SignalEx: Relating the Channel to Modem Performance

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LONG-TERM GOALS

To understand how the ocean-channel affects acoustic communications, thereby develop tools to predict system performance, and produce a channel-adaptive signaling scheme for optimal communications.

OBJECTIVES/BACKGROUND

The objective of the SignalEx tests is to develop insights about how different environmental conditions affect different signaling schemes. The importance of this is illustrated by the recent (September 2002) SeaWeb testing in RDS-4 near Halifax, Canada. The SeaWeb network was being used to maintain remote contral access to an offboard acoustic surveillance array (Hydra). The network has often worked with internode spacings of 5 km in other sites. In this site, the multipath spread was large, possibly due to the deployment in an ocean canyon. The result was that even direct path vertical connections proved difficult and only spotty connectivity was obtained under the best conditions. Perhaps most significantly, the acomms community does not have a capability to reliably predict network performance in new sites.

APPROACH

We have adopted a two-pronged approach in which we independently field our own signaling schemes, yet also kept the experiments open to virtually any participant that have a scheme to test. The list of participants is shown in Table 1. Currently, the internally fielded schemes are a ‘research type-a’, a type-x, and a PPM system. The type-a signaling scheme is a simple FSK approach with several channel-coding options and is virtually identical to the Benthos/Datasonics system. The type-x system is a classical DSSS (Direct-sequence, Spread-Spectrum) method using DPSK and a RAKE receiver not too different from the IS95 standard developed by Qualcomm. The code was originally developed by NEU (Proakis and Sozer).

Table I: Partial list of waveforms tested in SignalEx.

SPAWAR type designation	Method	Analysis group
A	Multi-frequency shift keyed (MFSK)	SAIC/SPAWARSSC
B	Frequency-Hopped FSK (FH-MFSK)	Benthos
	Time-reversal	Naval Postgraduate School (Smith)
X	Differential phase-shift keyed (DPSK)	Northeastern Univ. SAIC/SPAWARSSC
D	N-QAM (BPSK, QPSK, 16-QAM)	Northeastern Univ., Delphi, NUWC, Benthos
E	Pulse-Position Modulation (PPM)	SAIC
G	Orthogonal Frequency Division Multiplexing (OFDM)	Polytechnic Univ.
H	Multi-Carrier Code Division Multiple Access (MC-CDMA)	Polytechnic Univ.
	QPSK (Iterative Decoding)	Naval Undersea Warfare Center
	QPSK	University of Birmingham
	OFDM	Naval Postgraduate School (Christi)
	DSSS	Naval Postgraduate School (Duke)
	FHFSK (novel hopping scheme)	BAE Systems (Edelson)
	PPC	BAE Systems (Edelson)
	Turbo coding	Delphi
	Interop Standard (FH-FSK)	SAIC
	Biologic FSK	SPAWARSSC/SAIC

The key to this testing program is the versatile Telesonar Testbeds (Fig. 1), which have fully programmable mission-control software allowing us to transmit and receive all waveforms in any sequence. The hardware itself is now well tested and has performed flawlessly in recent tests.

WORK COMPLETED

The SignalEx program has now completed 5 distinct tests, including two additional tests under this year's funding. The two new tests were at Ship Island in connection with AUVFest and the Coronado Bank test that actually involved two separate deployments. The test locations are shown in Figure 2. These tests have included the two main spread spectrum techniques (FH-FSK and DSSS) being evaluated for a SeaWeb upgrade, as well as a large number of 'guest' participants who took advantage of the SignalEx tests to do preliminary tests of new modulation techniques. Finally, the so-called Interop Standard proposed by WHOI was also tested.

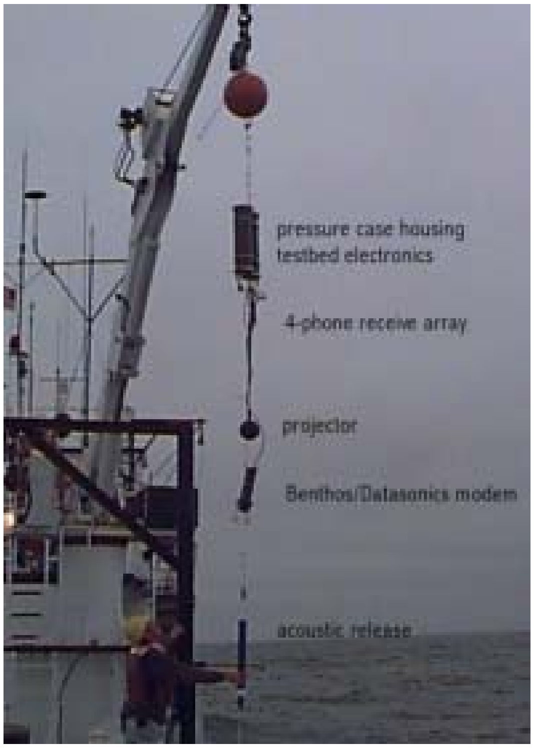

Fig. 1: Testbed configuration.

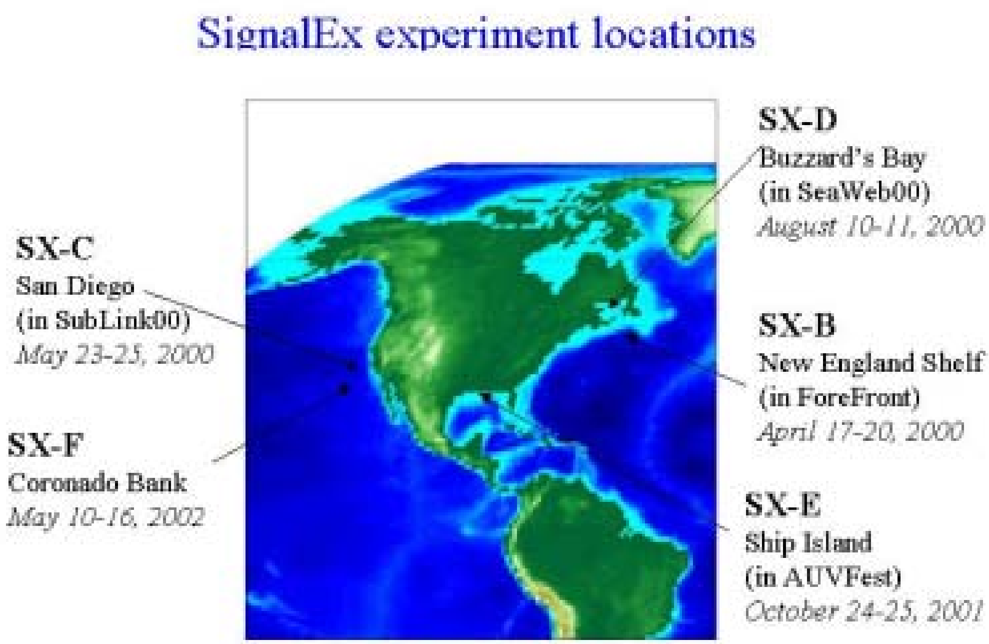

Fig. 2: Locations of the SignalEx tests.

On the hardware end, a large number of upgrades have been made to the “telesonar testbeds” or T2’s used to collect the acoustic data.

Real-time, temperature-compensated clock added (accurate to 1 min/year). The master controller polls this precision clock every minute and synchronizes the on-board computer clock to it.

Remote modem control. Using a Benthos modem, we can send and receive messages to an operating T2 and monitor mission progress/status, including battery voltage, clock, and disk space. Soon we will also be able to upload sample receptions remotely also.

Double-disk option: The T2's now run with two disks in tandem and the master-controller checks free space and automatically switches to the second disk when the first is full. Our next deployment will record 40 gig. of data.

4-channel record at 48 kS/s: Upgraded A-to-D's to reliably handle this significantly greater data throughput. Also built 2 new 4-channel receive arrays.

Compact amplifier board: In the process, also added a linear phase, 4th-order Bessel filter between the D-to-A which greatly improves amplifier stability.

New 25-50 kHz band (complementing the existing 8-16 kHz): A 2-channel receive array has been built. A separate monitor element has been built. The matching network has been designed and is currently being manufactured.

Finally, the SignalEx website (http://sunspot.spawar.navy.mil/seaweb/signalex.htm) was updated with complete information on the sea tests and results of the data analysis.

RESULTS

The sites selected for this year’s tests were specifically chosen to capture short multipath and long multipath situations. We find the former case tends to occur in very shallow water, e.g. less than 10 m. The water depth in the Ship Island test was about 5 m and shows multipath spread of just a few milliseconds as anticipated before the experiment. For the later Coronado Bank test we consulted a seafloor geologist/geoacoustician to recommend a site nearby with a very hard (reflective) ocean bottom. The multipath spread in that site, as desired, showed quite long multipath spread of perhaps 50 msecs (depending on your precise definition).

The important aspect of this comparison is that we can systematically compare the performance of the different modulation schemes as a function of both SNR and multipath spread. We have done these comparisons for DSSS, Benthos FH-FSK, Passive Phase Conjugation, and the proposed Interop Standard amongst others. A consistent observation from all of these schemes is that multipath spread can be just as important as SNR. For instance, in Figure 4 we show the results of the Interop standard at 160 bps. The various deployments (Ship Island, Coronado May 10 and Coronado May 16) involve a progressive increase in the multipath spread. Equally obvious is the progressive decrease in channel errors as the multipath spread increases (or the SNR decreases).

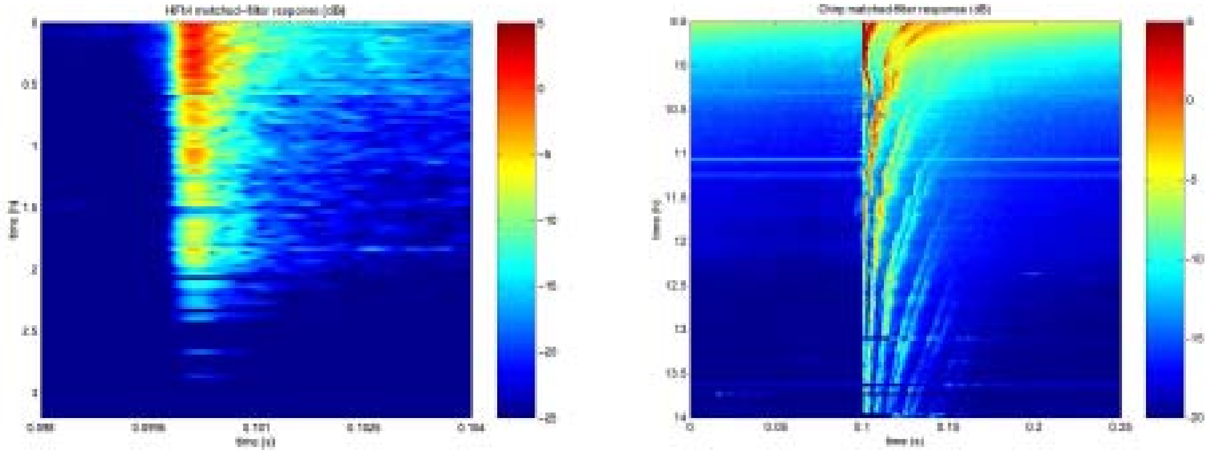

Figure 3: Change in the multipath structureover the course of the day, during which time source/receiver separationincreased from about 0-5 km. Ship Island test (left), Coronado Bank test (right).

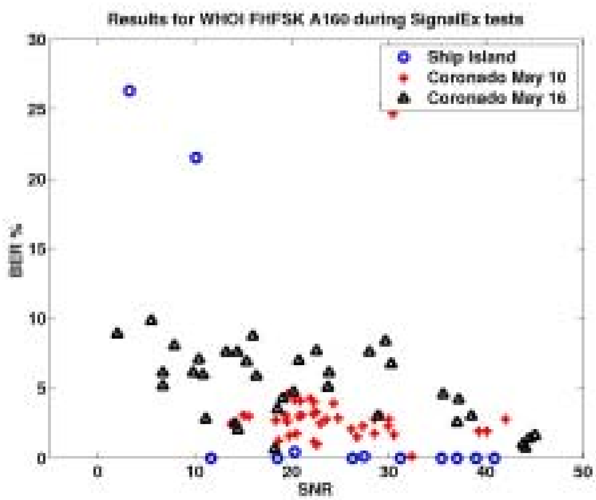

Figure 4: Bit-Error Rate vs. Signal-to-Noise Ratio in 3 separate tests (involving different multipath spread).

IMPACT/APPLICATIONS

Just as cellular phones have greatly enhanced our personal freedom, wireless underwater systems provide tremendous flexibility in connecting to underwater systems, including ocean measurement systems such as CTD's and ADCP's; AUV's; and autonomous surveillance arrays. Wireless systems based on 802.11b and Bluetooth are currently emerging as the physical layer of the terrestial internet; similar systems based on acoustic technology will likewise form the backbone of the oceanic internet. Rapid and reliable signaling schemes will obviously be critical. Furthermore, being able to predict system performance in new deployment areas (or optimally select deployment sites) requires these careful SignalEx studies.

RELATED PROJECTS

This work is linked to the SeaWeb program at SPAWARSSC. Additional support was provided by ONR 321OA.

PUBLICATIONS

Michael B. Porter, Paul Hursky, Martin Siderius, Vincent K. McDonald, and Paul Baxley (invited talk), “High-Frequency Propagation for Acoustic Communications”, in Impact of Littoral Environmental Variability on Acoustic Predictions and Sonar Performance, Eds. Nicholas G. Pace and Finn B. Jensen, Kluwer (2002).

Paul A. Baxley, Homer Bucker, Michael B. Porter, and Vincent McDonald “Three-dimensional Gaussian Beam tracing for shallow-water Applications”, J. Acoust. Soc. Am., 110:2618, Pt. 2, 142nd Meeting, Acoust. Soc. of Am., Fort Lauderdale, FL, 3-7 December 3-7 2001.

Paul Hursky, Martin Siderius, Michael B. Porter, “Passive phase-conjugate signaling for autonomous systems in the ocean”, J. Acoust. Soc. Am., 111:2438, Pt. 2, 143rd Meeting, Acoust. Soc. of Am., Pittsburg, PA, FL, 3-7 June 2002.