Appendix B

VOLTAGE COUPLING LOSS MEASUREMENT

When a hydrophone containing a preamplifier or other kind of associated network is calibrated, a choice must be made as to where the hydrophone output terminal points are. That is, where are the terminals across which the open-circuit voltage is to be measured? If the terminal points are selected at the end of the cable, then the preamplifier and the cable become an integral part of the hydrophone and affect the hydrophone sensitivity. If the terminal points are selected as close as possible to the generator (e.g., electrodes of a high-impedance piezoelectric element) then a measurement of the hydrophone voltage coupling loss becomes necessary.

Hydrophone voltage coupling loss is defined as the ratio of the open-circuit voltage of the hydrophone generator (usually a piezoelectric element) to the open-circuit voltage at the output of the preamplifier and cable or other type of associated network. Note that with this definition a true loss is a number greater than one or is a positive number of decibels.

The coupling loss and its measurement is theoretically straightforward. In practice, however, the theoretically assumed conditions and the measurement are subject to several types of subtle errors that make the measurement difficult and, in some circumstances, impossible. Although we are concerned primarily with a hydrophone that contains a preamplifier, the theory and practice here apply equally well to any passive hydrophone and the first amplifier in the voltage-measuring system.

The coupling loss is the sum of two effects. One is the gain or loss of the preamplifier itself. The other is the voltage loss due to the fact that the preamplifier does not have an infinite input impedance and, consequently, the voltage across the preamplifier input is not a true open-circuit voltage. Figure B1 is a schematic diagram of a hydrophone with a preamplifier. The piezoelectric generator is represented according to Thevenin's Theorem by the generator open-circuit e_{oc} in series with the generator impedance Z_g. The amplifier input impedance is Z_a. The amplifier input voltage e_a will always be measurably less than e_{oc}, unless $Z_a >> Z_g$. Since Z_g often is many megohms, the assumption $Z_a >> Z_g$ generally is not valid, and the voltage e_{oc} is attenuated before it is applied to the preamplifier.

The coupling loss is, by definition, the ratio e_{oc}/e_o. The loss is measured by inserting a calibration signal in series with both the piezoelectric generator and the preamplifier input in the manner shown in Fig. B1. The calibration resistor is kept small (typically 10 Ω) so that it does not measurably attenuate the voltage e_{oc} and so that the calibration input voltage e_i is essentially an open-circuit voltage across the resistor. Then e_i can simulate e_{oc}. That is, the input/output ratios e_{oc}/e_o and e_i/e_o are the same.

The voltage e_i is measured across a second external 10-Ω resistor as e_i'. This procedure is valid, if the shunt capacitance of the cable shown by the dashed symbols in Fig. B1 has an impedance much larger than 10 Ω. Alternatively, the voltage e_i'' in Fig. B1 can be used if the series inductance and resistance of the cable can be neglected. If the cable is very long (e.g., more than about 100 ft) neither e_i' nor e_i'' is the same as e_i, and the measurement becomes impractical. In such a case, end-of-cable calibrations are used.

Designers and users sometimes are tempted to use one conductor to serve as the low-potential or ground conductor for both the calibration circuit and the preamplifier output circuit. This is a mistake, since the two circuits then are coupled by the common small but finite impedance of the common conductor. Signals from the calibrator circuit are induced into the preamplifier output circuit, bypassing the preamplifier.

A common source of trouble in coupling measurements is the electrical grounding conditions. There are no simple rules to avoid such trouble except that the user should be alert to circuit complications due to stray impedance and multiple ground points. Crystal electrodes, cable shields and the transducer housing all have measurable capacitance to ground or to the water medium. A single ground or zero potential point is difficult to achieve in practice. Fresh water is a much poorer conductor than salt water, and the electrical grounding conditions in the two media can be quite different. Figure B1 illustrates various stray impedances.

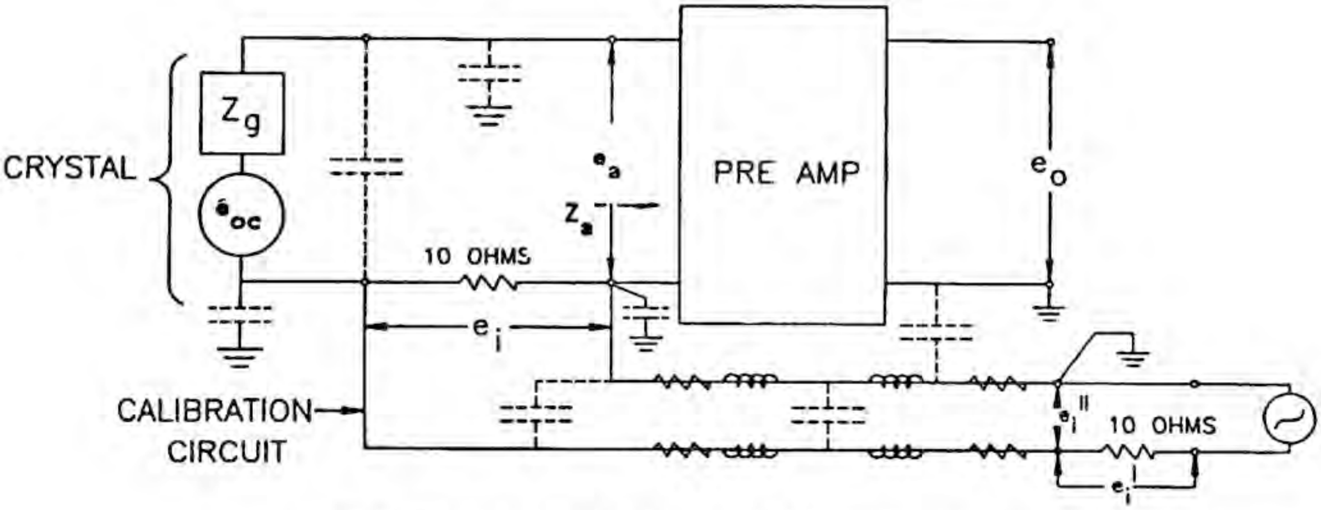

Fig B1 - Hydrophone circuit as represented by a Thevenin generator and a preamplifier. Stray impedances are shown in dashed lines.

Near resonance frequencies when the motional impedance of the piezoelectric generator is a significant part of Z_g, the acoustic load on the generator during the coupling loss measurement must be the same as that during the sensitivity measurement.