AN INFRASTRUCTURE FOR ACOUSTIC DATA GATHERING

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1. INTRODUCTION

Although extensive characterisation of the underwater acoustic environment has been undertaken, permitting the exploration of concepts through simulation, it remains necessary to undertake in-water experiments. These experiments act either as a complement to simulation, or as a form of Quality Assurance, or to refine environmental models. In addition they provide firm in-water experimental results where an unequivocal benchmark is required or simulation would be inappropriate.

A capability developed by the Defence Research Agency, Maritime Division, Portland, UK for the acquisition, processing and recording of weapon frequency acoustic data is presented in this paper.

A description of all aspects of an acoustic data gathering system deployment from a trials vessel is given, with particular emphasis on those system components affecting angular accuracy. In particular:

a) The azimuth actuation system and its associated control loop
b) The magnetic and inertial azimuth sensors and the attitude estimator which processes their measurements
c) The Global Positioning System which is used to provide true bearings for sensor alignment

The integration of these components to form a system, suited to the task of pointing an acoustic payload, is then described. Attention is paid both to the functions and characteristics of individual components, and to their symbiotic interaction.

2. THE ACOUSTIC DATA GATHERING FACILITY

Deployment of the Defence Research Agency, Maritime Division Acoustic Data Gathering Facility (ADGF) from a craft of opportunity is depicted, in figure 1. The consort assists with azimuth alignment.

2.1 Array Pointing Equipment (APE), figure 2

The electro-mechanical infrastructure to which instrumentation and payloads are attached is termed the APE. The strain cable, carries power, control, instrumentation, and payload signals. Cables of 250 and 900 feet are available, containing 19 quads and 18 interstitial cores.

The diamond frame, an octagonal fabrication, is suspended from the training head, and can rotate through 360°. System and user instrumentation is attached to three locations. One on the centre line, and two on the flanks.

The training head provides eight power and 52 signal slip ring connections between the strain cable and diamond frame, an AC servomotor [1] for slewing and a two axis fluxgate compass which is transmitted in synchro format. Torque reaction is provided by fins attached on arms to the training head, and by the strain cable.

2.2 Attitude Instrumentation, Figure 3

To provide attitude data of the accuracy, << 1°, essential for the full analysis of acoustic data, the fluxgate compass has been augmented with a horizontal axis displacement gyro, and three pairs of orthogonal accelerometers and rate gyros.

The accelerometer and rate gyro outputs are digitised within the Attitude Sensor Unit (ASU) housing where the underwater telemetry package and most non-acoustic sensors are located. Sixteen channels of 100Hz, 16bit, DC-10Hz telemetry are provided. The horizontal axis gyro is mounted in a second ASU housing mounted on the opposite flank of the diamond frame.

Only four slip ring passes and one strain cable quad are required for dedicated use by the ASU and gyro. The BBC AES/EBU ASIC [2] is used to provide up and down links at 512 kb/s.

All attitude data is processed, at the surface, by a Kalman filter to provide attitude estimates. A selection of measurements and estimates can be recorded for post processing, or as a complement to acoustic records.

Control of the APE is exercised, by a Digital Signal Processor (DSP), through the Training Control Unit. Heuristic control algorithms are currently used, the complex dynamics of the APE make the development of optimal algorithms challenging.

2.3 Acoustic Arrays

The DRA has several acoustic arrays, providing a wide range of capabilities, suitable for deployment on the APE. Customers arrays can also be deployed on the APE. Typical arrays provide both fans of beams and split beam pairs. An ultra short baseline array for panoramic reception of acoustic tracking pulses is usually fitted below the diamond frame to assist with target capture, see figure 2.

2.4 Supporting Instrumentation, see figure 1

Consistent alignment of the APE, with true north, is a demanding yet essential requirement. The horizontal axis gyro provides a medium term reference, a drift rate of ~1°/hr being typical. To estimate both gyro bias and drift, the difference between true geographic bearing and (gyro) relative acoustic bearing must be computed at regular intervals.

A consort fitted with a synchronised acoustic transmitter (SAT), and acoustic beacons, provides a contact to which (gyro) relative acoustic bearings can be taken. The most practical approach to determining the geographic bearing between strain cable and consort, is to difference the outputs of differential GPS receivers. Using UHF telemetry the consorts position is available on the trials ship with latency of a few seconds.

The GPS base station enables positional accuracies of 2-8 m at 95% confidence level to be obtained, through the use of Differential GPS techniques [3]. This is particularly important if Selective Availability is on, and GPS data is to be used for geographic positions, as uncorrected GPS positions would wander, over periods of minutes, by ±100 m.

2.5 Recording and Processing Facilities, figure 4

To provide trials recordings of the highest standard, a recording system, the Stream Interface (SIF), capable of recording and reproducing multiple asynchronous streams on an Ampex DCRSi recorder is used. The SIF can both digitise analog data, and accept direct digital inputs. SIF throughput is limited by the DCRSi to <107 Mb/s, the maximum throughput is strongly dependent on packet length.

Typically 4 to 16 channels of analog signals and digital data from two or more DSPs are recorded. The digital data typically includes non-acoustic data and digitised voice tracks. Reproduction, in real time of newly recorded data for quality checks by DSP and the experimenter is provided. Subsequently, data can be replayed to the DSPs at any speed up to the maximum throughput of the DCRSi, or DSP.

Acoustic data is processed by Digital Signal Processors, typically Motorola 56001 DSPs are used, either singly or in pairs [4]. Several processing chains are normally used to implement multiple detection algorithms, possibly operating on different beam sets or frequencies.

The output of the DSPs is monitored, both aurally and on video displays to provide the acoustics operator with a "picture" of the acoustic situation. Positional data derived from both tracking ranges and GPS can be used to complement the acoustic information. As both acoustic and geographic data are available in the Micro VAX, real time computation of bearing error is feasible. Such information, and the raw data underpinning it, is of course recorded, on the Micro VAX, for post analysis.

3. INTEGRATION OF THE AZIMUTH POINTING CAPABILITY

The DSP which performs both the attitude estimation task and the azimuth control function, figure 3, is interfaced to both the attitude instrumentation and the azimuth controller. A schematic of the dataflows involved in attitude estimation and azimuth control is given in Figure 5. The control function can also be performed by the Micro VAX if, for example, a sequence of bearings or third party information is to be followed.

3.1 Magnetic Azimuth Sensors.

While the fluxgate and magnetometer provide plausible bearings in most circumstances. They are subject to several sources of error. Particularly:

a) Displacement from the horizontal, and deviation due to the magnetic influence of the ship, which is not generally invariant with ships heading.

b) Changes in the ships magnetic influence, due to changes in machinery operating states or array depth.

Consequently, magnetic sensors are of marginal use where a stable and accurate azimuthal reference is required.

Although, the fluxgate compass gives false readings whenever it is out of the horizontal plane. Improved azimuth estimates can be computed by mixing the fluxgate bearing with rate gyro measurements in a Kalman filter. This provides a good palliative for fluxgate fluctuations due to short term changes in the vertical, but as the fluxgate is the long term sensor the azimuth estimates will be consistent only for the time-constant implied, in the Kalman Filter, for the fluxgate measurements.

3.2 Horizontal Axis Gyro

The horizontal axis gyro provides a stable, albeit slowly drifting, azimuth reference with unknown bias, drift and random walk terms. To provide a link to an external frame of reference, calibration of the horizontal axis gyro is necessary. This can be performed in the fashion of figure 5, by comparing GPS derived and acoustic bearings.

Error sources for this calibration process include :

a) Acoustic errors due to, for example, indirect paths. By taking all measurements within a small arc of normal, to the array, these errors can be eliminated.

b) Parallax between the acoustic array, or noise source and GPS antennae which can occur due to cables streaming in a tide.

3.3 Azimuth Control

With low bias and low variance azimuth estimates a stable azimuth control loop can be implemented. A previous control loop using a 1950's AC servo-mechanism, with fluxgate and tacho-generator outputs for proportional and rate feedback was frequently quite unstable.

The azimuth actuator is instrumented for control winding voltage (albeit torque is dependent on motor speed), motor speed (from the tacho-generator), and azimuth actuator displacement.

As the upper body fins, and the strain cable, provide the torque reaction for slewing the upper body will relax when the actuator torque is removed, resulting in overshoot if a control algorithm which ignores this effect is used.

Changes in ships heading are a disturbance to the azimuth control loop. It has been observed experimentally, that in the absence of control, azimuth tracks ships head. Pitch and roll motions, often coupled as a vertical motion, can also cause disturbances due to the array "flopping". Tidal action can also be a significant source of disturbance.

The algorithm in current use is heuristic, rather than optimal.

4. CONCLUSIONS

The Defence Research Agency, Maritime Division, Acoustic Data Gathering Facility (ADGF) is an extremely capable, world class facility to which this brief review is only an introduction.

The attitude instrumentation and estimators used with the ADGF provide instantaneous attitude estimates in 3-D, sequences of azimuth estimates consistent over tens of minutes, and the ability to reference azimuth to true north.

The azimuth pointing capability of the ADGF is commensurate with this extremely difficult task. The importance, for minimising second order effects, of a stable instrumentation platform is well known. Small azimuth instabilities invariably cause degradation of experimental measurements, which can be so severe as to render the data worthless.

While the ADGF is primarily employed in support of work by DRA for the UK MOD, it is also used by other customers, either on a dedicated basis, or as part of a composite program of trials.

5. REFERENCES

[1] A R Upson & J H Batchelor, 'Synchro Engineering Handbook', Hutchinson, 1966
[2] 'AESIC : AES/EBU Interface Transceiver' data sheet, BBC, EDI10594, 1990
[3] P K Enge, R M Kalafus & M F Ruane, 'Differential Operation of the Global Positioning System', IEEE Comms Mag, 26 p48 (1988)
[4] M J D Bishop, 'On Experience of Integrating Motorola 56001 Processors with Micro VAXes', Proc IOA, 11 pt8 p1 (1989)

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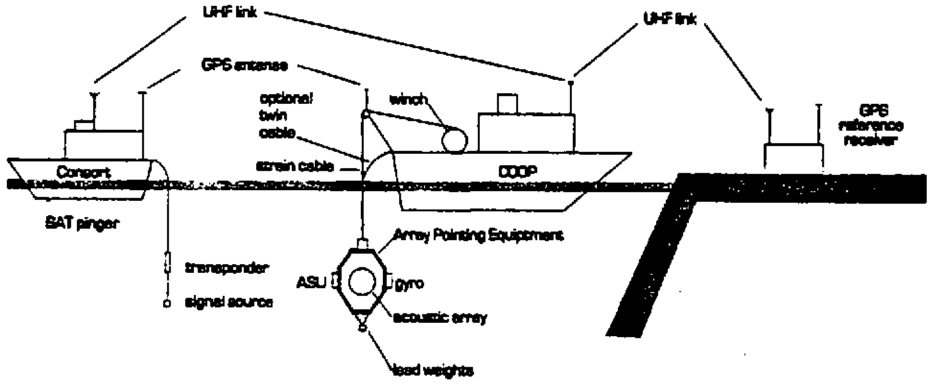

Figure 1 Deployment of the Acoustic Data Gathering Facility

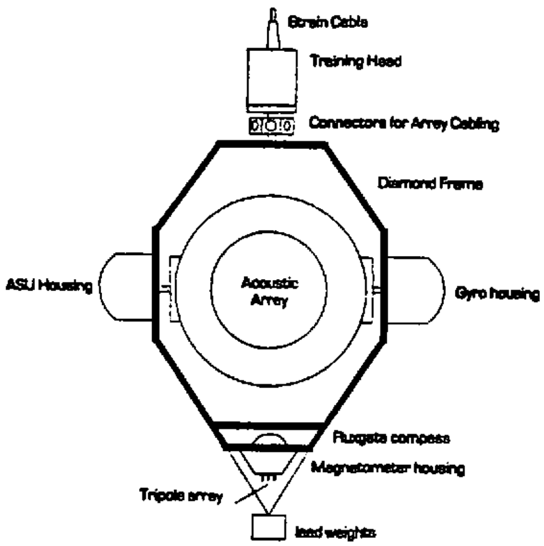

Figure 2 Array Pointing equiptment

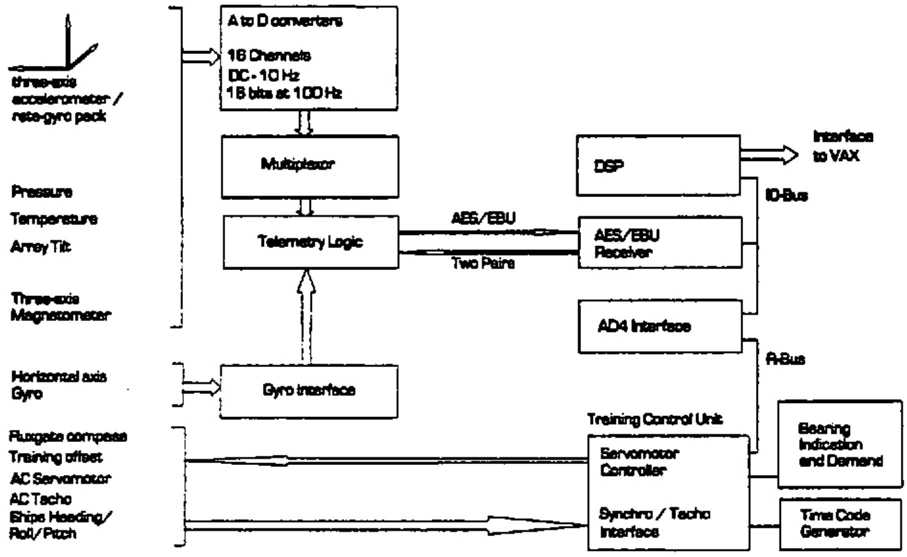

Figure 3 Attitude Instrumentation and Azimuth Control

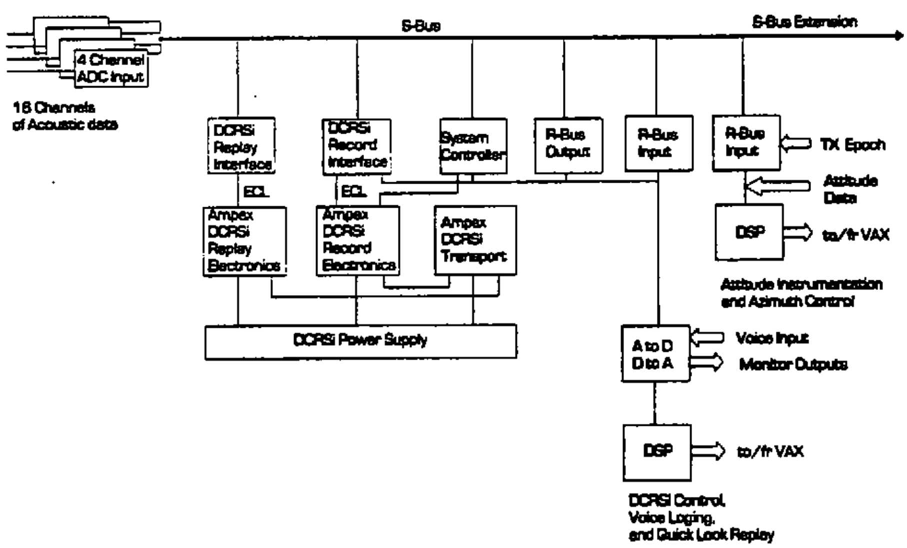

Figure 4 Recording and Processing Facilities

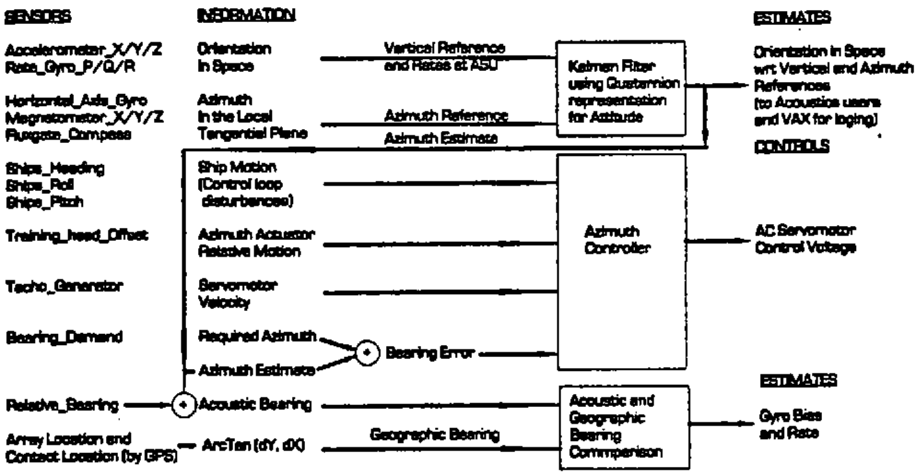

Figure 5 Dataflows for Attitude Estimation, Azimuth Control and Acoustic Experiments