Performance Evaluation of Phase Coherent Underwater Acoustic Communications During the LWAD 98-1 Experiment

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Abstract: Underwater coherent acoustic communications experiments were conducted during the Littoral Warfare Advanced Development (LWAD) 98-1 exercise. The signals were projected from both a drifting modem and from a towed acoustic source. Data of several different baud rates were transmitted and used to (1) test the capability of the acoustic modems for real-time receiving and processing of phase coherent signals, and (2) evaluate the performance of the phase coherent communication algorithm. The performance of the communication algorithm is correlated with the phase and amplitude fluctuation statistics, the signal-to-noise ratio (SNR), and other system and environment parameters. The results of this and future analysis will be used to guide future algorithm development and system design.

INTRODUCTION

The ocean represents a band-limited and rapidly fading communication channel. The multipath structure is temporally unstable due to random fluctuations in the ocean medium. Coherent data transmission using quadrature phase shift keying (QPSK) allows for efficient use of the available bandwidth. Recently an acoustic communications (ACOMM) experiment was conducted as part of the Littoral Warfare Advanced Development (LWAD) series of experiments. The main goals of the ACOMM experiment were to test the performance of the coherent communications method in the littoral environment, including real-time (in situ) processing of the received data using SHARC DSPs and post-experiment processing of the ACOMM signals at multiple platforms.

The experiment was conducted using mid and high frequency transmissions. The signals were projected from both a drifting modem and from a towed acoustic source at different baud rates, ranging from 1000 b/s to 15000 b/s. Real-time processing using SHARC DSP processors was possible when the signal-to-noise (SNR) at the receiving modem was greater than 10 dB.

COHERENT ACOMM RECEIVER

The receiver design is complicated due to the time varying nature of the oceanic communication channel. An adaptive signal processing algorithm is being used where the receiver parameters are updated using a recursive-least square (RLS) method [1]. The received signal is frame synchronized prior to any processing. This is accomplished by matched filtering to a known probe (Barker code). The received signal may be sampled at the symbol rate, in which case an accurate symbol timing is crucial for satisfactory equalization. Otherwise, a fractionally spaced equalizer which uses sampling interval \( T_s \) smaller than the reciprocal of the signal bandwidth is insensitive to the timing phase of the received signal [2]. The sampled signal is then fed into a tap delay line (the feed-forward part of the equalizer), see Fig. 1. After the linear equalization, the carrier phase is compensated for by its estimate \( \hat{\Phi}(n) \). The feed-forward filter has \( N \) weights to reduce the effect of the inter-symbol-interference (ISI). The output of the linear equalizer and synchronizer is fed to the decision-feedback part of the receiver. The feedback filter has \( M \) weights to produce an estimate of the residual ISI caused by previously detected symbols. This estimate is subtracted from the output of the linear equalizer to produce the estimate of the received data symbols \( \{ \hat{d}(n) \} \). The decision \( \hat{d}(n) \) is found by attributing the estimate \( \{ \hat{d}(n) \} \) to the nearest QPSK symbol. The estimation error is \( e(n) = d(n) - \hat{d}(n) \). Therefore, the \( MSE = E\{ |e(n)|^2 \} \).

ACOMM EXPERIMENT

The ACOMM experiment was conducted on December 9th, 1997 in the Gulf of Mexico, 30 miles south of Key West, Florida. Three vessels participated in the exercise, NAWC-38, LCU-1647, and NAWC-03. The acoustic modems were on the NAWC-38 and NAWC-03, the towed source was on the LCU, see Fig.2. The modems range
separation was about 5 km, and the LCU was moving from 1 km to 12 km from NAWC-38 and back. Also, there was a distribution of six single-phone sonobuoys in the area. Acoustic data were received and recorded on the three platforms, also, environmental measurements were collected, before, during and after the experiment.

IN SITU RESULTS

In situ data processing was performed on the NAWC38 using SHARC DSP processors. Various source/receiver configurations (range and depth) were tested. A large portion of the experiment was conducted at mid frequency (3.5 kHz) for baud rates 1000, 1500, and 2000 b/s. The SNR during the experiment was between 10 to 30 dB, see Fig.3. The modem was able to detect and successfully equalize more than 90% of the transmitted packets when the source/receiver separation was less than 6 km. The maximum bit error rate (BER) for this data (Range < 6 km) was on the order of 10^{-4}, see Fig.4. This ratio could be increased if the receiver parameters were adjusted during the exercise. When the LCU approached the 12 km range, the signal fading became very prominent and the SNR dropped below 10 dB very often, during this period the modem was neither able to detect nor to equalize the ACOMM signals.

SUMMARY AND FUTURE WORK

Quality ACOMM data were collected and processed in situ. Post data analysis will be conducted to study the impact of the acoustic environment on phase coherent communications, such as the correlation of the algorithm performance with the signal fluctuation statistics.

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REFERENCES