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First operation of AWI HEM-bird for sea-ice thickness sounding

A new, extremely small helicopter-borne frequency-domain electromagnetic induction sensor (HEM bird) has been developed by Alfred-Wegener-Institute (AWI), Aerodata Systems GmbH, Ferra Dynamics Inc., and K.-P. Sengpiel for extensive surveys of sea-ice thickness. In the summer of 2001 it has been successfully operated for the first time from the German research icebreaker Polarstern over sea ice in the central Arctic. This paper describes the system and shows some results of the first deployment.

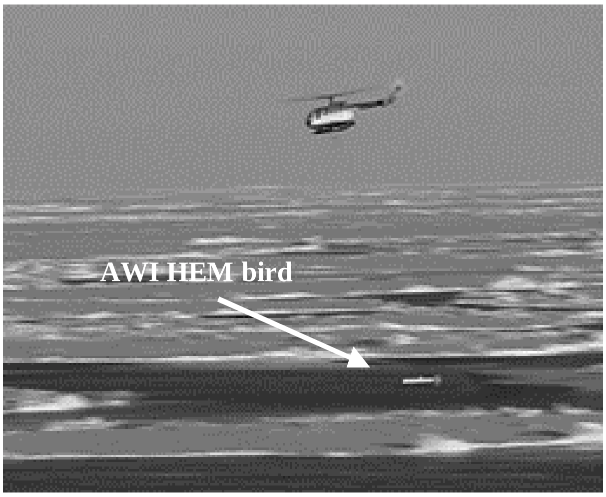

Figure 1: Operation of AWI HEM bird over Arctic sea ice

In the first phase of development, the bird is operated by helicopters based on icebreakers taking-off and landing from small helicopter-decks. Therefore, certain size and weight limitations had to be addressed during system design. The main parameters of the two-frequency system are summarized in the table below.

Table 1: Main characteristics of AWI frequency-domain HEM bird.

Length	3.4 m
Weight	103 kg
Frequency	3.68 kHz (f1)
	112 kHz (f2)
Coil separation	2.77 m (f1)
	2.05 m (f2)
Sampling frequency	10 Hz (100 Hz for laser altimeter)
Towing cable length	20 m
Operation speed	60-80 knots (30-40 m/s)
Operation altitude	10-15 m above ice surface

The bird shell with towing interface and tail unit is mechanically separated from a rigid tray inside the bird, carrying all coils and electronics. This gives the freedom to optimize design for best aerodynamic behavior and to reduce noise and drift for the coil system at the same time, both responsible for the overall performance of the small instrument.

As traditional HEM systems, the AWI bird consists of four coils per frequency, i.e. transmitting, receiving, bucking and calibration coils. All coils are rectangular, to take full advantage of the small space available and to enable exact calculation of magnetic flux through the coils.

A laser altimeter to measure bird altitude and a standard GPS system add to the EM components in the bird. The laser data are shown in real-time on an analog display in the cockpit as a navigational aid to the pilot, enabling to maintain bird heights of 10 to 15 m for profile lengths of 20 km without any problems.

Signal generation, acquisition, and processing are performed digitally within the bird, by means of a Windows-based PC. The bird computer is completely controllable through an Ethernet radio link from the main notebook computer operated in the helicopter. This notebook also stores the data in ASCII files. The fully digital system as well as the radio data transmission reduce noise to an absolute minimum. Thus, the 20 m long towing cable only serves as a power transmission line for the 350 W, 150 VDC supply which is transformed from the helicopter 28 V generator. This design actually makes the system completely platform-independent, enabling operation from different helicopters as well.

Take-off and landing proved to be unproblematic from the 15 by 15 m helicopter deck of RV Polarstern. Profiles were flown along equal-sided triangles, with 20 km long legs. While bird height on the legs was 10 to 15 m, heights of >50 m were chosen for the turns between legs. During those high altitude sections where the conductive ocean was no more visible to the system, nulling as well as phasing and calibration procedures were carried out with the internal calibration coils.

The paper addresses noise and drift properties of the system, which are shown to be sufficiently low to enable ice thickness to be determined with an accuracy of about 0.1 m. The EM response of the system depends on the bird height above the water surface under the ice. We will show examples of ice thickness profiles obtained by subtracting laser and EM derived distances to the water and ice surfaces. The half-space inversion of the measured secondary field strength (ppm's) into bird altitude above the conductive sea water is fairly simple, as en-route traverses of open water leads between ice floes provide extra calibration possibilities.

Overall, the system accuracy was evaluated by means of comparing coincident airborne and ground- or ship-based ice thickness profiles, as well as by comparing the general ice thickness distribution of the Transpolar Drift. In summary, operation of the HEM bird could clearly resolve all main thickness classes represented in the validation data sets, i.e. open water (thickness zero), first-year (1.2–1.5 m), and multiyear ice (2 m), see Figure 2.

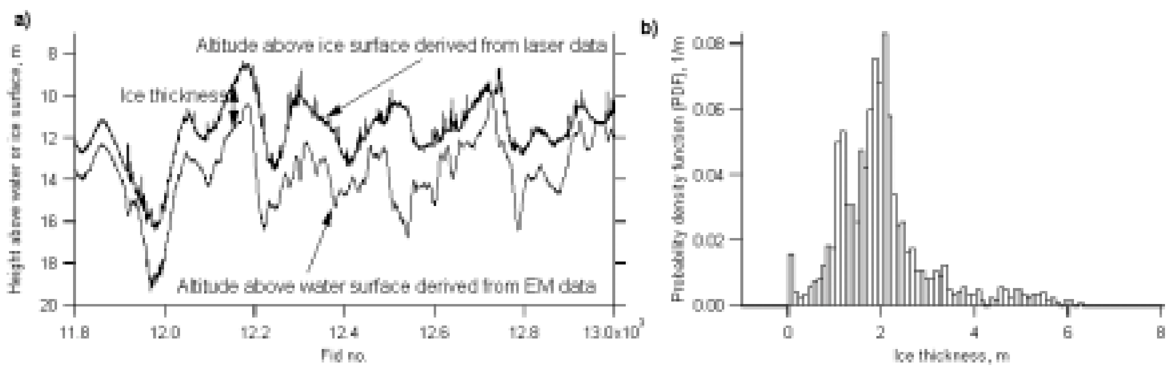

Figure 2: a) 6 km long profile of bird height above ice and sea-water surface (note that changes in bird altitude are generating the low frequency variations). b) Corresponding thickness distribution.