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I.O.S.

THE RANGE MASTER

Final report on IOS attempts to make the system operational

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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THE RANGE MASTER

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July 1978

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INTRODUCTION

THE RANGE MASTER SYSTEM

The Range Master is an acoustic underwater positioning aid. Originally the Range Master was ordered to fix the position of a submersible, Consub 1, carrying out bottom surveys on features such as "Pock Marks". The development arose from the successful "Rangemeter" diver-held underwater positioning system which used similar basic principles except that the interrogator was directional.

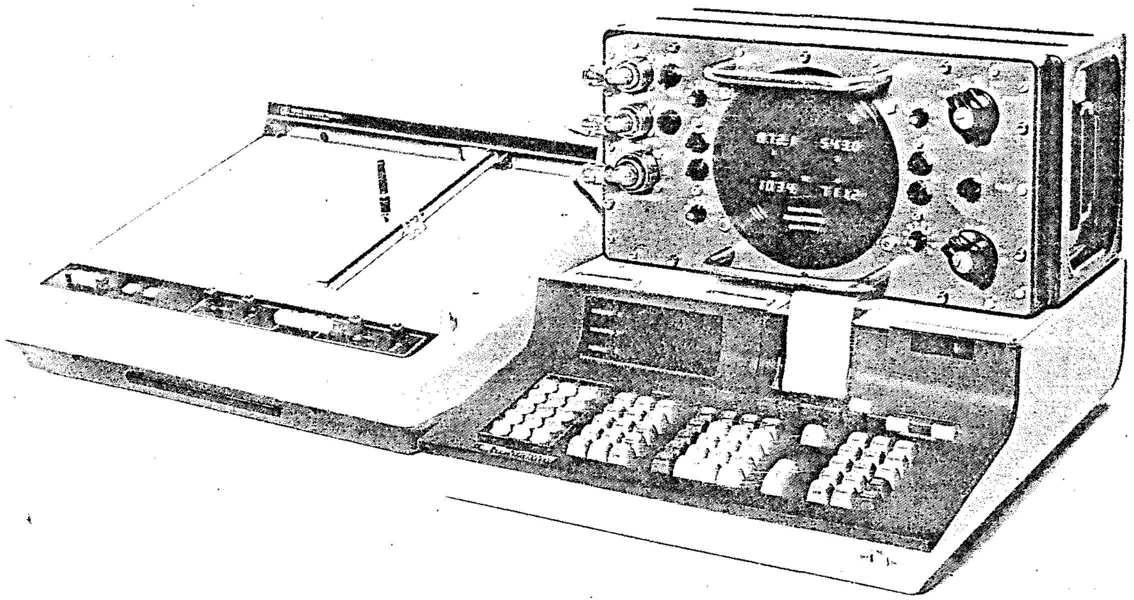
Various problems, and long delays on the part of the manufacturer, led to the system being withdrawn from a scheduled pock mark survey. Modifications and trials by the manufacturer gave some improvement in the system performance when used in a static mode under quiet conditions, but attempts to use the equipment from a NERC vessel under realistic conditions even in a static mode were unsatisfactory. A programme and interface, ordered to enable the system to give an underway track plot on a Hewlett Packard 9810 calculator and XY plotter combination also had developmental problems (see Fig 1).

At about this time the pock mark surveys were cancelled, but some interest was expressed within IOS for the Range Master system for sea bed survey work in areas such as Start Bay, Sandettie, and the Thames Estuary. The response of the manufacturer to demands for making the system work to its specification was slow and little progress was made, mainly due to pressure from his other commitments.

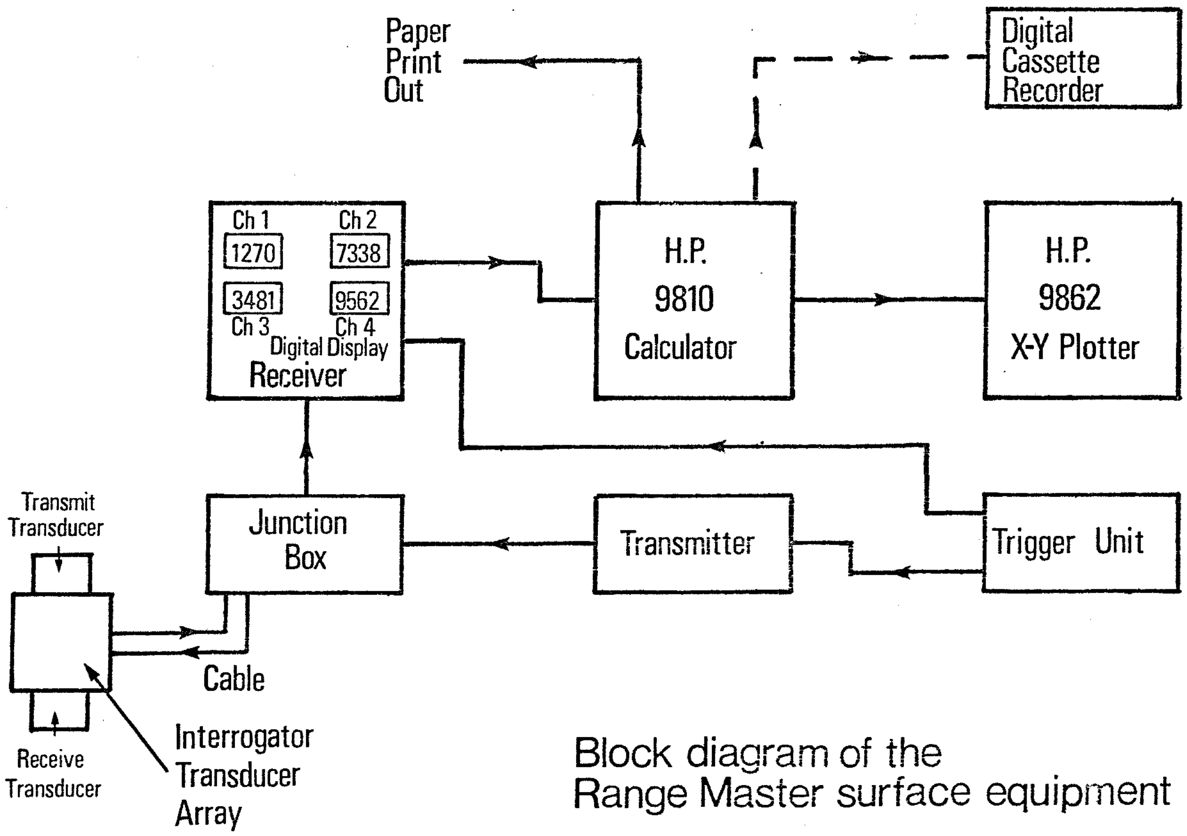
Eventually the track plotting facility was cancelled and the development of the system was taken over from the manufacturer by IOS(T).

The digital receiver/transmitter unit was purchased back by the manufacturer, although transponders, interrogator transducer array and cable were retained by IOS(T) (see Fig 2). In place of the receiver/transmitter a unit comprising of a transmitter, pre-amplifier and an analogue recorder sweep phasing unit was to be supplied.

It was IOS(T)'s intention to first obtain a satisfactory analogue display before proceeding with the more difficult digital technique, but to make provision for future digital development. The main problems were to obtain or construct a suitable main receiver, to obtain an analogue recorder of suitable specification, to resolve the problem of spurious triggering by the transponders, and to test the system.



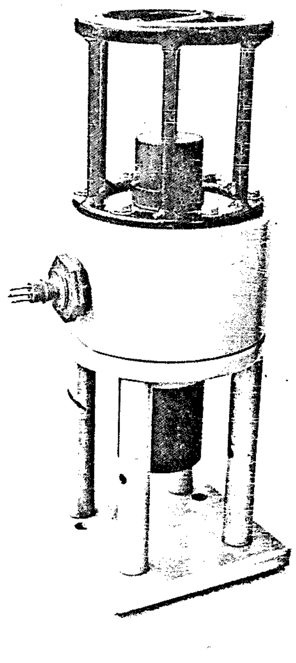
Part of the Range Master surface equipment
as originally intended



Block diagram of the
Range Master surface equipment

Fig.1

Typical Range Master Transponder



Interrogator Transducer Array

Fig. 2

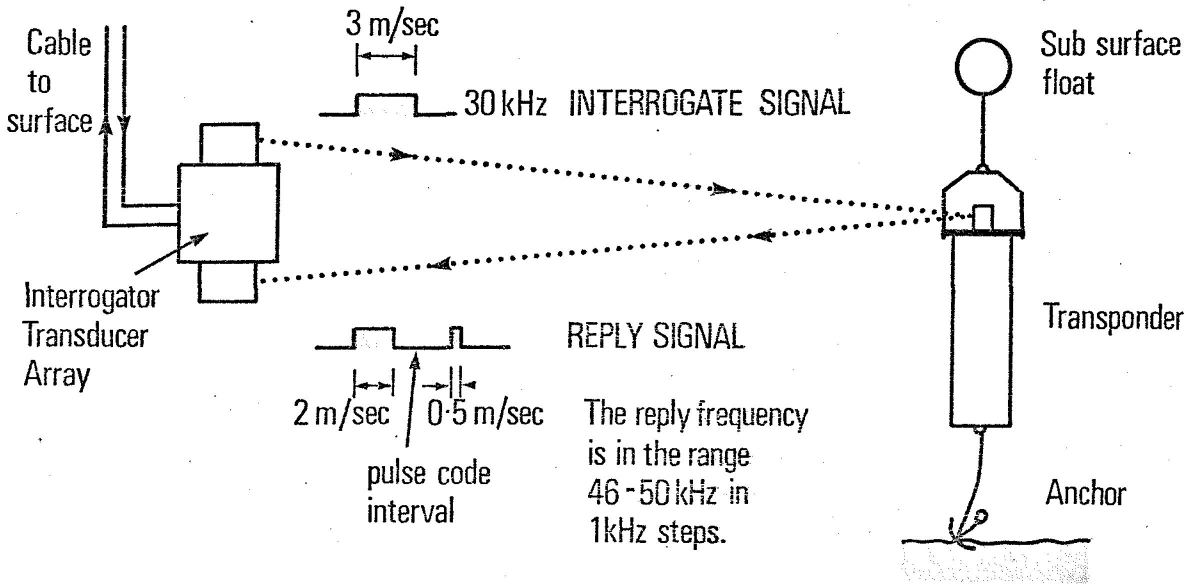
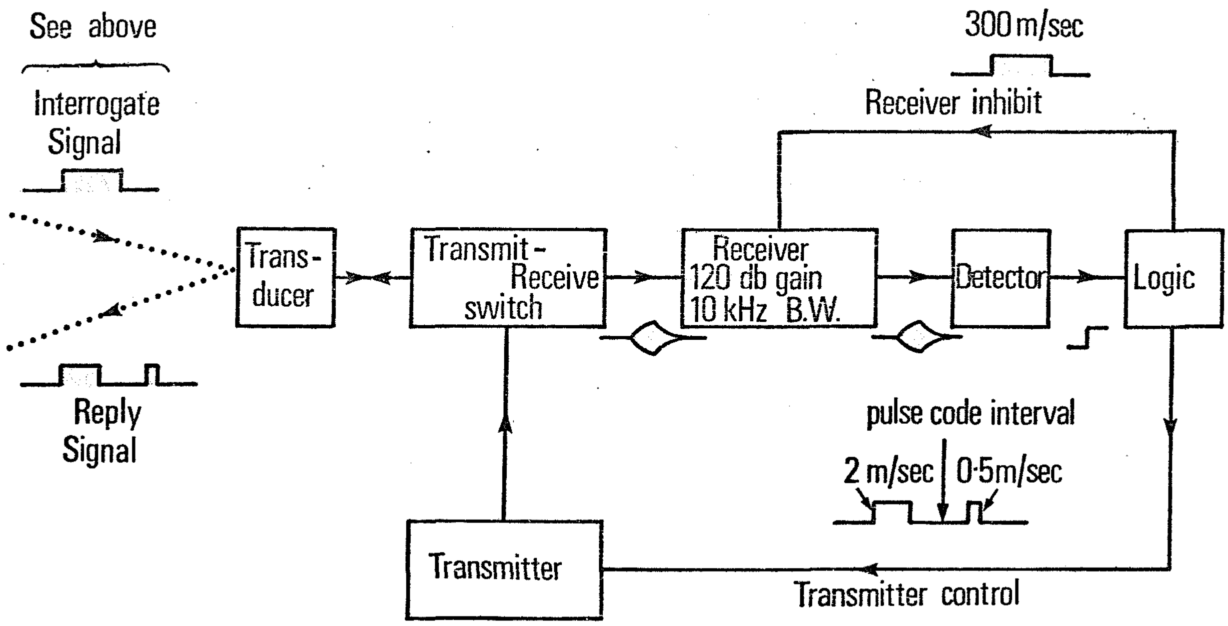


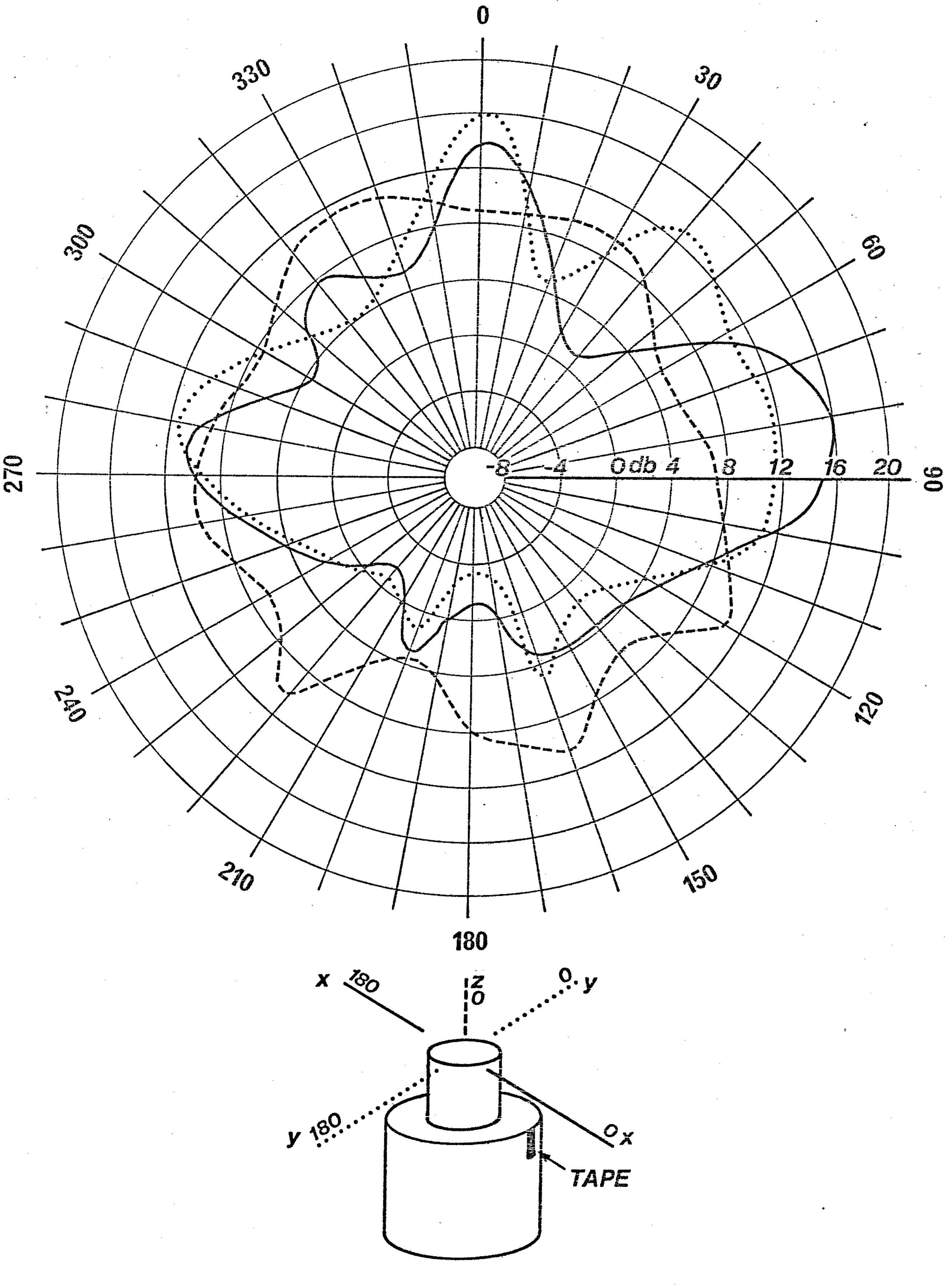
Diagram of Range Master Transponder operation.



Block diagram of the Range Master Transponder.

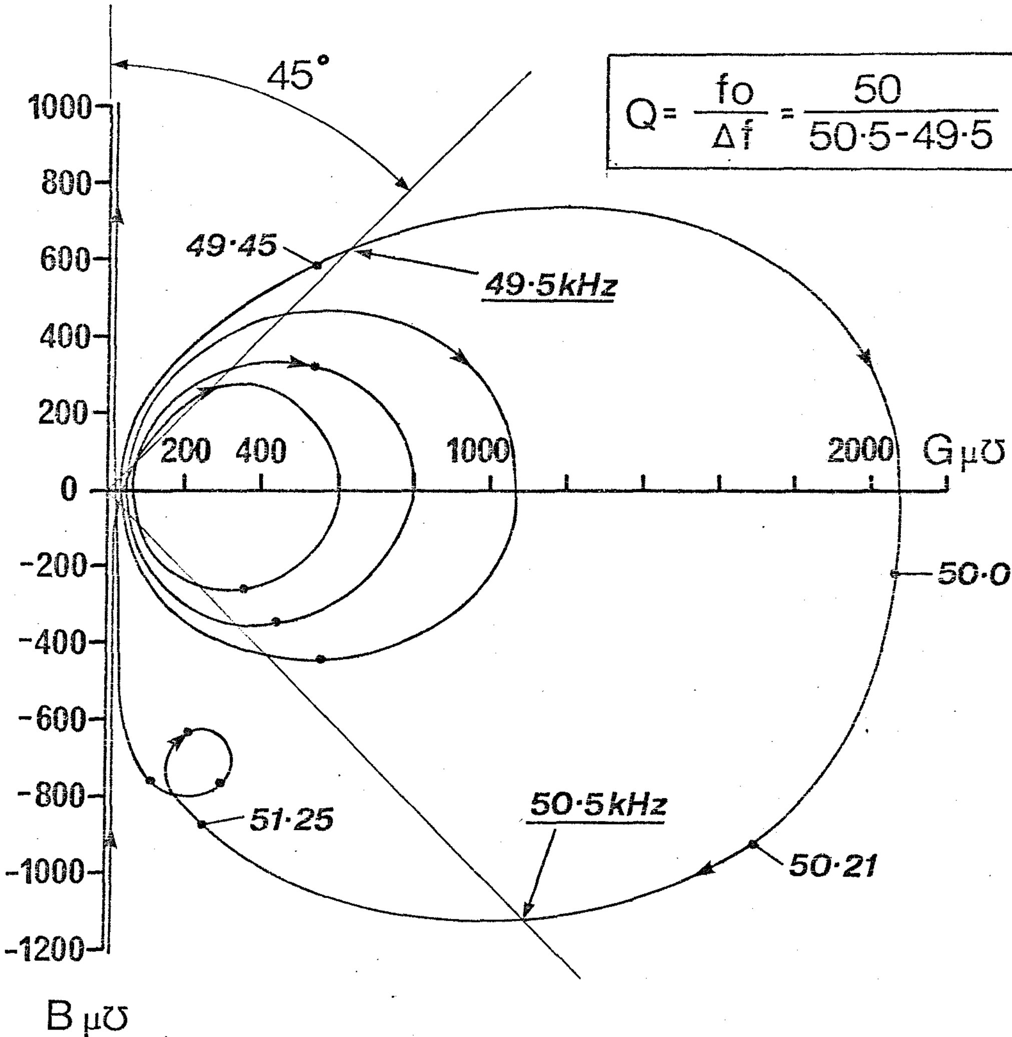
Fig. 3

TRANSDUCER DIRECTIVITY DIAGRAM



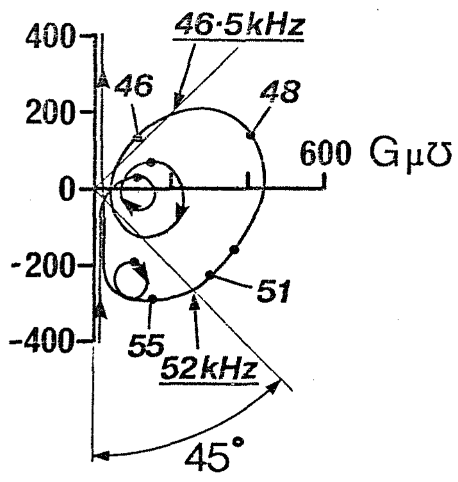
TRANSPONDER NO. 474

Fig. 4



$$Q = \frac{fo}{\Delta f} = \frac{50}{50{\cdot}5 - 49{\cdot}5} = 50$$

Admittance diagram for Range Master transponder transducer no. 474 in air.



$$Q = \frac{fo}{\Delta f} = \frac{50}{52 - 46{\cdot}5} = 9{\cdot}09$$

Admittance diagram for Range Master transponder transducer no. 474 in water.

Fig. 5

INITIAL TRANSPONDER CHARACTERISTICS

While awaiting delivery of the transmitter unit an investigation of the transponder performance was started. Circuit diagrams had to be drawn, as none were available from the manufacturer.

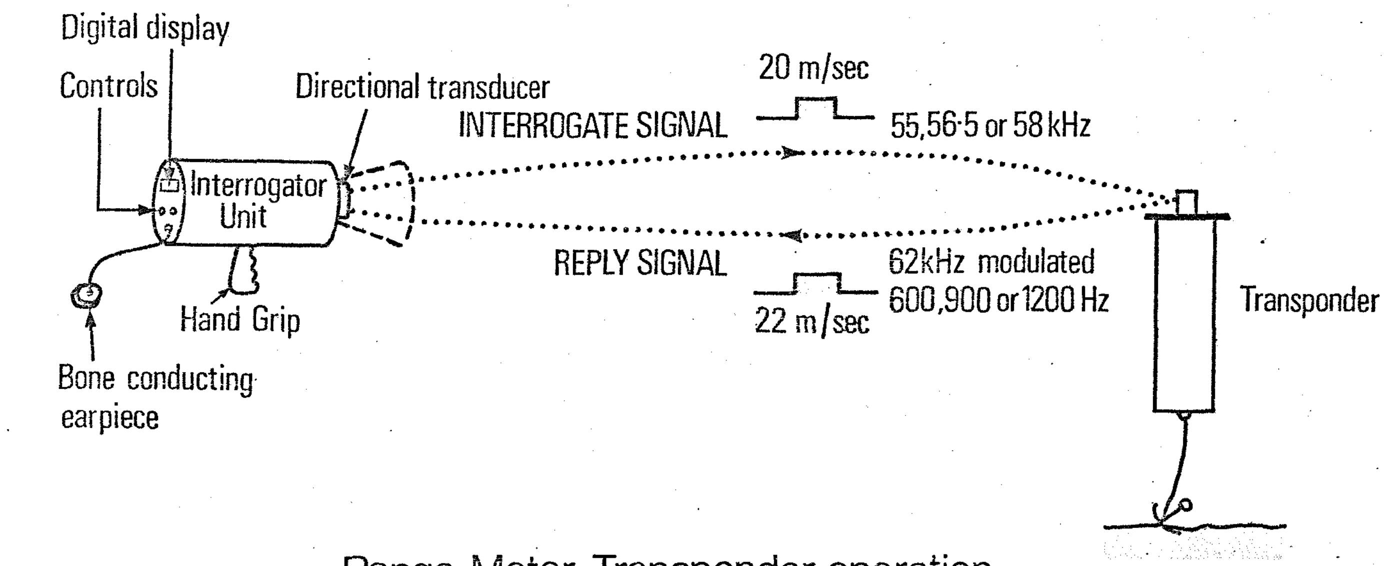
A number of transponders are simultaneously interrogated by a 3m s pulse of 30 kHz.

Replies from the transponders are both frequency and pulse coded (see Fig 3), with an output level similar to that of the interrogator. Frequencies of 46 to 50 kHz in a 1 kHz step identified particular transponders in addition to a pulse code consisting of a 2m s pulse followed by a 0.5 m s marker pulse, the gap being adjustable between 7.5 and 25 m s . It was discovered that the transponders had very little discrimination against noise. The receiver was a straight tuned amplifier with a gain of about 120 dB and a bandwidth of between 7 and 10 kHz, centred on 30 kHz. Both the transmitter and its gating logic were found to be simple, but effective.

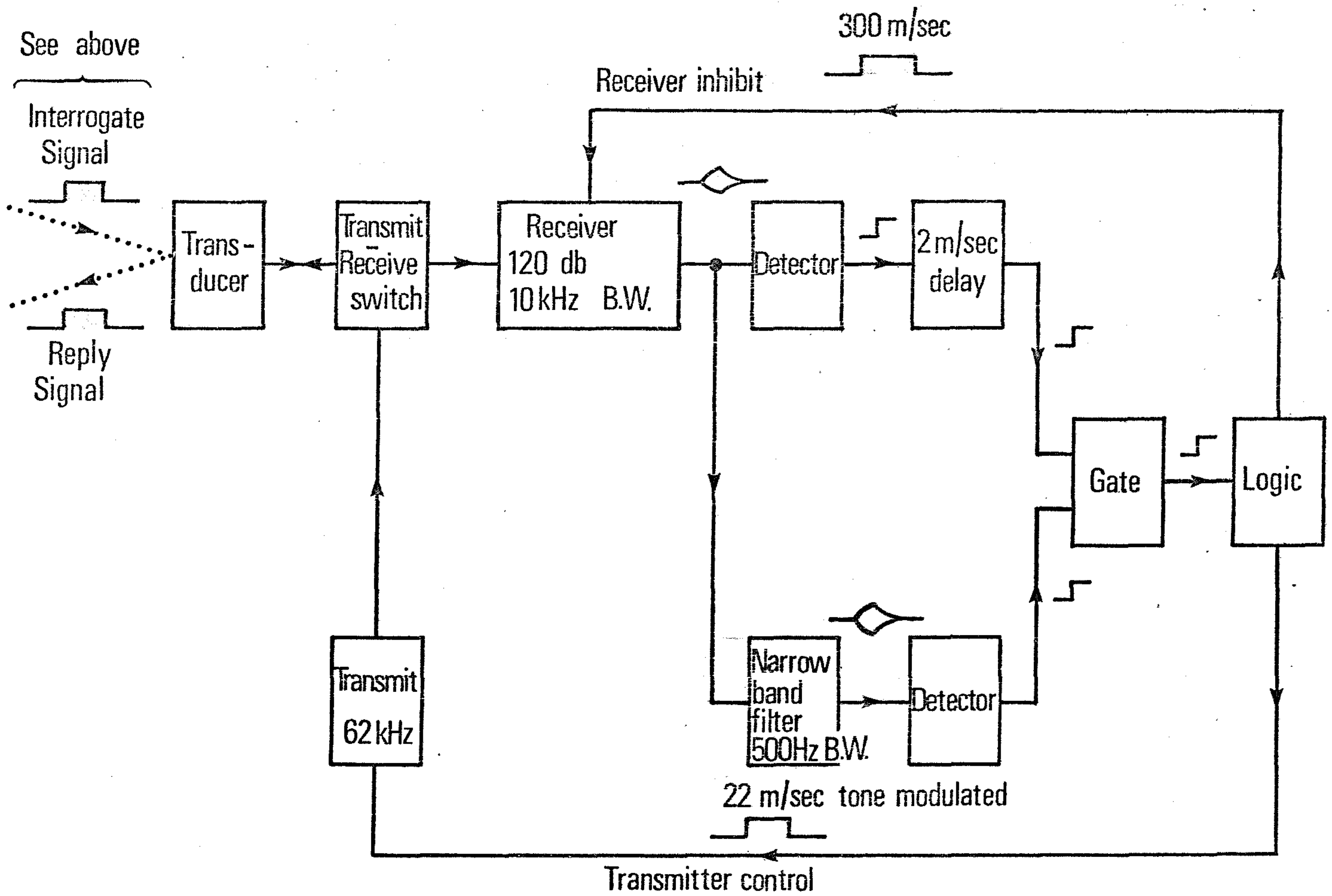
Circle diagrams of the transducers from the transponders, and from the interrogation array were plotted. Transducers were of the piezo electric type, the material was estimated to be PZT4 or similar. A spread of about 7 kHz in the main resonances encompassed the band of frequencies used, although not all transducers were matched to the nearest nominal frequency in use. In air a Q of about 50 was found, and in water about 15 was characteristic. Many smaller resonances were found extending from about 15 kHz to about 100 kHz. These results were later confirmed by a small sample tested at IOS(W) in a larger tank and with more sophisticated test equipment, (see Figs 4 and 5). No change was made in the transducers apart from selecting, where possible, a main resonance close to a given nominal transmit frequency.

Construction of the Rangemeter transponders was very similar to that of the Rangemaster, but their response was relatively immune to noise. It was decided to draw up the schematic diagrams of these transponders, as being useful in itself from a maintenance point of view as the Range Meter Mk III was by then obsolete, and also to ascertain the difference between the two types of transponder. Up to three transponders could be interrogated sequentially by a diver using a directional interrogator unit, all would reply with a common frequency which was modulated by a tone to enable aural identification of transponders.

The interrogation signal consisted of a 20m s pulse of 55, 56.5 or 58 kHz. The transponder replies were a 22 m s pulse of 62 kHz modulated by 600, 900 or 1200 Hz. Noise discrimination was obtained by a more complex signal recognition system than that used by the Range Master (see Fig 6). An interrogation signal would have to



Range Meter Transponder operation.



Block diagram of Range Meter Transponder.

Fig. 6

be within 500 Hz of the nominal interrogate frequency and also have a pulse length of not less than 2m sec, before a transponder would reply. The trade off was an extra but well defined 2m sec delay in the transponder response time.

This circuit worked well enough to reject the noise from an outboard motor operating only a few metres away, and all three of a set of Range Meter transponders could be used in physical contact with each other without mutual interference.

A prototype hybrid transponder circuit was built having the same frequencies and coding as the Range Master, but using the Range Meter type of signal recognition. Laboratory tests indicated that this circuit should perform as expected. Trials were arranged at the Queen Elizabeth II reservoir near East Molesey.

TRANSMITTER PHASING UNIT

This was received in October 1976. The unit as supplied by the manufacturer consisted of a transmitter, a facsimile recorder sweep phasing unit, and a preamplifier. The transmitter delivered was not suitable for direct use with the system, because the output was matched for a Rangemeter typ of transducer. Consequently the output transformer was rewound to match its impedance and power output to the existing transducer and cable. An analogue gate circuit was also added to enable the output stage of the transmitter to be driven from an external oscillator. This was to allow different interrogation frequencies to be used during the trials. A range of from 10 kHz to 100 kHz could be used.

The phasing unit allowed a transmission on any multiple of trigger pulses up to 8, and would allow marking of every sweep, or any particular sweep of a recorder up to 8. The trigger input circuit was modified to accept a switch closure or a pulse as is commonly used with recorders.

The preamplifier had a voltage controlled gain with a range of about 60 dB. Its maximum gain was 52 dB, with a noise figure of about 7 dB (measured by oscilloscope) and a bandwidth of 20 kHz. The whole system was in a metal case and required a 24 volt power supply.

FIELD TRIALS

The foregoing instrumentation was field-tested and modified in a series of trials on the Queen Elizabeth II reservoir at East Molesey and on board the Research Vessel RRV John Murray and RV Edward Forbes in the English Channel (Appendix 1 - 6). The main conclusions from the trials were:

Transponders

The modification to the transponders reduced the false triggering to an acceptable level although the receiver stability still required improvement, and the setting up procedure made less critical.

Receiver

The receiver was good enough to enable measurement of digital time delays in a quiet environment such as a reservoir. Under realistic conditions at sea, improvements need to be made before digital range information could be obtained. Automatic gain control and time varied gain produced a large degree of immunity from reverberation and general continuous background noise, and are thought to be useful and necessary refinements. The use of a common preamplifier could be improved by using a separate preamplifier for each channel and/or some amplification at the transducer. Saturation of the preamp by large signals may entail some redesign.

Transducer Array

The transducer was originally designed for static use, or for use with a submersible such as Consub 1. It does not tow well nor is it screened from ship noise in any way. In some instances it is possible that the mounting plates/guards screened the transponders.

TECHNICAL PROBLEMS IDENTIFIED DURING EQUIPMENT TRIALS

A review of progress held on 4 October 1977 identified four technical problems to be investigated before the development of the Rangemaster to the stage of being an operational manual analogue system would be complete.

1. The interrogator transducer array should be housed in a properly designed towed body.
2. The Mufax recorder should be replaced by a more suitable form of display, an EPC flat bed recorder was recommended.
3. The main receiver preamplifier should be modified to prevent saturation on large signals. The preamplifier could also be relocated in the towed body.
4. A complete redesign of the transponder receiver circuits, the inclusion of AGC and more positive signal detection was necessary.

However, at this review it became obvious that not only could the system never be made to operate to anything approaching maximum operating ranges of 1 km (see appendix 7) in a digital mode, but that it was going to require a lot of further work to achieve an optimum analogue system which even then would have a limited performance. In view of the recent development of satisfactory commercial systems it was therefore decided to terminate the project. Most of the hardware could readily be adapted to other uses, and would not be wasted.

SUMMARY OF WHY THE SYSTEM WAS A FAILURE

(1) The insuperable difficulty was that Rangemaster appears to have been a simple extension of the Rangemeter system but without a comparison of signal to noise ratios being made.

Sonar equation calculations (Appendix 7) show that operation over useful ranges should have been possible using analogue recording, in which line integration gives a large improvement in the detection threshold.

(2) The reasons why it took us so long to realise that we should abandon the system were as follows:

(a) We naturally assumed originally that we had a basically viable system, so that when it did not work we assumed that there was a malfunction. It slowly appeared that not only were most component functions not working properly due to bad design, but that the basic system was unsound. In hindsight, we should have sat down originally and checked the basic acoustic calculations and tested each component of the system systematically. The latter is not easy to do without some rather specialised facilities, only some of which were available.

(b) We could obtain no effective cooperation from the manufacturer, so that even the originally specified system was never fully delivered and delivery of agreed modifications was excessively delayed, in some cases by years. We were unable to obtain circuit diagrams or other design information.

(c) We were reluctant to abandon a considerable capital investment without being sure that it was necessary to do so.

APPENDIX I

RANGE MASTER TRIALS AT WORMLEY AND THE QUEEN ELIZABETH II RESERVOIR, EAST MOLESEY:. OCTOBER 1976.

OBJECT

To evaluate the relative performance of modified and unmodified transponders, in a test tank, and a large body of open water.

EQUIPMENT

Two unmodified, and one modified transponders. (The modification was to include the Range Meter type of signal recognition in the transponder receiver and logic circuits).

A transmitter of similar specification to the original Range Master interrogation transmitter.

The interrogator transducer array with 30m of cable.

An 18" EPC flat bed recorder.

A trigger unit, and a selection of tuned and untuned amplifiers to be assembled into a receiver.

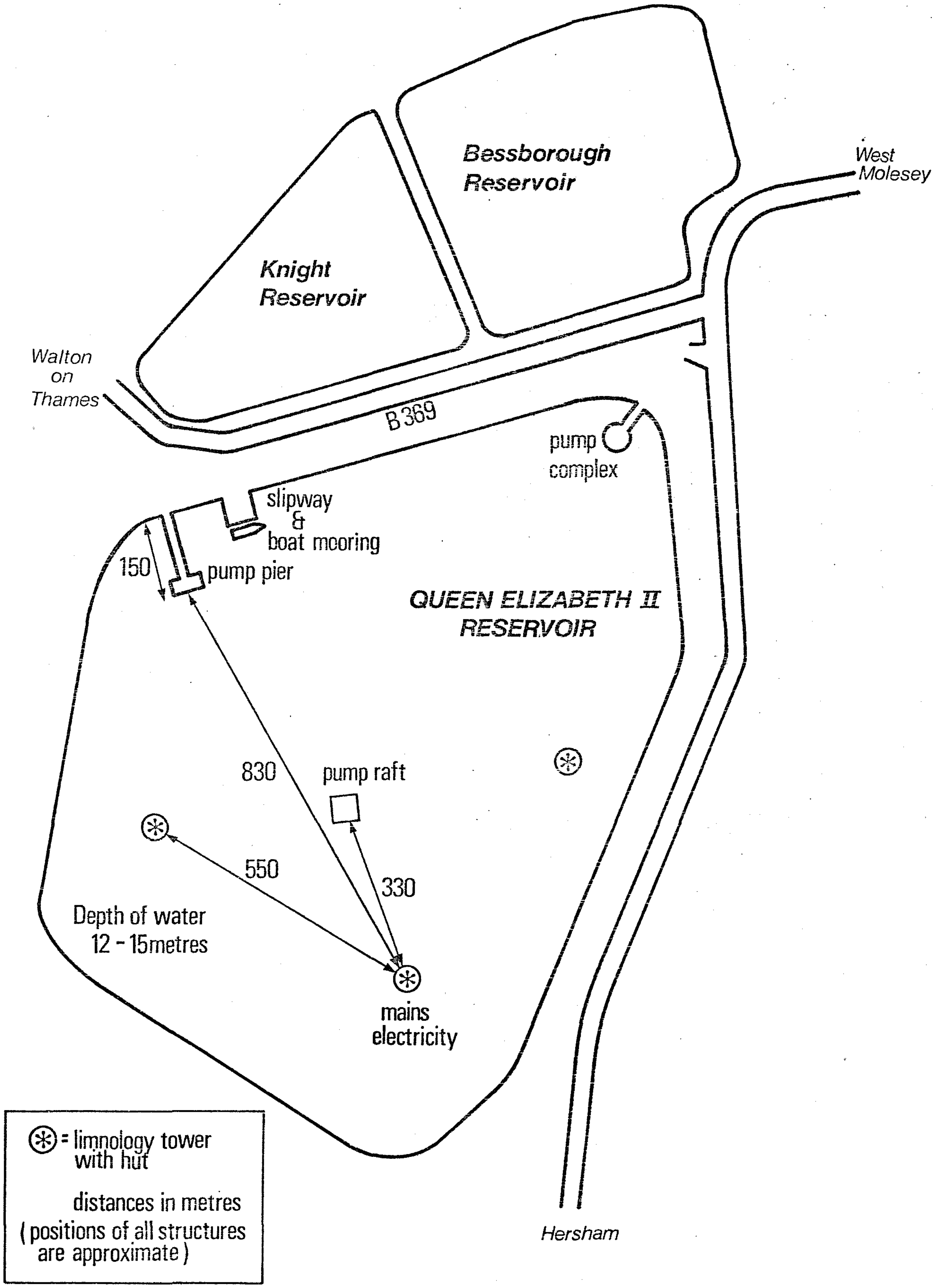
PRELIMINARY TESTS

These were performed in a large test tank at IOS Wormley. The power output of the transponder transmitters was measured. Plots were made of the transponder transducers polar and admittance diagrams. Tests were then performed in which the amplitude, pulse length, and frequency of the interrogation signal were varied individually and in combination.

RESERVOIR TRIAL

All three transponders were suspended from various structures in the reservoir (see Fig 7) at about midwater (6m). The interrogation transducer array was suspended from a limnology tower which had mains power supply. An EPC recorder, receiving equipment and the interrogation transmitter were located in a hut on top of the tower.

Variations in pulse length, amplitude and frequency of the interrogation signal were made for several permutations of transponder range. A low level of pump noise was present in the reservoir. Extra noise was provided to test the susceptibility of the transponders by operating an outboard motor (10 HP) in the vicinity of particular transponders.



Sketch of Queen Elizabeth II Reservoir.

Fig. 7

CONCLUSIONS

The tank tests established that the output power level of the transponder transmitters, and the admittance diagram of the transducers agreed with lab results. When a pulse of nominal pulse length (3m s) and frequency (20 kHz) was used to interrogate the transponders, all three would reply over ranges (simulated by varying the amplitude) of a few 10's of metres to over 1000m. Variations of pulse length and frequency of the interrogation signal indicated that over the nominal operating range of the system, the unmodified transponders would reply to frequencies in the range of approximately 1 kHz to 100 kHz, and to pulse lengths of from 100 μs upwards.

The modified transponder on the other hand only replied to frequencies in a band of about 1 kHz centred on the nominal 30 kHz, and to pulse lengths of not less than 2 m s . The unmodified transponders could also be interrogated by transient noise, whereas the modified one could not.

The reservoir trials confirmed most of the tank tests. Ranges of 1000 m were obtained from all transponders.

Variation of pulse length and frequency also gave similar results to the tank tests. Noise both from the pumps, and from an outboard motor caused false replies from the unmodified transponders. The modified transponder was found to have a lower noise discrimination than the lab and tank tests had indicated. This was later found to be due to instability and a tendency to self-oscillate in the transponder receiver circuits; this reduced the effectiveness of the Range Meter modification in conditions of continuous low level ambient noise.

In general the Range Meter modification was effective in reducing false replies. Only signals whose frequency was within 500 Hz of the nominal and having a pulse length of greater than 2 m s , could interrogate the transponder.

APPENDIX 2

RANGE MASTER TRIALS ON BOARD THE RRS JOHN MURRAY: 26.10 to 11.11.76

OBJECT

Time and weather permitting, to test the Range Master under realistic conditions at sea.

EQUIPMENT

A Range Meter modified transponder, special attention having been paid to reducing its receiver instability to a minimum.

An interrogation transducer array and cable.

The manaufacturer's replacement interrogator transmitter and trigger unit.

An 18" Mufax recorder.

A tuned receiver.

TRIALS

In Great Yarmouth South Quay, the interrogation transducer array was hung over the bow and the transponder over the stern at about 6m down. The effects of transmitted pulse length and interrogation frequency were noted. The test was continued while the main engines were started, and during the berthing of a rig supply vessel in the next bay.

While at anchor in Start Bay, the transponder was floated off the stern suspended under a buoy to about midwater (9m). The interrogator array was hung over the bow. The drift of the transponder was observed out to a range of about 100m.

During diving operations the transponder was taken in the divers' inflatable. On their return to the ship the transponder was towed at an estimated depth of 5m. The interrogator array was hung over the side of the ship which was steaming at about 2 knots. The transponder replies were observed from the time they were first identified until the transponder had to be stowed (from about 700 m to about 200 m from the ship).

CONCLUSION

Variation of interrogation frequency and pulse length produced similar results to previous tests of modified transponders. Even with high background noise very few false replies were observed.

In the confined dock area reverberation and propeller noise caused very poor recordings, and receiver gain adjustment was very critical.

In open water at close range, reverberation was a problem. Under way or in strong tide conditions the interrogator array towed very badly causing loss of signal, and a high level of water noise. Even with poor sea conditions, and bad towing characteristics of both the transponder and interrogator, replies could be identified up to 700 m range.

The trial indicated that provided the transponder receiver could be kept stable, operation of the transponders was possible even in fairly high levels of background noise. The main receiver amplifier did not have sufficient discrimination against reverberation and acoustic noise.

APPENDIX 3

RANGE MASTER TRIALS AT THE QUEEN ELIZABETH II RESERVOIR, EAST MOLESEY: DECEMBER 1976

OBJECT

To evaluate an MS43 sonar recorder with built in receiver, and a pulse code discriminator circuit, with respect to their rejection of reverberation and background noise.

EQUIPMENT

Three Range Meter modified transponders.

An interrogation transmitter, interrogation transducer array and cable.

An MS43 sonar recorder.

A pulse code discriminator and counter unit.

TRIALS

As before the transducers were hung from various structures in the reservoir, hung under buoys, or towed behind a small boat. The transponders and the outboard motor were used to simulate conditions of reverberation and high background noise, while the recorder settings were adjusted to obtain the best trace possible.

The pulse code discriminator was then set up and various tests performed using it in conjunction with the recorder, and a counter.

CONCLUSION

The MS43 was not a suitable recorder for this type of operation, however it did show that 'Automatic Gain Control' (AGC) could reduce the effects of reverberation and background noise. Under quiet conditions at moderate range (200m) the pulse code discrimination gave very good results, it could be used to start and stop a counter in response to the interrogation and reply of a transponder and so display the range in the form of a time delay.

In the face of reverberations or high noise levels the discriminator became erratic in operation, and many false ranges were indicated.

It was decided not to continue with the development of the pulse code discriminator but to concentrate on providing a main receiver incorporating Automatic Gain Control, and time variable gain, to be used with a recorder such as an 18" Mufax or an 18" EPC.

APPENDIX 4

RANGE MASTER TRIALS AT QUEEN ELIZABETH II RESERVOIR, EAST MOLESEY: JUNE 1977

OBJECT

To evaluate a three channel superheterodyne receiver incorporating Automatic Gain Control and Time Variable Gain.

EQUIPMENT

Three Range Master modified transponders.

An interrogation transmitter, interrogation transducer array and cable.

A superheterodyne receiver.

An 18" Mufax recorder.

TRIAL

As for the previous trial various ranges and noise levels were used, the transponders being hung on structures or towed behind a small boat fitted with an outboard motor.

The main receiver was set up to obtain the best trace consistent with obtaining long ranges and high noise levels.

CONCLUSION

The traces obtained were the clearest yet obtained. Ranges of up to 800 m were obtained with good indication that a maximum range of well over 1000m should be possible. Range measurements taken from the Mufax recorder were in close agreement with measured ranges taken from a large scale map. One transponder became erratic and unstable, but subsequent lab tests revealed no apparent fault.

AGC and TVG were very effective in reducing noise and reverberation.

It was decided (time permitting) to take this system on next RV Edward Forbes cruise for sea trials.

APPENDIX 5

RANGE MASTER TRIALS ON RV EDWARD FORBES CRUISE 23/6: 11.7.1977

OBJECT

To evaluate the Range Master system under realistic conditions in an area where it might be required to operate.

EQUIPMENT

Three modified transponders.
An interrogation transmitter and trigger unit.
The interrogation transducer array and cable.
A three channel superheterodyne receiver.
An 18" Mufax recorder.

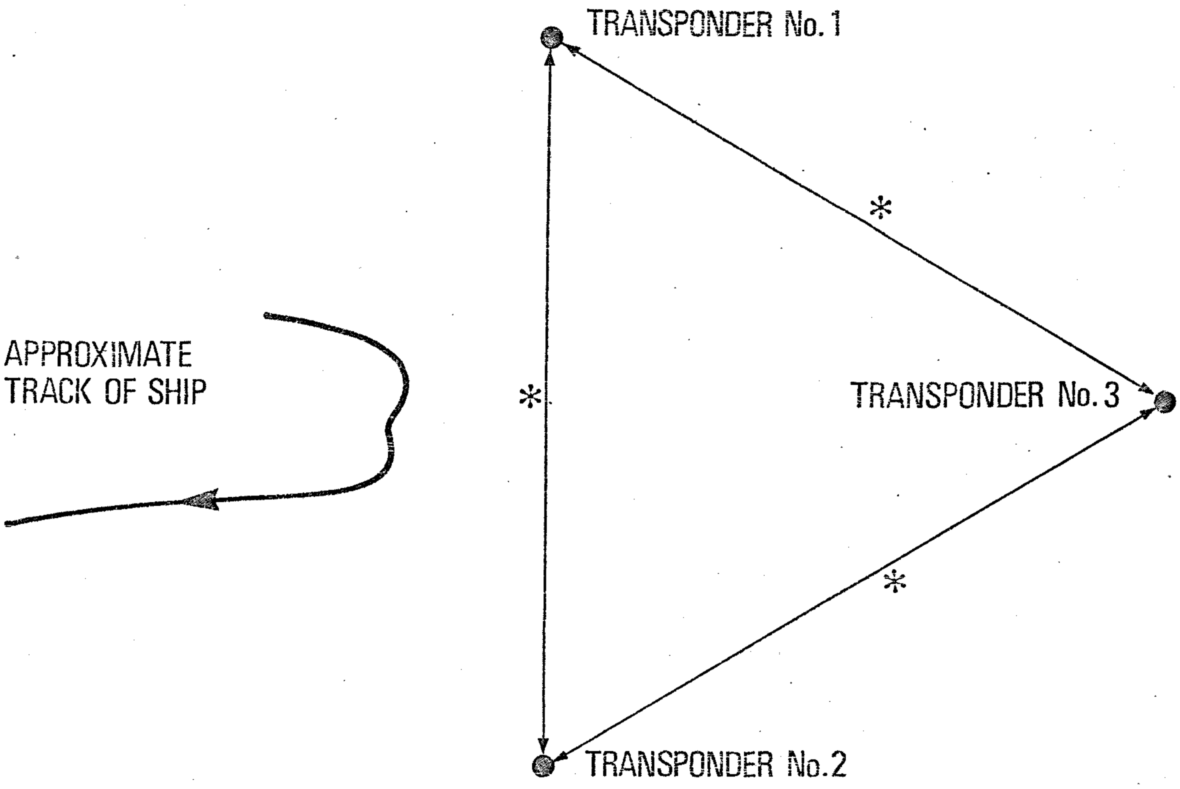
TRIALS

Three transponders were deployed in a triangle whose sides were approximately 500m (see Fig 8). The transponders were moored about 2m from the sea bed by means of chain anchors with sub-surface flotation, and surface marker buoys. A water depth of 20m over a fairly flat bottom was chosen.

At about 500m outside the triangle the ship was anchored, and the effects of the AGC, TVG noise, and transducer depth were noted. As in the case of the reservoir trials (13 - 15/6/77), transponder 469 was found to be giving weak and erratic replies although a lab check had shown no fault. Continuous background noise could be suppressed by means of the AGC and TVG, and AGC control level could be seen to change by clutching and declutching the propeller. Reverberation was also reduced. In addition to the background noise there was some very spiky noise with high frequency components.

(During an exercise later in the cruise programme, acoustic noise was found on the record of the EG and G side scan sonar, which was being used as a transit sonar. This noise was eventually traced to a recently-installed 25 kVA generator set, which was not resiliently mounted. In order to obtain satisfactory sonar records, the 25 kVA set had to be shut down, and the old 15 kVA set used instead).

At anchor the record was disappointing, impulse noise was getting through the receiver, and some reverberation could be seen. . On a 2 sec sweep rate the traces could be identified by their pulse coded replies, and by means of time markers the delay between transmission and reply



* All distances approximately 500 metres

Approximate layout of Transponders.

Fig. 8

could be measured. Attempts were made to measure the time delay directly with a counter but with the noise present a high proportion of false times were displayed, the true time could only be obtained by careful observation over a period of time.

The ship was then allowed to drift with the tide with its propeller rotating, but feathered. Traces on the record were followed out to about 1200 m, (see Fig 9). Attempts to steam back towards the transponders failed completely, the unfaired transducer array streamed almost to the surface and the record was obliterated by water noise.

A 50 kg lead fish was fitted to the transducer assembly, but steaming even at 1 - 2 knots still caused the transducer to stream, and a large increase in noise on the Mufax record. Although traces could be followed up to about 5 knots, the record was poor.

Tape recordings were to have been made on a subsequent exercise using the Hewlett Packard four track tape recorder. After running one tape while drifting past the triangle it was found that the tape recorder was faulty.

CONCLUSIONS

The Rangemeter modification to the transponders is effective in reducing false triggering although the setting up is critical.

Continuous noise and reverberation can be reduced by AGC and TVG.

Discrimination against impulse noise requires some improvement.

Some evidence of saturation by high level signals of the pre-amp was noted.

In order to obtain time delays directly from a counter an improvement in signal to noise ratio is required, together with more sophisticated signal processing. As an analogue display the 18" Mufax recorder was adequate, the recordings at anchor and drifting could have been used to determine a relative position to perhaps 5 m.

Previously established problems with the transducer array require redesign both for towing qualities and to reduce noise from the ship by perhaps screening from above or making the transducers directional.

ANALOGUE RECORD OBTAINED ON AN 18 INCH MUFAX FROM A NETWORK OF THREE TRANSPONDERS

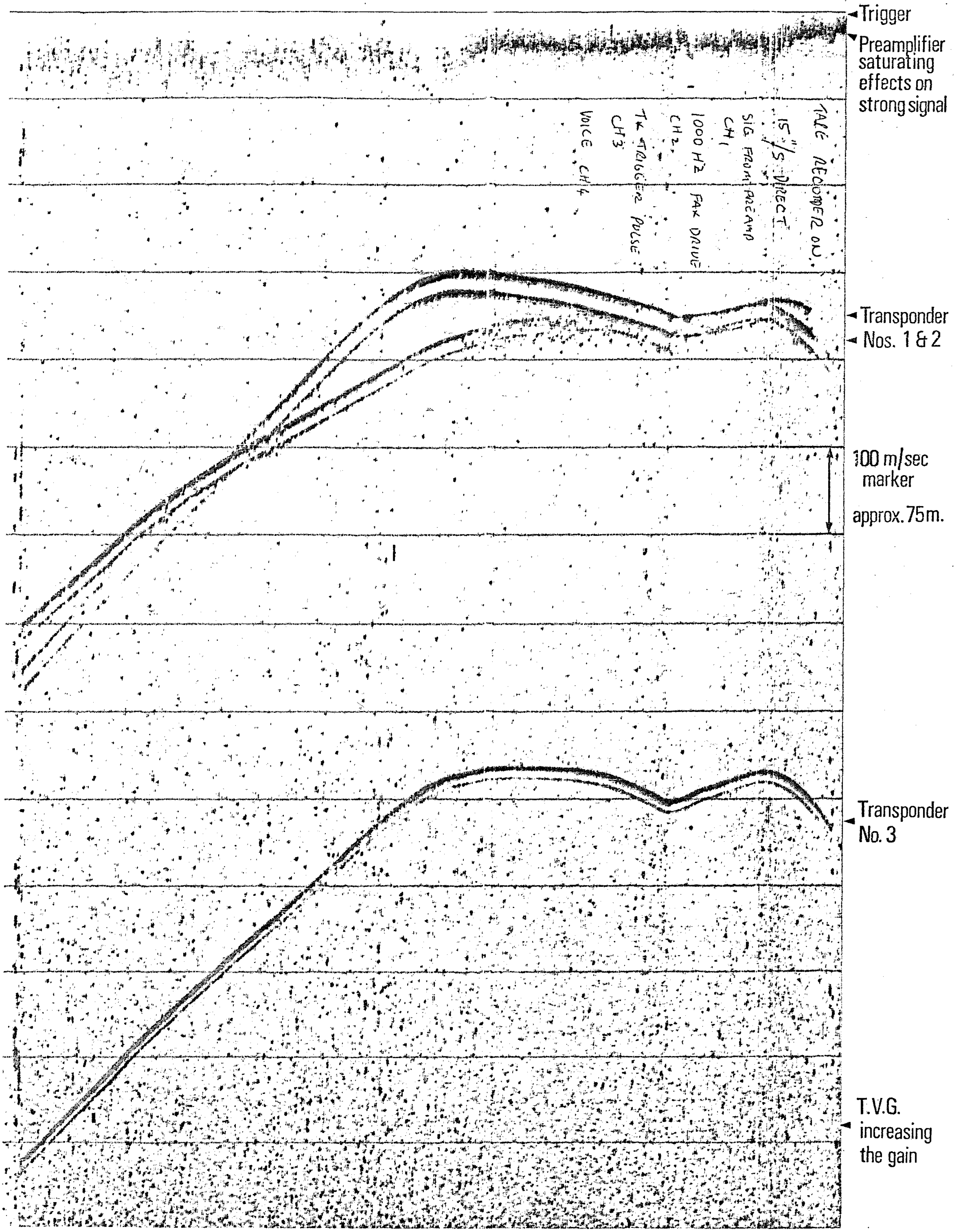


Fig.9

APPENDIX 6

TRIALS ON RV EDWARD FORBES CRUISE: 13/9/77 to 21/9/77

OBJECT

1. To test the transducer array in its new configuration.
2. Evaluate the effects of longer pulse lengths.

EQUIPMENT

Three transponders modified to Range Meter characteristics.
Superheterodyne receiver with AGC and TVG.
Transducer array fitted into a small fish with built in pre-amp.
Mufax 18" recorder.
HP 4 track tape recorder.

TRIALS

Due to bad weather the only trials were made in a static mode in Dartmouth harbour. Transponders were suspended from mooring buoys at various distances from the ship up to a range of about 750 m, in a water depth of about 10 - 12 m.

The interrogation array had been altered and the two transducers fitted horizontally in a plastic tube with a nose cone and EG & G fins. Neoprene sheet covered the top $\frac{1}{3}$ of the fish to act as a screen from ship noise. A 40 dB pre-amp with a bandwidth of 10 kHz was included in the fish. This pre-amp was found to be damaged on arrival, and a replacement had to be constructed.

In a strong tide the fish was quite stable and horizontal and its depth could be adjusted by the amount of cable let out.

Replies from the three transponders could be observed, but they were very erratic. The depth of the fish was found to be critical; one reply could be improved at the expense of the others. The Neoprene shielding was removed from the fish, this gave a slight improvement. If the fish was held vertically a large improvement was seen, but depth was still critical. It was concluded that mutual screening between the transmit transducer and the receive transducer was a problem, (the transponders were almost in line upstream of the fish) and that the shallow water made the transducer depth critical. Time Variable Gain and Automatic Gain Control reduced the reverberation to a reasonable level.

Extending the interrogation pulse, and the reply pulse from a transponder to about 20 m s each gave no definite improvement.

A tape recording of the replies of two transponders was made, one having a normal pulse length, the other an extended one.

CONCLUSION

In shallow water the small fish configuration was not as successful as had been hoped. Mutual screening and the effects of a high range to depth ratio caused loss of signal.

Increased pulse length gave no appreciable improvement, but caused a larger drain on the transponder batteries.

A pre-amp, located at the interrogator array gave slight improvement with a short cable, but may be essential if used with longer cables.

Ship noise was still a problem when the transducer is located close to the ship's hull as in the shallow water situation.

APPENDIX 7

SONAR EQUATION CALCULATIONS

The Range Master and Rangemeter systems both operate with active transponders, therefore assuming that the transponder is triggered the important consideration is the signal to noise ratio at the interrogator receiver.

The required signal to noise ratio at the input of the receiver is dependent on the type of system. A lower signal to noise ratio is required by a system which is based on a repetitive intensity modulated display, than for an 'automatic' system which provides range information to a digital computer navigation suite. These examples are at the extreme ends of the scale and systems such as the Rangemeter, with a repetitive numerical display of range which can be 'sorted' by eye, fall somewhere in between.

Sonar equation calculations are therefore made for theee system types:

(1) Rangemaster system with an analogue 'Mufax' display
(2) Rangemaster system providing data to a computer navigation system
(3) Rangemeter with numerical readout

An appropriate form of the sonar equation is given by

$$SL - TL + DI - NL = S/N$$

where SL is the transponder source level
TL is the transmission loss
DI is the receiver directivity index
NL is the noise level
S/N is the signal to noise ratio at the receiver input

The above parameters are measured in decibels and definitions may be found in any standard text, for example, URICK (1976).

The values of the above parameters for the Rangemaster and Rangemeter systems are as follows:

Source Level (SL)

Range Master	87 dB
Rangemeter	87 dB

Directivity Index (DI)

Range Master	0 dB
Rangemeter	12 dB

Noise Level (NL)

Range Master -3 dBs

(Typical case for ship with feathered variable pitch propeller)

Rangemeter -15 dBs

(Best care with diver stationary)

Transmission Loss (TL)

Transmission loss, assuming the simplest situation in which spherical spreading applies, is given by

$$TL = 20 \log_{10} r + \alpha r \quad dB$$

where r = range in metres

α = attenuation in decibels/metre

For the Rangemeter: α_{48} = 0.0145 @ 48 kHz)
) In typical conditions of use
For the Range Master: α_{60} = 0.0206 @ 60 kHz)

Signal to Noise ratio (S/N)

System type (1)

For detection of the signal to be just possible, a signal to noise ratio of -3dB may be taken as a typical figure. This figure is low by virtue of visual integration of many echo returns, which is found to give an effective signal enhancement of $5 \log_{10} n$ dB, where n incoherently added signals are displayed (Urick, (1976). The improvement decreases for large n, but 10 - 12 dB is a realistic figure for a typical Mufax display.

System type (2)

In order to achieve reasonably reliable operation a signal to noise ratio of about 20 dB is required. This may be reduced at the expense of additional time and complexity, if computer based averaging techniques which are equivalent to line integration are implemented.

System type (3)

The Rangemeter requires a signal to noise ratio of about 12 dB to operate reliably.

Calculation of theoretical maximum operating range

The theoretical maximum operating range may be calculated by rearranging the sonar equation and calculating the range from the transmission loss.

$$TL = SL + DI - NL - S/N$$

System type (1)

TL = 93 dB ≋ 1400 m

System type (2)

TL = 70 dB ≋ 650 metres

System type (3)

TL = 102 dB ≋ 2400 m

Operating ranges obtained in field trials

The results given in Appendix 4 indicate that ranges in excess of 1000 m were possible using the Range Master system, and a Mufax display.

As shown in Appendix 5 satisfactory returns were obtained from 1200m, this is in satisfactory agreement with the theoretical 1400m range prediction for the system configuration.

No Range Master system coupled to a computer navigation suite has been tested by IOS(T).

The Rangemaster has only been used up to a maximum range of 1000 m, because longer ranges have never been required under normal operational situations. At this range the performance was satisfactory with no noticeable problems caused by a decreasing signal to noise ratio. In order to check the theoretical range of 2400 m, trials would have to be conducted in deeper water than the system is normally used, in order to prevent complex shallow water pulse propagation effects, which tend to give misleading results in shallow water at longer ranges.

URICK R J, (1976) "Principles of Underwater Sound"