WEST COST SHALLOW WATER UNDERSEA WARFARE TRAINING RANGE

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ABSTRACT

Undersea warfare (USW) was perceived as a large-area, deep-water operation in the past therefore Fleet USW training ranges were designed to meet these requirements. Currently the bigger threat is the likelihood of regional conflict throughout the world by aggressive nations in littoral waters. The U.S. Navy must stand ready to respond to these regional conflicts when national interests are threatened. Consequently, naval forces must train to operate in the littoral environments where such regional conflicts are likely to occur. The West Cost Shallow Water Undersea Warfare Training Range (WC SWUWTR) is being developed to provide this training.

KEY WORDS

Shallow Water Training, Digital Signal Processing, Acoustic Telemetry, SONET ATM, OC3

INTRODUCTION

The US Fleet has decided to develop and install Shallow Water Undersea Warfare Training Ranges (SWUWTR) on the East Coast and West Coast of the continental United States. Undersea-instrumented ranges provide a training climate of high accuracy localization of participants involved in naval operations. This high accuracy real-time operation can only be accomplished on a precision underwater range. Shallow water however limits sensor performance, weapons utilization, and tactical maneuvering. The SWUWTR provides the operational capability to allow USW training and assessment under these adverse conditions for air, surface and subsurface vehicles.

The primary WC SWUWTR mission will be to support Fleet USW readiness through training and tactical development of submarine, surface ship, and aircraft**.** USW includes both the traditional AntiSubmarine Warfare (ASW) as well as Mine Warfare (MIW). The WC SWUWTR will support the development of realistic combat exercises through platform vs. platform operations as well as weapon firings at mobile targets. The WC SWUWTR will also provide operators, units, and staffs with timely post-exercise analysis, evaluation, and feedback data as an input for training and to permit sensor performance evaluation, refinement of tactics and to focus requirements and acquisition efforts.

Organic Mine Counter Measures (MCM) is becoming an ever-increasing concern for Fleet units. Currently the Submarine Force provides little or no mine training for its deployers. A concept to provide real time mine avoidance training based on real-time measurements of the platform's non-acoustic signature; along with precision tracking and real-time mine trip feedback is feasible. This concept would allow unit level training for both ASW & MCM during one range visit by the unit, saving operational costs. The concept of multi-mission training would provide a better mission rehearsal scenario and improve readiness over current training opportunities. This concept builds on the current application of providing tracking and acoustic communications through bi-directional acoustic nodes multiplexed on an undersea fiber optic cable. The SONET ATM telemetry employed in the current designs of these arrays has a large unused bandwidth that can be utilized with the addition of magnetic, electric and pressure sensor data. Adding these non-acoustic sensors to the tracking and communication nodes and installing portable inert mine shapes next to the nodes will provide real-time measurements to emulate a threat mine on shore (in software) as well as the appropriate (in-water) stimulation to the platform's mine sonar. The immediate feedback would be via an acoustic transmission from the range to the platform.

In order to accomplish the requirements for the WC SWUWTR, telemetry is employed in several aspects of the program. Telemetry is used in the following areas: fiber optic SONET ATM, over Microwave Data Links (MDL) and in-water using an Underwater Acoustic Telemetry System (UATS). WC SWUWTR is planned and sponsored by the Navy's Tactical Training Ranges Office OPNAV 789. WC SWUWTR is a multi-phase program beginning in FY03 with a Request For Proposal (RFP) therefore this is a good opportunity for telemetry industry to become involved in the system development.

THE SWUWTR SYSTEM

The basic SWUWTR system consists of two main components an In-Water Subsystem (IWS) and a Shore Electronics Subsystem (SES). The IWS is made of underwater acoustic receivers, transmitters and electronics called nodes. Each node will contain a hydrophone providing an acoustic bandwidth of 50Hz - 40 kHz. The low end of the frequency band is desirable to monitor the activity of marine mammals on the range that are vocalizing. Each node has an acoustic transmitter integrated into the unit as well. There are low frequency transmitters (1.5-4 kHz) and high frequency transmitters (8-13 kHz) located in respective nodes. In additional to the acoustic sensors that have been clearly defined, the intent is to provide other sensors such as magnetic pressure, electric and seismic to aid in the MCM training. The hydrophones receive tracking signals, called pings, generated by electronics installed on each participant operating on WC SWUWTR. These cooperative ping signals are required to accurately position the underwater vehicle on the range as no passive tracking is performed. The vehicles tracked underwater are typically submarines, torpedoes or USW targets. Surface ships can also be tracked via this method although GPS based in-air tracking systems are more commonly used.

Analog data from the hydrophones is conditioned, digitized, formatted into ATM cells and telemetered to the SES over fiber optic cable on a SONET OC-3 carrier. Up to 64 nodes may be connected in series and multiplexed into one single mode optical data stream and interfaced to the SES. The SES receives the data, performs signal processing on the incoming pings and generates positional tracks for the underwater vehicles. Figure 1 provides a graphical depiction of the WC SWUWTR as currently planned. The IWS of WC SWUWTR will be located off the coast of San Clemente Island, California. The WC SWUWTR will be installed adjacent to the existing Southern California Offshore Range Expansion (SCORE). WC-SWUTR will utilize the infrastructure already established at SCORE both on San Clemente and North Island off of San Diego, California.

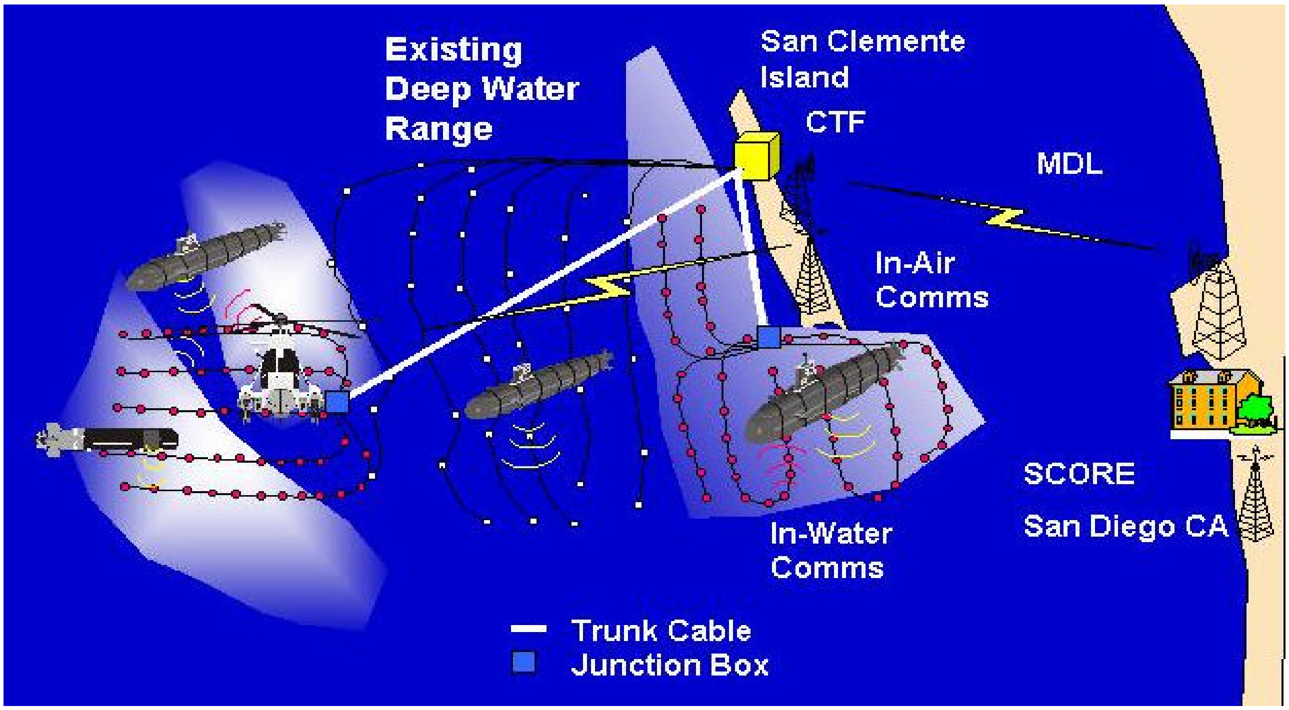

Figure 1 – WC SWUWTR System Configuration

FIBER OPTIC TELEMETRY

The in-water data transfer mode utilized is SONET ATM at an OC-3 rate of 155.5 MB/s. A collapsed ring is currently being used requiring two single mode fibers per string of nodes. Ultimately 12 sensors strings could be installed for WC SWUWTR by utilizing a 24-fiber trunk cable. Data from a total of 64 hydrophones can be multiplexed onto this collapsed ring. Each sensor is A/D converted at a rate of 104,375 Hz with 16 bits per sample. A single ATM cell contains 24 A/D samples. Along with the sensor data there are five ATM Header Bytes. The header includes a unique channel address for each sensor, a string identification number and a digital time stamp. The digital time stamp allows data from all sensors to be aligned on shore by the tracking processor. From the SES commands and data are sent to the in-water nodes. These commands include providing the digital time reference, system initialization, laser control, acoustic transmitter control sensor control and transmit data cells. The transmit data cells are similar to the receive format. The sample rate and word size are reduced to 75 KHz and 8 bits per sample due to the reduced bandwidth and dynamic range requirements. The transmit data cells can be either voice or digital data.

The WC SWUWTR program requires highly reliable fiber optic telemetry because the cost to repair in-water systems such as this is prohibitive and the lifetime goal of the system is 20 years. Each node has an electronic and optical network topology designed to maximize reliability. A functional block diagram for the nodes is shown in Figure 2. All signal conditioning, multiplexing and optical electronics are fully redundant with two complete sets per node. One of the two lasers is turned off to prevent signal conflict although both optical receivers function at all times. In addition to this redundancy an optical bypass path exists for the optical data stream. The bypass uses a series of couplers to feed optical data both to and around a node. At the output of each node the bypass signal is combined with the direct signal for relay to the next node. The optical network design maintains a minimum power separation of 6 dB between the optical signals by adjusting the ratio used in each coupler. Thus the lower level signal appears only as noise at the downstream receiver and is ignored until a laser failure occurs. In this passive manner the optical loop integrity can be maintained even with the loss of two consecutive sets of redundant telemetry electronics. The result is a highly reliable optical network.

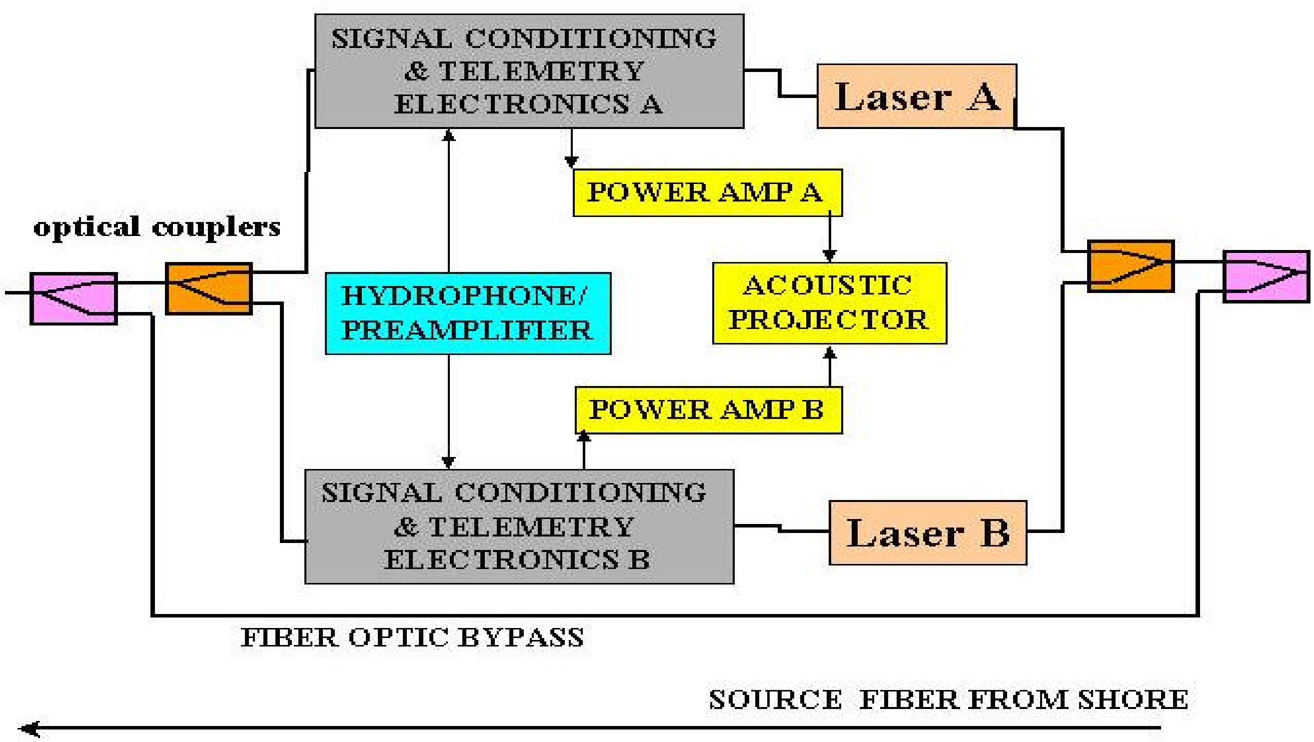

Figure 2 - In-water Electronics Functional Block Diagram

SHORE ELECTRONICS SUBSYSTEM

The SES has the capability to receive and to send signals and commands between the nodes and the Range Operation Center (ROC). On the receive side sensor signals are feed into the Digital Signal Processor (DSP) and on the transmit side commands and signals are sent to the nodes for the purpose of acoustic transmission or node control. The SES includes DC power supplies for powering the in-water string electronics. Each string uses a constant current power supply providing up to 2000 Watts. Supply voltage is adjusted based on the string length, the number of sensors and to augment the power amplifiers during acoustic transmission. The SES also contains an SONET/ATM electro-optic transceiver similar to the units located in the water. An optical amplifier is required on the transmit side of the optical network. The SES originates the optical data stream communicating from shore to the last node, typically more than 80 nmi away from the SES.

The DSP is the front end of shore systems developed by the Naval Undersea Warfare Center (NUWC). These systems consist of the interface to the SES, the Digital Signal Processor, tracking software function, underwater communication controller, data display and control functions. The hardware for these systems will be distributed at two primary sites interconnected by an Ethernet network. The network uses a microwave data link as its backbone. The first site is the ROC, which provides command, control and support at the Naval Facilities at Naval Air Station, North Island. The Cable Termination Facility (CTF) located on San Clemente Island is the second site.

Integrated with the WC SWUWTR is an in-air communications system originating at the ROC. The ROC utilizes communication towers located on San Clemente and at North Island to communicate with ships and helicopters on WC SWUWTR. The height of the tower, which is located on MT Thurst provides 100% Line of Sight coverage to all range participants.

UNDERWATER ACOUSTIC TELEMETRY SYSTEM

An Underwater Acoustic Telemetry System (UATS) is also planned as part of the WC SWUWTR. Preliminary work has been done with the UATS however the exact modulation method is not yet settled on. Basically a Quadrature Phase Shift Keyed (QPSK) or a Multiple Frequency Shift Keyed (MFSK) approach will be implemented. The initial use of the UATS will be to support the Virtual Torpedo Program (VTP). VTP simulates the launch and run of an MK48 ADCAP torpedo. The UATS provides wire commands to a submarine coupled with a Hardware-In-The-Loop simulator operating at NUWC in Newport, RI. The submarine launches a water slug, which is an empty torpedo tube then the UATS stimulates the submarines fire control system to simulate the run out of a torpedo. Below are the data needing to be transferred for VTP operation:

1. Message Header for each message sent to modem = 10 bytes
2. TELCOM for 2 weapons = 8 bytes/block x 4 blocks/sec x 2 secs x 2 weapons + 4 byte header = 132 bytes
3. Posits for 3 participants = 20 bytes/participant x 3 participants = 60 bytes
4. Event Message (worst case - freeform) 52 bytes/message = 52 bytes
5. Encryption Overhead (not usable for data) = 60-70 bytes
6. Minimal Growth and Error Correction = 10%

Grand Total = ~360 bytes

Data is acoustically transmitted on the downlink to the nodes from the submarine at a center frequency of 17 kHz and on the uplink from the node at a center frequency of 10.5 kHz. The telemetry signal bandwidth is approximately 5 KHz.

The use of UATS for other applications is also being pursued. These include simulation and stimulation, cueing of onboard sensor systems and data exchange for immediate and in-situ feedback on training performance while at the range. Less complex applications such as tele-text communication and data file transfer are also possible. Figure 3 is a graphical depiction of the UATS.

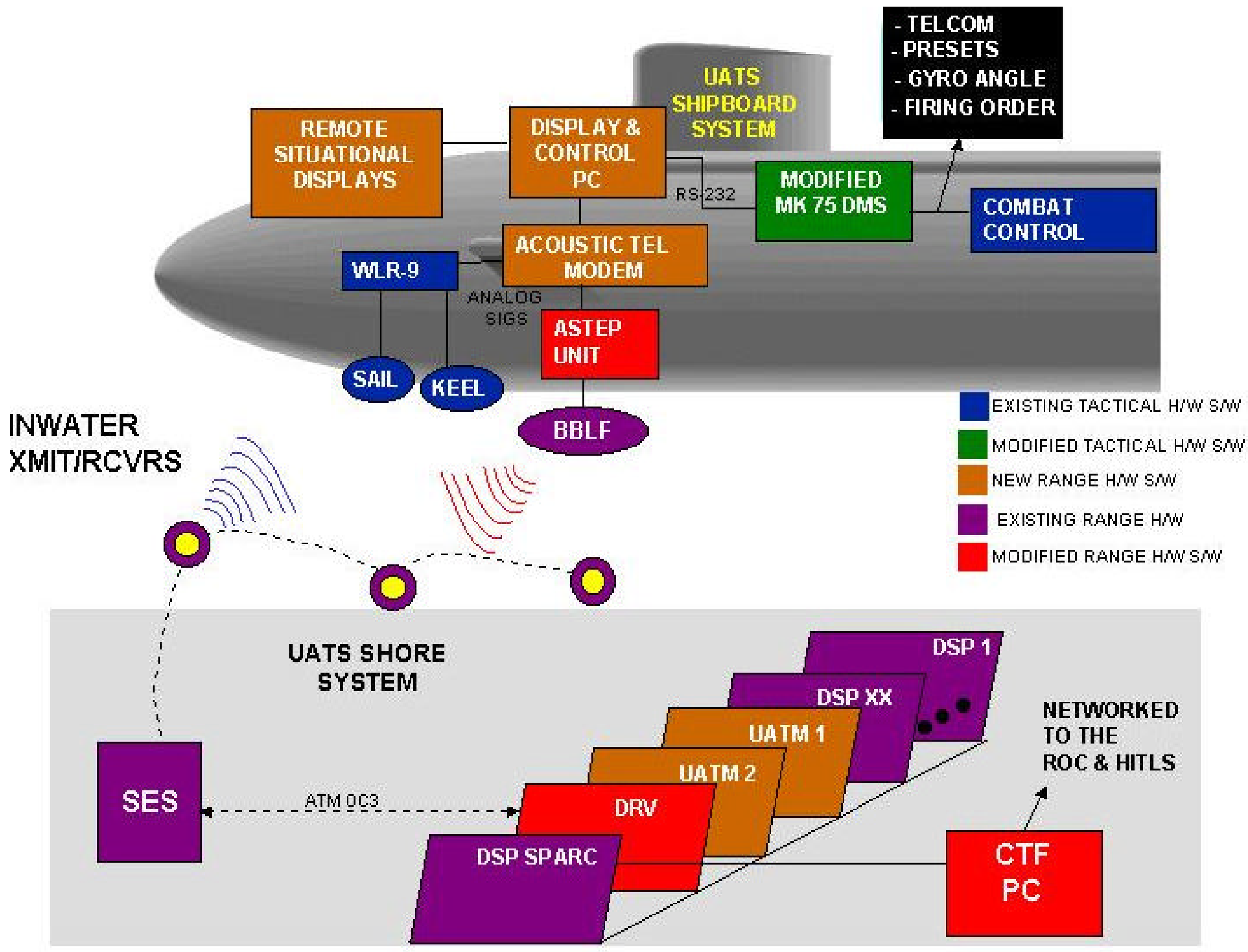

Figure 3 – Underwater Acoustic Telemetry System

MINE SENSORS

Planned improvements to WC SWUWTR are MIW sensors. These sensors include but are not limited to, magnetic, pressure, electric and seismic sensors. These sensors will be integrated into the nodes and provide the Fleet MIW training and readiness. In particular WC SWUWTR is focusing on the Organic MIW that individual platforms are responsible for. The MIW sensors will need to be sampled and interfaced to the SONET ATM data stream. The SES in turn would have to interpret these signals and provide a real-time indication to the range user of the situation. There will be mine sensing and detonation algorithms imbedded in the SES software. Because of the acoustic bi-directional functionality of the range there is the capability to provide an aural indication (pseudo explosion) to a ship or Unmanned Undersea Vehicle (UUV) crossing a mine detonation threshold.

CONCLUSION

There are several areas that need innovative solutions in order to accomplish the requirements of WC SWUWTR. Key technologies are underwater systems, SONET ATM, underwater acoustics, magnetic, pressure and electric sensors, DSP and several others. Several opportunities for industry exist to support these Fleet requirements since there are 4 phases of WC SWUWTR planned.

ACRONYMS

A/D	Analog to Digital
ADCAP	ADvanced CAPability
ASTEP	Advanced Synchronous Torpedo Equipment Portable
ASW	AntiSubmarine Warfare
ATM	Asynchronous Transfer Mode
BBLF	Broad Band Low Frequency
CTF	Cable Termination Facility
DC	Dirrect Current
DMS	Digital Missile Simulator
DRV	Digital Routing over the VME
DSP	Digital Signal Processor
IWS	In-Water Subsystem
KHZ	Kilohertz
MCM	Mine Counter Measures
MDL	Mircowave DataLink
MFSK	Multiple Frequency Shift Keyed
MIW	MIne Warfare
NUWC	Naval Undersea Warfare Center
OC-3	Optical Carrier
QPSK	Quadrature Phase Shift Keyed
RFP	Request For Proposal
ROC	Range Operations Center
SCORE	Southern California Offshore Expansion

SES	Shore Electronics Subsystem
SONET	Synchronous Optical NETwork
UATM	Underwater Acoustic Telemetry Modem
UATS	Underwater Acoustic Telemetry System
USW	UnderSea Warfare
VTP	Virtual Torpedo Program
WC SWUWTR	West Cost Shallow Water Undersea Warfare Training Range
WLR-9	Wideband Receiver