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NON-CONTACT THROUGH-THE-ICE SOUNDING OF ARCTIC WATERS

TELESONDAGE DES MERS ARCTIQUES

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SUMMARY

The sounding of Canadian Arctic waters presents the special problem that these waters are often covered with ice eleven or twelve months per year. Often thus, through-the-ice sounding has to be employed to chart the depths of these waters. Current methods consist in using an electro-acoustical transducer in contact with the (often snow-covered) sea ice, more or less as a conventional echo-sounder. The complete system as it is presently used is deployable from a small helicopter or tracked vehicle.

This method has the drawback of yielding a relatively slow mapping rate as the helicopter has to land the and the tracked vehicle has to stop for each sounding point.

Under a contract with the Canadian Hydrographic Service (Department of Fisheries and Oceans), the authors are developing a through-the-ice sounding system that is capable of being operated from a helicopter in flight. Basically, the system performs acoustic sounding, with the excitation and receiving functions being separated and somewhat unconventional.

The transmission of an acoustic impulse in the water results from the impact on the ice of a high speed bullet shot from the helicopter; the reception of the pulse reflected by the sea floor is performed by means of a specially designed microphone system flown above the ice.

The water depth can be deduced from the echo delay and the other relevant parameters.

The paper outlines the current state of this research and development effort. Examples of the impact acoustic pulse generation are presented. Also, experimental results, obtained in the Arctic in May 1984 are presented to demonstrate the feasibility of the proposed sounding concept. These results include airborne echoes obtained from water depths of the order of thirty meters.

RESUME

Le sondage des mers arctiques présente une difficulté spécifique en raison de la banquise qui recouvre ces mers, souvent toute l'année durant. Souvent donc, la profondeur de ces eaux doit être mesurée à travers la glace. Pour ce faire, on utilise généralement un système semblable en principe à un écho-sondeur classique où le transducteur est mis en contact avec la glace (souvent recouverte de neige) plutôt qu'avec l'eau. Tel qu'il est utilisé actuellement, ce système peut être mis en oeuvre à partir d'un véhicule à chenilles ou d'un hélicoptère.

Cette méthode présente le désavantage d'être asser lente, car l'hélicoptère ou le véhicule à chenilles doivent s'arrêter à chaque point sondé.

Le travail décrit dans ce papier (effectué pour le compte du service hydrographique canadien, ministere des pêches et océans) vise à la mise au point d'un système de sondage à travers la glace, qui puisse être mis en oeuvre à partir d'un hélicoptère en vol.

Essentiellement, on effectue un sondage acoustique, mais l'émission et la réception sont réalisées par des procédés relativement originaux.

L'impact sur la glace d'une balle de fusil tirée à partir de l'hélicoptère produit une implusion acoustique dans l'eau; l'écho de cette impulsion, réflétée par le fond de la mer, est reçu dans l'air par le moyen d'un système microphonique suspendu à partir de l'hélicoptère.

La profondeur de l'eau est calculée à partir du délai de l'écho et des autres paramètres de la mesure.

Le papier décrit plusieurs aspects de la mise au point de ce système. Ou montre notamment des exemples d'impulsions acoustiques produites par les impacts sur la glace, de même que des résultats expérimentaux obtenus dans l'Artcique en mai 1984 où des échos aériens sont obtenus par la méthode proposée par des fonds de l'ordre de trente mètres.

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1.0 INTRODUCTION

The sounding of Canadian Arctic waters presents the special problem that these waters, being often covered by ice a large portion of the year are not readily accessible to hydrographic ships. For this reason, the Canadian Hydrographic Service (Department of Fisheries and Oceans) which sponsors the work described here, is actively pursuing research and development relating to sounding in these special conditions.

For example, current over-ice hydrographic surveys are carried out from a helicopter (Bell 206-B) that is instrumented with a special echo-sounding device. To perform one sounding, the helicopter first lands, then an electro-acoustic transducer, carried by a mechanical ram outside the helicopter is applied against the (often snow-covered) ice. The system then measures the delay between the transmission of an acoustic impulse and the reception of an echo, which is a measure of the water depth. This, and similar systems feature relatively slow mapping rates, as the vehicle needs to stop at each sounding point.

In order to circumvent this problem, the authors have been developing a method and a prototype that permits continuous sounding of ice-covered waters from a helicopter in flight. This method is outlined in the following section, whereas subsequent sections discuss current results.

2.0 GENERAL OUTLINE OF THE METHOD

The principle of the proposed sounding method is best explained with reference to figure 1. It is seen that an acoustic impulse 17 is produced in the ice 13 and propagated into the water 14 by the effect of the impact of a bullet 15 which is shot from a gun 12 carried by the helicopter. The impulse so produced travels through the ice (of thickness T, generally not exceeding 2 or 3 meters) and then through the water, where is reflects from the sea floor; after travelling through the water and the ice a second time, it is transmitted into the air where it is received by a microphonic device 30 suspended from the helicopter.

The water depth can be calculated on the basis of the delay between transmission of the pulse and reception of the bottom echo, the speed of sound in air, ice and water, as well as the geometry.

The performance of the sounding method outlined above depends, of course, on the performance of the various components of the system. Some of these are discussed below, in their present state of development.

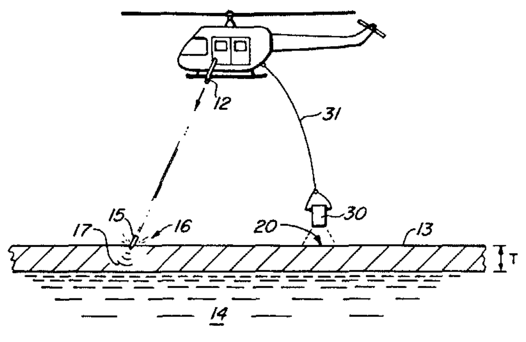

FIGURE 1: Proposed sounding method

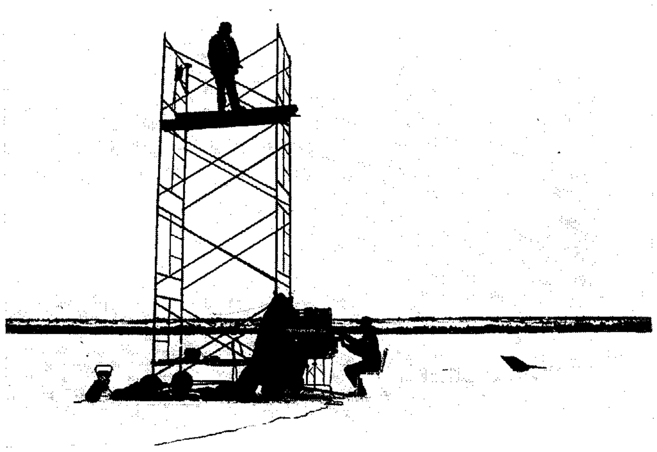

FIGURE 2: Ottawa River trials (February 1984)

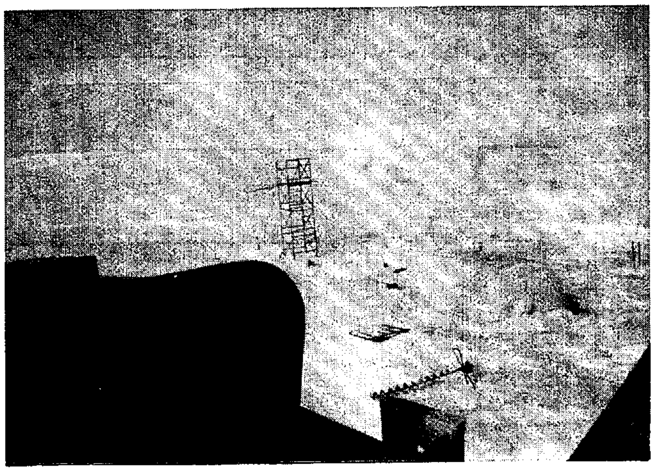

FIGURE 3: Arctic trials (May 1984)

3.0 EXPERIMENTS

Measurements relative to this project were carried out on the ice of Ottawa River in February 1984 and 1985 and in the high Arctic (near Resolute Bay, NWT) in May 1984. Figure 2 illustrates the experimental conditions on the Ottawa River, and figure 3 shows the installations used in the Arctic in 1984.

Acoustic pressure levels were received by (B&K 8103) hydrophones suspended in the water through augered holes as well as by a (B&K 4921) microphone placed at various heights above the ice. The various bullets used were shot at the ice either from the elevated platform seen on figures 2 and 3 or from the ice level.

In the results discussed here, no measurements were carried out from a helicopter. This is planned for the 1985 field season.

4.0 SOUND GENERATION BY BULLETS IMPACTING THE ICE

A number of experiments were carried out to measure the sound pressure levels, as well as the spatial and spectral characteristics of the noise resulting from the impact of the bullets onto the ice. The sound pressure levels were measured by hydrophones suspended at various depths below the ice surface, and were then corrected for spherical spreading to refer them to one meter distance from the point of impact. This correction, which does not take into account the diffraction between ice and water, is nonetheless approximately valid when the depth of the hydrophone is several times the ice thickness, a condition which was verified in practice.

For the purpose of the experiments described here, bullets of .22, .3 and .46 calibres were used. Although commercial (military and hunting) ammunition was used, most of the work was carried out with specially developed bullets and loads.

The observations made are summarized below.

(i) Pulse Shape

The pulse shapes that were obtained in most conditions are surprisingly "clean" and repeatable. Figure 4 shows as an example the pressure signatures (referenced to one meter range) obtained with specially designed 140 grain bullets of calibre .30. These signatures were measured under two meter Arctic ice with a hydrophone at a depth of 18 m.

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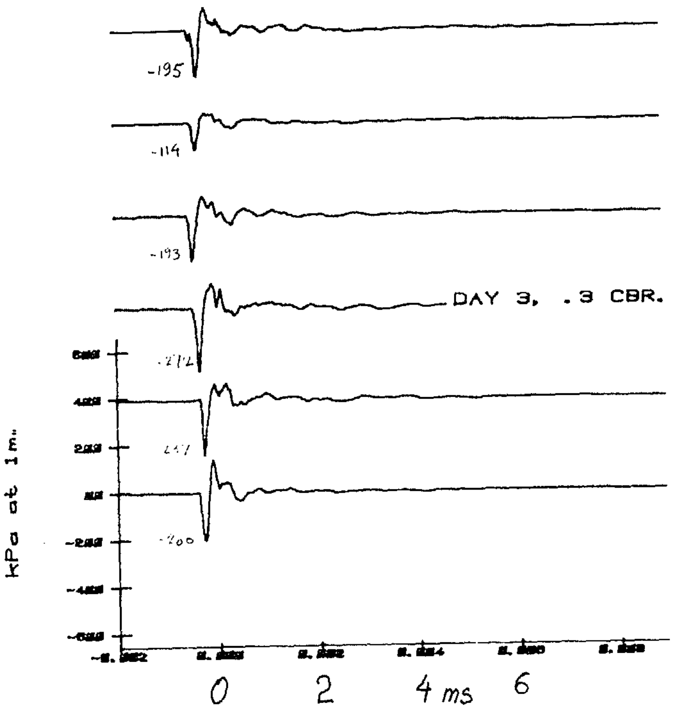

FIGURE 4: Consecutive shots of a .3 calibre 140 grain bullets

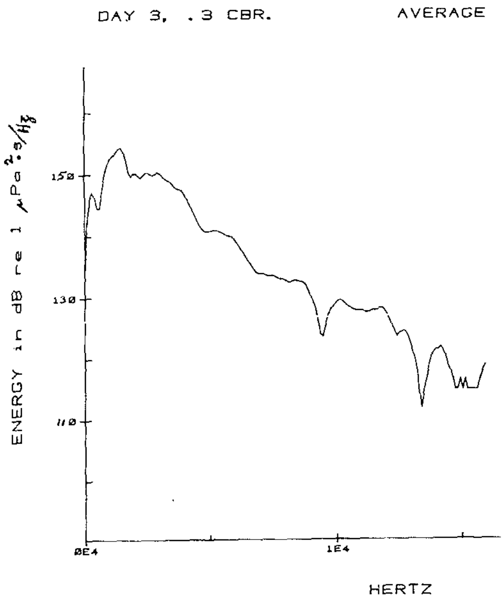

FIGURE 5: Average energy spectral level of shots of figure 4

(ii) Peak sound pressure levels, in excess of 235 dB Re 1μPa at 1 m were measured for the part below 20 kHz. A small part of the energy generated by the impact is also contained above that frequency. The average energy spectrum level of the shots of figure 4 is presented in figure 5 as an example.

(iii) It was also observed that the peak pressure generated in the water is generally an increasing function of the bullet speed, whereas it does not depend strongly on the mass of the bullet. This observation was made on the basis of preliminary results obtained with .3 and .46 calibre bullets; further experiments and theoretical and data analysis are being presently carried out in order to refine this observation, which does not appear to hold for some of the .22 ammunition tested most recently.

(iv) Beam Pattern Effects

It was observed that the energy radiated under the water as a result of the bullet impact is confined in a beam 25° or 30° wide. This is a consequence of the refraction of the acoustic energy at the ice-water interface. This effect is illustrated in figure 6. The effect of the off-axis angle on the pulse shape is indicated in figure 7.

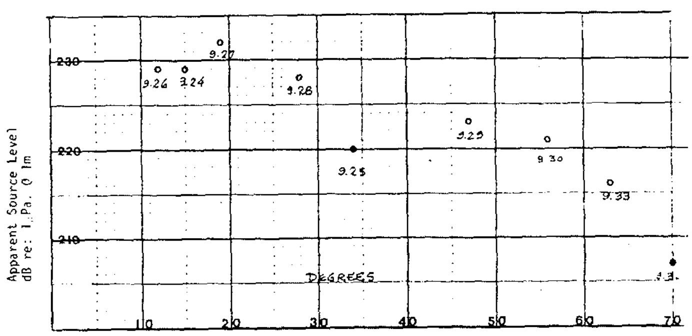

FIGURE 6: Beam pattern of a .3 calibre bullet

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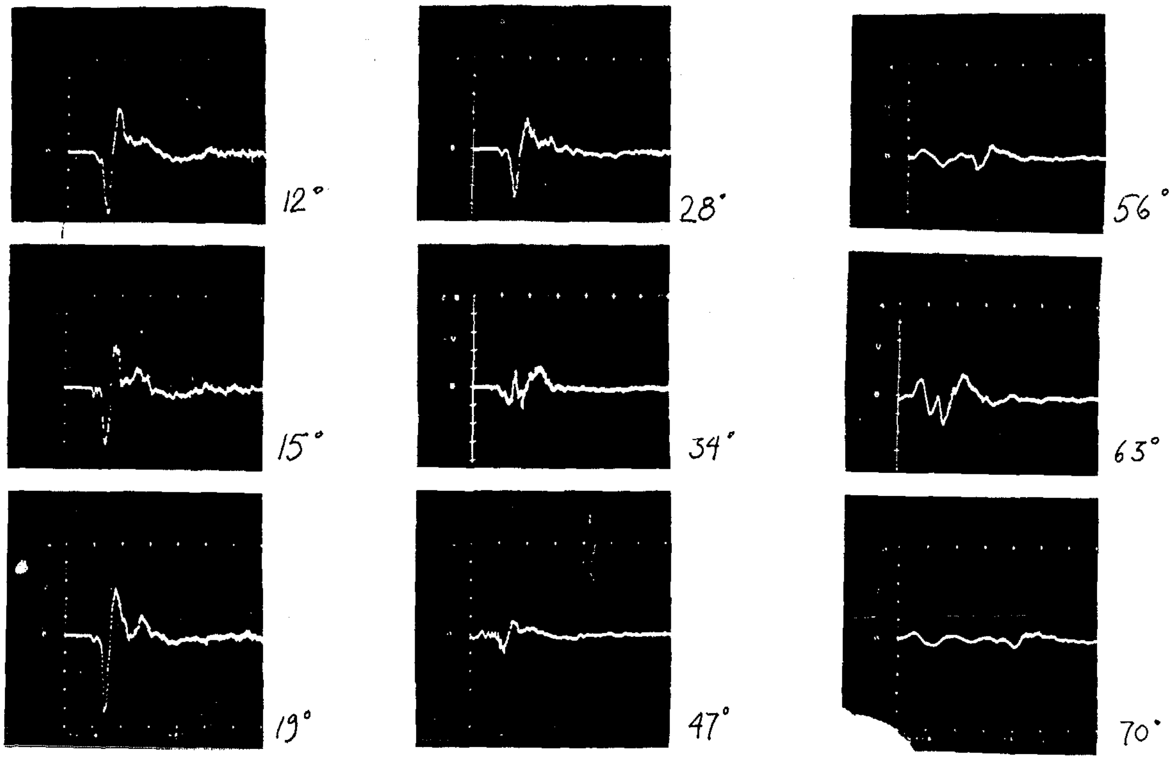


FIGURE 7: Pulse Shapes

5.0 AIRBORNE ECHOES

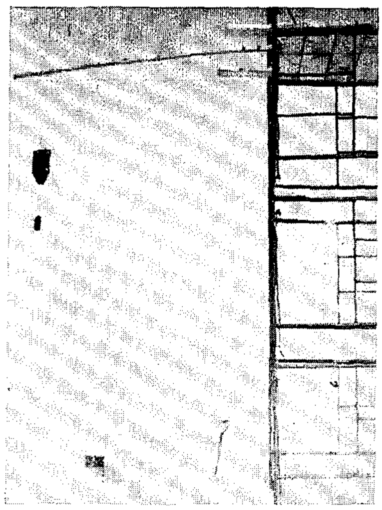
During the May 1984 Arctic Trials, echoes were obtained from the sea floor in a water depth of 29 m. The ice was about 2 meters thick, and was covered by 10 to 15 cm of snow.

The bullets were shot into the ice from the surface, whereas the reception was made by a microphone unit suspended at heights up to 2.6 m on a scaffolding (see figures 8 and 9). The data acquisition was performed by an Analogic Data 6000 signal analyzer. The sound pressure level was monitored by a hydrophone located on essentially the vertical of the microphone, one meter below the bottom of the ice.

In these tests, the horizontal distance between the point of impact and the receiving microphone was chosen in order to both satisfy the beam condition 4(iv) and to have the (airborne) muzzle blast arriving to the microphone after the sea floor echo. The constraints resulted in a shot-microphone distance of the order of 30 meters.

FIGURE 8: Transmission in the depth measurement experiment

FIGURE 9: Reception in the depth measurement experiment



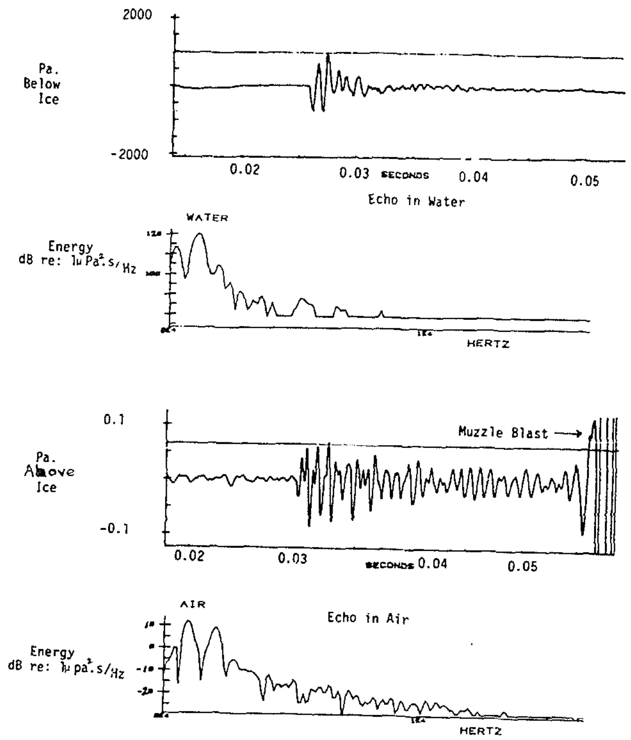


FIGURE 10: Typical waterborne and airborne echoes.

Figure 10 exemplifies the type of returns which were obtained. All the returns are high-pass filtered above 500 Hz. It should be observed that the air echo has a quasi-harmonic character: this is due to the band-pass characteristics of the ice sheet resonating in the thickness mode coupled to the low-pass effect of the overlying snow.

6.0 CONCLUSIONS

In the preceding discussion, several aspects of the development work for the non-contact through-the-ice sounding system represented in figure 1 have been covered. Based on data available at the time of writing, it appears that the system should be capable of sounding down to depths of several hundred meter.

Current work includes testing an operational prototype from a flying helicopter and improving the helicopter noise rejection from the received signal.

7.0 ACKNOWLEDGEMENTS

This work would have been impossible without the logistic support offered by the Polar Continental Shelf Project (Department of Energy, Mines and Resources). Also, the support of Bryan White and George MacDonald, project scientific authorities, is gratefully acknowledged. Finally, many thanks to the members of the Hunters and Trappers Association of Resolute Bay (N.W.T.) for their interest in-and help with the project.