Experiment Description

1. **Experiment time:** September 29th, 2015
2. **Experiment location**: Node2 at Seattle Boat Company (SBC), Node3 at Pocock (Fig1.)

Figure 1: Experiment Location

3. **Experiment purposes**:
   a) Channel Characterization
   b) Finding delay spread between SBC to Pocock.
4. **Performance Metrics and Measurements:** Measuring packets sent, received, and CIR
5. **Experimenters**: Noshad Bagha, Yanling Yin.
6. **Experiment procedure**:

a . SBC to Pocock:

i. Sending 1 packet every 10s from node2 to node3.
ii. Packet size = 187 bytes data + 13 bytes header = 200 Bytes
iii. Goal was to send at least 100 packets per trial.
iv. Acceptable TXPWR values are between 0 to -50 dB. It wasn't possible to collect more data points for MODE1, since we had 100% delivery rate at -50 dB for the first trial.

Table 1: Trial description

Trial	Mode	Transmission power (dB)
1	1	-50
2-4	2	-50, -40, -30
5-7	3	-35, -30, -25
8-10	4	-30, -15, -10
11-13	5	-14, -12, -6

Table 2: Mode description

MODE	Code rate(rc)	Modulation	R(kb/s)
1	1/2	BPSK	1.38
2	1/2	QPSK	2.9
3	3/4	QPSK	4.42
4	1/2	16QAM	5.94
5	3/4	16QAM	8.99

7. Data, results, and analysis

The goal was to send at least 100 packets per trial. Mode5 trials was cut short since there was no packets received and ESNR was consistently below 10dB (minimum ESNR needed for mode5, Ref 1.)

Last row in Table 3, orange background, is the lab trial to insure that modems are capable of MODE5 transmission. Lab trial should %99.7 success rate thus modems are operating correctly.

Trial	Time	TXPWR	Mode	Mean ESNR	Mean Signal	Mean Noise RMS	SNR(dB)	pkt sent	pkt rec
1	10:03	-50	MODE1	8.8	3.49E+00	3.10E-02	2.05E+01	102	102
2	10:20	-50	MODE2	8.3	3.18E+00	3.66E-02	1.94E+01	109	96
3	10:42	-40	MODE2	8.9	2.76E+00	3.33E-02	1.92E+01	104	97
4	11:04	-30	MODE2	9.6	2.80E+00	9.46E-03	2.47E+01	120	118
6	11:27	-25	MODE3	9.5	6.72E+00	1.56E-02	2.64E+01	142	138
5	11:53	-30	MODE3	9.57	2.51E+00	1.73E-02	2.16E+01	106	95
7	12:16	-35	MODE3	9.1	2.00E+00	2.10E-02	1.98E+01	103	72
8	12:43	-30	MODE4	9.75	2.66E+00	3.16E-02	1.93E+01	103	44
9	13:09	-15	MODE4	9.5	6.08E+01	5.83E-02	3.02E+01	116	85
10	13:32	-10	MODE4	8.84	1.58E+02	1.42E-01	3.05E+01	110	50
11	13:56	-12	MODE5	8.7	8.85E+01	1.07E-01	2.92E+01	90	0
12	14:23	-6	MODE5	7.826	2.37E+02	2.66E-01	2.95E+01	51	0
13	15:09	-14	MODE5	8.7	5.98E+01	7.21E-02	2.92E+01	39	0
lab_mod5	NA	-40	MODE5	14.2	1.17E+00	8.68E-04	3.13E+01	395	394

Figure 2 depicts the packet delivery ratio (PDR) for each mode. Expected behavior is to see improvement in PDR as TXPWR increases. The expectation was met for MODE1 to the second trial of MODE4, however, possible channel change dropped performance of the 3rd trial (-10dB) and failed to transmit at MODE5 all together.

$$PDR(\%) = \frac{Packets\ Received}{Packets\ Sent}$$

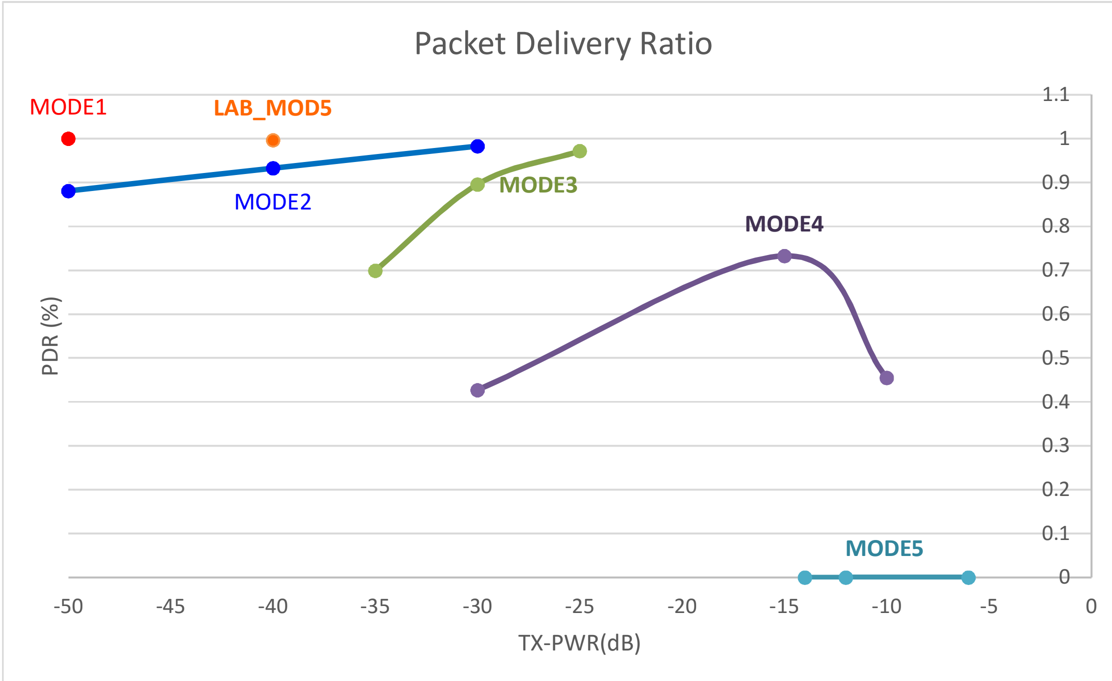

Figure 2: Packet Delivery Ratio

Figure 3 shows high Noise at trial 10 to 13. Trial 10 is the last MODE4 trial, which had a drastic drop compare to the last trial with lower TXPWR. Trial 11-13 had zero successful transmissions at MODE5.

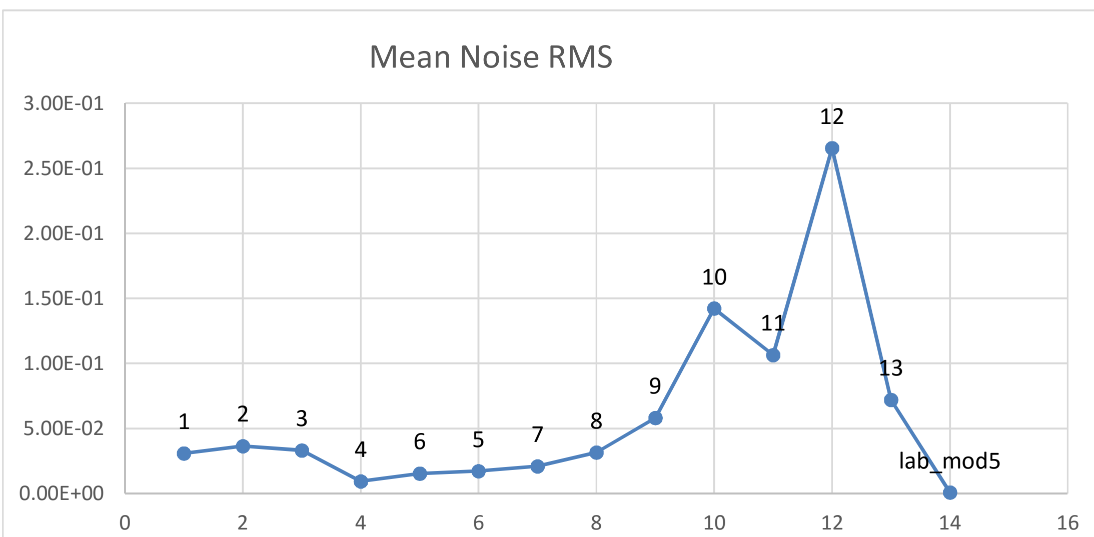

Figure 3: Mean Noise RMS vs trials. Worse performance between trials 10-13.

Figure 4 presents the ESNR performance in this experiment (definitions can be found in Ref.1) Generally speaking, ESNRs increase with transmission power increment, until at certain points they reach constant levels. ESNR achieves constant level much earlier due to the limitation brought by channel estimation error. Overall, ESNR values in this test condition are low (average 9 dB), which indicates channel couldn't handle high data rate (Ref. 2.) Ideal channel should consistently produce ESNR above 10 dB to enable high data rates (Mode4 and 5.) Moreover, ESNR seems to be mode **independent**.

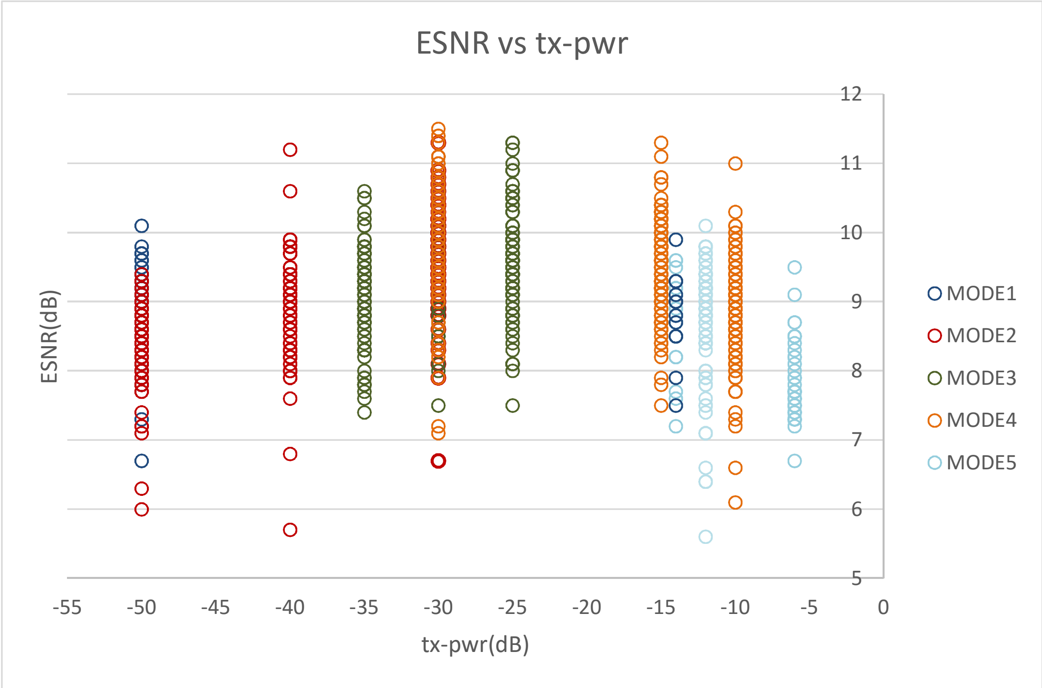

Figure 4: ESNR as a function of TXPWR, seems mode independent.

CIR results consistently show a delay spread of around 25ms (Figure 5.)

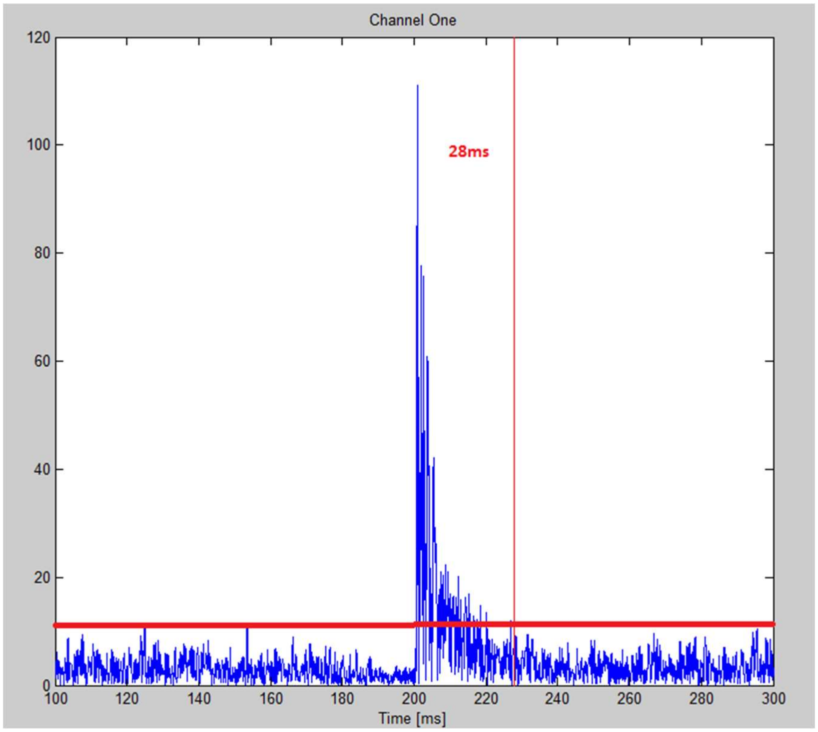

Figure 5: Example CIR reading

Figure 5 shows CIR in frequency domain between to different CIRs, one taken in the morning with a “good behaving channel” and the other in the afternoon with “harsh channel conditions.” It seems noise levels in magnitude response in the afternoon CIR is larger than the morning one. This can be a good reason for lower ESNR despite transmitting signals with considerably higher TXPWR. Moreover, phase change seems to be faster in the afternoon, which is the main influence factor of the performance.

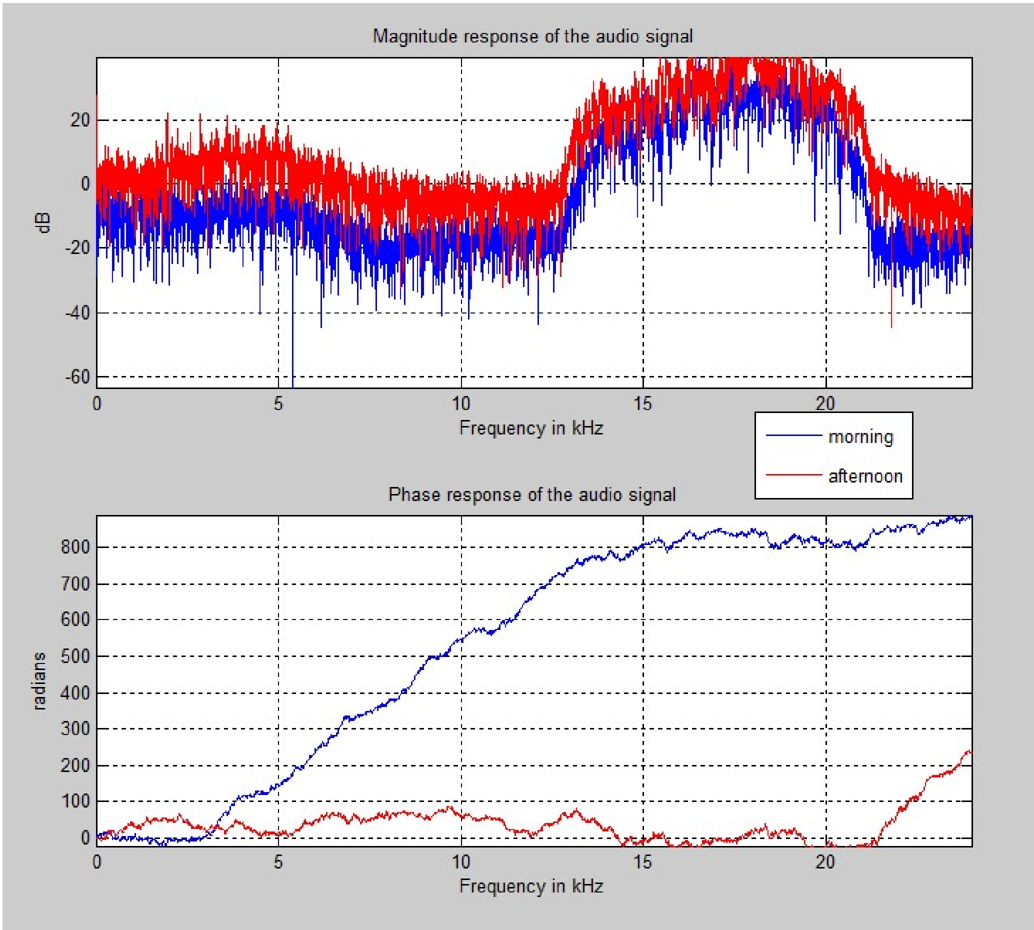

Figure 6: Comparison between CIR taken in morning and afternoon

8. References

[1] L. Wan, H. Zhou, X. Xu, Y. Huang, S. Zhou, Z. Shi, and J.-H. Cui, “Field Tests of Adaptive Modulation and Coding for Underwater Acoustic OFDM,” in The 8th ACM International Conference on Underwater Networks and Systems (WUWNet’13), Kaohsiung, Taiwan, 2013.

[2] Zheng Peng; Li Wei; Zigeng Wang; Lei Want; Zuba, M.; Jun-Hong Cui; Shengli Zhou; Zhijie Shi; O'Donnell, J., "Ocean-TUNE UCONN testbed: A technology incubator for underwater communication and networking," in Underwater Communications and Networking (UComms), 2014 , vol., no., pp.1-4, 3-5 Sept. 2014