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Pulse Modulation Schemes for Underwater Communication System Using Different Laser Sources

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Abstract : Under water optical communication provides huge benefit in data transmission. The optical beam passing through the sea water mainly suffers of particle concentration of salty and other impurities present in it. The water wave movement inside the sea also obstructs healthy signal flow in sea water. To study the effect of sea water communication to the optical signal getting through it, test bench sea water like module has been built. Real time optical signal modulated by different pulse modulation schemes (PAM, PPM, PWM,DM, ADM) are set to flow through the undersea water module. At the receiver end the signal is demodulated. 3dB bandwidth, phase jitter and time jitter are measured for analysis using Spectrum Analyzer. The experimentation is repeated for each pulse modulation scheme by varying the concentration of salty particle impurities using Red laser. Jitter observed in pulse position modulation is very low (9.8373 radians) compared to other pulse modulation schemes making it most preferable for under sea water optical communication. Also, this paper compares the performance measures of using different wavelength lasers such as red and green LASER.

Keywords : Underwater communication; PPM; PAM; PWM; DM; ADM; Phase Jitter; Time jitter; 3dB bandwidth; Red laser and Green laser.

1. INTRODUCTION

The undersea water wireless communication is preferred for its low cost, higher data rate, unlimited bandwidth and unlicensed spectrum (Andrews *et al*. 2001; Tsiftsis *et al*. 2006; Theodoros *et al*. 2009). The performance of data transmission in wireless optical communication varied according to the modulation scheme employed (Anguita *et al*. 2011; Zhao *et al*. 2010; Sui *et al*. 2009; Randel *et al*. 2010; Aldibbiat *et al*. 2001). Data transmission in undersea water suffers due to absorption and scattering (Lermusiaux *et al*. 2006). Rayleigh scattering in water is due to salt ions present in it (Mullen *et al*. 2009). Mie scattering is due to suspended particles, such as phytoplankton and other transparent biological organisms (Mobley *et al*. 1994). This scattering due to particles in water affect the directional nature of laser light beam being transmitted challenging long range data transmissions (Mullen *et al*. 2009). The spatial dispersion of optical beam decreases the data transmission efficiency in optical communication (Arnon *et al*. 2009). Fluctuation in optical signal received affects the consistence reception of data. The experimental study to find out the best modulation scheme that provides a good backup to the optical signal being transmitted is vital important. Because a best modulation scheme will considerably reduce the fluctuation (Andrews *et al*. 2001). In underwater optical communication fluctuations are caused to the intensity, field amplitude and the phase of the received light signal, weakening the optical link performance. To transmit a signal with high consistency, a suitable modulation scheme should be used. A better modulation scheme give decreased signal distortion and fluctuations their by achieving a better transmission efficiency. It is observed that varying salt densities under sea water affects wireless laser based optical communication. The two main problems with using LASERs underwater are water absorbs light, and small particles in water can disrupt the path of light. This however does not mean that LASERs are useless in the water(Jaruwatanadilok *et al*. 2008).To

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avoid signal distortion and maintain the confidentiality of the signal being transmitted, a suitable modulation scheme should be used. A better modulation scheme give decreased signal distortion and fluctuations their by achieving a better transmission efficiency. For a good communication system, it has high transmission speed with low cost and also gives stable output signal. One best way, used to evaluate the stability of these output signal waveforms is called "jitter". Jitter indicates a deviation or variation in the period of waveforms for a digital signal during transmission. In this experimental underwater laser communication analysis, the measuring parameters such as phase jitter, time jitter and 3dB bandwidth utilization are used. These parameters measured and compared by using two different wavelength lasers such as Red laser (650nm) and green laser (500nm).

The paper is arranged as follows: In section 2, describes the problem statement. In section 3 the various pulse modulation schemes are discussed. In section 4, various measuring parameters are discussed. In section 5 and section 6, the underwater LASER communication test bench description and result analysis are discussed respectively. The Performance analysis is highlighted in section 7 and photo detectors are discussed in section 8. The conclusion is given in section 9.

2. PROBLEM DESCRIPTION

The effects of several varying parameters of seawater to wireless optical communication are angular deviation beam from its correct line of sight, variations in the beam angle of reception, increased beam divergence due to beam scattering, variations in the spatial power density at the receiver, losses in phase coherence across the beam phase fronts, polarization fluctuations. The net effect of sea water over wireless optical communication link produces propagation loss followed by beam divergence. Fluctuation in the phase and intensity of the laser beam containing data are the key factors that affect the quality of data transmission (Tyson *et al.* 2002; Ricardo *et al.* 2009). In addition to that jitter parameters are providing major problems. Controlling jitter is important because jitter can degrade the performance of a transmission system by introducing bit errors in the digital signals. Phase jitter refers to the amount of phase fluctuation that leads to shortening or lengthening the centre frequency. The Information contained in the phase of the optical signal being transmitted is very essential for consistent retrieval of data. Phase fluctuations of the optical beam caused by various factors of sea water, underneath the performance of optical communication. There for it is very essential to compensate the phase fluctuation so to achieve a very high data rate. The problems affluence the laser beam passing through sea water broadly categorized as scintillation, beam spreading and beam wandering. Proper studies and compensation techniques to reduce these problems were vital important, which in course increase the reliability of data transmission through wireless optical communication under sea water.

3. MODULATION SCHEMES

There are many different types of modulation schemes which are suitable for under water optical wireless communication systems(Snow *et al.* 1999) The prominence in this study will be on the following pulse modulations techniques: Pulse Position Modulation (PPM), Pulse Width Modulation (PWM), Pulse Amplitude Modulation (PAM), Delta Modulation (DM) and Adaptive delta Modulation (ADM) .The performance of various modulation techniques is compared in terms of the their performance with jitter(phase and time) and 3 dB Bandwidth caused by artificially varying salty concentration water conditions namely fresh water, low salt concentration water and high salt concentration water.

4. MEASURING PARAMETERS

In this experimental analysis we have used a standard spectrum analyzer to measure Phase Jitter, Time Jitter and 3dB bandwidth.

Phase Jitter and Time Jitter Measurements

Jitter refers to the amount of phase fluctuation and time fluctuation that leads to shortening or lengthening the center frequency.

3dB Bandwidth Measurement

This refers to the frequency bandwidth of a channel that covers the specified amplitude.

5. UNDER WATER WIRELESS OPTICAL COMMUNICATION SYSTEM TEST BENCH DESCRIPTION

The figure 1 shown is the test bench setup of under sea water wireless optical communication system experiment, which consists of three sections namely the transmitter, channel and the receiver. In the transmitter section the test data signal is given to a pulse modulator and then to the optical modulator which is a laser driving circuit and then to a LASER source of 650nm (red),500nm (green) wavelength. The transmitting and receiving points are kept in line of sight with the underwater chamber dimension $125 \times 25 \times 25$ cm^3 (Length × Height × Width). The modulated optical beam passed through sea water with no salt concentration, low salt concentration and high salt concentration. In this analysis, the collected sample fresh water salt concentration is too low, that is 1.5mg in one liter water. The sample sea water has moderate salt concentration is 35g of salt for one liter. For high salt concentration, sea water has salt concentration of 40g for one liter. The whole experiment has done with 20 litter water with corresponding salt has been added for different concentration. After travelling through the sea water chamber the LASER beam affected by the salt impurities and are set to receive in a PIN photo detector. After proper demodulation the received signal is measured for phase and time jitter by a standard spectrum analyzer. The experimentation is repeated for each modulation technique Pulse Position Modulation (PPM), Pulse Width Modulation (PWM) and Pulse Amplitude Modulation (PAM) Delta Modulation (DM) and Adaptive delta Modulation (ADM). The Red laser and Green laser sources are used and analyzed separately.

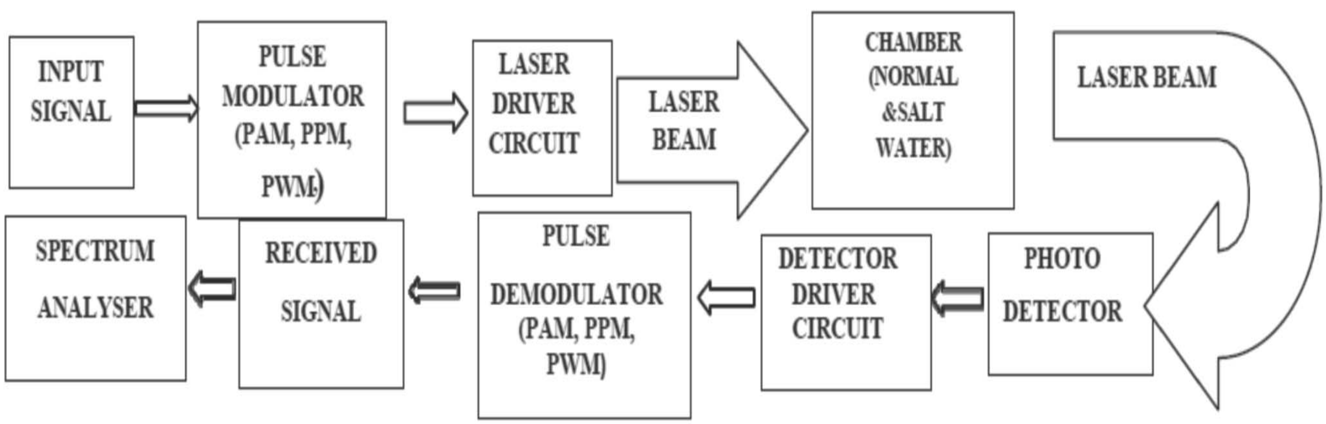

Fig. 1. Underwater Optical Communication Test Bench Experimental Setup.

6. RESULT ANALYSIS

The experiment is done on the underwater chamber with fresh water, medium salt concentrated water and high salt concentrated and measured the phase jitter, time jitter and 3dB bandwidth by using different modulation schemes (PPM, PWM, PAM, DM ,ADM). For this measurement the modulated input signal is given to the LASER driver circuit and the LASER light (Red, Green) is passed through the underwater chamber and the signal is received using the photo detector and then the received signal is demodulated for this demodulated signal the jitter and bandwidth measurements are taken using spectrum analyzer. For these measurements the spectrum analyzer is set with Start frequency of 0KHz, Center frequency of 1.5GHz, Stop frequency of 3GHz, Resolution bandwidth of 4MHz, Vertical bandwidth of 300KHz, Span frequency of 3GHz, Sweep speed of 92ms.Also, for the phase and time jitter measurement the Start offset is set to 0.01MHz, Stop offset is set to 150 MHz and these set up is set initially.

Fig. 2 and 3 shows the circuit diagram of Pulse Amplitude modulator and Pulse width modulator respectively.

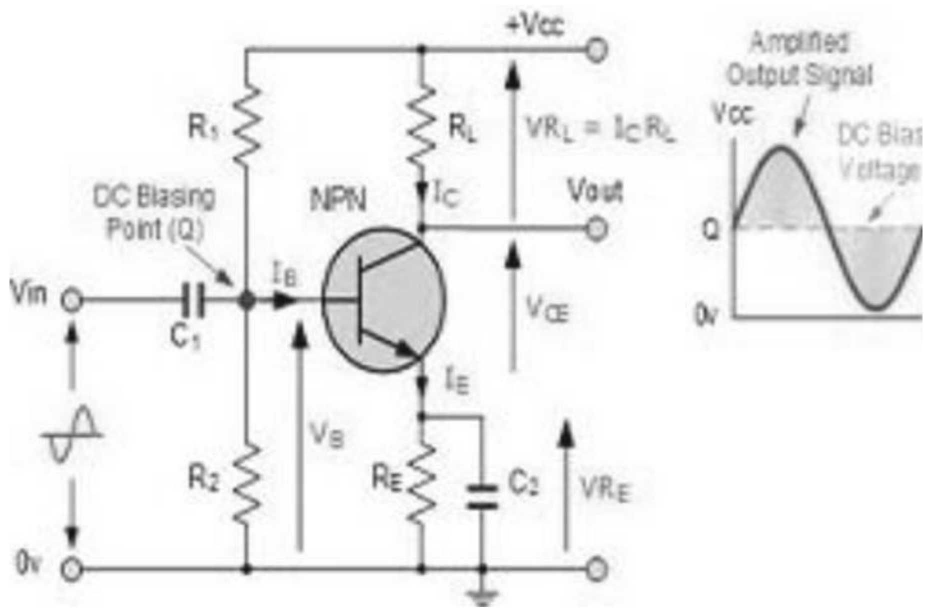

Fig. 2. PAM circuit diagram

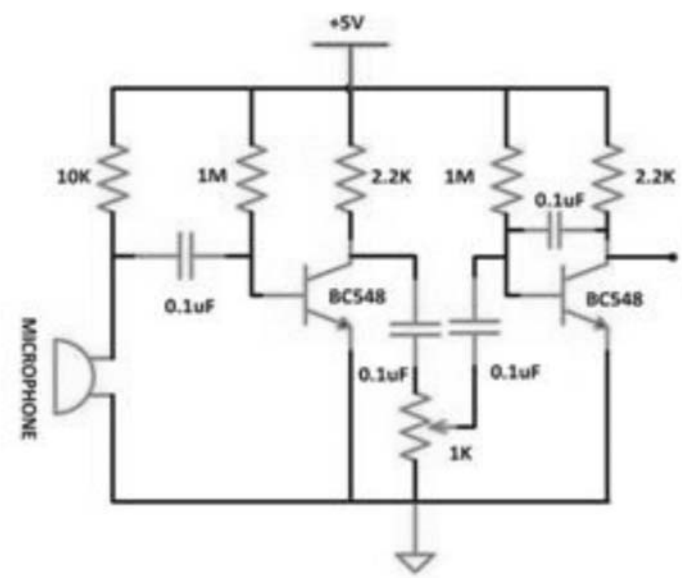

Fig. 3. PWM circuit diagram

7. PERFORMANCE ANALYSIS

Table 1 shows the experimental result of different pulse modulation using red and green LASER under fresh water, medium and high salt concentrated water. Using red LASER, in fresh water PPM has 9.3009rad phase jitter and 1.0334nsec time jitter, PWM has 10.270rad phase jitter and 1.1412nsec time jitter, and PAM has 10.941rad phase jitter and 1.2157nsec time jitter of these PPM is best. For medium salt concentrated water, the phase jitter and time jitter values are found to be increased when compared with fresh water that is PPM has 9.6286rad phase jitter and 1.0698nsec time jitter, PWM has 10.406rad phase jitter and 1.1563nsec time jitter, and PAM has 11.251rad phase jitter and 1.2501nsec time jitter of these PPM is best. The same result is being observed for high salt concentrated water whereas the jitter values are slightly increased than medium salt concentrated water that is PPM has 9.8373rad phase jitter and 1.0930nsec time jitter, PWM has 10.814rad phase jitter and 1.2016nsec time jitter, and PAM has 11.645rad phase jitter and 1.2939nsec time jitter of these PPM is best. For 3dB bandwidth analysis, the bandwidth values are same for both fresh water as well as for different salt better bandwidth utilization. And for green LASER, in fresh water PPM has 9.1935rad phase jitter and 1.0215nsec time jitter, PWM has 9.7457rad phase jitter and 1.0828nsec time jitter, and PAM has 10.131rad phase jitter and 1.1257nsec time jitter of these PPM is best. The same result is being observed for high salt concentrated water whereas the jitter values are slightly increased than medium salt concentrated water that is PPM has 9.7560rad phase jitter and 1.0540nsec time jitter, PWM has 10.171rad phase jitter and 1.1302nsec time jitter, and PAM has 10.737rad phase jitter and 1.1930nsec time jitter of these PPM is best. For 3dB bandwidth analysis, the bandwidth values are same for both fresh water as well as for different salt concentrated water PWM has 6MHZ bandwidth, PPM and PAM has 12MHZ bandwidth of these PWM has better bandwidth utilization.

The phase jitter analysis of pulse modulation schemes using red and green LASER under fresh water, medium and high salt concentrated water shows that PPM is best for both red and green LASER compared with PWM and PAM under fresh and both salt concentrated water. Of these two LASER graph shows that green LASER is giving best performance.The time jitter analysis of pulse modulation schemes using red and green LASER under fresh, medium and high salt concentrated water shows that PPM is best for both red and green LASER compared with PWM and PAM under fresh and both salt concentrated water. Of these two LASERS graph shows that green LASER is giving best performance.

Concentrated water PWM has 12MHZ bandwidth, PPM and PAM has 18MHZ bandwidth.PWM has For medium salt concentrated water, the phase jitter and time jitter values are found to be increased when compared with fresh water that is PPM has 9.5021rad phase jitter and 1.0557nsec time jitter, PWM has 9.9654rad phase jitter and 1.1072nsec time jitter, and PAM has 10.235rad phase jitter and 1.1373nsec time jitter of these PPM is best.

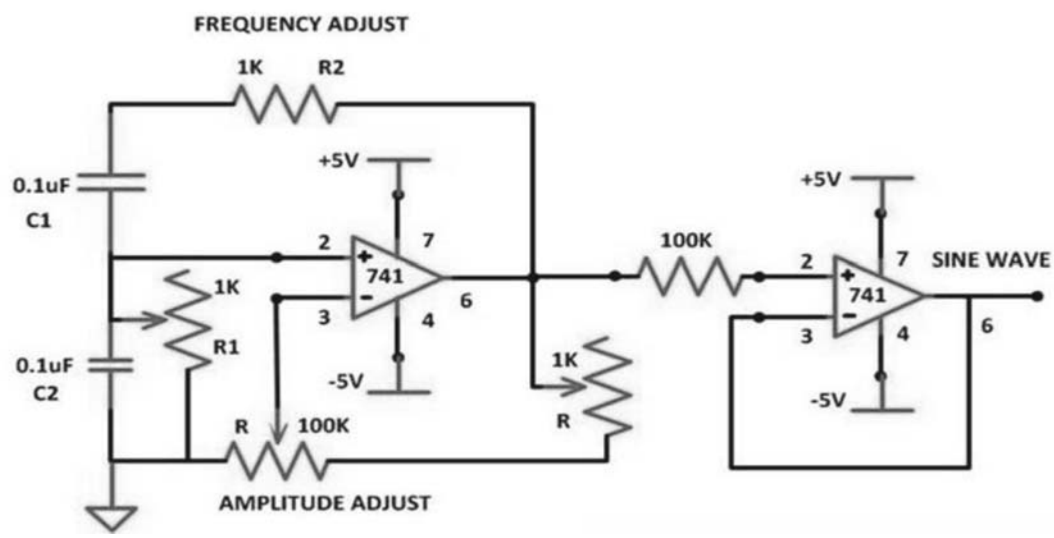

Fig. 4. PPM circuit diagram

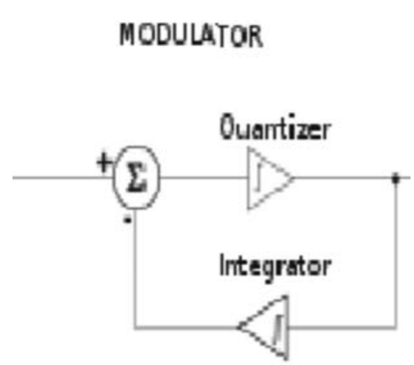

Fig. 5. Delta Modulator circuit diagram

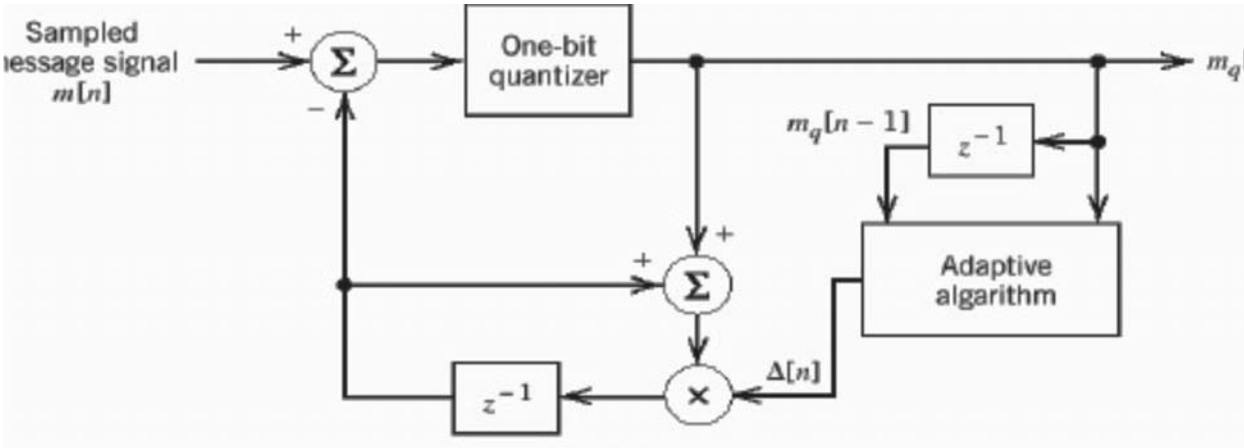

Fig. 6. Adaptive Delta Modulator circuit diagram

Table 1. Phase Jitter, Time Jitter and 3dB Bandwidth Readings

Modulation Schemes	*Salt Concentration of Water*	*Phase Jitter (rad)*		*Time Jitter (nsec)*		*3 dB BW (MHZ)*	
		Red	***Green***	***Red***	***Green***	***Red***	***Green***
PPM	Fresh Water	9.3009	9.1935	1.0334	1.0215	18	12
	Medium Salt Concentrated Water	9.6286	9.5021	1.0698	1.0557	18	12
	High Salt Concentrated Water	9.8373	9.7560	1.0930	1.0840	18	12
PWM	Fresh Water	10.270	9.7457	1.1412	1.0828	12	6
	Medium Salt Concentrated Water	10.406	9.9654	1.1563	1.1072	12	6
	High Salt Concentrated Water	10.814	10.171	1.2016	1.1302	12	6
PAM	Fresh Water	10.941	10.131	1.2157	1.1257	18	12
	Medium Salt Concentrated Water	11.251	10.235	1.2501	1.1373	18	12
	High Salt Concentrated Water	11.645	10.737	1.2939	1.1930	18	12
DM	Fresh Water	10.370	9.865	1.4121	1.0928	12	6
	Medium Salt Concentrated Water	10.506	10.265	1.5630	1.1702	12	6
	High Salt Concentrated Water	10.904	10.461	1.2160	1.1709	12	6
ADM	Fresh Water	10.277	9.726	1.2121	1.1028	10	4
	Medium Salt Concentrated Water	10.556	10.625	1.5360	1.1802	10	4
	High Salt Concentrated Water	10.890	10.641	1.1260	1.1609	10	4

8. PHOTO DETECTORS

There are different types of opto-electrical devices that can be used as photo detectors. Photodetectors will respond quickly to all incident photons sent by the transmitter without introducing additional noise. Additionally it would be small, robust, cheap and power efficient. In the application, switching speed is the top priority for a photon detector, followed by light sensitivity. Of course, this is assuming that power and size constraints are met.

Different types of photo detectors as photodiode and phototransistors were used. The received signal strength has not got much variation by changing the photo diode and phototransistor.

9. CONCLUSION

The results obtained from the above experimental analysis shows that the performance measures are good in fresh water, it decreases when the salt concentration get increased. According to the phase and time jitter analysis the PPM is the best choice for both red and green LASER. ADM is the best scheme in accordance with the bandwidth utilization. By comparing the overall performance, green LASER provides better performance than red LASER by employing different modulation schemes.

Laser based underwater communication system has been tested successfully. In case of increased power output of laser light, the range of communication will expand to low submarines' voice communication. Also the system could be arranged for exploration purposes in unmanned navy vehicles and autonomous underwater vehicles.

In future distance of communication can be increased and the same modulation techniques can be employed to analyze the signal strength at the receiver end.

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