ACTIVE SONAR DETECTION OF ICEBERGS

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RESUME

On présente des résultats d'une campagne de mesures en sonar actif des propriétés (indice, durée) des échos d'icebergs observés dans l'Arctique canadien durant l'été 1986 en mer ouverte et dans la banquise. Un modèle empirique rendant compte de ces propriétés est proposé. L'importance de ces résultats résulte de ce qu'ils peuvent servir de base à la définition d'un sonar actif conçu spécialement pour la détection d'icebergs.

ABSTRACT

The paper gives results of field measurements of active target strength and echo duration made on icebergs in open and ice-covered waters in the Canadian Arctic during the summer of 1986. A plausible phenomenological model relating average values for these quantities to the estimated mass of the berg is proposed. These results are a basis for the design of an active sonar dedicated to iceberg detection.

INTRODUCTION

Safe navigation in arctic waters has always presented a major problem to mariners. The presence of ice and icebergs demand the utmost vigilance on the part of the ship's personnel. In addition to visual detection, radar has been the traditional method of detecting obstacles at sea. Radar systems have reached a relatively sophisticated stage but have certain limitations with respect to small targets, weather and sea conditions. As regards icebergs, approximately 9/10 of their mass is below the water line and thus, invisible to radar. Other circumstances (slope, size, water cover, clutter) may result in the above-water part of the iceberg to be practically undetectable to radar.

Sonar can be considered as a method complementary to radar for iceberg detection for the following reasons:

(i) Sonar operates within a communication channel which is totally separate from marine radar.

(ii) The major part of an iceberg is below the water line, and potentially a better target for remote detection using sonar.

However, the use of the sonar in this role is not without its own problems, as acoustic detection of underwater targets is dependent on background noise, propagation, target strength and reverberation parameters. Little knowledge is available in the public domain about some of these parameters.

As a contribution to the solution of these problems, the work described in this paper is aimed at obtaining field measurements of the acoustic target strength of icebergs. The acoustic data was acquired during field tests conducted from the M.V. Arctic in Lancaster Sound, Baffin Bay and Davis Strait during the summer of 1986 (see Figure 1) using a specially-calibrated commercial sonar.

Propagation, reverberation, self-noise and ambient noise were also measured on this occasion, but the present paper concentrates on properties of the iceberg echoes.

ICEBERGS AND THEIR ACOUSTIC TARGET STRENGTH

Icebergs, as opposed to sea ice, originate from land glaciers, most of which are on the west and south coasts of Greenland. They come in a wide variety of shapes and sizes, depending on their calving and melting history. Melting results in icebergs periodically becoming unstable, rolling or breaking into smaller pieces.

Sizes vary from a few meters to a few hundred meters, with above-water heights in excess of 70 meters and keel depths in excess of 200 meters, with a few tens of meters being typical. Their shapes are very varied: they can be classified as Block and Tabular, the least eroded shapes, or Drydock, Dome or Pinacled which are more eroded. Bergy bits and growlers are smaller pieces of glacial ice of typical sizes ranging from that of a small cottage to that of a grand piano.

When icebergs (as well as any other sonar target) are insonified, they scatter a portion of the acoustic energy incident upon them, because of the ice being characterized by an acoustic impedance some two times larger than that of water. The effectiveness with which icebergs backscatter acoustic energy can be characterized (see Urick, 1982) in the far field by their Target Strength, a quantity analogous to the radar cross-section and generally expressed in dB (0 dB characterizes the reflectivity of a perfectly reflecting sphere, large with respect to the wavelength, of two meters radius). The target strength of an object generally depends on the acoustic frequency, the geometry, the object shape, size and composition.

The target strength can be measured by comparing the acoustic energy received from a target to the energy transmitted by the sonar system in the target direction, taking into account the appropriate sonar and propagation parameters.

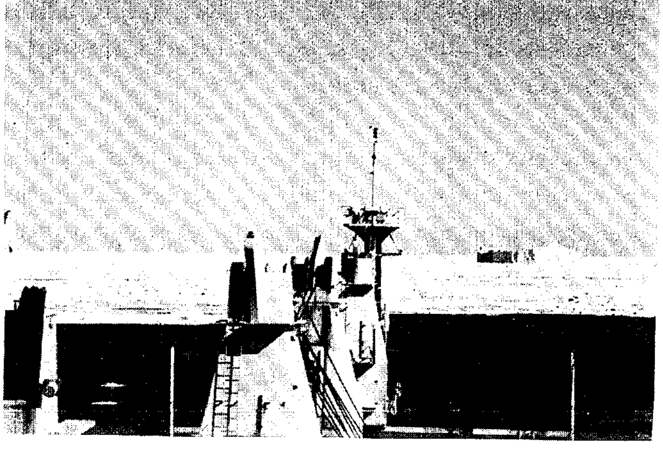


Figure 1 1986 trials

DATA COLLECTION AND ANALYSIS

The results herein described were obtained from data collected from the M.V. Arctic (of the Canarctic Shipping Company of Ottawa) in the summer of 1986 in the Lancaster Sound and Baffin Bay regions of the Canadian Arctic.

The sonar (see Figure 2) used was the CDS-40A made by C-Tech, Canada, a specially calibrated fish finding sonar system, operating at a frequency of 36 kHz with pulse durations ranging from 1 to 16 ms, depending on the range scale selected. This sonar offers, in addition to a PPI display, an audio steerable channel of a combined transmit/receive beamwidth of 12° x 16° (vertical x horizontal). The sonar transducer was deployed through a gate valve in the hull of the M.V. Arctic at a depth of eleven meters. Echo data was digitized and also recorded on magnetic tape for back-up.

Data was obtained from a variety of iceberg targets at ranges varying from 200 meters to some 2,000 meters, both in open water and in sea ice cover conditions. In the latter case, the sea ice cover varied from 1/10 to 10/10 first year ice, and had a thickness of 0.5 meters to 1.6 meters. During the data acquisition, the ship was stationary or drifting. The target aspect was randomized as much as possible, and a representative sample of iceberg shapes and sizes was covered. In total, data was obtained from eleven icebergs with a total of some 1,000 echoes.

During the tests, the acoustic propagation was characterized by a downward refracting sound speed profile in the open water tests (due to the near surface temperature gradient) and a slightly upwards refracting profile for under ice propagation.

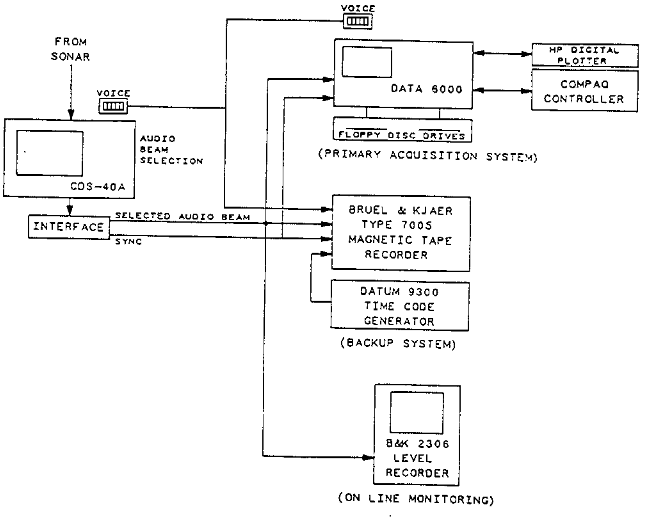
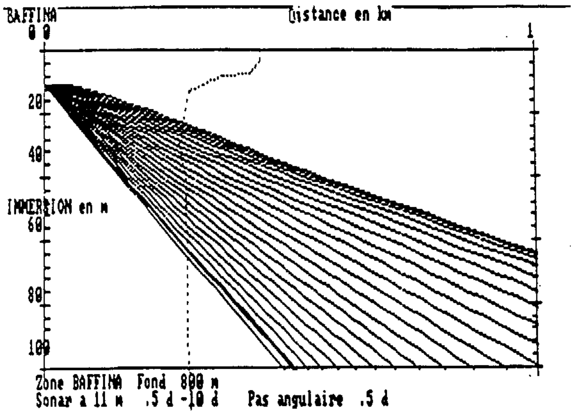


Figure 2 Data acquisition flowchart.



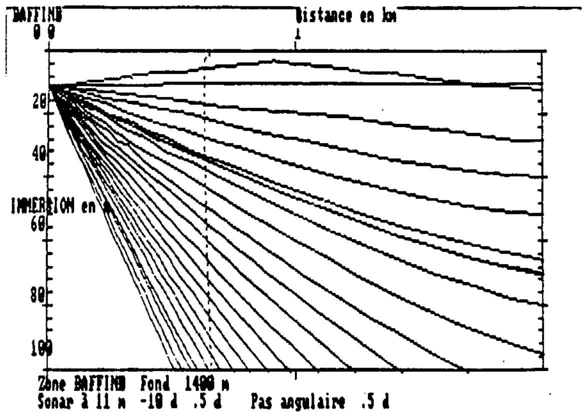


Figure 3 Representative ray-traces - BAFFIN A: Open Water, Downward Refracting; BAFFIN B: 10/10 Ice Cover, Slightly Upward Refracting.

Figure 3 gives representative examples of ray traces for the first (Baffin A) and the second (Baffin B) situation. Modelling of the ice-covered conditions revealed a propagation loss which was very close to that expected under spherical spreading plus absorption (see Urick, Ch. 5 and 6). On the other hand, the open water conditions are characterized by a close range "shadow zone" which is visible on Figure 3. However, and somewhat unexpectedly, the modelling of the propagation under these circumstances revealed that the shadow zone would not, in general, affect the measured target strength significantly, as long as a significant portion of the berg keel was insonified.

The target strength estimates were obtained by substituting the appropriate values (such as source level, received level, etc.) in the appropriate sonar equation. At the same time, peak target strength, defined here as the target strength of the 8 ms "slice" in the echo having the largest energy, was obtained in a similar manner. Finally, the echo duration was defined and measured as the time interval covering the central 80% of the echo energy.

RESULTS AND DISCUSSION

The observed mean target strength estimates are given in Figure 4 and the peak target strength estimates are given in Figure 5. In both cases they are seen to be a generally increasing function of the iceberg estimated mass. No systematic difference is apparent between open water and ice-locked bergs.

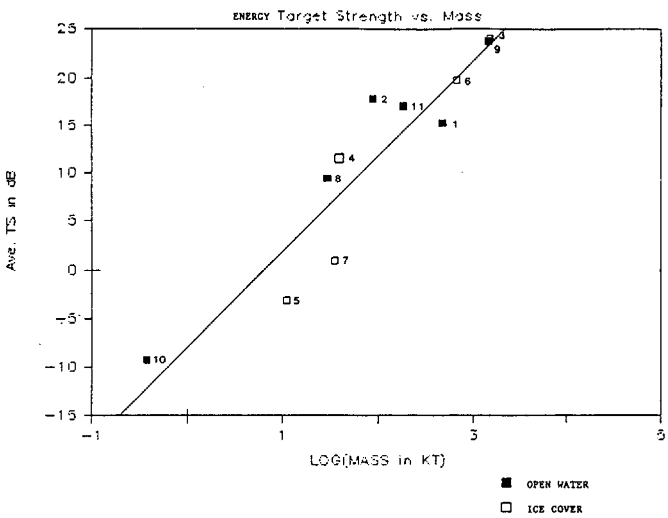


Figure 4 Measured target strength means as a function of estimated mass (36 kHz). Open squares - 1986 icebergs in ice cover Black squares - 1986 open water icebergs.

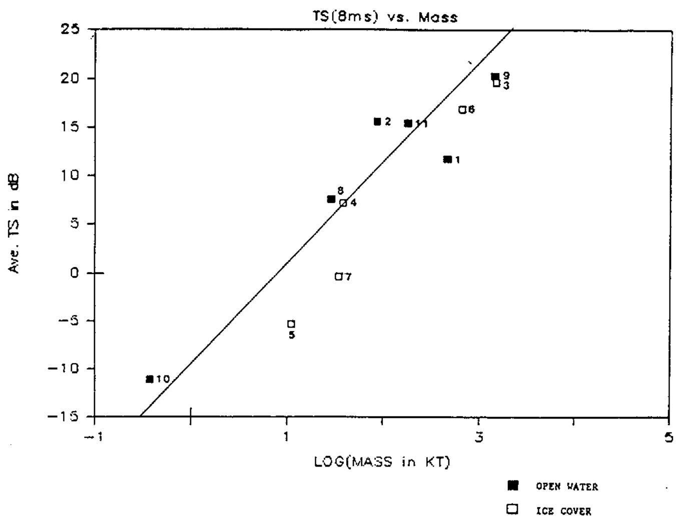


Figure 5 Peak target strength means as a function of estimated mass (36 kHz). (see Figure 3 for explanation of symbols)

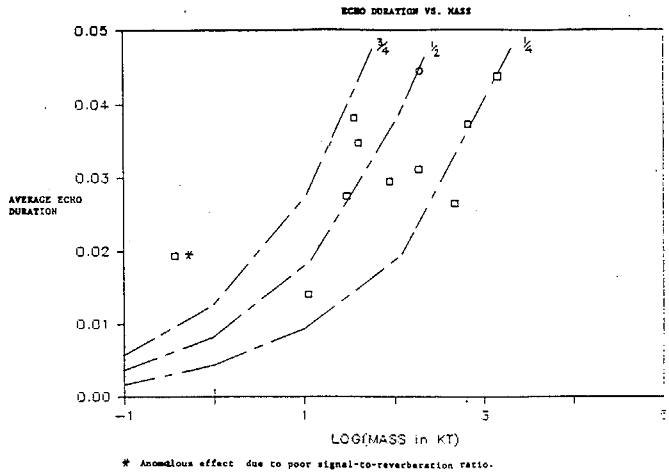


Figure 6 Average echo duration (ms) as a function of iceberg estimated mass. Echo durations corresponding to range extents of 1/4, 1/2, and 3/4 of the radius of an ice sphere of mass equivalent to that of the berg.

To model the average target strength (TS) of a berg, it is natural to try a smooth ice sphere with no internal reflections and of a mass (M) equivalent to that of the berg. This model can be expressed (Urick, Chapter 5) as:

$$TS = 6.7\ M - 18\ dB$$

where TS is expressed in dB (Re 1 m^2) and M is expressed in metric tonnes. This simple model, represented by the slant line on Figures 4 and 5 is seen to fit the data suprisingly well.

Comparison of the average target strength (Figure 4) of each berg corresponding with the average peak target strength (Figure 5) reveals that the latter is, in general, some 3 dB lower than the former. This indicates that, on average, half the echo energy is concentrated in an 8 ms time interval or, equivalently, that half the echo energy, on average, originates from a range slice some 6 meters in length.

Finally, Figure 6 gives the observed average echo duration observed during the trials.

Here again, the simplest model, that of an ice sphere of mass equivalent to that of the berg, is seen to provide a good indication for echo duration.

SIGNIFICANCE

The results outlined above are important in the context of the active acoustic detection of icebergs: they constitute, together with a description of the relevant environmental sonar quantities (propagation, self-noise, reverberation), the basis for a reasoned acoustic design for an iceberg detecting sonar, as well as for the a priori evaluation of its performance.

ACKNOWLEDGEMENTS

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REFERENCES

Urick, R.J., Principles of Underwater Sound (3rd Edition), McGraw Hill, 1982.