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TESTING OF HIGH FREQUENCY SCANNING ARRAYS.

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1. Introduction.

During the development and manufacture of arrays the following tests may be of value in achieving the desired acoustic performance.

a. Admittance measurements.
b. Geometrical Measurements.
c. Beam Pattern Measurements.
d. Source Level Measurements.
e. Cross Talk Measurements.
f. Insulation Resistance measurement.
g. Receiving Sensitivity Calibration.

These tests may serve two purposes, firstly they provide monitoring information to ensure successful manufacture and secondly that the completed array will meet the design specification.

The following comments about each of these test procedures are related to the manufacture of a 75 channel 300KHz receiving array and its associated curved transmitting array.

2. Test Procedures.

a. Admittance Measurements.

The need to select elements from a manufacturer's batch requires that all elements are individually tested over a period to establish their centre frequency, internal losses and their ageing characteristics. During manufacture each element in the array is retested after mounting and again after the application of the solid front window. This procedure ensures a uniform performance before the construction has proceeded to a point where an element changing operation becomes expensive. Further admittance measurements are made on individual elements when water loaded before and after cabling, and in the case of the transmitter with all the elements paralleled together.

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2. b. Geometrical Measurements.

During prototype manufacture measurements are made of the relative positions of the elements when mounted to ensure that the backing material provides the required profile for the array. This test has been particularly significant during the construction of the curved transmitter array where the backing material is machined in two steps and there are difficulties in ensuring that the two halves of the array are correctly aligned.

c. Beam Pattern Measurements.

The receiving array under consideration has a half power beamwidth of about ½ ^{o} . This narrow beamwidth requires a very stable testing facility with adequate range capacity, and to avoid these requirements the array is normally tested in sections. The recorded results are used to calculate the directivity index of the array sections for use in the source level calculations. The level of the diffraction secondary lobes of the multi element array is a useful index of the accuracy of the positioning of the individual elements.

d. Source Level Measurements.

A calibrated hydrophone is required for this measurement. The measured source level may be used to confirm the efficiency of an array if the directivity index and the admittance of the array are known. If the measured source level differs significantly from the level calculated from a knowledge of the input power, directivity index and array efficiency (computed from the admittance measurements) the dis crepancy may be due to errors in some or all of the following; Hydrophone Calibration, Directivity Index, Admittance Measurements, Power Measurements , Other sources of loss (ie. Acoustic Windows,Water Absorption , Non Linear Effect and cavitation).

e. Cross Talk Measurements.

Low cross talk between elements of a multi element array ensures high efficiency in electro - acoustic conversion and the maintenance of resolution in scanned receivers. Two methods of cross talk measurement are used , either individual elements are

excited and the cross talk level on the remaining elements measured, or all elements but one are excited and the received level on the remaining element recorded.
High levels of crosstalk observed during manufacture generally indicate the pres ence of foreign bodies between elements.

f. Insulation Resistance.

This test is used to ensure that adjacent element wiring is well insulated from that of its neighbours and that the connections to the ceramic surfaces are sound. Tests on the cable tails before water immersion provide a useful reference resistance value for future reference when water ingress into the cable is suspected. A portable capacitance meter has also proved very useful during field trials when the failure of a few elements is suspected and the capacitance of the element at the end of 50 metres of cable can be detected.

g. Receiver Sensitivity.

This test is generally a confirmation exercise only , and either a known source level is transmitted towards the array or a calibrated hydrophone is positioned adjacent to the array.

3. Field Testing of Multichannel Arrays.

With the advent of "portable scanning sonars" the problem of faultfinding on multichannel arrays on board ships with minimal test equipment and untrained staff has arisen , not necessarily because of array failure but the incorrect operation of the system means that each part of the system has to be tested for elimination purposes. The tests outlined in f. above are used to search for obvious faults, but in order to provide a convincing result of satisfactory array operation a small transmitter is passed along the receiver acoustic window exciting each element in turn and a simple switch box connected to the cable tail connects each element to an oscilloscope or similar instrument.
The arrays in use are of a completely sealed type and if there is no obvious cause of failure the arrays are returned to the

manufacturer for a full investigation. One such investigation was carried out on a receiver array which'suddenly ' failed during operation. There was no outward sign of damage and the tests revealed that 63 of the 75 elements were disconnected from their cables. The DC tests on the cables suggested that there was a problem near to the array case. Since the array case has to be unsealed to replace the cables this was done and the terminations were uncovered. They all appeared in perfect order and it was subsequently found that 63 of the 75 cables had been completely parted about 15cm from the array casing. Although no confirmation has been forthcoming the evidence suggests that the cable suffered a sharp angled pull most probably from the hydraulic training gear. The cable was reterminated and the array back in operation within four days.

4. Discrepancies in Source Level Measurements.

In section 2d it is suggested that the source level measurement should confirm the efficiency of an array by taking account of the power input and making due allowance for the various sources of power loss. Confirmation of the acoustic power in the water is of considerable importance in terms of meeting design specifications. The system under consideration in this paper has a transmitter electronics package capable of supplying in excess of 20 KW of pulse power. The large array required to handle this amount of power together with the electronics form a considerable portion of the material costs.

The following results are presented to illustrate the difficulty in achieving repeatable results when attempting to confirm array efficiency by source level measurement.
The array under test was a fifteen element section of the receiver array which has half power beamwidths of $1.8^{\circ} \times 30^{\circ}$ and is therefore easy to align for short range measurements. Its theorectical directivity index (by full integration) is 32.7dB. The directivity index obtained from a beam pattern measurement

was 32 dB. Using a hydrophone calibrated by the reciprocity method at the frequency of interest (300KHz) repeated efforts to obtain a directivity index yielded an average value of 24 dB. Assuming that the directivity was in fact 32 dB it appears that the array had an efficiency of about 15%. The admittance circle diagrams suggested an efficiency of about 90%. Certain allowances may be made for measurement inaccuracies, losses in acoustic window materials and misalignment of the array and the hydrophone, and a worst case allowance may be of the order of 3 dB. This leaves a discrepancy of 5dB, between the electrical power supplied to the array and the acoustic power measured in the water by the hydrophone. The above experiment was carried out at many values of excitation voltage up to a maximum of 550 volts p - p . The impedance of the array was 60 ohms resistive yielding a RMS power into the array of 520 watts. Tests to confirm the linearity of the source level were carried out between excitation voltages of 100 mV p-p up to 1400 V p-p. At 1500 V p-p and above non linearity occurs and the elements fracture at typically 1800 V p-p . Apart from this non linearity which is presumable due to excess strain no evidence of non linear operation either of the element or of the acoustic waves in the water was observed.

If the array efficiency was indeed low then the power not converted to acoustic waves would presumably appear as heat. To test this theory a resistor and an element were placed in an insulated oil bath and each excited in turn with the voltage required to produce similar heat generation. The rise in temperature due to the resistors heat generation was duly observed but the rise in temperature due to the element was commensurate with its expected high electro acoustic efficiency.

Since this result confirmed the admittance measurement efficiency calculation, it appears that the hydrophone calibration may have been in error. To test the calibration a pressure balance was used. A 4cm x 4cm plate was suspended on the end of an 80 cm pole pivoted at the top and a laser beam was deflected by a mirror mounted at the top end of the pole. The laser beam deflection was measured on a wall chart about 8 metres from the mirror and 1cm deflection of the beam corresponded to a force of 10^{-5} newtons applied to the plate. After a series of experiments at different excitation voltages and duty cycles the pressure balance measurements yielded a directivity index for the array under test of 29 dB. This result is more realistic since the 3dB discrepancy which remains includes 1dB due to the array efficiency and the remainder of 2 dB represents an acceptable experimental error, for measurements of this type.

The inaccurate reciprocity calibration procedure is still under investigation.

5. The electrical tuning of high frequency arrays.

A key feature in achieving high acoustic power is the correct matching of the transmitting array to the electronics. Although the lengths of cable between the electronics and the array are comparatively short (about 50 metres), at 300 kHz this cable is one eighth of a wavelength long. If the array is matched to the cable impedance (typically 50 ohms), at the array end of the cable, and tuned to look purely resistive, then, at the end of 50 metres of cable, the normally expected orientation of the admittance circle is rotated by about 180^{o} and the apparent resonant frequency is 10 to 15 KHz from the mechanical resonance of the array. Apart from yielding the incorrect value of impedance for all but the frequency at which the array is resistive and of the same value as the cable characteristic impedance, the frequency response is very assymetrical and gives very poor pulse response. Correct tuning has been achieved by inserting a transformer between the cable and the array and using a series capacitor and shunt inductor at the electronics end of the cable to achieve the correct orientation of the admittance circle and the correct value of admittance at mechanical resonance for maximum power transfer between the electronics and array. A full report on this work is in the course of preparation.