Radiowave Transmission Characteristics in Antarctica

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ABSTRACT

The preliminary results of observations on studies on radio propagation in the upper atmosphere during the First Indian Antarctic Expedition are reported in this paper. The studies made were mainly on high latitude D-region using VLF observation, atmospheric radio noise, VHFTV signal propagation, HF propagation and communication aspects.

INTRODUCTION

The first Indian Antarctic Expedition provided a valuable opportunity to conduct several experiments on radiowave propagation and communication aspects. The experiments were conducted in two phases- during the cruise and on the Antarctic landmass. The entire volume of data obtained has not yet been analysed in complete detail. However, it has been possible to obtain some preliminary results. This paper reports the various experiments conducted and the preliminary results obtained in each case..

OBSERVATIONS AND PRELIMINARY RESULTS

VLF propagation studies

This experiment consisted of measuring the phase and amplitude of VLF signals transmitted from two OMEGA transmitters situated at La Reunion (20° 58' S, 55° 17' E) and Argentina (43° 03' S, 65° 11' W). The equipment used for this purpose were two TRACOR VLF receivers with OMEGA gating units and loop antennae fixed on the topmost deck of the ship. The receivers were fed with standard frequency (for phase comparison) from a rubidium vapour frequency standard. The VLF experiments had two main objectives:

(a) To investigate whether there is any difference in the solar zenith angle dependence of the VLF phase (and hence of D-region electron density profile) between the high and low latitudes.
(b) To investigate whether there are "radio holes" (complete loss of signal strength) at some places in the Indian Ocean from the nearby transmitter at La Reunion and to study the spatial phase variation in the near zone of the transmitter.

For the first objective the experiment was carried out in two stages. Observations were made at NIO, Goa (15° 36'N, 73° 42' E) with signals from O/La Reunion on 12.3 KHz for a few days around 28-29 Nov. '81. This propagation-path (Path I) was trans-equatorial and was 4538 km long (i.e., long enough so that during daytime only the first order mode $n = 1$ is predominant). Observations were again taken on reaching the Antarctic continent (70°S, 11°E) for two days, 9-10 Jan. '82 with signals from O/Argentina on 12.9 and 11.06 KHz. The propagation path to O/Argentina (Path II) was 5060 km long and traversed mainly mid-high latitudes..

Although the total duration of the stay in the Antarctic continent was about 10 days, observations could be made only for the first two days when the ship was alongside the ice shelf and stationary. No observations could be made thereafter as the ice shelf collapsed and the ship had to cruise about in the nearby waters. Carrying the VLF equipment to the base camp was not feasible because these would not work at such low temperatures.

The variations of phase over two full days are shown in Fig. 1(a) for path I and Figs. 1(b) and 1(c) for path II. For investigating the solar zenith angle dependence we have confined our attention only to the daytime portion where at any point on the path the solar zenith angle $\chi \leq 70°$. This is guided by our earlier experience that the linearity between VLF phase and $\cos\chi$ is maintained only for χ less than about 70°. To calculate the average zenith angle effect over the entire path, the path was divided into 10 equal segments,

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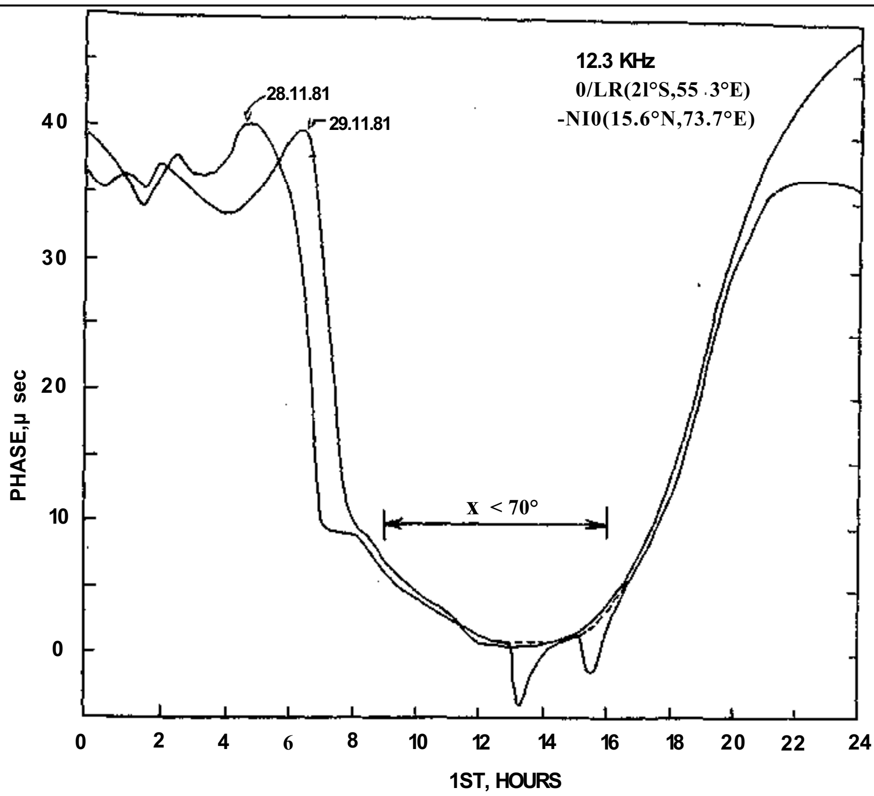

Fig. 1 (a) : Diurnal phase variation at 12.3 kHz over the Reunion — Goa path.

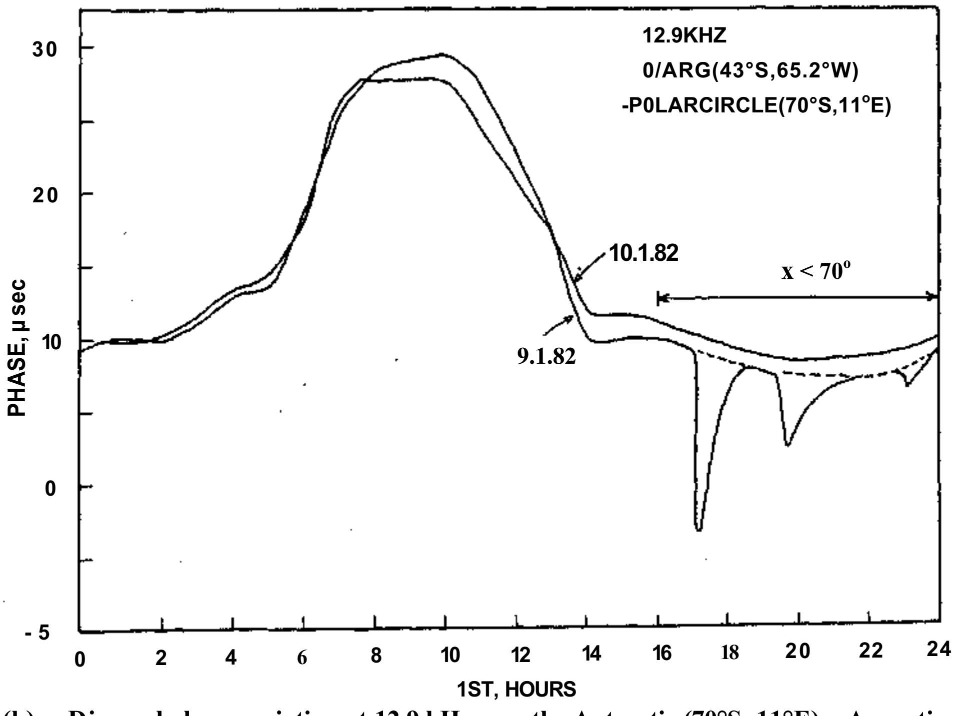

Fig. 1 (b) : Diurnal phase variation at 12.9 kHz over the Antarctic (70°S, 11°E)—Argentina Path.

$\overline{\cos\chi}$ determined at the middle of each segment, and the average of these values taken to give the path average $\overline{\cos\chi}$. The values of $\overline{\cos\chi}$, were calculated for the daytime period at half hourly interval. It was just fortuitous that the value of solar declination angle S was the same (8 = - 21°) for both periods of observations 28-29 Nov. '81 and 9-10 Jan. '82, thus ensuring that there would be no seasonal contamination in the two data sets.

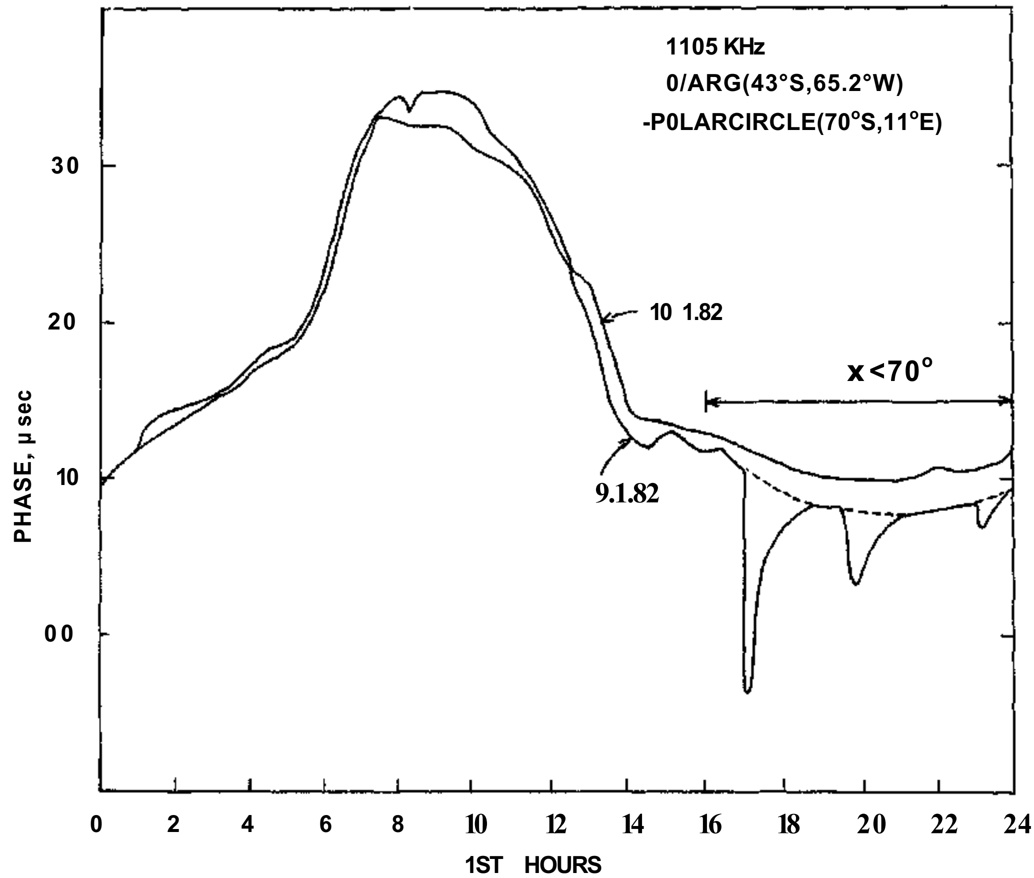

Fig. 1 (c) Diurnal phase variation at 11.05 kHz over the Antarctic (70°S, 11°E)—Argentina path.

The relationships between the phase and $\overline{\cos\chi}$ are shown in Fig. 2(a) for path I and 2(b) and 2(c) tor path II for two days each. The parameter chosen on the abscissa is (1- $\overline{\cos\chi}$) since phase is inversely related wi $\overline{\cos\chi}$. In all cases shown in Fig. 2(a), (b), (c) the relationship is linear, with slopes: (a) for path 1,11.0 and 11.8 for the two days, and (b) for path II, 11.3,10.9,12.0,14.5 for two days and two frequencies each. Thus we observe the significant feature that the solar zenith angle dependence for both paths I and II is the same within experimental errors.

In order to interpret the above observations using the waveguide mode theory of Wait and Spies (1964) we proceed the following way. We assume that during daytime for x ≤ 70° the value of the conductivity parameter, W_r (= W_0 $e^{-ß}$ h -h_0) for the upper wall of the waveguide varies with x in such a way that ß is constant and only h_0 varies. This is justified at least for one condition, equatorial path and equinox condition as shown in Fig. 7(b) of Wait and Spies (1964). This amounts to assuming that the electron density profile in the D-region retains its shape and its magnitude is scaled linearly with variation of h_0. We deduce from the waveguide theory that for small variation of h_0 around the daytime value of about 70 km the phase velocity of the 1st order mode n = 1 and f ≈ 12 KHz varies linearly with h°. Quite

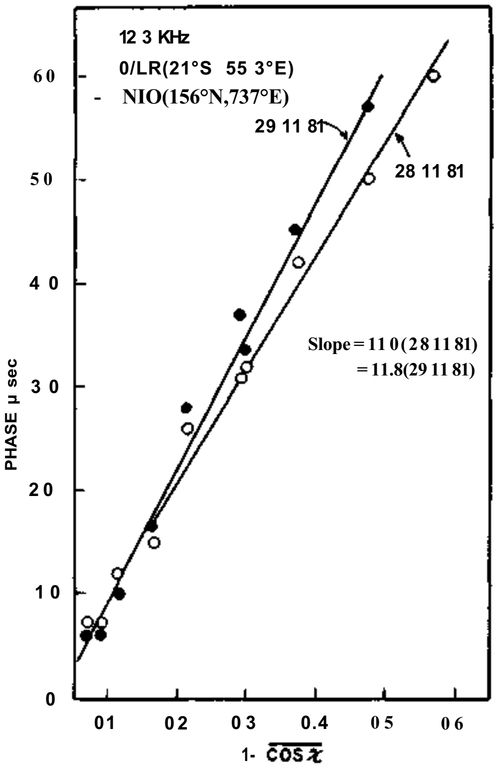

Fig. 2 (a) : Relationship between daytime phase and (1 — cosχ) at 12.3 kHz over path I.

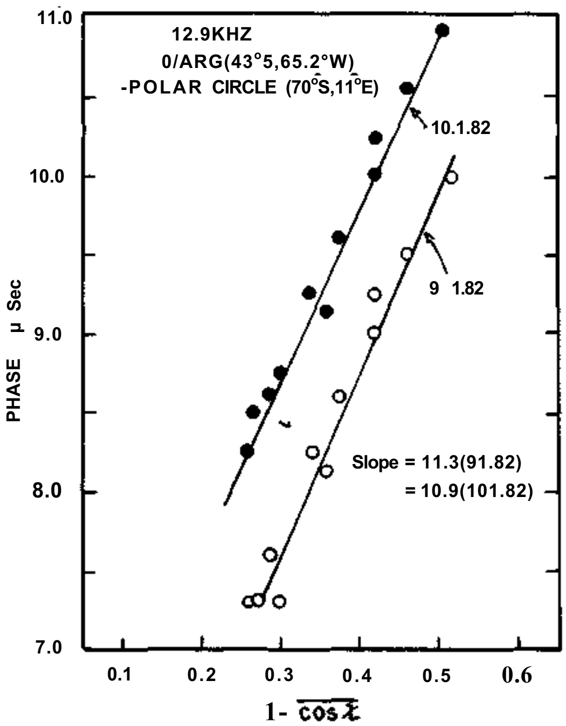

Fig. 2 (b) : Relationship between daytime phase and(1— cosχ) at 12.9 kHz over path II.

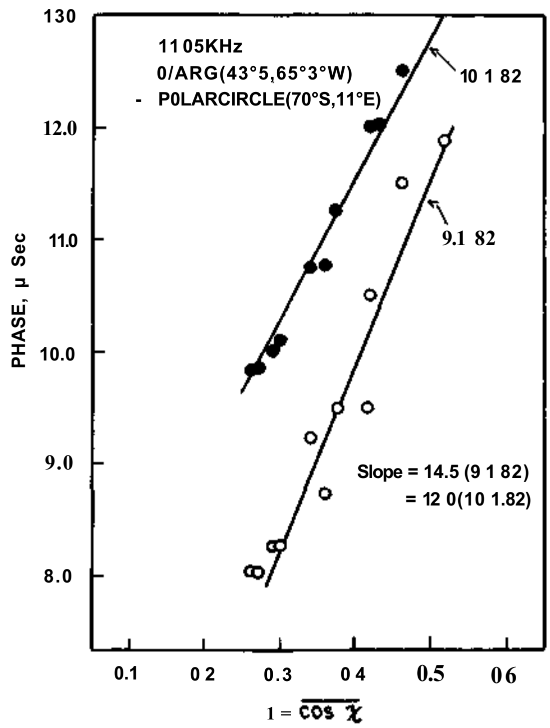

Fig. 2 (c) : Relationship between daytime phase and (1 — cosχ) at 11.05 kHz over path II.

clearly then, for a fixed location of observations the phase of received signal (which varies linearly with the phase velocity) is linearly related with the scaling of the magnitude of the electron density profile.

We thus arrive at the conclusion from Figs. 2(a), (b) and (c) that : (a) for the daytime $x \leq 70°$, the D-region electron density profile retains its shape (assumption) and varies linearly with $1-\overline{\cos \chi}$ (b) the slope of this variation is same for the equatorial and mid-high latitude regions.

We realise, however, that in reaching the above mentioned conclusions the amount of data used is not very extensive. It is hoped that in future expeditions this limitation will be overcome, and the present conclusion will be substantiated.

For the purpose of the second objective of the VLF experiment the phase and amplitude monitoring was done continuously during the cruise as the ship moved towards and away from Mauritius which is only 150 miles from the transmitter at La Reunion. The data collected are still in the process of analysis and the results will be reported later. However, preliminary investigations clearly indicate that there are no radio holes for the frequencies monitored during the present observations.

Measurement of Atmospheric Radio Noise Field Strength (ARNFS)

This experiment was aimed at measuring the radio noise level in the VLF and HF bands. The equipment used for this purpose was a calibrated Field Intensity Meter (FIM) with a ship antenna. The measurements were made regularly during the cruise as well as at the base camp set up on the ice shelf. However, at a later stage it was realised that the data collected on board the ship during the cruise were badly contaminated with the noise generated by the ship's electrical systems. Also, the antenna of the FIM was affected greatly by the clutter of several other antennae and metal structures on the deck of the ship. This was evident as the reading of the field strength changed drastically by changing the position of the antenna. Thus, all the measurments of ARNFS made during the cruise were discarded.

For measurements at the base camp on the ice shelf, the antenna had to be installed with an artificial ground to avoid the problem of non-conducting ice cover. This was prepared with the help of wire radials spread out evenly at the base of the ship's antenna. The antenna was installed as far away as possible from the rest of the equipment. It was noticed that, inspite of this, the small petrol generator used at the base camp to power the various equipment and charge batteries produced enough noise to swamp the actual noise level. Thus, at the time of measurements it was made sure that this generator and most other equipment were switched off.

The average results of measurements for about 5 days at the base camp are summarised in Table - I. The measurements were made every alternate hour. No significant diurnal variation was noted. It is interesting to compare the present results with published CCIR ARNFS charts, which indicate for our location and season a value of -25 dB μ^{v} /m at 1000 KHz.

TABLE 1

Frequency (KHz)	10	100	1000	10,000	30,000
ARNFS dB μ^{v}/m	7 ±02	- 6 ± 02	- 15 ± 1	- 17 ± 1	- 19.5 ± 1

The above measurements of ARNFS for this specific site are understandably not very exhaustive. However, these should provide helpful inputs for planning radio communication links for future expeditions.

VHF long distance propagation experiment

Reception of VHF television signals propagated over long distances was attempted using a sensitive multichannel TV receiver and a six element yagi antenna. The aim was to monitor TV signals from Bombay and Karachi stations during the first few days when the ship was in the Arabian Sea and near the coast. After about 3-4 days when the ship was nearing the equator, we attempted to receive signals from the Madras Station. However, at no time during these attempts it was possible to receive any signal. The TV experiment could not be repeated during the return journey as the large yagi antenna had got badly damaged during our passage in rough seas through the 'roaring forties'.

HF propagation time delay studies

Propagation time delay of several HF standard time and frequency signals was measured during the cruise. In order to do this, a synchronized atomic clock was carried in running condition from NPL on board the ship. The various HF stations monitored were ATA (NPL's own transmission), WWV, WWVH, RID, RWM, ZUO and BPM at frequencies of 10 and 15 MHz. The propagation delays varied from 10 msec to about 90 msec from distant stations. The propagation delay measurements of the HF signals, which propagate via the F-region of the ionosphere, are being analysed to derive (a) the exact mode of propagation of signal and (b) the electron density profile of the F-region. The profiles should either agree with or improve the existing International Reference Ionosphere (IRI). This analysis is in progress at present and the results will be reported shortly.

As a byproduct of this experiment it was observed that the NPL's standard time signal station ATA was very well received in the Indian Ocean upto the equator. The reception continued on 15 MHz upto about 10°S. On a few occasions, ATA signals were received at Mauritius (20°S).

HF radio communication on board the ship

On board Polar Circle a 400 W SSB transmitter was used to maintain HF communication link with Norway (Rogaland Radio) and India (NIO). The link with NIO lasted only upto about 5°S and during the rest of the cruise the link was via Rogaland Radio.

The transmission channels of Rogaland Radio are listed below:

Transmit (KHz)	Receive (KHz)	
13075	12495	
13081	12501	0000 — 2400 UT
13097	12517	
17199.5	16662	0630 — 2100 UT
17223	16686	
22563.5 .	22194.5	0700—1900 UT
22587	22218	

M. V. 'Polar Circle' had several transmitting frequencies in the 22, 16, 12, 8, 6, 4 and 2 MHz bands and a continuously tunable AM/SSB receiver.

The transmitter at NIO, Goa was a 400 W SSB with transmission frequencies: 12540, 8196, 6211, 4078.7 and 2080 KHz.

During the cruise and while within the Antarctic circle, in communicating with Rogaland Radio the transmission band most commonly used was the 16 MHZ band. Occasionally, the link was established on 22 MHz band. It was noticed that on the first two days after reaching the ice shelf the HF link was completely disrupted. This was very puzzling. Although the exact reason for this phenomenon is still unknown, one very plausible explanation could be the following: The ship being right alongside the ice shelf the transmitting antenna was not radiating in the proper manner because of the non-conducting ice cover. This problem was overcome when the ice shelf cracked after two days and the ship had to come into the middle of the water. Problem of malfunctioning of the antenna was faced again when it was attempted to set up a 25 W transmitter at the base camp on the ice shelf for the helicopter beacon. The ship antenna provided with this transmitter could not be matched properly and made to radiate enough power.

Communication link with NIO lasted upto about 5°S. Experiments were performed to study the most suitable frequencies of operation. The process of measurement was qualitative in that the judgement was made listening to the nature of the received signals and noise. The results of these experiments can be summarised as follows: Over the region between 5°S and 10°N i.e., a distance range of about 1500 km to 600 km, best reception was possible on the 12 MHz band during daytime (10001ST—16001ST) while 16 MHz was occasionally received, 22 MHz was never received strongly enough. Within the range of 600 km from NIO all frequencies in 12, 8, 6, 4 MHz bands were received well. This is the region of groundwave propagation for these frequencies.

During most of the cruise the communication was via Rogaland Radio of Norway. In future expeditions, it would be desirable to have a direct radio communication between the ship and some place in India. For this purpose, considering that the transmitter on board the ship cannot be made much more powerful and the antenna cannot be different from a vertical monopole (as it has to be omnidirectional) one would have to (a) increase the power of the transmitter on land considerably (~50 KW) and roughly beam it towards the ship, and (b) have a sensitive receiving setup on land with a highly directional antenna. Communication with the Indian Satellite INSAT is also worth looking into.

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