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DESIGN AND DEVELOPMENT OF INDIGENOUS SHIPBORNE ACOUSTIC SOUNDER FOR REMOTE SENSING OF THE ABL OVER OCEAN

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Abstract

Probing the lowest 1 km of the planetary boundary layer over ocean is important for various practical purposes, and to understand the dynamics of atmosphere over ocean. This is achieved on continuous basis by an acoustic sounder which captures the thermal picture of the atmosphere, on a time-height scale on continuous basis. We have designed and developed shipborne acoustic sounders which were installed on the ships M.V. Thuleland and M.S. Brinknes. These ships sailed to Antarctica from Goa as part of the Indian Scientific . Expeditions to Antarctica. This paper provides detailed information on the basic design criteria for the PC controlled shipborne acoustic sounder and the studies over the ocean. User-friendly software for the system has been developed as to display the dynamic features of the atmosphere, in colour on SVGA monitor and to print them on a B&W dot matrix printer.

Introduction

Acoustic sounding is an important technique to probe the Atmospheric Boundary Layer (ABL) on round-the-clock basis. It is due to its effectiveness and simplicity, probing the ABL, that almost all the atmospheric science programmes all over the world, utilise acoustic sounding system, as an integral part of the probing systems. The technique has been developed to study the' ABL over various terrains (hilly as well as flat), valleys, Antarctica, and even over the floating vessels.

The ABL group at NPL has designed and developed various types of monostatic acoustic-sounders, including the one deployed at Maitri, Antarctica: The group has to its credit transfer of technology of the equipment to a private company, and thus holds total grip on the hardware, software, and other associated problems.

The development of shipborne systems is a technological challenge, as the vessel is moving, and at the same time, it experiences pitching and rolling, apart from squatting. Ship also experiences high vibrational noise under the impact of sea waves, tides and swells. This also makes the moving platform noisy, and offers a challenge to acoustic sounding of the ABL over ocean.

In India, the first shipborne acoustic sounder was deployed onboard the ship M. V. Thuleland during its return journey from the Indian Bay in Antarctica (69.98°S lat. and 11.2°E long.) to Goa (15.2°N lat. and 73.8°E long.) during February-March, 1993 (12th Indian Scientific Expedition to Antarctica). However, in this system, the antenna was stationary and no correction was applied for the pitch and roll of the ship. Moreover, the data was received on facsimile chart and no correction could be applied to ensure the quality of data. However, this development made India as one of the six nations to have developed the indigenous technology of shipborne acoustic sounder.

To overcome the limitation of pitch and roll, gyrostabilised antenna was mounted onboard the ship M/S Brinknes during its journey to Antarctica in the year 1 995-96 (15 Indian Scientific Expedition to Antarctica), and the whole system was PC controlled.

This paper presents the details of this system and the efforts required for its upgradation in future.

Technique

In the acoustic sounding, a powerful pulse of sound is transmitted vertically up into the atmosphere and scattered signals from the thermal perturbations of the atmosphere are received back by the same transmitting antenna. Fig.l presents basic system concept of a monostatic acoustic sounder. The returned signals carry information of the thermal structure of the atmosphere and display almost all the known atmospheric phenomena including convection, inversion, gravity waves, KH-waves, land and Seabreeze, trade wind inversions, hot and cold fronts etc. The records are displayed on a PC and printed on a dot matrix printer.

Design Philosophy

The shipborne acoustic sounder has to operate over a moving, noisy platform, therefore, the design criteria must take care of the following :

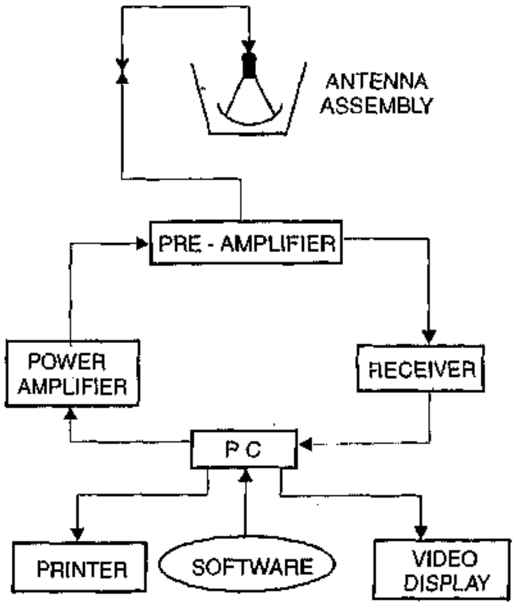


Fig. 1: Basic system concept of monostotic Acoustic Sounder

1. High Doppler shift of scattered signals due to the moving ship and high relative wind speed over ocean.
2. Movement of the ship causing loss of returned signals. Pitch and roll of the ship.
3. High noise due to the ship engine, striking oceanic waves and tides. In the Antarctic ocean, the ice breaking by the ship causes high vibrations and noise, requiring a high degree of isolation of the whole antenna assembly.
4. To keep system operational frequency low so as to keep the absorption of sound due to moisture as low as possible.

The overcome these problems, the following steps were implemented :

1. To counter the loss of signals due to the movement of the ship, an auxiliary antenna was mounted whith acted as a transmitter illuminating the atmosphere, much ahead of the ship, compensating for the average ship speed. To counter the pitch* and roll, the parabolic antenna was mounted on a mechanical gyrostabilised platform. The platform has two

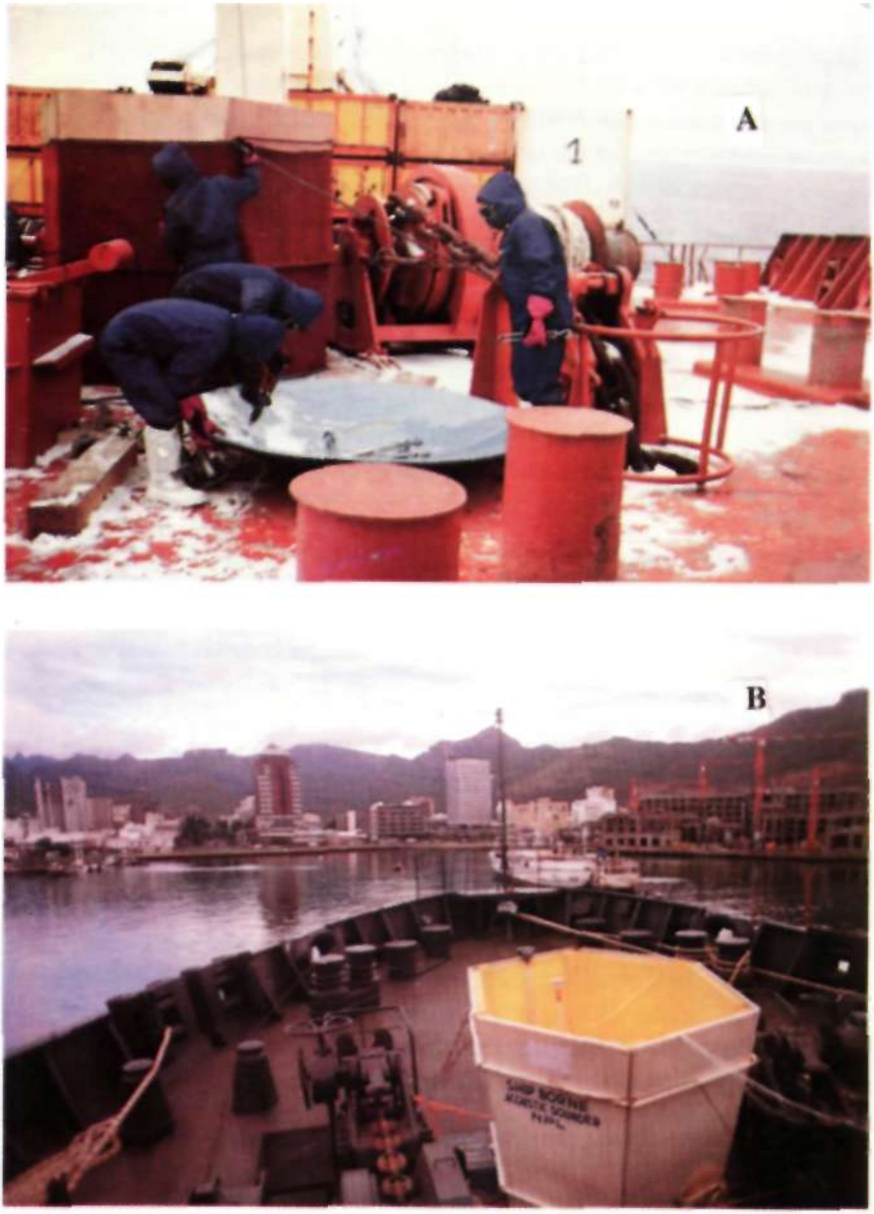


Fig. 2: (A)Shipbome acoustic sounder being installed onboard the ship M. V. Thuleland. It was built around a 6 feet parabolic dish seen in the photograph. (B)The shield installed onboard the ship M. S. Brinknes in the bow region. The 4 feet parabolic dish is inside the shield placed on a gyrostabilised platform

perpendicular motions stabilising the antenna in the vertical direction upto 20 degree of tilt. **Fig.2** shows the actual system installed onboard the ship M.S. Brinknes. It shows the hexagonal shield installed in the bow area of the ship. However, in the bow area, once the ship reaches Antarctica, the noises caused by various operations like helicopter, crane operations etc. frequently interrupt the system functioning.

2. To counter the various noises, a survey of the noise onboard was conducted and antenna was mounted in the bow area, wherein, noise was recorded to be the minimum under normal circumstances.
3. To keep the option for the selection of the operational frequency, a survey of the ship noises due to the mechanical vibrations and natural ones, like wind, splashes of sea waves etc. was carried out. It was then decided to operate the system at 1560 Hz; wherein, the transducer efficiency was also found to be optimum.

The PC based electronics system was installed in the carpenter-hut just below the antenna to minimise the cable length etc.

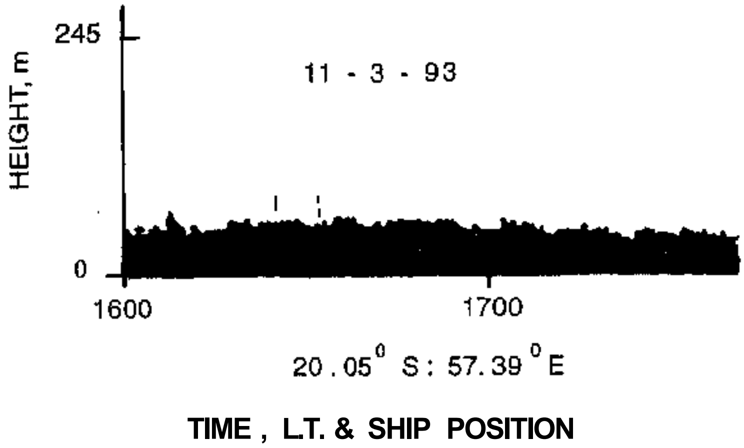
Performance of the System Onboard

The performance of the system onboard the ship, depends basically on the sea-state and/or wind-velocity which is ultimately controlled by the prevailing atmospheric pressure. Unfortunately, for the ships sailing for Antarctica, beyond 40°S lat., sea-state and the wind-velocity are high, due to a number of cyclones moving around the Antarctic continent.

Therefore, the expedition to Antarctica provided an acid test for monitoring the health of the system, quality of data and gained experience for further improvement of the system parameters.

In normal circumstances, the sea is calm and the sea-state remains within 4. The system worked well giving satisfactory observations as shown in **Fig.3.** This figure shows a low lying surface based inversion in the evening hours.

However, as soon as the sea-state crossed 5, the system performance decreased rendering the data useless. The observed noise caused by the high sea splashes, striking pack ice, squatting, and pitch and roll being so high, that system performance came to a standstill. At the same time, antenna shield was physically damaged onboard the ship M.S. Brinknes, when she sailed through a cyclone. In fact, M.S. Brinknes is much smaller in size compared to M.V. Thuleland. Therefore, its pitch and roll was much higher than experienced onboard M.V. Thuleland.



Fie. 3: Facsimile chart showing inversions over the ocean

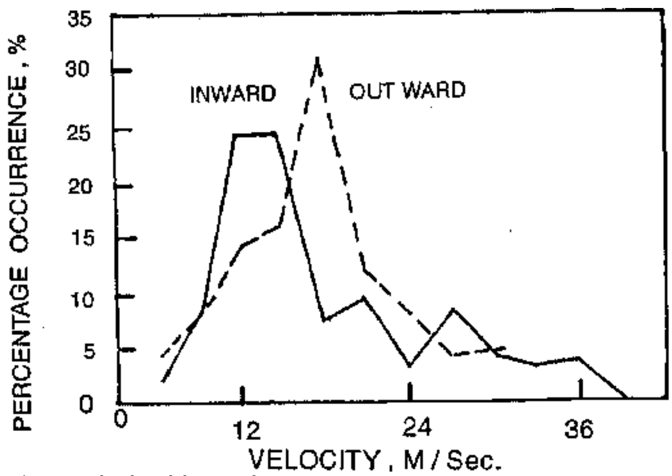


Fig. 4: Magnitude of the wind encountered during the 12th Antarctic expedition.

Fig.4 shows the observed wind velocities that were encountered during the journeys in the 12th expedition. It is observed that system performance is unacceptable once wind-velocity crosses the magnitude of 8 m/sec on the ship. The high winds are the basic cause for high waves, tides and swells in the ocean.

Results and Conclusions

The data have recorded various types of structures, but the system still needs certain modifications, before its technology can be transferred for a commercial production. This limitation of the technique to work at much higher wind-speed/sea-state, can be overcome by adopting the following modifications in the hardware :

1. Transmission of digital coded pulses and reception.
2. Shield height to be at least 8 feet.
3. Belter antenna mounting to isolate it from vibrations.
4. On-line FFT of the received signals.

The group is working on the development of a coded pulse transmission and reception to gain a S/N ratio by 20 dB. At the same time, FFT of the received signals is being implemented through indigenously available components.

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