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Analysis of Pulse Modulation Schemes in Underwater Communication Using Different Laser Sources

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Abstract

Under sea 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) are set to flow through the undersea water module. At the receiver end the signal is demodulated and measured for 3dB bandwidth, phase jitter and time jitter. 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; 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

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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 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, the problem descriptions are discussed. In section 3 and section 4, the measuring parameters and modulation schemes are discussed respectively. 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 the conclusion is given in section 8.

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) and Pulse Amplitude Modulation (PAM) .The performance of modulation techniques is often compared in terms of the their performance with jitter(phase and time) 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.

4.1 Phase Jitter and Time Jitter Measurements

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

4.2 3dB Bandwidth Measurement

It 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 125x25x25 cm^3 (Length x Height x 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 1.2mg in one litre water. The sample sea water has collected from two different places. The calculated value of moderate salt concentration is 35g for one litre. For high salt concentration, the calculated value is 40g for one litre. 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). The Red laser and Green laser sources are used and analyzed separately.

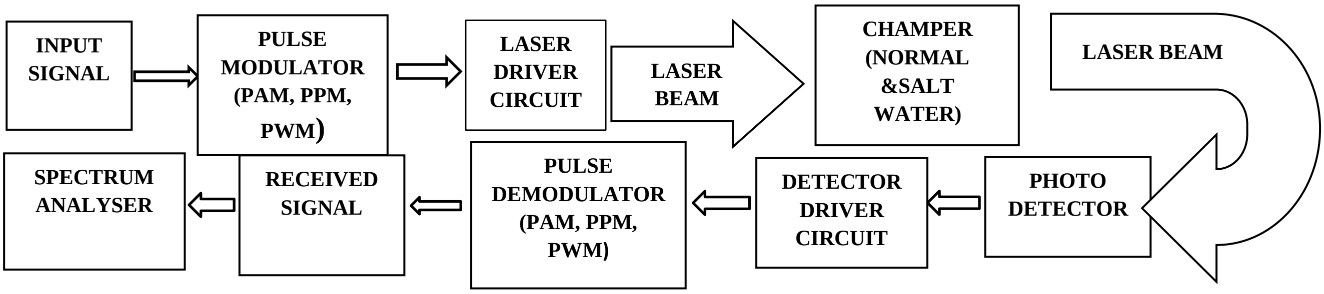


Fig. 1: Underwater Optical Communication Test Bench Experimental Setup

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). 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 analyser. For these measurements the spectrum analyser 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.

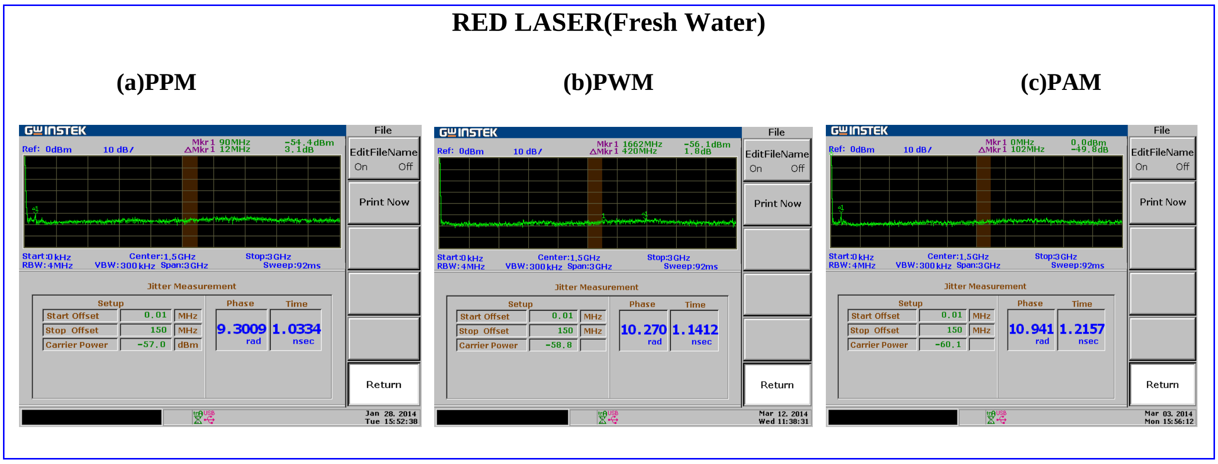


Fig. 2: Phase jitter and time jitter under Fresh water Using Red Laser

RED LASER(Medium salt concentrated water)

(a)PPM **(b)PWM** **(c)PAM**

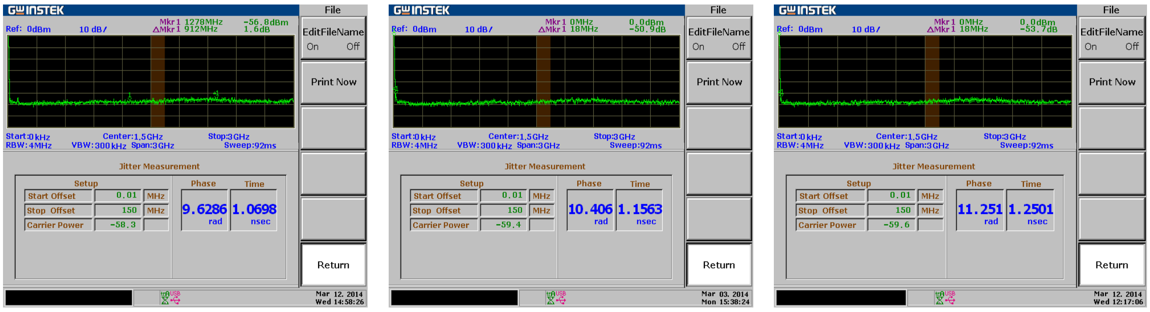


Fig. 3: Phase jitter and time jitter under medium salt concentrated water using Red Laser

Fig 2(a). Shows the phase jitter and time jitter for Pulse Position Modulation (PPM) with fresh water using Red LASER, in this analysis the phase jitter observed is 9.3009radians and the time jitter is 1.0334nsec. Fig 2(b). Shows the phase jitter and time jitter for Pulse Width Modulation (PWM) with fresh water using Red LASER, in this analysis the phase jitter observed is 10.270radians and the time jitter is 1.1412nsec. Fig 2(c). Shows the phase jitter and time jitter for Pulse Amplitude Modulation (PAM) with fresh water using Red LASER, in this analysis the phase jitter observed is 10.941radians and the time jitter is 1.2157nsec. Fig 3 (a). Shows the phase jitter and time jitter for Pulse Position Modulation (PPM) with medium salt concentrated water using Red LASER, in this analysis the phase jitter observed is 9.6286 radians and the time jitter is 1.0698nsec. Fig 3 (b). Shows the phase jitter and time jitter for Pulse Width Modulation (PWM) with medium salt concentrated water using Red LASER, in this analysis the phase jitter observed is 10.406 radians and the time jitter is 1.1563nsec. Fig 3 (c). Shows the phase jitter and time jitter for Pulse Amplitude Modulation (PAM) with medium salt concentrated water using Red LASER, in this analysis the phase jitter observed is 11.251 radians and the time jitter is 1.2501nsec. Fig 4 (a).Shows the phase jitter and time jitter for Pulse Position Modulation (PPM) with high salt concentrated water using Red LASER, in this analysis the phase jitter observed is 9.8373 radians and the time jitter is 1.0930nsec. Fig 4 (b). Shows the phase jitter and time jitter for Pulse Width Modulation (PWM) with high salt concentrated water using Red LASER, in this analysis the phase jitter observed is 10.814 radians and the time jitter is 1.2016nsec. Fig 4 (c). Shows the phase jitter and time jitter for Pulse Amplitude Modulation (PAM) with high salt concentrated water using Red LASER, in this analysis the phase jitter observed is 11.645 radians and the time jitter is 1.2939nsec. Fig 5(a). Shows the 3dB bandwidth for Pulse Position Modulation (PPM) with fresh water using Red LASER, in this analysis the 3dB bandwidth observed is 18MHZ. Fig 5 (b). Shows the 3dB bandwidth for Pulse Width Modulation (PWM) with fresh water using Red LASER, in this analysis the 3dB bandwidth observed is 12MHZ. Fig 5 (c). Shows the 3dB bandwidth for Pulse Amplitude Modulation (PAM) with fresh water using Red LASER, in this analysis the 3dB bandwidth observed is 18MHZ. Fig 6. (a). Shows the 3dB bandwidth for Pulse Position Modulation (PPM) with medium salt concentrated water using Red LASER, in this analysis the 3dB bandwidth observed is 18MHZ. Fig 6 (b). Shows the 3dB bandwidth for Pulse Width Modulation (PWM) with medium salt concentrated water using Red LASER, in this analysis the 3dB bandwidth observed is 12MHZ. Fig 6 (c). Shows the 3dB bandwidth for Pulse Amplitude Modulation (PAM) with medium salt concentrated water using Red LASER, in this analysis the 3dB bandwidth observed is 18MHZ.

RED LASER(High salt concentrated water)

(a)PPM (b)PWM (c)PAM

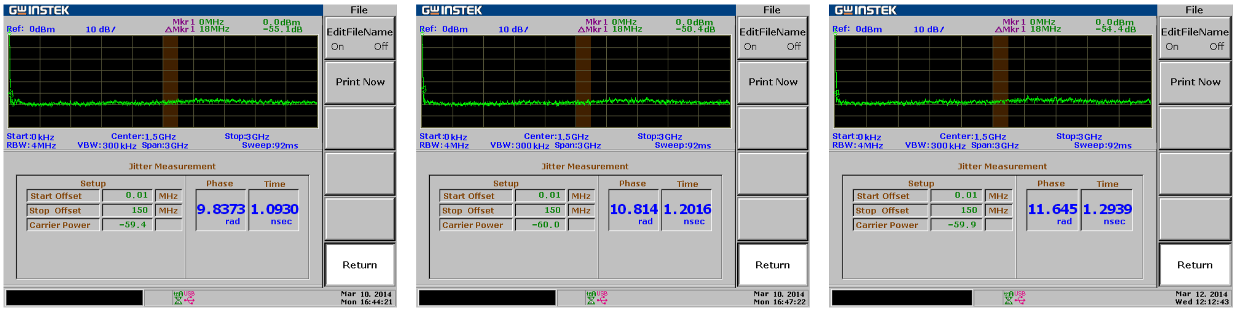


Fig. 4: Phase jitter and time jitter under high salt concentrated water Using Red Laser

RED LASER(Fresh water)

(a)PPM (b)PWM (c)PAM

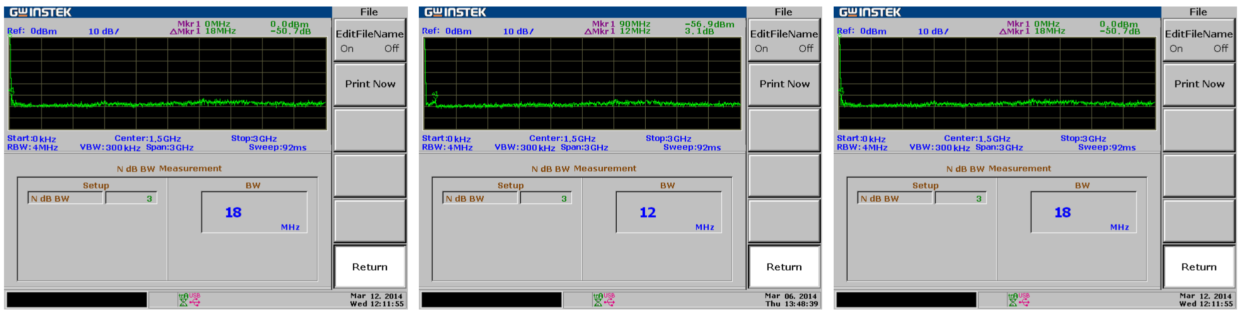


Fig. 5: 3dB Bandwidth under fresh water Using Red laser

RED LASER(High Salt Concentrated Water)

(a)PPM (b)PWM (c)PAM

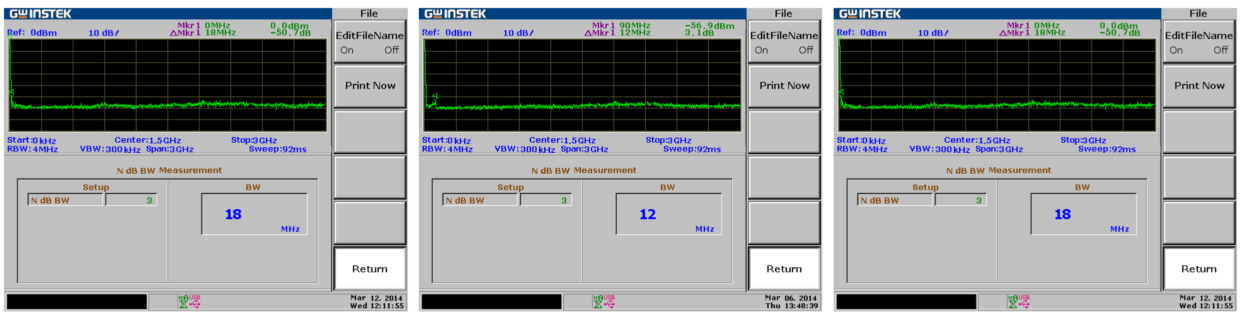


Fig. 6: 3dB Bandwidth under medium Salt Concentrated Water Using Red laser

RED LASER(Medium Salt Concentrated Water)

(a)PPM **(b)PWM** **(c)PAM**

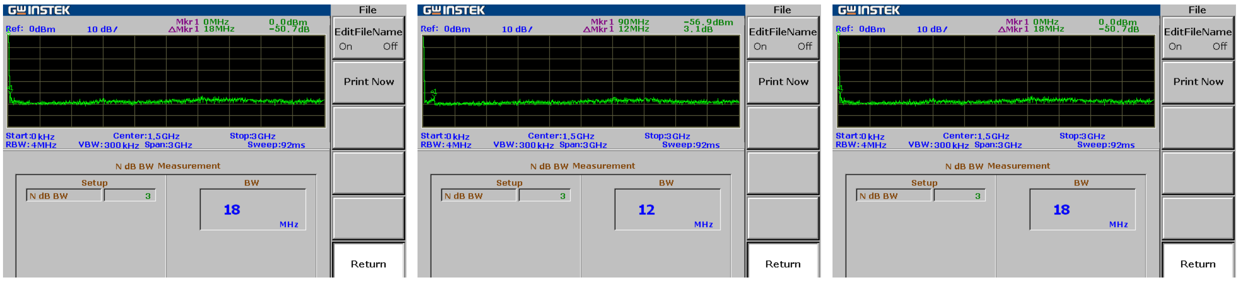


Fig. 7: 3dB Bandwidth under high Salt Concentrated Water Using Red laser

GREEN LASER(Fresh water)

(a)PPM **(b)PWM** **(c)PAM**

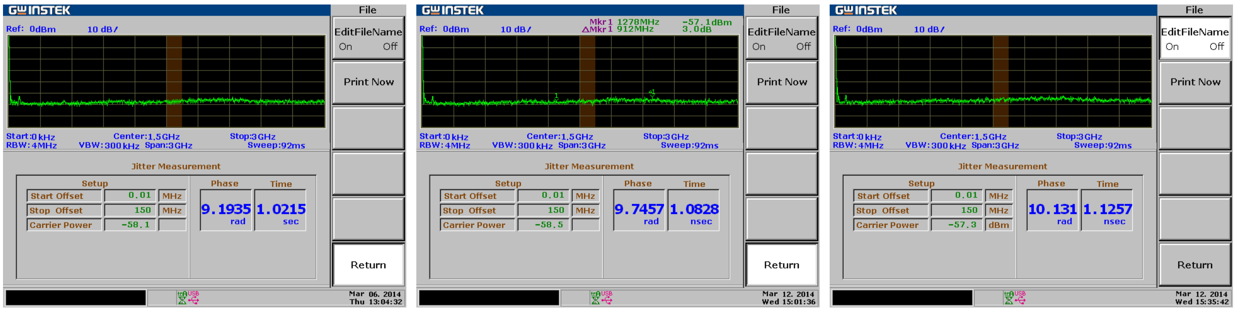


Fig. 8: Phase jitter and time jitter under fresh water using Green laser

GREEN LASER(Medium Salt Concentrated Water)

(a)PPM **(b)PWM** **(c)PAM**

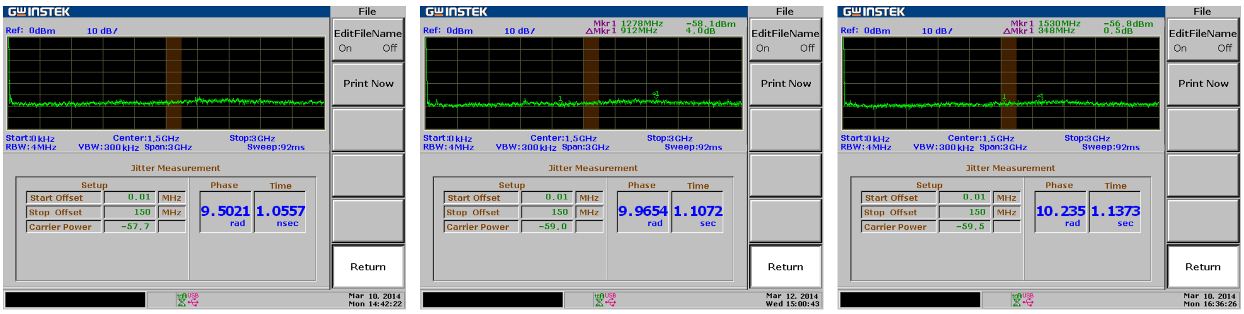


Fig 9. Phase Jitter And Time Jitter under medium Salt Concentrated Water using Green laser

GREEN LASER(High Salt Concentrated Water)

(a)PPM **(b)PWM** **(c)PAM**

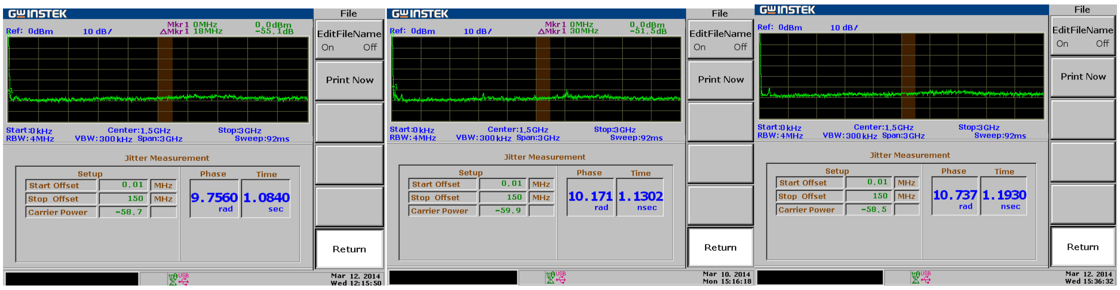


Fig. 10: Phase Jitter And Time Jitter under high Salt Concentrated Water Using Green laser

Fig 7 (a). Shows the 3dB bandwidth for Pulse Position Modulation (PPM) with high salt concentrated water using Red LASER, in this analysis the 3dB bandwidth observed is 18MHZ. Fig 7 (b). Shows the 3dB bandwidth for Pulse Width Modulation (PWM) with high salt concentrated water using Red LASER, in this analysis the 3dB bandwidth observed is 12MHZ. Fig 7 (c). Shows the 3dB bandwidth for Pulse Amplitude Modulation (PAM) with high salt concentrated water using Red LASER, in this analysis the 3dB bandwidth observed is 18MHZ. Fig 8 (a). Shows the phase jitter and time jitter for Pulse Position Modulation (PPM) with fresh water using Green LASER, in this analysis the phase jitter observed is 9.1935radians and the time jitter is 1.0215nsec. Fig 8 (b). Shows the phase jitter and time jitter for Pulse Width Modulation (PWM) with fresh water using Green LASER, in this analysis the phase jitter observed is 9.7457radians and the time jitter is 1.0828nsec. Fig 8(c). Shows the phase jitter and time jitter for Pulse Amplitude Modulation (PAM) with fresh water using Green LASER, in this analysis the phase jitter observed is 10.131 radians and the time jitter is 1.1257nsec. Fig 9 (a). Shows the phase jitter and time jitter for Pulse Position Modulation (PPM) with medium salt concentrated water using Green LASER, in this analysis the phase jitter observed is 9.5021 radians and the time jitter is 1.0557nsec. Fig 9 (b). Shows the phase jitter and time jitter for Pulse Width Modulation (PWM) with medium salt concentrated water using Green LASER, in this analysis the phase jitter observed is 9.9654 radians and the time jitter is 1.1072nsec. Fig 9 (c). Shows the phase jitter and time jitter for Pulse Amplitude Modulation (PAM) with medium salt concentrated water using Green LASER, in this analysis the phase jitter observed is 10.235 radians and the time jitter is 1.1373nsec. Fig 10 (a). Shows the phase jitter and time jitter for Pulse Position Modulation (PPM) with high salt concentrated water using Green LASER, in this analysis the phase jitter observed is 9.7560 radians and the time jitter is 1.0840nsec. Fig 10 (b). Shows the phase jitter and time jitter for Pulse Width Modulation (PWM) with high salt concentrated water using Green LASER, in this analysis the phase jitter observed is 10.171 radians and the time jitter is 1.1302nsec. Fig 10 (c). Shows the phase jitter and time jitter for Pulse Amplitude Modulation (PAM) with high salt concentrated water using Green LASER, in this analysis the phase jitter observed is 10.737 radians and the time jitter is 1.1930nsec. Fig 11 (a). Shows the 3dB bandwidth for Pulse Position Modulation (PPM) with fresh water using Green LASER, in this analysis the 3dB bandwidth observed is 12MHZ. Fig 11 (b). Shows the 3dB bandwidth for Pulse Width Modulation (PWM) with fresh water using Green LASER, in this analysis the 3dB bandwidth observed is 6MHZ. Fig 11 (c). Shows the 3dB bandwidth for Pulse Amplitude Modulation (PAM) with fresh water using Green LASER, in this analysis the 3dB bandwidth observed is 12MHZ. Fig 12 (a). Shows the 3dB bandwidth for Pulse Position Modulation (PPM) with medium salt concentrated water using Green LASER, in this analysis the 3dB bandwidth observed is 12MHZ. Fig 12 (b). Shows the 3dB bandwidth for Pulse Width Modulation (PWM) with medium salt concentrated water using Green LASER, in this analysis the 3dB bandwidth observed is 6MHZ. Fig 12 (c). Shows the 3dB bandwidth for Pulse Amplitude Modulation (PAM) with medium salt concentrated water using Green LASER, in this analysis the 3dB bandwidth observed is 12MHZ. Fig 13 (a). Shows the 3dB bandwidth for Pulse Position Modulation (PPM) with high salt concentrated water using Green LASER, in this analysis the 3dB bandwidth observed is 12MHZ. Fig 13 (b). Shows the

3dB bandwidth for Pulse Width Modulation (PWM) with high salt concentrated water using Green LASER, in this analysis the 3dB bandwidth observed is 6MHZ. Fig 13 (c). Shows the 3dB bandwidth for Pulse Amplitude Modulation (PAM) with high salt concentrated water using Green LASER, in this analysis the 3dB bandwidth observed is 12MHZ.

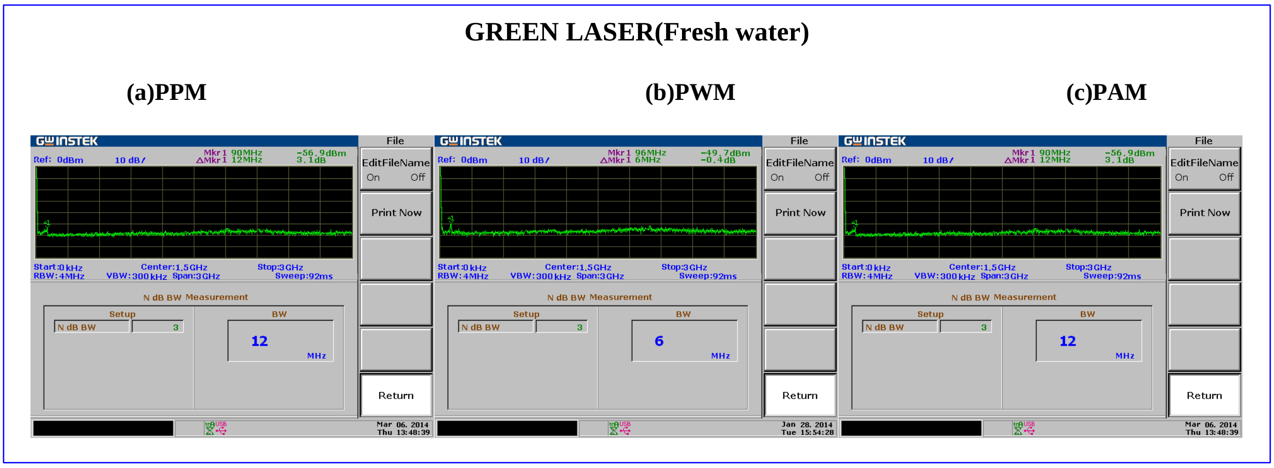


Fig. 11: 3dB Bandwidth under fresh Water Using Green laser

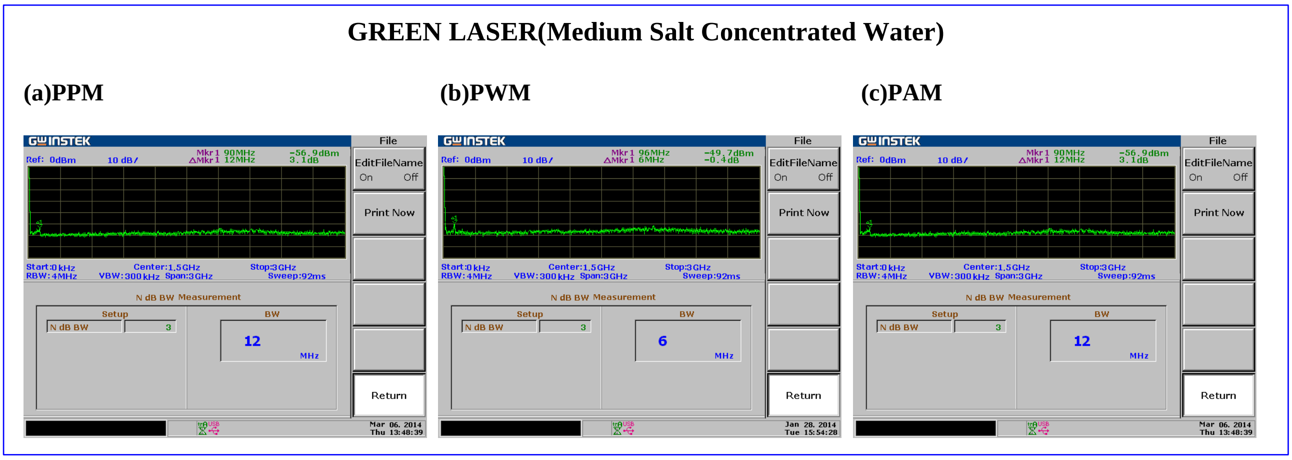


Fig. 12. 3dB Bandwidth under medium Salt Concentrated Water Using Green laser

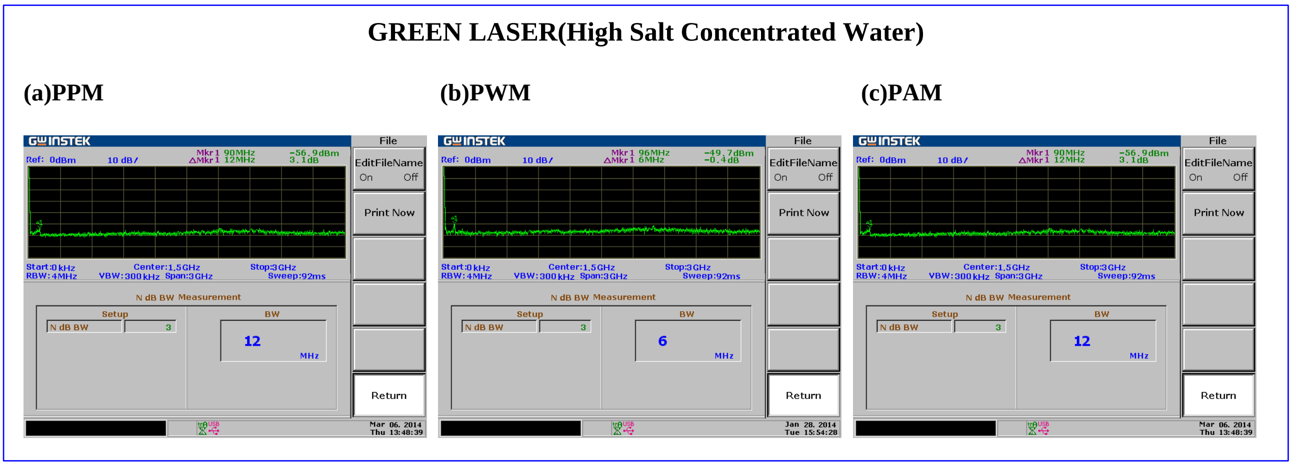


Fig. 13: 3dB Bandwidth under high Salt Concentrated Water Using Green laser

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 concentrated water PWM has 12MHZ bandwidth, PPM and PAM has 18MHZ bandwidth of these PWM has 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. 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. 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.

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

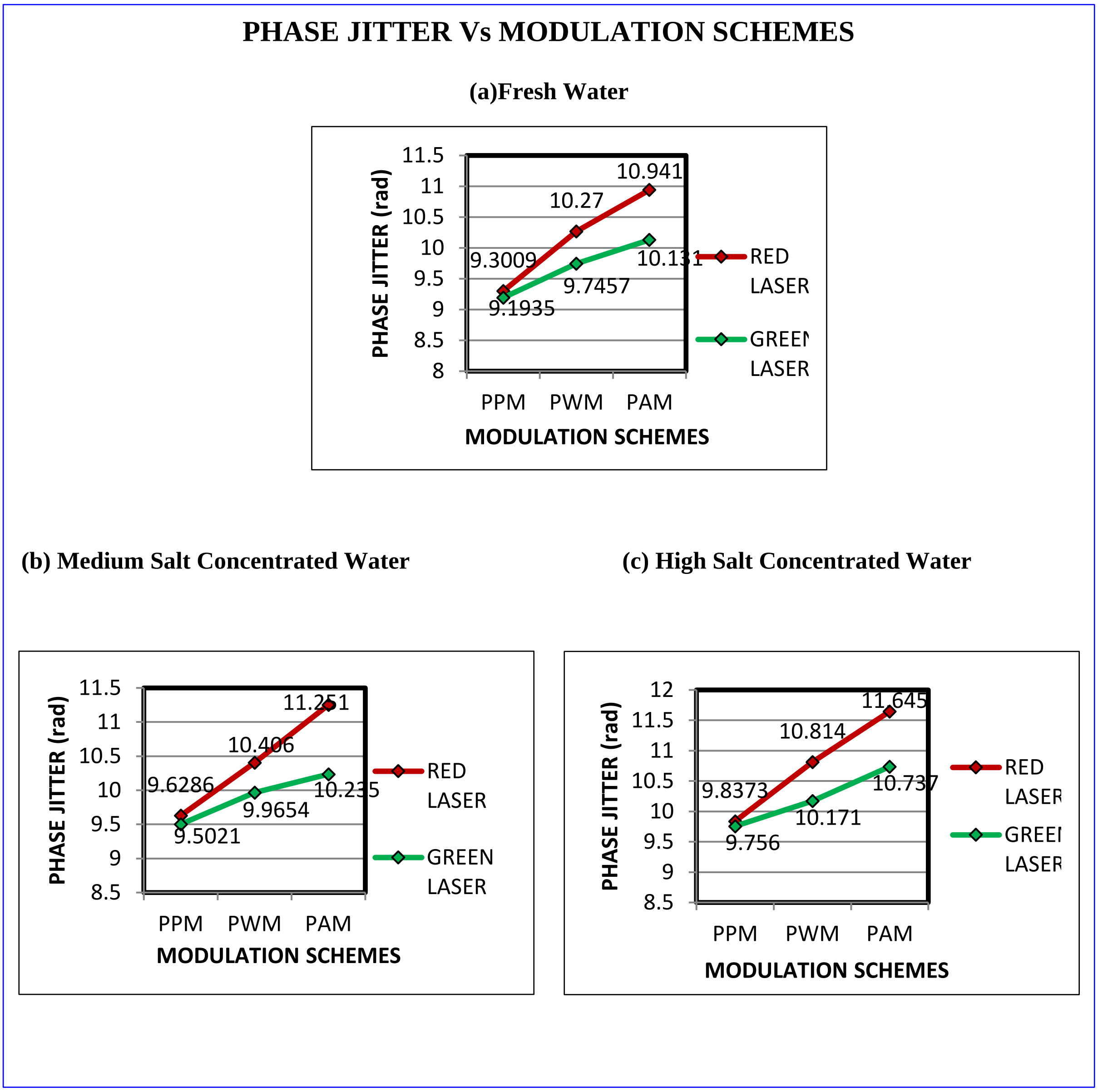


Fig. 14: Phase Jitter Analysis

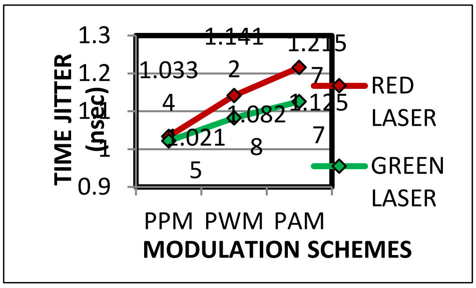
Fig 14. Shows the phase jitter analysis of pulse modulation schemes using red and green LASER under fresh water, medium and high salt concentrated water. The graph shows that PPM is best for both red and green LASER compared with PWM and PAM under fresh and both salt concentrated water. Of these two LASER graph shows that green LASER is giving best performance.

Fig 15. Shows the time jitter analysis of pulse modulation schemes using red and green LASER under fresh, medium and high salt concentrated water. The graph 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.

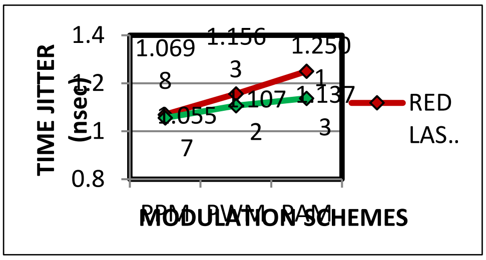
Fig 16 Shows the 3dB bandwidth analysis of pulse modulation schemes using red and green LASER under fresh, medium and high salt concentrated water. The graph shows that PWM has best bandwidth utility for both red and green LASER compared with PPM and PAM under fresh and both salt concentrated water. Of these two LASERS graph shows that green LASER has better bandwidth utility.

TIME JITTER Vs MODULATION SCHEMES

(a) Fresh Water



(b) Medium Salt Concentrated Water



(b) High Salt Concentrated Water

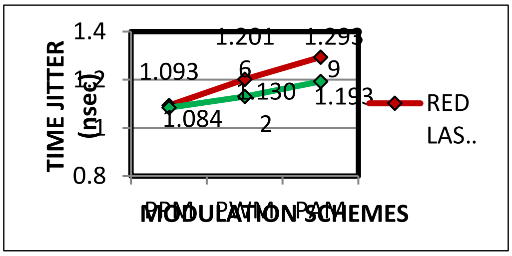
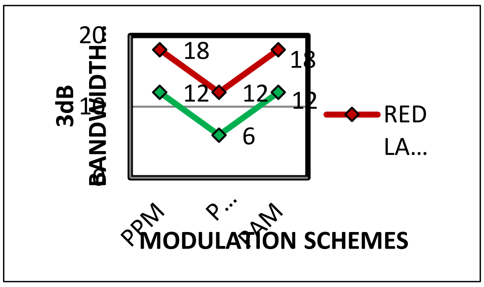


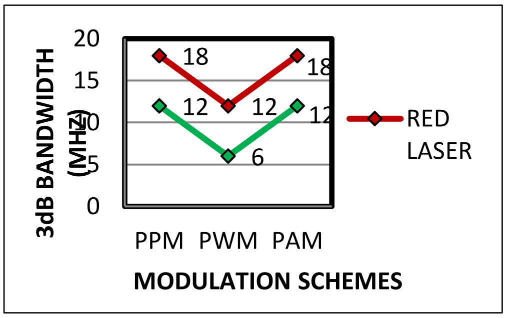
Fig. 15: Time Jitter Analysis

3dB BANDWIDTH Vs MODULATION SCHEMES

(a)Fresh Water



(b)Medium Salt Concentrated Water



(c)High Salt Concentrated Water

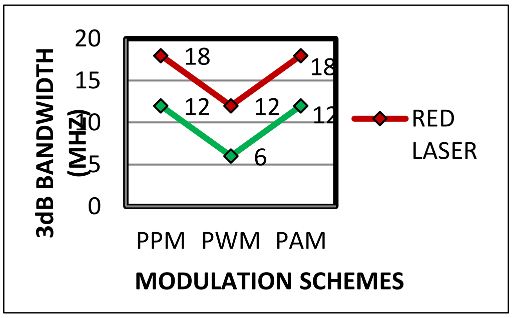


Fig. 16: 3dB Band width Analysis

8. 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. PWM is the best scheme in accordance with the bandwidth utilization. By comparing the overall performance, green LASER provides better performance than red LASER.

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