Poster Abstract: AquaModem Field Tests in Moorea

Tricia Fu, Daniel Doonan, Chris Utley, Bridget Benson, Ryan Kastner
University of California, Santa Barbara

1. INTRODUCTION

Advanced underwater eco-sensing heavily involves telemetry of marine environmental data (conductivity, temperature, depth, currents). There is a great need for undersea wireless networks for eco-sensing allowing remote monitoring and adaptive sampling without requiring physical retrieval of instruments. These underwater wireless networks rely on acoustic modems for underwater communication. In order to be practical for eco-sensing applications, these acoustic modems need to be power efficient, relatively inexpensive and robust to multipath- the fundamental obstacle to underwater acoustic communications.

The UCSB AquaModem is an acoustic modem designed for short range (< 1km) eco-sensing applications in a shallow horizontal underwater channel. The AquaModem uses only 2 Watts of acoustical power and operates at a center frequency of 24 kHz and a double-sided bandwidth of 7.8 kHz, with a bit rate of approximately 160 bps. It uses M-ary direct sequence spread spectrum signaling, with joint detection and channel estimation performed by matching pursuits to effectively handle multipath interference.

From July 24th – July 28th 2007, the AquaModem was field tested in Cook's Bay and in the Viapahu Lagoon off the UC Berkeley Richard B. Gump South Pacific Research Station, on the French Polynesian island of Moorea. This site is part of the Moorea Coral Reef Long Term Ecological Research (LTER) program established by the National Science Foundation to support research of long-term ecological phenomenon.

This poster presents the test set-up and some test results of the Moorea Modem field experiments. At ranges up to 440 m, the UCSB AquaModem yielded symbol error rates averaging < 1% in water less than 4 m deep, while Doppler spreads from modem channel estimates were found, on average, to be on the order of 0.01 Hz.

2. TEST SET-UP

Each test was conducted off two small motor boats, one carrying the AquaModem transmitter and the other carrying the AquaModem receiver. Each boat was equipped with a Trimble GPS unit and transect tape for distance measurements and a marine radio for voice communication between the two boats. Modem tests were conducted at various distances between the receiver and transmitter in varied water depths. Over 1e4 message symbols were transmitted per test.

2.1 Test 1

The first test was conducted in Cook's Bay in approximately 30 meters water depth. Because of the depth, the receiver and transmitter boats could not be anchored and therefore floated freely with the current during testing. Tests were conducted at approximately 25 m, 50 m and 60 m distances with the transducers hung over the side of the boats about 1 meter below the surface. These tests were conducted primarily to confirm proper operation of the AquaModem before taking the AquaModem into a more challenging shallow water environment.

2.2 Test 2

Test 2 was conducted in Viapahu Lagoon, where water depth slowly varied between 2 and 4 meters and the boats could be anchored. Test locations were chosen where the bottom substrate was mostly soft white sand with a sparse scattering of short (< 1 ft) coral heads (aka bommies) (Figure 1). The transducers were once again hung over the side of the boats about 1 meter below the surface and tests were conducted at a nominal 28 meters distance. The transducers experienced significant motion (approx. 1m up and down) as the boats bounced up and down with surface waves.

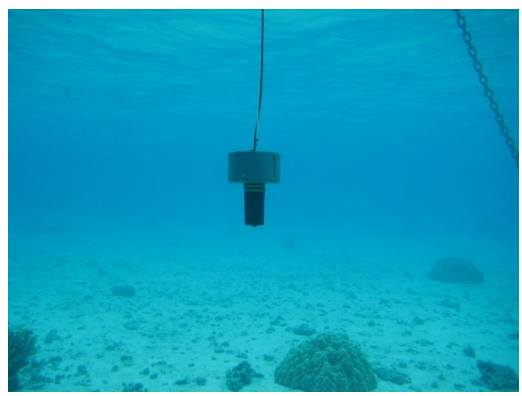

Figure 1: Test 2 transducer set-up. Photo depicts receiver transducer suspended from the boat in about 3 meters water depth in the Viapahu Lagoon

2.3 Test 3

Test 3 was conducted in the same location as Test 2, but the transducers were roped to cement blocks and placed on the lagoon floor to eliminate motion. Tests were conducted at 125 m, 280 m, 330 m, and 440 m distances.

2.4 Test 4

Test 4 was also conducted in the Viapahu Lagoon, but this time in the 'bommie field', to offer an even more challenging underwater acoustic channel. Water depths still remained between 2 and 4 meters, but the lagoon bottom was covered with a dense spread of small and large (up to 2 meters tall) coral heads. (Figure 2) The transducers, still roped to cement blocks, were placed between or on top of large bommies to obtain a direct path between transmitter and receiver. Tests were conducted at 50m distance.

Figure 2: Test 4 transducer set-up. Photo depicts receiver transducer placed on the bottom of the Viapahu Lagoon in the 'bommie field' at about 2 meters water depth

3. TEST RESULTS

Tables 1-4 show the results for the modem tests 1-4 respectively. The first column represents distance between the transmitter and receiver, the second column represents the number of multipaths the modem was programmed to find (where Est. means estimated), the third column represents the symbol error rate calculated for 1e4 symbols sent, the fourth column represents the Doppler spread calculated from channel coefficients by averaging results for each delay/arrival time and then applying a 5 element median filter, and the last column represents the average number of paths the modem detected. Multiple tests were conducted at each distance to prove repeatability of the experiment. In-band Signal to Noise Ratio (SNR) data was only collected for tests 1 and 3, the results of which are presented in Table 5.

Table 1: Test 1 Results (30 m depth, un-anchored clear water)

Distance (m)	NF	SER	Doppler Spread (Hz)	Mean NF
25	Est.	0 %	1.258	1.017
25	Est.	0 %	0.442	1.000
50	Est.	0 %	1.256	1.000
50	Est.	0 %	2.056	1.000
60	Est.	0 %	2.136	1.000

Table 2: Test 2 Results (4m depth, un-anchored, clear water)

Distance (m)	NF	SER	Doppler Spread (Hz)	Mean NF
28	Est.	0 %	2.367	1.092
28	Est.	0 %	4.577	1.117

Table 3: Test 3 Results (4m depth, anchored, clear water)

Distance (m)	NF	SER	Doppler Spread (Hz)	Mean NF
125	Est.	0.78%	0.020	1.21
125	Est.	0.02%	0.018	1.01
125	5	0.08%	0.026	4.97
125	5	0.19%	0.031	4.99
125	8	0%	0.032	7.81
125	8	0.91%	0.088	7.82
125	Est.	0.52%	0.036	1.01
280	Est.	0.19%	0.028	1.00
280	Est.	0%	0.036	1.04
280	8	0.52%	0.384	7.84
330	Est.	1.98%	1.468	1.15
330	Est.	0.31%	2.810	1.18
330	5	0.18%	0.022	1.15
330	5	0.63%	0.023	4.95
330	5	0%	0.044	4.96
330	5	0%	0.039	4.95
330	3	0%	0.026	3.00
330	3	0%	0.024	3.00
440	Est.	0.06%	0.030	1.12
440	Est.	0.06%	0.044	1.20
440	3	1.21%	0.032	3

Table 4: Test 4 Results (4m depth, anchored, 'Boomie Field')

Distance (m)	NF	SER	Doppler Spread (Hz)	Mean NF
50	Est.	0%	0.0222	1
50	Est.	0%	0.0196	1
50	5	0%	0.0218	4.98
50	5	0%	0.0332	4.98
50	3	0%	0.0612	3.00
50	3	0%	0.0204	3.00

Table 5: SNR Results for Tests 1 and 3

Test	Distance (m)	SNR (linear)	SNR (dB)
1	50	55.98	17.48
3	125	372.77	25.71
3	280	83.40	19.21
3	330	151.48	21.80
3	440	61.39	17.88

The results show excellent operation of the modem at all distances as the average symbol error rate per test per distance was less than 1%. The anchored tests (Tests 3 and 4) showed much lower Doppler spreads (on the order of 0.01Hz) than the un-anchored tests (Tests 1 and 2) which was expected due to the reduced motion induced on the transducer while sitting on the lagoon floor. Though more paths were expected to be detected by the modem in the bommie field, the results do not show any distinct correlation between the number of paths detected and the number of bommies present.