North Elba Sea Trial Summary

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Introduction

In October 1993 the SACLANT Centre conducted a sea trial in the Mediterranean Sea, the primary objective was to collect data on a vertical array in shallow water for verifying the performance of geoacoustic and geometric parameter estimation methods based on the inversion of acoustic field observations. The trial was conducted in an area where the geoacoustic properties were reasonably well known from previous SACLANT Centre experiments. In order to collect data that would be useful for verification of acoustic inversion methods every effort was made to collect well documented acoustic and environmental data. Analysis of the data to date indicates this objective was met.[1]

I. Experimental Setup

The experimental data were collected over a two day period on 26 and 27 October 1993 in a shallow water area North of the island of Elba, off the Italian west coast, where environmental conditions are known from earlier SACLANT Centre experiments.[2][3] [4] The area North of Elba is characterized by a flat bottom covered with clay and sand-clay sediments. The trial was conducted in a flat area between the 120 m and 140 m isobaths along a track running parallel to the isobaths. The propagation conditions were typical downward refracting summer conditions. The weather over the two day period was favorable, a sea state of 2 to 3, the wind on the 26th was variable between 12 and 20 knots and on the 27th it averaged about 7 knots.

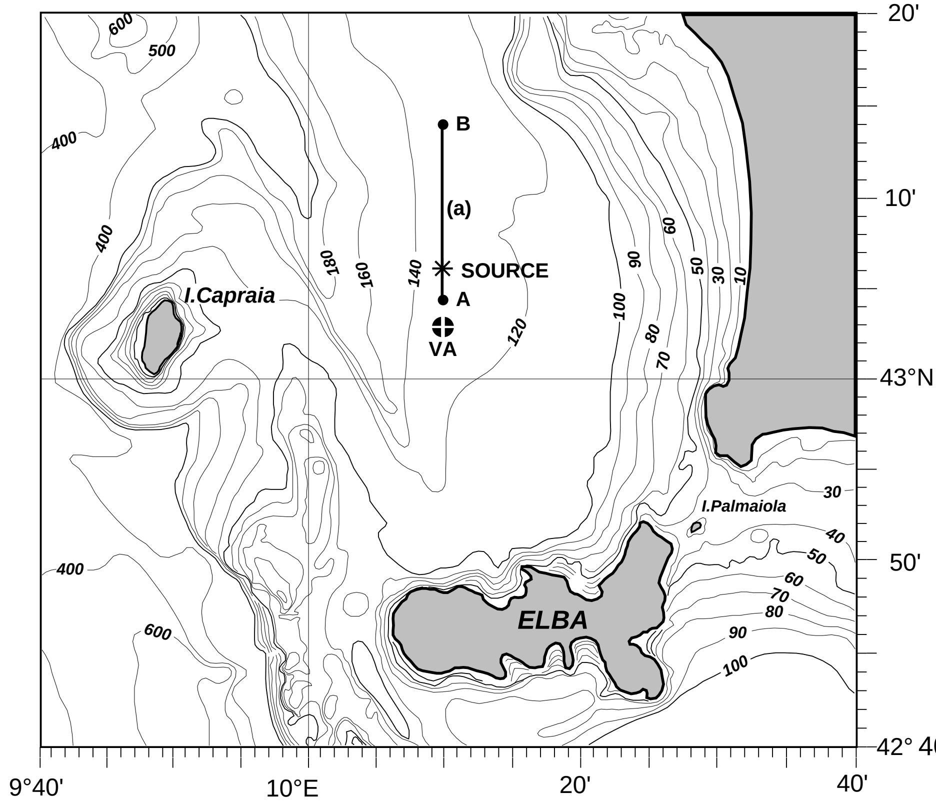

Figure 1: Bathymetry, equipment locations and ship track.

On the morning of the 26th the vertical array was deployed, array navigation transponders were deployed in an equilateral triangle surrounding the vertical array, and a stationary source buoy was deployed about 5.8 km North of the vertical array. On the afternoon of the 27th a support ship, the ITN Palmaria, provided a moving source along the track indicated by points A and B on Fig. 1. Figure 1 also indicates the relative locations for the vertical array and the source buoy along with the local bathymetry. All equipment remained in place until the evening of the 27th. Acoustic field data from the two sources, array navigation data and sound speed data were acquired over the two day period.

II. Vertical Array and Array Navigation

The vertical array was deployed at 43 02.86 N 10 10.01 E. Due to the limited accuracy of the GPS system on board the R/V Alliance the position of the vertical array is only known to within an accuracy of about 100 m. The water depth was measured to be

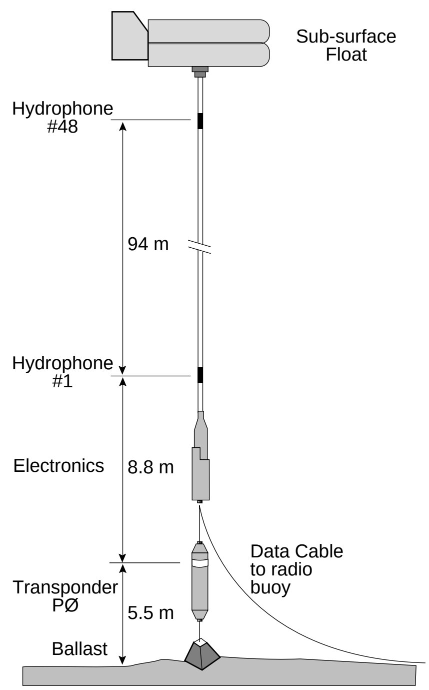

Figure 2: The SACLANT Centre vertical array as deployed in a bottom moored configuration.

approximately 127 m at the array site. The deployment configuration for the vertical array is shown in Fig. 2. The vertical array was deployed in a bottom moored configuration with ballast and a sub-surface low drag float. The multi-channel array hydrophone data was digitized in the array, transmitted via a cable to a surface radio buoy and then transmitted via an RF link to the real-time processing and archival storage system on board the R/V Alliance. The vertical array had a total aperture of 94 m, within the 94 m aperture there were a total of 80 hydrophones. The array contained three nested sub-apertures ranging from a spacing of 0.5 m to 2.0 m. The 2 m spacing option was selected for this data collection, which provided 48 hydrophones spanning the full 94 m aperture. Based on the physical configuration shown in Fig. 2 and the measured water depth of 127 m at the array site the bottom hydrophone, referred to as number one, was at a depth of 112.7 m. The hydrophone closest to the surface, referred to as number 48, was correspondingly at a depth of 18.7 m. These are nominal depths based on the above assumptions, the actual depths will be different due to array tilt, imprecise measurement of the water depth and ballast penetration into the sediment.

In order to determine the variation of the array hydrophone positions in the water column due to tilt induced by the current an acoustic array navigation system was deployed with the vertical array. The array navigation hardware consisted of four acoustic transponders and a shipboard interrogation unit. The R/V Alliance deployed the three transponders in the vicinity of the vertical array at a range of approximately 250 m. Each transponder was bottom moored with ballast and sub-surface floats to keep the transponders a few meters (5.5 m) away from the bottom. The fourth transponder was attached to the bottom of the vertical array.

The data acquisition for array navigation used a subset of eight hydrophones spaced at 12 m, the sample rate for the array navigation data was 48 kHz. The acquisition of acoustic data and array navigation data could not be carried out simultaneously. Thus, the acoustic data acquisition was interrupted for five minutes about once every hour for the acquisition of array navigation data. The time of arrival information obtained by analyzing the vertical array data (subset of eight hydrophones) from the four transponders was sufficient to localize the transponders with respect to each other and the array hydrophone positions in a local coordinate system. After deployment of the vertical array and the three transponders, a one time acquisition of transponder position data using both the shipboard GPS measurements and two-way travel time measurements between the shipboard transponder and the bottom moored transponders was conducted. This data was used to accurately estimate the positions of the transponders with respect to global coordinates. Knowing the GPS positions of the transponders allowed the positions of the array hydrophones to be presented in terms of global coordinates. A detailed description of the array navigation system and methods is available in Ref.[5].

Figure 3 illustrates estimates of the array shape on the 26th at four time samples; 1040, 1400, 1517 and 1650 as estimated by the array navigation system. It can be seen

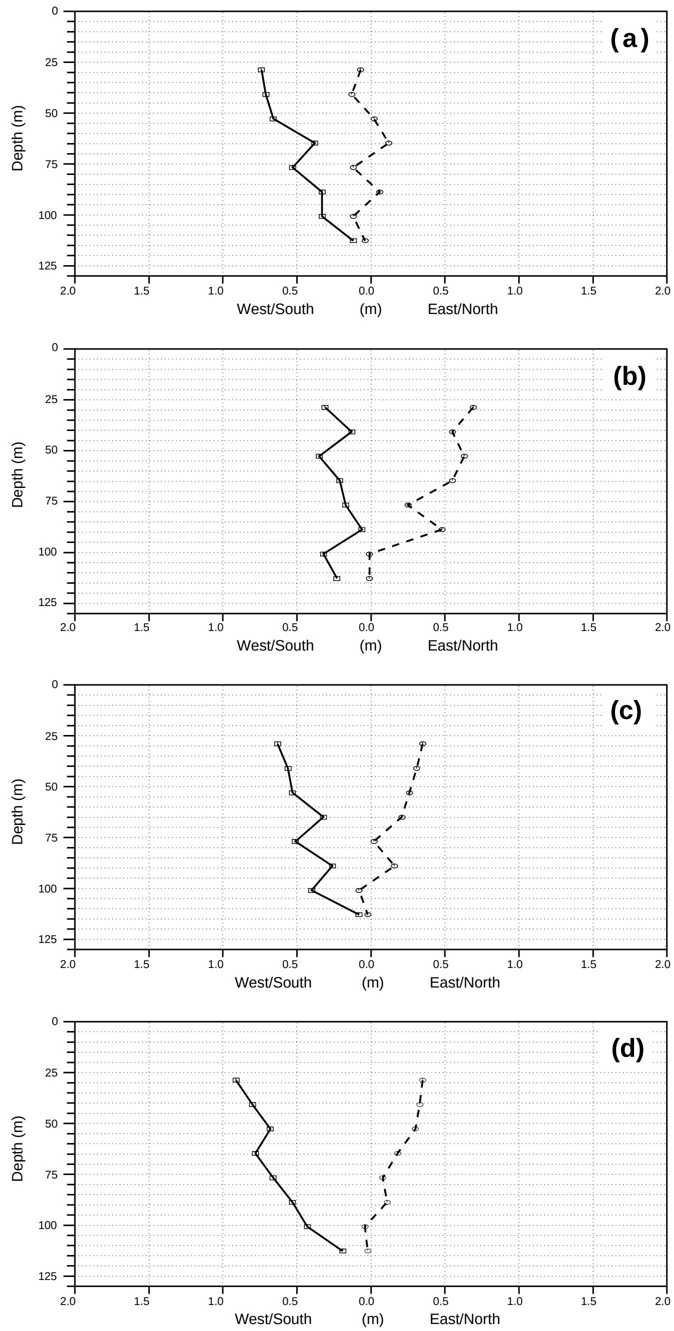

Figure 3: Navigated estimates for array shape on 26 October 1993 at times: (a) 1040, (b) 1400, (c) 1517 and (d) 1650, solid curve is East/West and dashed is North/South component.

from this figure that for the first three time samples the maximum deflection from vertical is on the order of 0.75 m and it occurs at the top hydrophone. For the fourth time sample the maximum is somewhat greater, i.e., 0.98 m, again at the top hydrophone. Figure 4 illustrates estimates of the array shape on the 27th at four time samples; 0930, 1038, 1216 and 1349. On this day the average maximum deflection from vertical was on the order of 0.4 m, the location of the maximum deflection can be seen to be distributed throughout the mid portion of the array.

III. Source and Signal Characteristics

The stationary source, referred to as the RECMAS buoy, was deployed at approximately 5.8 km due North of the vertical array site, see Fig. 5 for the deployment configuration. The ballast was deployed at 43 06.01 N 10 09.91 E. As shown on Fig. 5 the surface buoy was tethered to a ballast on the bottom, the length of the tether cable was such that the position of the source was only known to be within a 200 m circle around the ballast point. Depending on the direction of the wind the buoy could be 200 m closer or further from the vertical array position. At the source location the water depth was measured to be 130 m. The RECMAS buoy contained a HX-90G source, the transmitting sensitivity spectrum is provided as Fig. 6. Two signals were transmitted by the RECMAS buoy, not simultaneously. The first signal, referred to as RM5, was a continuous transmission of pseudorandom noise produced using a Maximal Length Sequence (MLS) based on a six bit shift register and bit length of 52.9 msec modulated onto a carrier with center frequency of 170 Hz. The repetition length for this sequence was 3.15 sec, the -3 dB bandwidth was approximately 12 Hz, and the source level was approximately 163 dB re 1 $\mu\mathrm{Pa}/\sqrt{\mathrm{Hz}}$. The second signal, referred to as RM2, was also a continuous six bit MLS but with bit length of 20 msec modulated to a center frequency of 335 Hz. The repetition length for this sequence was 1.3 sec, the -3 dB bandwidth was approximately 30 Hz, and the source level was approximately 164 dB re 1 $\mu\mathrm{Pa}/\sqrt{\mathrm{Hz}}$. For further information on MLS see, for example, Ref. [6]. The HX-90 source was lowered to depth of 79 m below the surface for

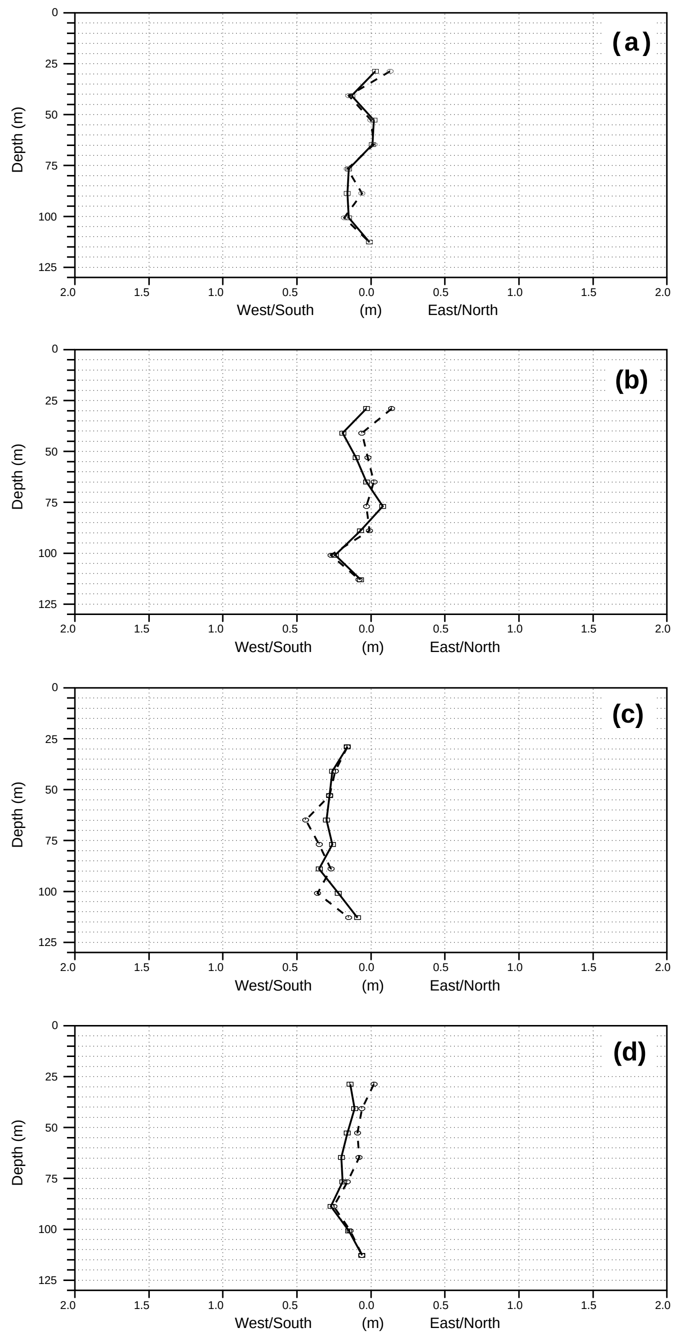

Figure 4: Navigated estimates for array shape on 27 October 1993 at times: (a) 0930, (b) 1038, (c) 1216 and (d) 1349, solid curve is East/West and dashed is North/South component.

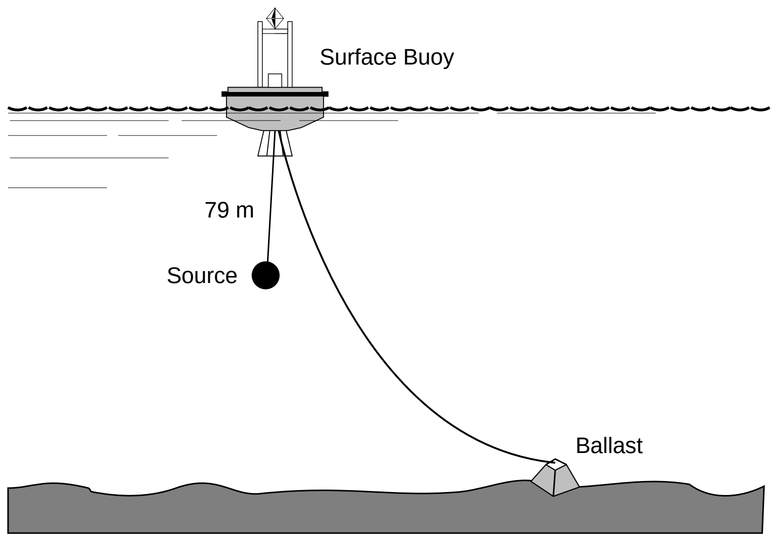

Figure 5: The RECMAS source buoy as deployed in a bottom moored configuration

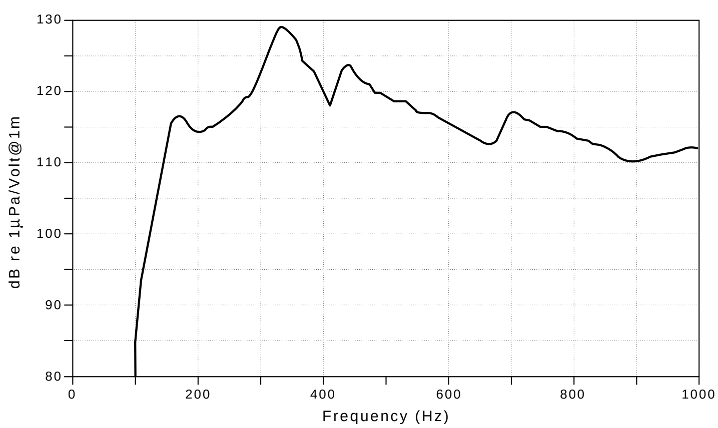

Figure 6: RECMAS buoy HX-90G transmitting sensitivity as a function of frequency.

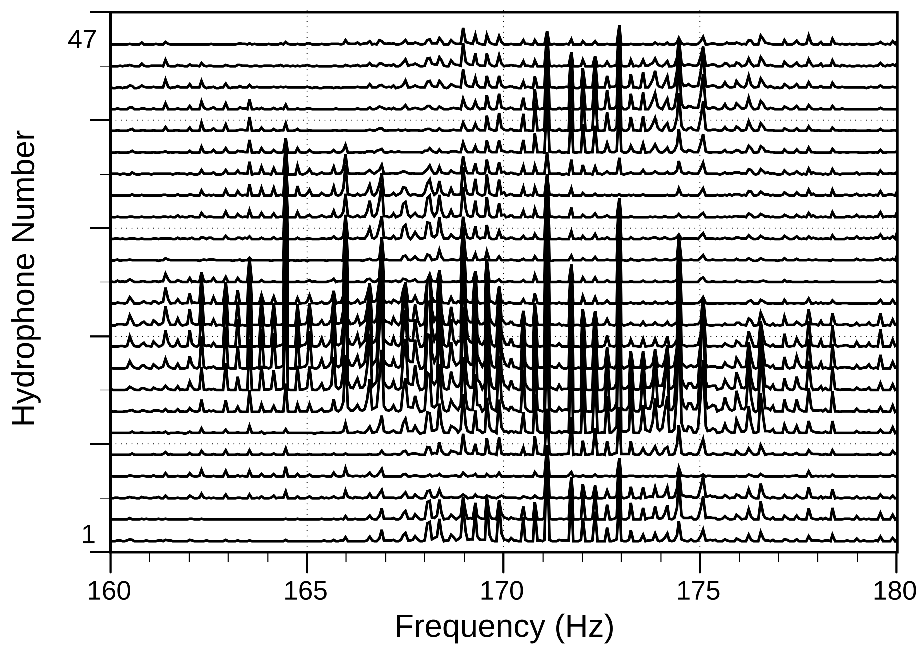

Figure 7: Spectrum for signal RM5 as received on the vertical array at 1549 26 October 1994.

transmission.

IV. Data Acquisition and Archival

The acoustic data acquisition system acquired the output of 48 hydrophones sampled at 6 kHz. During the archival process the data was filtered using a 255 coefficient FIR lowpass filter. The cutoff frequency was 420 Hz and the transition band was 60 Hz, thus at 480 Hz the filter response was 60 dB below the inband response. The output of the filter was decimated in time by a factor of six, yielding an output sample rate of 1 kHz per channel. The 48 channels of time series data were archived onto optical disks in files containing five minute blocks of data. The header of each file contained the time of acquisition and the parameters used in the data acquisition process.

Figure 7 illustrates an example of the RM5 signal in the frequency domain, for the band 160 to 180 Hz, as a function of hydrophone number (odd numbered hydrophones only) for a 16 sec snapshot taken at 1549 on 26 October 1993. Note the discrete 'pickets' in frequency which are characteristic of the spectrum of MLS signals. Figure 8 illustrates

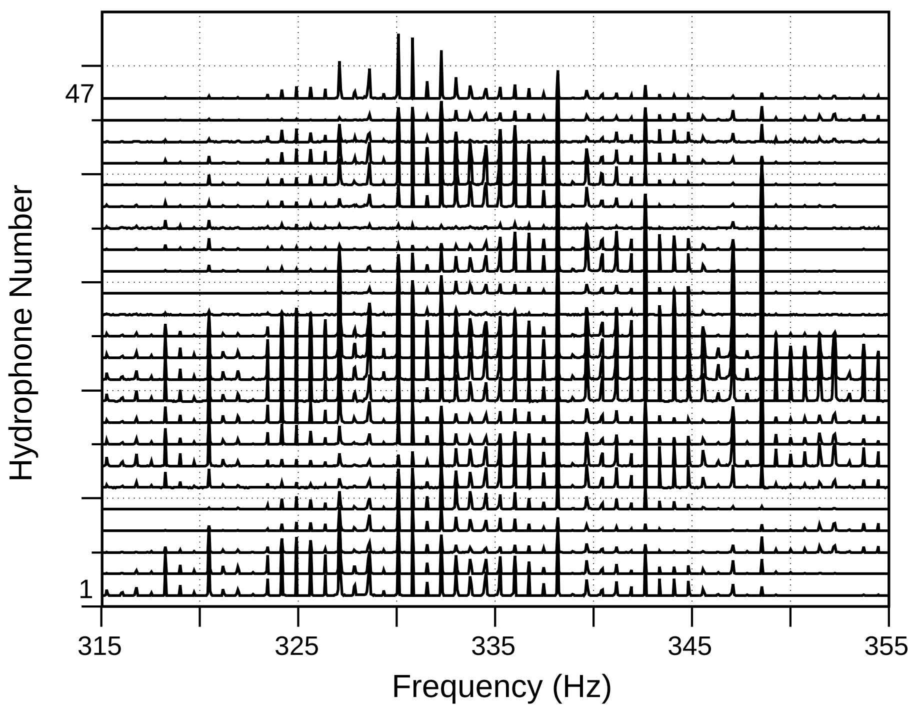

Figure 8: Spectrum for signal RM2 as received on the vertical array at 1453 26 October 1994.

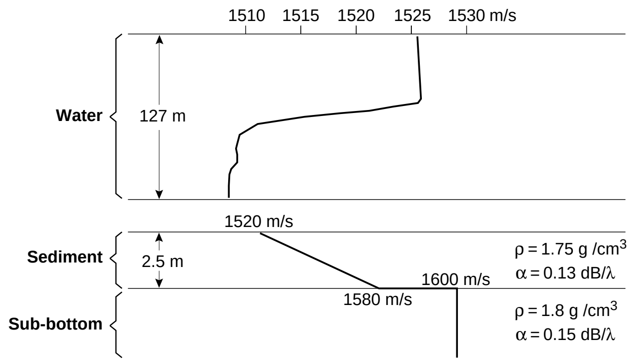

Figure 9: Measured sound speed profile and historical geoacoustic parameters for the North Elba experiment site, geoacoustic parameters are from Ref. [3]

an example of the RM2 signal in the frequency domain, for the band 315 to 355 Hz, as a function of hydrophone number (odd numbered hydrophones only) for a 16 sec snapshot taken at 1453 on 26 October 1993.

On the 27th of October, starting at 1400, a support ship towed a HX-90G source on the track from point A to B as shown on Fig 1. The signal and source characteristics were quite similar to those of the RECMAS buoy except that the signals were not continuous, they were on for 30 out of every 60 sec.

V. Environmental Conditions

The measured water sound speed profile and average geoacoustic parameters are illustrated on Fig. 9. As seen on Fig. 9 the water sound speed profile was a summer profile, almost isovelocity down to 60 m and then a strong thermocline extending to about 80 m. This CTD was taken at 43 02.65 N 10 09.63 E at 1012 on 26 October 1993. The three layer environmental model with sediment and bottom parameters was derived from Fig. 4 of Ref. [4]. Note that the sediment and bottom parameters are average parameters determined by matching predicted transmission loss with measured transmission loss in the North Elba basin, but not at the exact site of the October 93 trial.

The above baseline environmental model, Fig. 9, can be used with the SACLANTCEN Normal-Mode Acoustic Propagation Model (SNAP) [7] as a 'starting point' for propagation prediction comparisons with the real data collected at the North Elba site. Some perturbation of this baseline environmental model will be required to adjust the water, sediment and bottom parameters for the exact site and frequency used in this data collection.

References

[1] D. F. Gingras and P. Gerstoft, "Global inversion of acoustic field data in shallow water using genetic algorithms" in *Full Field Inversion Methods in Ocean and Seismic Acoustics*, O. Diachok *et al.,* Kluwer Academic Publishers, 1994, pp.xxx-xxx.

[2] T. Akal, "Bathymetry and bottom structure of zones near the island of Elba used for acoustical trials in shallow water," TM No. 162, SACLANT ASW Research Centre, La Spezia, Italy, 1970.

[3] T. Akal, C. Gehin, B. Matteucci, and B. Tonarelli "Measured and computed physical properties of sediment cores, Island of Elba zone," SR M-82, SACLANT ASW Research Centre, La Spezia, Italy, 1972.

[4] F. B. Jensen, "Comparsion of transmission loss data for different shallow water areas with theoretical results provided by a three-fluid normal-mode propagation model," in *Sound Propagation in Shallow Water*, edited by O.F. Hastrup and O. V. Olesen, Rep. CP-14, SACLANT Undersea Research Centre, La Spezia Italy, 1974.

[5] D. F. Gingras, L. Troiano, and R. B. Williams, "Acoustic array navigation in shallow water," submitted to IEEE J. Oceanic Eng.

[6] S. W. Golomb, *Shift Register Sequences*, Holden-Day, San Francisco, CA, 1967.

[7] F. B. Jensen and M. C. Ferla, (1979) SNAP-The SACLANTCEN normal mode propagation model, SACLANT Undersea Research Centre, SM-121, La Spezia, Italy.