(code rate=0.3) over existing convolution(code rate=0.75) ,RS(code rate(0.8), Turbo(code rate=0.3), LDPC(code rate=0.5) codes. Analysis can be expressed in terms of an image performance characters such as PSNR, MSE, SSIM, bandwidth efficiency and visual quality. JPEG image can be passed through underwater modeled channel and the corresponding results shown in Table 1 ,Table 2 and Table 3 along with figures for variant Doppler frequency shifts (fd) from 1 Hz to 200Hz and three multipath delays[0 1.5e-4 2.5 e-4] along with path gains of [0 -1 -9].

Table 1. JPEG image transmission in underwater modeled channel

Doppler_ freq(f_d)	**NO_CHANNEL CODE**	**CONVOL**	**LDPC**	**TURBO**	**RS**	**UPGRADED_ CONVOL**
	Peak Signal to Noise Ratio(PSNR)					
1	15.774	Inf	40.750	Inf	Inf	Inf
50	12.595	17.085	17.495	25.335	25.749	52.799

100	7.787	8.687	11.889	10.118	16.572	19.346
150	5.332	3.438	8.602	3.265	9.470	11.801
200	3.205	0.269	5.700	0.483	5.475	5.730

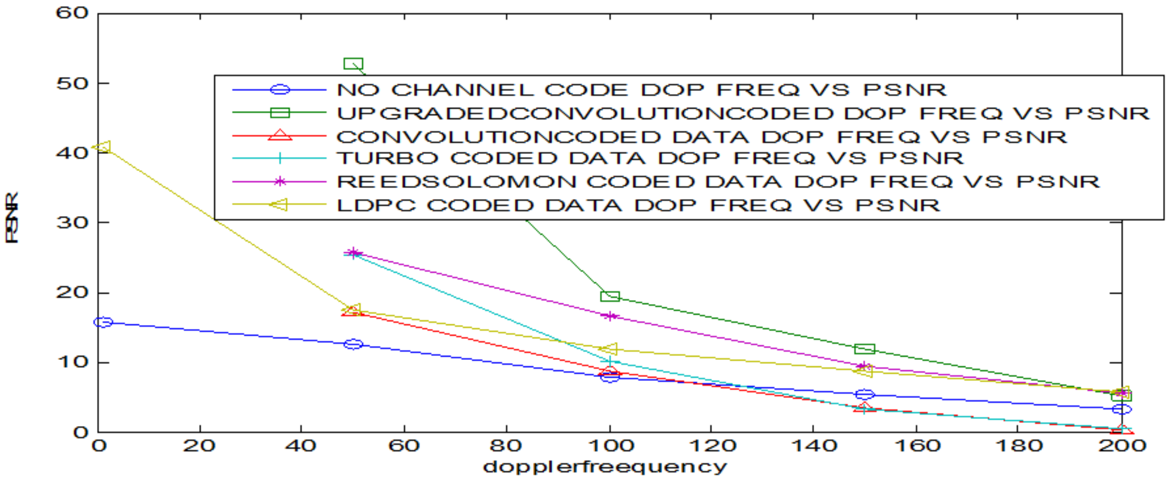


Fig 2. fd versus PSNR plot for upgraded convolution code and convolution ,turbo, RS, LDPC coded image for Underwater channel

Fig 2. Shows fd versus PSNR plot for upgraded convolution code and convolution ,turbo, RS, LDPC coded image for Underwater channel and Table1 also explains f_d variation of 1Hz to 200Hz ,corresponding PSNR changes from Infinity to 5.73 in upgraded convolution code where as in convolution code it is changed from inf to 0.269. If there are no errors in the received signal PSNR value equals Infinity. From that upgraded convolution code performs better over existing codes while fd is increasing from 1Hz bearing in mind that channel is suffered with transmission loss ,ambient noise along with multipath and variation in Doppler shifts (f_d) effect.

Table 2. JPEG image transmission in underwater modelled channel

Doppler_ freq(fd)	**NO_CHANNEL CODE**	**CONVOL**	**LDPC**	**TURBO**	**RS**	**UPGRADED_ CONVOL**
	Mean Square Error(MSE)					
1	105.012	0	0.333	0	0	0
50	218.389	77.659	70.666	11.618	10.563	0.021
100	660.629	537.015	256.895	386.2404	87.387	46.145
150	1162.763997	1798.538	547.586	1871.294	448.406	262.194
200	1897.422607	3730.790	1060.300	3551.434	1125.127	1050.293

Table2 explains f_d variation of 1Hz to 200Hz ,corresponding MSE changes from 0 to 1050 in upgraded convolution code where as in convolution code it is changed from 0 to 3730. If there are no errors in the received signal MSE value equals zero. From that upgraded convolution code performs better over existing codes while f_d is increasing from 1Hz bearing in mind that channel is suffered with absorption loss ,ambient noise along with multipath and variation in Doppler shifts (f_d) effect.

Table 3. JPEG image transmission in underwater modelled channel

Doppler_ freq(fd)	**NO_CHANNEL CODE**	**CONVOL**	**LDPC**	**TURBO**	**RS**	**UPGRADED_ CONVOL**
	Structured Similarity Index (SSIM)					
1	0.974	0.999	1.000	1	1	1
50	0.944	0.981	0.981	0.998	0.998	0.9992
100	0.846	0.866	0.934	0.893	0.968	0.9897
150	0.747	0.652	0.871	0.701	0.888	0.9312
200	0.634	0.422	0.778	0.549	0.749	0.7785

Table3 explains f_d variation of 1Hz to 200Hz ,corresponding SSIM changes from 1 to 0.7785 in upgraded convolution code whereas in convolution code it is changed from 0.999 to 0.422. If there are no errors in the received signal SSIM value equals one. From that upgraded convolution code performs better over existing codes while f_d is increasing from 1Hz bearing in mind that channel is suffered with absorption loss ,ambient noise along with multipath and variation in Doppler shifts (f_d) effect. Bit rate can be expressed by equation-(11)

$$Bit\ rate = Bandwidth * log_2 M \quad (11)$$

Overall bandwidth efficiency is the one of the performance factor for deciding the Efficiency of a digital system can be expressed by equation-(12)

$$\text{Overall Bandwidth efficiency} = (\text{Bit rate} * \text{Code rate})/\text{Bandwidth}. \quad (12)$$

Table 4. JPEG image transmission of underwater modeled channel

Band width=8kHz, BER=10e-3,Frequency Hopped M-ary FSK Modulation (M-16)			
COFDM TYPE	**Code rate**	**Bandwidth efficiency bits/sec/Hz**	**SNR in dB**
UPGRADED CONVOLUTION	0.3	1.2	14.4

CONVOLUTION	0.75	3	25.2
TURBO	0.3	1.2	19.5
REED SOLOMN	0.8	3.2	22.2
LDPC	0.5	2	21.3
NO_CHANNELCODE	1	4	35.5

From Table4. Bandwidth efficiency of upgraded convolution code is less compared to other codes ,but it performs well with less SNR on an average of 10dB saved by maintaining constant Bandwidth of 8kHz and BER of 10e-3 leads to power requirement is less compared to other codes, which is very important parameter for underwater communication .As Utilization of energy considered to be important because of recharge and replacement of batteries in under water environment is quite difficult.

upgraded convolution code for dop.freq=1HZ

NO CHANNELCODE for dop.freq=1HZ

REED SOLOMON code for dop.freq=1HZ

LDPC for dop.freq= 1 HZ

convolution code for dop.freq=1HZ

TURBO for dop.freq=1HZ

upgraded convolution code for dop.freq=100HZ

NO CHANNELCODE for dop.freq=100HZ

REED SOLOMON code for dop.freq=100HZ

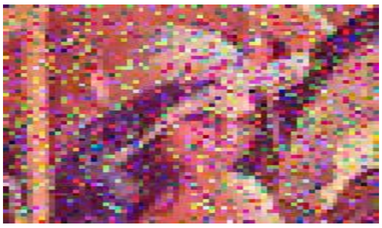
LDPC for dop.freq= 100 HZ

convolution code for dop.freq100HZ

TURBO for dop.freq=100HZ

upgraded convolution code for dop.freq=200HZ

NO CHANNELCODE for dop.freq=200HZ



REED SOLOMON code for dop.freq=200HZ

LDPC for dop.freq= 200 HZ

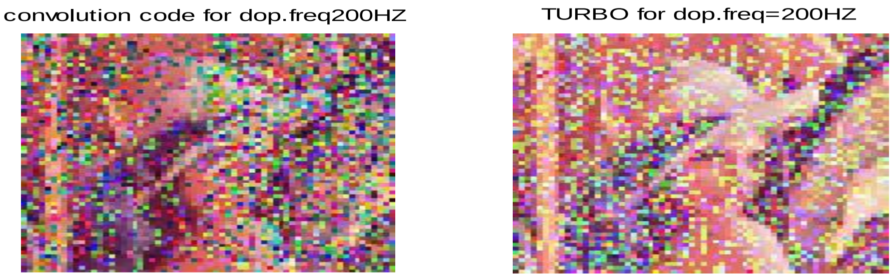

convolution code for dop.freq200HZ
TURBO for dop.freq=200HZ

Fig 7. Shows Visual quality analysis of a JPEG image in UWA channel for upgraded convolution coded, convolution coded image ,RS ,LDPC,TURBO coded against the Doppler frequency shift which is varying from 1Hz to 200Hz .

From the table 4 upgraded convolution code visual quality is better over existing codes while f_d is increasing bearing in mind that channel is suffered with both multipath ,variation in Doppler shifts (f_d) effect transmission and ambient noise .

Table 5.JPEG image transmission of underwater modeled channel.

Doppler_ freq(f_d)	**NO_CHANNEL CODE**	**CONVOL**	**LDPC**	**TURBO**	**RS**	**UPGRADED_CONVOL**
	Visual Quality					
1	Visible	Good	Good	Good	Good	Very good
100	Poor quality	Visible	Visible	Visible	Visible	Good
200	Invisible	Invisible	Visible with less quality	Poor quality	Poor quality	Visible

4. Conclusions

A comparison study can be done for upgraded convolution coded, convolution coded image .RS, LDPC, TURBO coded in reverberant channels (consider three multi paths and Doppler frequency variation, transmission loss and ambient loss) by using JPEG image through this paper. The objective is to specify that upgraded convolution code performs better than convolution code, RS ,LDPC,TURBO coded in adverse channels also by comparing the performance measures such as PSNR,SSIM, MSE, and visual quality.

Although Bandwidth efficiency of upgraded convolution code is less compared to other codes , but it performs well comparatively with good PSNR, better SSIM, less MSE and less SNR on an average of 10Db (by maintaining Bandwidth of 8kHz,BER of 10e-3 and hence power requirement is less, which is very important parameter for underwater communication) over other codes.

It is quite realized that for low f_d variation all codes performs well in Under water channel , while f_d changes from 1Hz to 200Hz upgraded convolution code performs well over existing convolution code, RS ,LDPC,TURBO codes. As far as visual quality is concerned as the fd is increasing upgraded convolution code provides good quality image.

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