WAKE ACOUSTIC MEASUREMENTS AROUND A MANEUVERING SHIP

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1. INTRODUCTION

Ships are significant source of underwater sound, and their bubbly wakes generate significant disturbances to the near-surface underwater acoustic environment. Wakes are important because medium- to high-frequency acoustic systems, such as active sonars and underwater acoustic telemetry modems, are often operated from moving ships. Additionally, certain types of torpedoes exploit wakes to home in on a ship. The wake bubble properties while a ship is cruising on a straight course are reasonably well known (e.g. Trevorrow et al. 1994). However, ship maneuvers are thought to significantly increased wake depths and bubble densities. Since aggressive maneuvering is key to torpedo evasion, it is important to understand bubbly wake properties under these conditions.

In a collaboration between DRDC Atlantic and the Institute of Ocean Sciences, a set of four Broad-band Underwater Recording Buoys (BURBs) were built, providing a means for recording both underwater radiated noise and man-made acoustic transmissions. These self-contained buoys digitally record two hydrophone channels along with their differential GPS position. These buoys were built upon earlier systems for marine mammal monitoring on the B.C. coast (Vagle et al. 2004). In the case of ship trials with BURBs, GPS receivers on all surface craft provide sufficient information to calculate the ship's radiated source levels and acoustic propagation losses in the wake.

This work describes an initial underwater acoustic measurement trial conducted in April 2005 utilizing the *CCGS Vector* (40 m LOA) in Saanich Inlet, B.C. A variety of straight-line and maneuvering runs past the BURBs were made with the ship. Simultaneously, a separate acoustic source, transmitting 2 - 18 kHz LFM pulses, was utilized to probe the wake. This work focuses on the acoustic propagation measurements.

2. INSTRUMENTATION

The BURB system was composed of a set of four, identical self-contained buoys, each complete with the necessary hydrophones, cables, connectors, batteries, and GPS receivers. A detailed description of the BURBs is given in Trevorrow et al. 2005. Each buoy supported two independent hydrophone channels, each digitized at 40,000 samples per second with 16-bit resolution. Each BURB was equipped with a differential GPS receiver, providing position and time synchronization data at 1-s intervals. Mechanically, each buoy was constructed around a 20.3 cm diameter by 92 cm long pressure housing, with a 20-cm high by 61-cm diameter foam floatation. The total weight of each buoy (in air) was 47 kg. Connection to the internal computer for configuration and data download was provided through industry-standard VNC protocols over ethernet.

The BURB hydrophones were omni-directional, broad-band (10 Hz to >20 kHz) receivers with an integral 20 dB pre-amplifier. The receiver electronics were designed for a maximum sound pressure level (SPL) of approximately 185 dB re 1 μPa. Up to a 55 dB in data-adaptive gain was provided. In these trials the two hydrophones on each BURB were suspended at depths of 5 and 15 m.

For the pulse propagation tests, a Medium-Frequency Multi-Mode Pipe Projector (MF-MMPP, see Fleming 2003) was used to transmit 2 - 18 kHz x 10-ms duration LFM pulses twice per second. Using a portable audio amplifier, the nominal acoustic source level was 180 dB (re 1 μPa at 1 m) across this band. The transmit pulse was pre-compensated for the frequency response of the MF-MMPP. This transmitter was deployed at 5 m depth from a small boat, which was allowed to freely drift on the opposite side of the ship wake from the BURBs. Acoustic transmissions were started approximately 2 minutes before the ship run, and continued for approximately 10 minutes after the ship passage. Ship speed during the runs were between 10 and 12 knots. At the same time other small boats conducted CTD casts and HF echo-sounder transects across the wake.

3. RESULTS

Although detailed analysis of the pulse propagation data is still underway, some preliminary results are presented here to show typical features of the field data. The first stage of processing was to match-filter the received time-series, extracting peak power of the LFM pulses. Corrections for spherical spreading loss (absorption is negligible at these frequencies and ranges) were applied . Figures 1 and 2 show comparisons of the received pulse power at the two BURB hydrophones for a straight-line and 180° turning runs. Direct and surface-reflected arrivals were separated by less than 1 ms; bottom-reflected paths arrive more than 100 ms later. In both cases the separation of the source and BURB was approximately 200 m. There was a negligible near-surface sound-speed gradient during these trials, so refraction effects can be ignored.

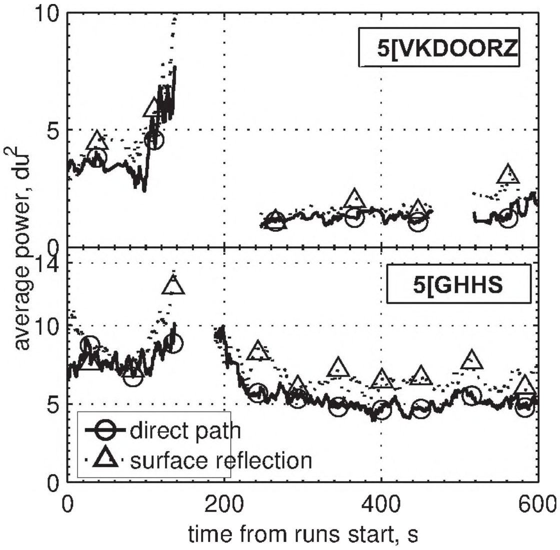

Figure 1. Matched-filter output power vs. time for LFM pulses received at 5 and 15 m depth for a straight-line ship run. Ship crosses line between source and receiver at time = 150 s.

In both cases the received pulse power prior to transit of the ship provided a baseline, which although different between the shallow and deep hydrophones, were similar for the two run types. In both cases there was a significant drop-out of roughly 60 to 100 s duration, coincident with the ship passing by the BURB. Analysis of the pulse signal-to-noise ratio reveals that this drop-out was simply due to the masking effect of the ship radiated noise.

In general the wake effects were more pronounced for the shallow receiver, where both the direct and surface-reflected paths were similar in length and had to traverse the bubbly wake, which extends downwards to approximately 2 ship drafts, or 10 m depth. In both cases the continued reception of pulses after the ship noise drop-out was delayed in the shallow hydrophone relative to the deep hydrophone, due to acoustic masking in the wake. This was particularly evident in the case shown in Fig. 2 with an additional drop-out of at least 3 minutes relative to the deeper hydrophone. In both figures the shallow hydrophone power after ship transit was attenuated by approximately a factor of 2 to 4, an effect clearly attributed to acoustic extinction within the wake.

As expected the masking effects for the deeper hydrophone were less pronounced. In Fig. 1 the direct path power was reduced to about 60% of its baseline state. In Fig. 2 there appeared to be no significant reduction in deep hydrophone power relative to the baseline.

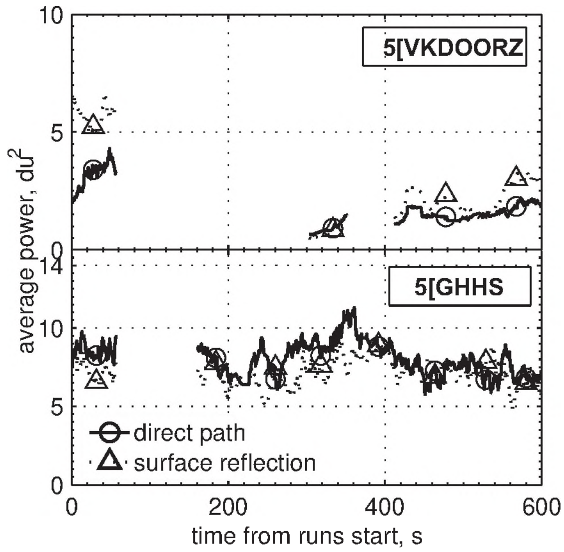

Figure 2. Matched-filter output power vs. time for LFM pulses received at 5 and 15 m depth for a 180° turn ship run. Ship crosses line between source and receiver at time = 90 s.

4. CONCLUSION

Significant acoustic dropouts due to the masking effects of ship radiated noise and the extinction effects from wake micro-bubbles were observed in near-surface pulse propagation, with the effects being more pronounced for shallow (< 5 m deep) acoustic paths. Maneuvering runs generally produced stronger wake acoustic extinction effects. Ongoing work will attempt to reconcile wake extinction losses described above with wake geometry and bubble densities that were measured by accompanying boats.

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