06-06 DEVELOPMENT AND TEST OF A FIXED WING AEM SEA ICE THICKNESS SOUNDER.

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Abstract

With five years of successful helicopter electromagnetic (HEM) sea ice thickness measurements the Alfred Wegener Institute (AWI) decided to construct an EM platform on a fixed wing aircraft in an attempt to overcome the helicopter flight range restrictions. The system operates in the frequency domain with 1990 Hz and a vertical coplanar coil configuration. The primary field voltage is electrically attenuated on the receiver coil which allows for increased amplification and resolution of the much smaller amplitude secondary field voltage. Before data are converted to ice thickness a correction for electronic drift and orientation effects is applied. First test flights show that the ice thickness accuracy of the fixed-wing system lies only between 1 m and 2.5 m in comparison to 0.1 m for the HEM systems. The lower accuracy is probably caused by electrical noise of the airplane engines and coil motion.

Introduction

Airborne frequency domain electromagnetic systems are a suitable tool for measuring sea ice thickness. Airborne electromagnetics (AEM) was first applied to sea ice in the 1980s by the US Army's Cold Regions Research and Engineering Laboratory (Kovacs et al., 1987). From 1991 to 1994 Multala et.al. (1996) used a fixed wing system for sea ice thickness mapping in the Baltic Sea. With the recent rapidly changing global climate, sea ice observations become more important. Therefore, in the 1990's, the Alfred Wegener Institut (AWI) started extensive EM sea ice thickness mapping in the Arctic, Antarctic and Baltic Sea. For this purpose, in 2001, two lightweight helicopter EM Birds were constructed, especially designed for ice breaker based operations (Haas et al., 2008[a]). Since then a couple of successful EM ice thickness campaigns were done using the two AWI 'mini' EM Birds (Haas et al., 2006, Haas et al. 2007, Haas et al., 2008[b], Pfaffling et al., 2007).

Sea ice thickness is an important parameter to understand and model processes driving the climate and oceanography of the polar regions. It influences the heat exchange between ocean and atmosphere, the drift of the sea ice, the light penetration into the ocean, the trafficability of the sea ice and last but not least it's interannual and decadal variability is an indicator for climate change. Therefore regular and wide area observations of regional sea ice thickness distribution are necessary. To overcome the limited range of helicopter measurements, the AWI constructed a new airplane based fixed wing EM system. Its' development status and results from first test flights will be presented on the AEM2008 conference.

EM ice thickness measurements differ from conventional exploration targets. Basically the EM signal measures the distance between instrument and ocean, which is the underside of the sea ice, while a laser altimeter measures the distance between instrument and surface of the sea ice. The difference of both altitudes is the ice thickness. It is a highly quantitative measurement which requires a vertical resolution of 0.1 m. This level of accuracy can be achieved due to the strong conductivity contrast between sea ice and ocean (~0.01 to ~3 S/m). The AWI EM Birds achieve this accuracy over level ice, a 1D situation. Since the sea ice thickness problem is not a multi layer problem, sea ice thickness measurements can be achieved with only one frequency. The sea ice layer is almost invisible for the EM signal. Furthermore noise and drift of a sea ice thickness system have to be very low.

Technical Parameters

The fixed wing system was constructed in order to mount it easily on the Dornier 228 polar airplane of the AWI. Two pylons, one under each wing, already existed on the airplane for installation of several other geophysical instruments, e.g. a ground penetrating radar. The most cost saving realization with respect to air certification and aerodynamics was a pair of vertical coplanar coils mounted below each of the pylons, starboard the receiver coil and port the transmitter coil. The technical parameters are listed in Table 1. The system is shown in Figure 1.

The fixed wing system uses an electrical compensation method to attenuate the primary field on the receiver coil. Calibration is done during high altitude flights in free space, by actively transmitting electric pulses of well known phase (quadrature pulses) and amplitude. These pulses can be used to determine the correct phase and amplitude of the signal in a post flight processing step.

Totally four EM signals are recorded: The transmitter reference voltage, the compensation voltage, the primary plus secondary field voltage on the receiver coil and the amplified residual secondary field voltage (post compensation). A laser altimeter records the altitude of the airplane with an accuracy of 0.02 m. To correct for orientation effects, pitch, roll and yaw of the airplane is recorded. In addition basic meteorological data are routinely recorded during flight.

Processing Steps

First the quadrature pulses are used to determine phase and amplitude of the signal. Then the electronic drift is corrected by using the difference of the free space signal at the beginning and end of each survey flight. Additional drift information is taken from the reference signal of the

Altimeter	100 Hz laser altimeter
Domain	Frequency
Frequency range	One frequency of 1990 Hz
Coil spacing	11.6 m
Coil configuration	Vertical coplanar
Sampling rate	Nominally 10 Hz, special mode 2 kHz
Range of Dornier 228	540 to 1400 nautical miles
Operation flight height	Nominally 100 ft
Operation speed	80 to 100 knots

Table 1. Technical parameters of the AWI sea ice thickness fixed wing system.

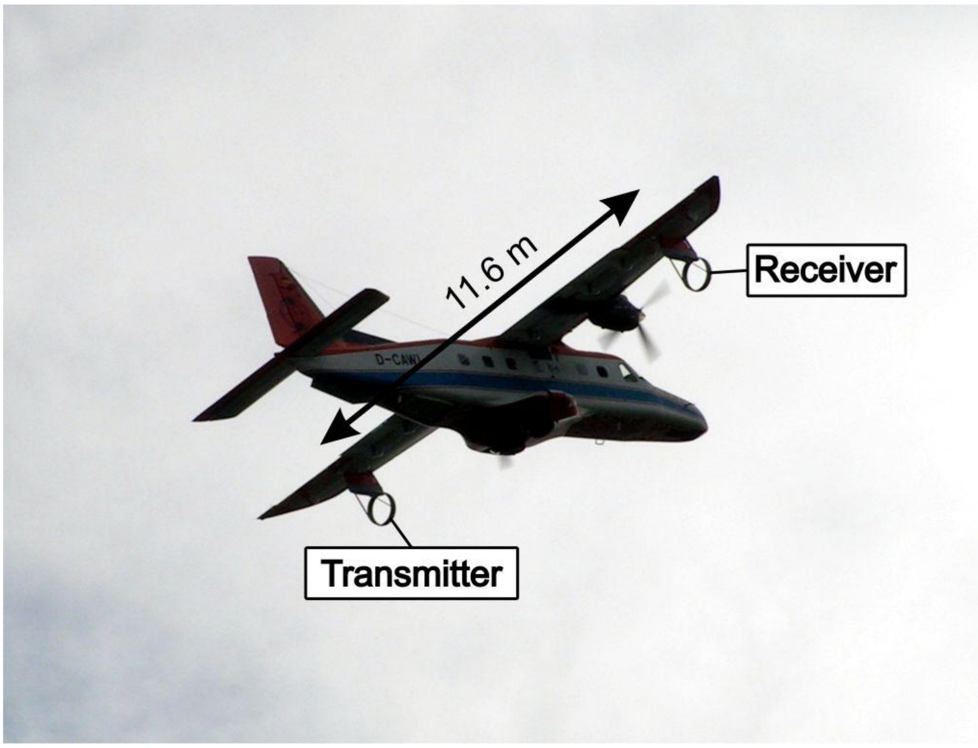

Figure 1. AWI Dornier 228 with the fixed wing sea ice thickness system

transmitter. Furthermore the reference signal can be used to correct for system internal voltage variations.

The system measures volts which need to be converted to parts per million (ppm). The conversion from volts to ppm is done by comparing the volt signal as a function of height over open ocean with model curves (see Figure 2). The ocean is a well known conductive half space. Finally the data are corrected for orientation effects, as they produce a bias in laser height and change the electromagnetic coupling between transmitter, ocean and receiver. As a last step the ppm data are converted to ice thickness data.

Performance of the system

The parameters signal to noise ratio, drift and vertical resolution were determined during test flights over open water, where the laser and EM altitude should be equal because ice thickness is zero. Figure 2 shows the drift corrected result of one flight over open water in ppm. Dots are the measured results and solid lines are the model curves. Especially in the Inphase signal a high noise level of 1000 ppm can be observed. The quadrature signal has a noise level of 100 ppm. Even the smoothed curves have a large mismatch to the model curve, which shows that strong noise is present in all frequencies, even lower than 0.1 Hz. Sea ice thickness measurements with this amount of noise result in an error of 1m for the quadrature and 2.5 m for the inphase. Measurements on ground with engines switched off show a noise level which is only 10 percent of the noise level with engines on.

Conclusions and Discussion

The new AWI fixed wing sea ice thickness EM sounder was tested successfully, all data were reasonable. Unfortunately the noise level is too high to achieve the same vertical resolution as with the AWI helicopter EM bird systems. The influence of the airplane engines is strong as it

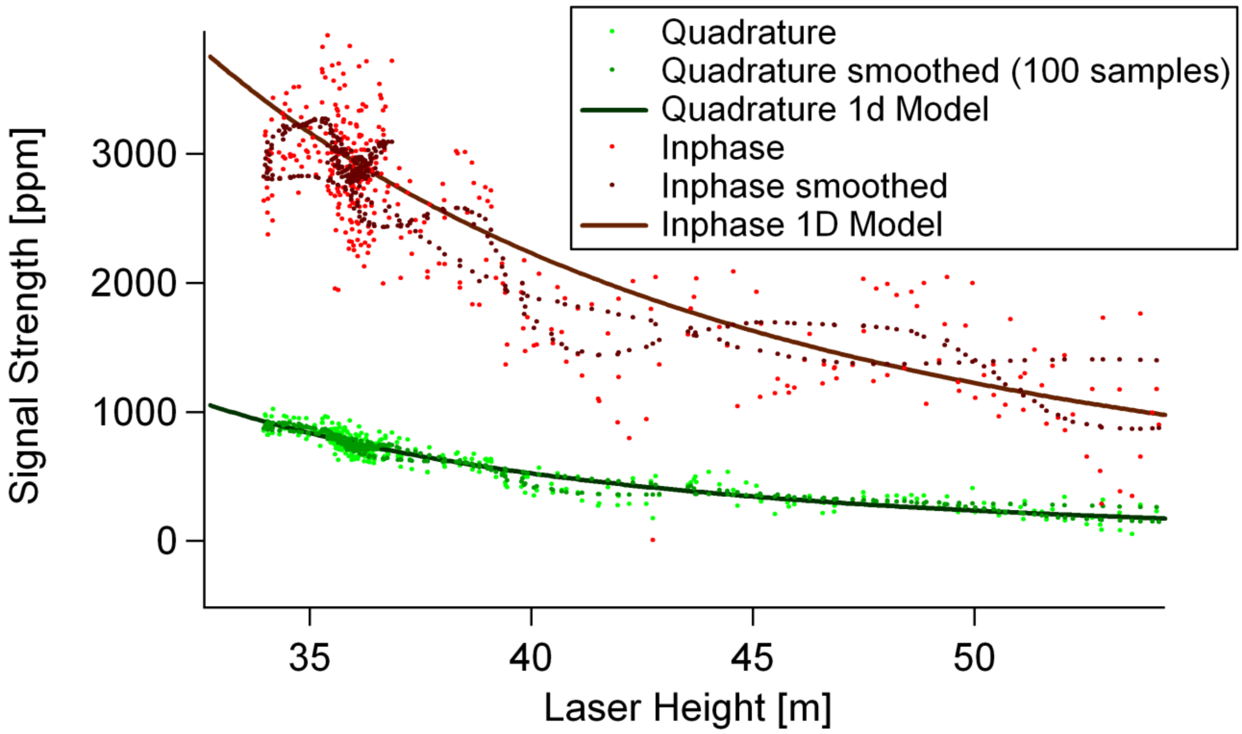

Figure 2. Modelled and measured Inphase and Quadrature signal in ppm plotted against altitude over open water in m.

raises the noise level by a factor of 10. The reason for this can probably be found in electromagnetic coupling effects between engine and EM system and in a vibration of the coils.

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