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ISAACS - AN INSTRUMENTED SEMI-AUTOMATIC ACOUSTIC CALIBRATION SYSTEM AND ATTACHMENTS THERETO

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1. INTRODUCTION

Named after perhaps the world's most famous physicist, the ISAAC system is what its contrived acronym suggests - a computer based acoustic calibration system. It has emerged from the need to simplify man's task in routine calibrations, together with the now commonplace ability to communicate easily between computers and measuring instruments.

The author was first involved in "computerising" calibrations in 1975, when a simple system for plotting polar diagrams was concocted jointly with staff of the Admiralty Marine Technology Establishment, Teddington, to assist in the calibration of noise measuring hydrophones. This system was extended on an ad hoc basis over the next several years, until in 1981 it was decided to rebuild it using more modern equipment and in a fully integrated design. Since producing the first system for ARE (Teddington) in 1982, dB Instrumentation Ltd have produced a further version for ARE (Teddington) and another system for ARE (Portland). The second "Teddington" system was for a different department, concerned with sonar calibration, and this system is currently based at DBE's Aldershot tank facility. The third system is based at ARE (Bincleaves) and has an advanced capability for measurements on high frequency, high resolution arrays.

2. SYSTEM CONCEPTS

2.1 General Aims

The calibration of broadband hydrophones presents a problem in that it is not easily possible to use the same method over all the frequency spectrum. A fundamental aim of the ISAAC system then, was to use a computer to assist in the integration of a number of different types of measurement. In order to do this, the computer had to carry out the three primary functions of:-

(i) reading data from a variety of instruments,

(ii) calculating the results of those measurements performed,

(iii) producing report-ready, integrated, calibration charts and tables.

It was also a general aim to make the system self-calibrating, as far as possible, with the computer being able to monitor and correct for the frequency response of instruments, and particularly the reference standards employed. Finally, the computer was to assist in setting-up the various configurations, and a "menu-based" software system was devised to achieve this.

2.2 Measurement Capabilities

The system was designed to accommodate most of the commonly used measurement techniques for reciprocal transducers, and in addition, a few special techniques for hydrophones.

The principal technique employed is the pulsed gating method which is usually used for sensitivity and polar plots in small or unlined tanks, over the frequency range 1 to 100kHz (Ref. 1). Later systems have the capability to extend this range up to 3MHz.

Another method used for sensitivities and "coarse" polar information employs continuous wave, noise transmissions (in an anechoic tank) to cover a wide band of frequencies in one measurement. This can provide a rapid assessment of polar response, by taking successive spectra, at say 90° intervals.

In addition to the above, the system has the capability of the following types of measurements:-

(i) hydrophone sensitivity from 10Hz to 2kHz using an air-water pistonphone.

(ii) hydrophone sensitivity from 0.1Hz to 10Hz using a dunking machine.

(iii) admittance loops from 1kHz to 100kHz.

2.3 Hardware Description

A block schematic diagram of the ISAAC system is shown in Figure 1. The equipment is mounted in two standard 19 in. racks standing 1.8 metres high. At the heart of the system is a Hewlett Packard 85 Computer which is used for system control, data evaluation and output of results. It is connected via the IEEE 488 bus to three measuring instruments, a spectrum analyser, a precision digital voltmeter and an analogue measuring amplifier.

The computer also acts as a controller serving two instruments, the frequency synthesiser for frequency and amplitude control, and a stepper motor drive system for polar plots and dunking calibrations. The remaining items on the IEEE 488 bus, the dual floppy disc drive, and the plotter, are concerned with data handling and plotting of results.

The remainder of the equipment shown performs the intermediate tasks of signal conditioning, pre and power amplification and monitoring with the exception of the white noise generator. This generator is a prime signal source but under manual control only. However, this is not a major disadvantage since its settings are rarely altered.

3. PRINCIPLES OF OPERATION

3.1 Substitution Calibration

This is the most frequently used method for determining the sensitivities of both transmitting and receiving devices. In practice, the pulse gating technique is often employed (in small or unlined tanks) in which valid measurements are taken in the short period of time before the arrival of disrupting echoes. Measurements are usually made using a gated peak detector, or a sampling DVM.

An illustration of the technique is shown in Figure 2, where the device to be calibrated (designated x) is a reciprocal one. To determine its transmit sensitivity, measurements in part (i) are made, from which

$$S_x = -M_{ref} + K_2 \tag{1}$$

$$\text{where } K_2 = 20 \log \left(\frac{Vout}{Vin}\right) + 20 \log d \tag{2}$$

where S_x, M_{ref} and K_2 are expressed in dB.

Similarly, the receiving sensitivity can be found by performing the measurements of part (ii), whence

$$M_x = M_{ref} + K_1 \tag{3}$$

$$\text{where } K_1 = 20 \log \left(\frac{Vx}{Vref}\right) \tag{4}$$

3.2 Reciprocity Calibration

The above substitution calibration of a reciprocal device can be converted into an absolute reciprocity calibration by the very simple expedient of measuring the admittance of the unknown.

The normal reciprocity equation (Reference 2) gives

$$m = \left[\frac{e_{hp}\, e_{ht}}{e_{tp} . i_t} . J\right]^{\frac{1}{2}} \tag{5}$$

$$\text{where } J = \frac{2d}{\rho f} \tag{6}$$

$$\text{However, since } i_t = V_{in}\ (G^2 + B^2)^{\frac{1}{2}} \tag{7}$$

it may be shown that

$$M_{ref}\ (\text{dBV/Pa}) = (K_2 - K_1 + K_3)/2 \tag{8}$$

where $\quad K_3 = -20 \log (f) - 10 \log (G^2 + B^2) + 6$

with f in kHz and G, B in µmho.

Similarly

$$M_x = (K_1 + K_2 + K_3)/2 \tag{9}$$

$$\text{and} \quad S_x = (K_1 + K_2 - K_3)/2 \tag{10}$$

Also, the sensitivities of the reciprocal device are related by:-

$$S_x = M_x + 20 \log f + 10 \log (G^2 + B^2) + 234 \tag{11}$$

(µPa/V) (V/µpa) (kHz) (µmho)

3.3 Dunking Machine

This is a well-known method of obtaining absolute calibration of hydrophones at very low frequencies (Reference 3). In the ISAAC system, a dunking machine has been incorporated into the polar plotting turntable mechanism, both being driven from stepper motors controlled by the computer as shown in Figure 3. In the dunking mode, the hydrophone is oscillated vertically in the water at frequencies between 0.1 and 10Hz, through an r.m.s. height change of x. It can be shown that the hydrophone sensitivity M_x is given by:-

$$M_x = 20 \log\left(\frac{e_x}{x\rho g}\right) \tag{12}$$

3.4 Air-Water Pistonphone

A standard form of air-water pistonphone is given in Reference 4. It can be shown that the pressure inside the chamber is given by

$$p = \frac{x}{Cm}$$

where x is the volume displacement,
and Cm is total combined compliance of the chamber and its contents. In the pistonphone used with the ISAAC system, shown in Figure 4, the driver used is a wideband, moving coil device. The need to measure Cm and x is obviated by installing a 13mm condensor microphone to measure the pressure directly. Such a microphone can be calibrated as a secondary reference standard with a high degree of confidence and full traceability.

Thus, calibrations reduce to exactly the same form as the normal substitution techniques used at higher frequencies in the tank.

4. Conclusion

The ease with which desk-top computers can be employed to assist man in routine tasks is manifest. Computer-based systems, like the ISAACS described herein, are becoming increasingly commonplace, with many users preferring to build their own systems, rather than to buy a complete package. However, the development cost of software and special purpose hardware can often exceed that of the instruments alone, which makes the cost of an integrated package more attractive when these additional costs are properly considered.

A more important question perhaps, is whether the system provides the performance and versatility required, for many users needs are quite different. Examples of the capabilities of this particular system, with measured test results will be shown in the presentation.

REFERENCES

1. "Underwater Electroacoustic Measurements", R.J. Bobber, NRL 1970, pp 143 et.seq.
2. ibid, pp 28 et.seq.
3. ibid, pp 60-61
4. ibid, pp 48-52

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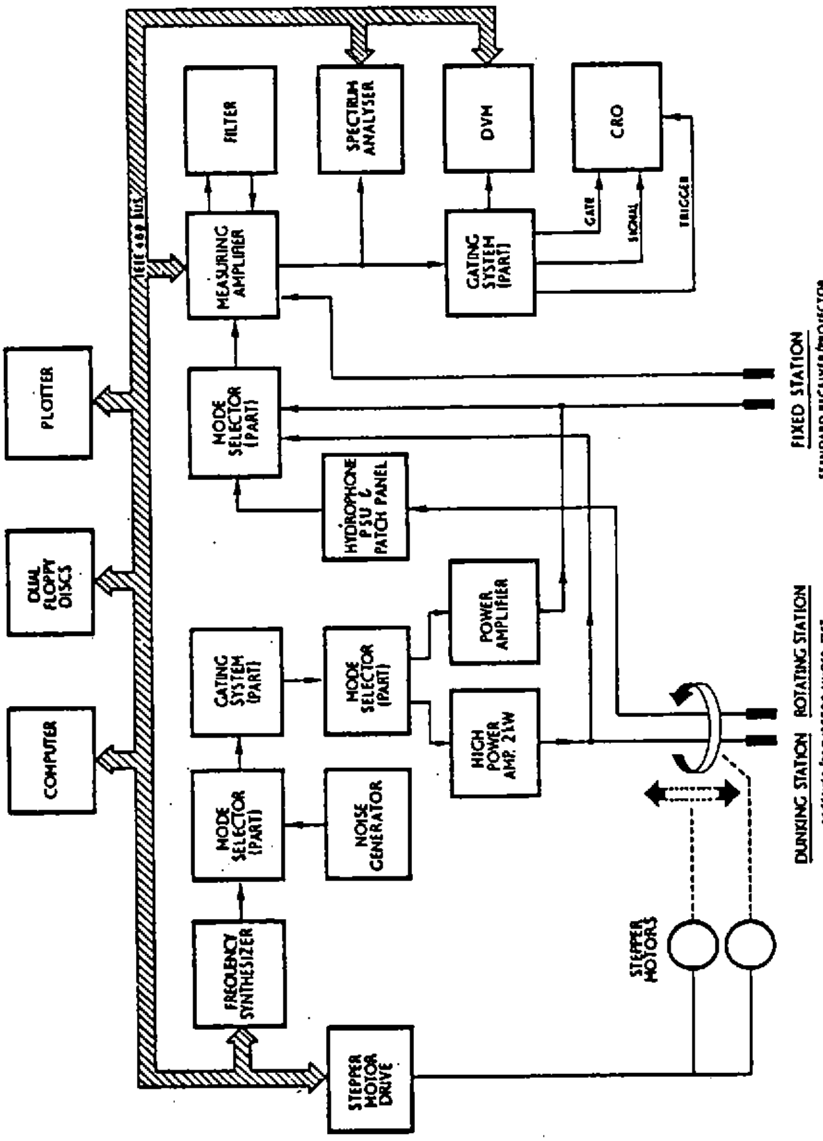

FIGURE 1 BLOCK SCHEMATIC OF ISAAC SYSTEM

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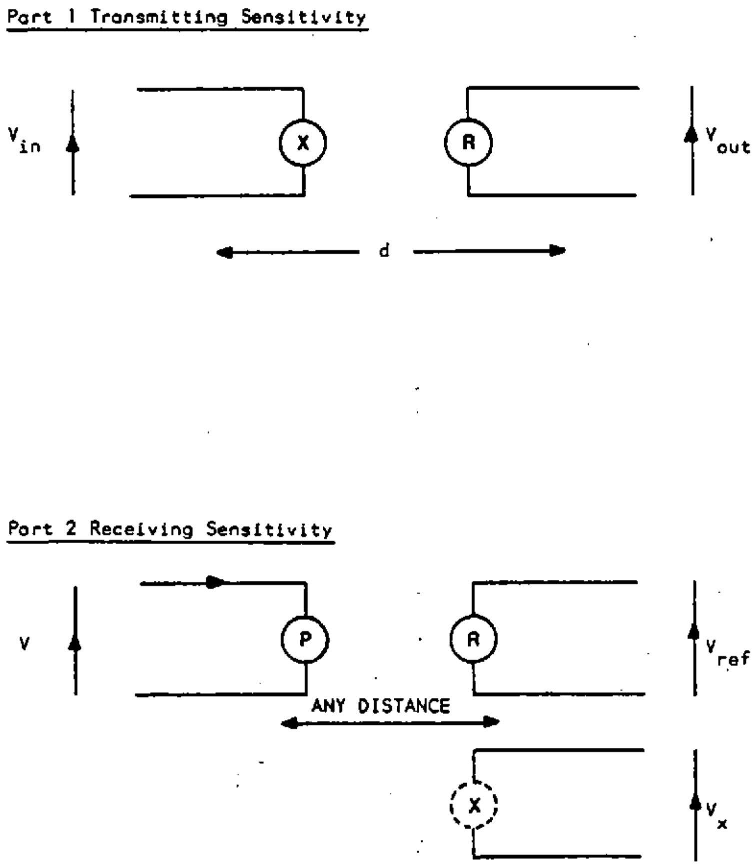

FIGURE 2 SENSITIVITY CALIBRATION METHODS

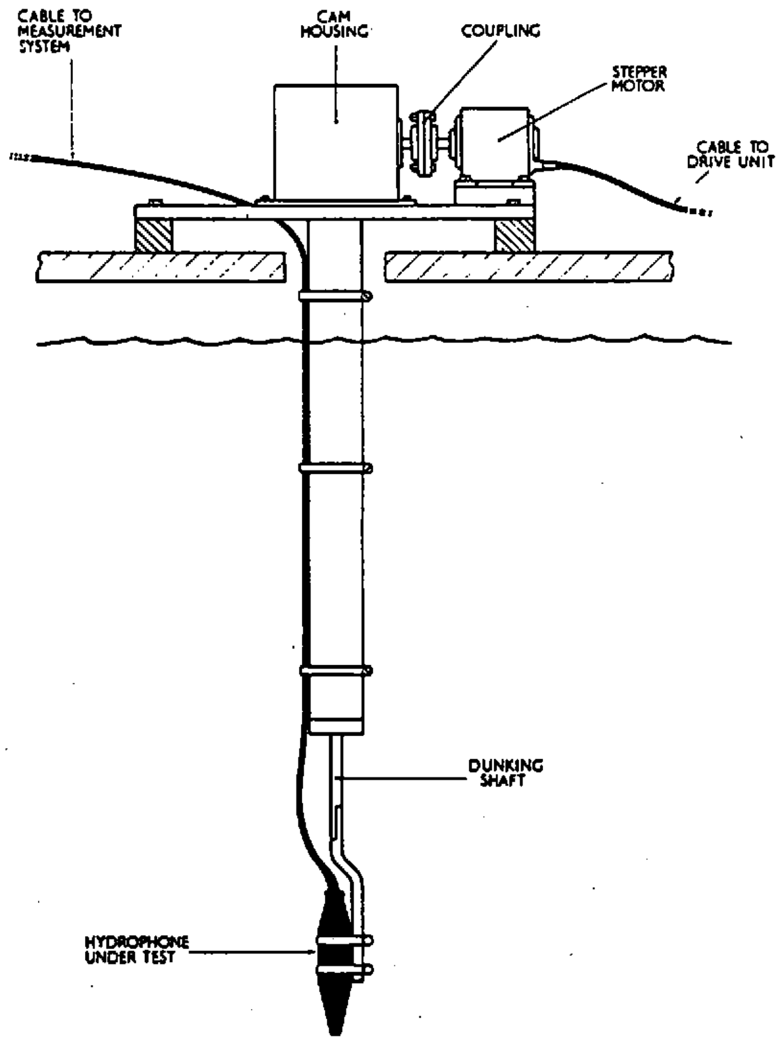

FIGURE 3 DUNKING MACHINE

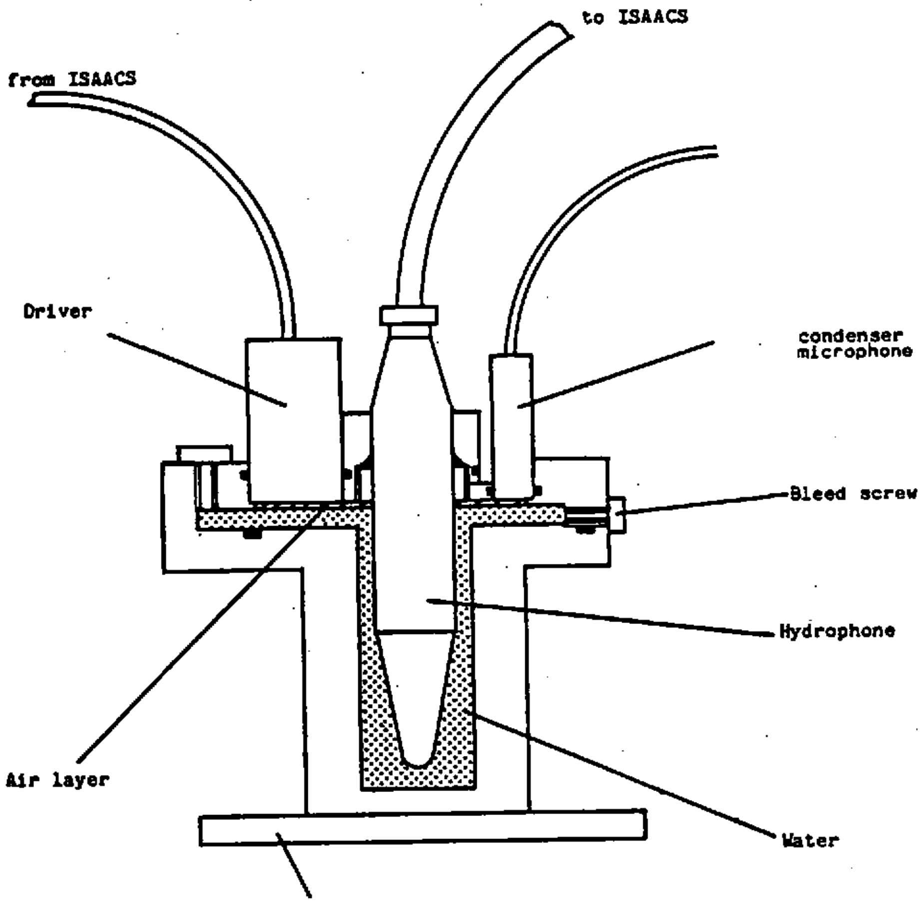

FIGURE 4 - WATER-AIR PISTONPHONE