CHAPTER V

5. SPACIAL VARIATION
OF CONDUCTIVITY

5.1. INTRODUCTION

The measurement of atmospheric electrical conductivities at various altitudes above the surface is important for obtaining a clear understanding of the electrical processes in the atmosphere. Instruments carried on rockets, balloons and aircrafts are used for this purpose. Each carrier works well in a particular region of the atmosphere, and has its own advantages and disadvantages. Rockets are useful when measurements above fifty kilometres are desired. Balloon-borne instruments usually give good data from about two to three kilometres up to around 35 km. The region between around 35 km and about 50 km is difficult to access. One method is to use parachute-borne instruments deployed from rockets, although this has limitations. Most of the balloon-borne experiments carried out so far have not given good data below about 2 km. This is the region where aircraft-borne measurements are very useful. This also happens to be a very interesting region since the effects of radioactive minerals in the soil are felt up to about two to three kilometres. Of the three platforms mentioned above, aircraft also happens to be the cheapest. Moreover, instruments can be carried in an aircraft over virtually any terrain, whereas special facilities are required for launching rockets or high altitude balloons.
Aircraft-borne instruments have been used by Gish & Wait (1950), Callahan et al. (1951), Kraakevik (1958), Paltridge (1966), and others for measuring electrical polar conductivities in the troposphere and the stratosphere. Gish & Wait (1950) found that electrostatic charge accumulates on the aircraft and affects the measured values. They also found that if the charge on the aircraft was positive, then it affected only the positive conductivity values and not the negative ones, and vice versa. Coroniti et al. (1952) investigated this phenomenon using both laboratory experiments and aircraft flights. They concluded that the effect is negligible under fair weather conditions.

In this chapter, the aircraft payload used for the present investigation is described, and the results obtained are presented and discussed. Before the air-borne measurements were carried out, the instrument was tested by carrying out a few test surveys at ground level with the instrument mounted on a jeep. Of these, only one gave continuous data. The results of this measurement are also presented.

5.2 PAYLOAD DETAILS

The Gerdien condenser aircraft payload consists of a sensor, the electronic circuitry for generating the driving voltage and for processing the output signal from the sensor, the system for recording the signal, and the power supply units for all these. The aircraft used for the surveys was a Pushpak trainer aircraft of the Kerala Aviation Training Centre (KATC), Trivandrum. The payload was designed with the capabilities and limitations of the aircraft in mind. These subsystems are discussed separately below.
5.2.1 Design of the sensor

The sensor developed for the present study, along with the clamp for mounting it, is shown in Figure 5.1. The driving electrode is 300 mm long and 60 mm in diameter. This is fixed inside a tube having a slightly larger diameter (65 mm) with two layers of Milnex insulating sheet in-between. The tube diameters are such that the driving electrode with the two layers of Milnex sheet over it fits tightly into the outer tube. The inner tube acts as the driving electrode and the outer one is electrically grounded and acts as a shield. The shield is slightly extended beyond the driving electrode at either end. The extensions act as guard rings and reduce the fringing of the applied field. The collector is a copper wire 0.6 mm in diameter. This is mounted at the axis of the tubes using two PTFE insulators at the ends. The PTFE pieces are held in place by 4 mm chromium plated mild steel bolts that run across the tube at either end. The driving electrode and the outer tube are fabricated in brass and chromium plated, and the collector wire is tin coated. The capacitance of the sensor is about 1.3 pF. The sensor was mounted with aircraft quality bolts and nuts onto a strut of the aircraft using a clamp. Neoprene rubber padding was provided between the clamp and the strut.

5.2.2 Design of the electronics

A block diagram of the aircraft payload is given in Figure 5.2. The electronic circuitry for the instrument consists of two parts - the signal conditioning circuits, and the fm modulator and associated circuits used for recording the data on tape.
Figure 5.1 The sensor used for aircraft measurements, along with the clamp for mounting it on the aircraft.
Figure 5.2 Block diagram of the measurement system for aerial survey.
The circuit diagram of the system is given in Figure 5.3. The saturation voltage of the sensor for an aircraft cruising speed of 80 kmph and for the type of ions normally encountered during the flight is about 800 volts. Therefore the driving voltage used was of the order of 200 volts. This was obtained from a bank of 9V dry batteries. Positive or negative driving voltage could be selected using a DPDT switch (SW1 in Figure 5.3). The reference level of the measurement system was obtained by grounding the driving electrode through the switch (SW2) at definite intervals. An alternative for the battery bank is a dc-dc converter run on batteries. In this case, care has to be taken to see that the inverter output is filtered properly since any ripple in the driving voltage would cause a large noise in the signal. Care has also to be taken to see that the inverter does not contribute electrical noise to the rest of the electronics.

The current range from the sensor for the conductivities normally expected in the region of measurement is from about 0.1 to 5 pA. The current was converted to voltage using a current to voltage converter (CVC) with a sensitivity of 0.1 V per pA, built around an Analog Devices AD515L operational amplifier. The output of the CVC was fed to a signal conditioner having three gain stages of $x_1$, $x_5$ and $x_{10}$ respectively. Thus the total circuit had a sensitivity of 5 V per pA. This is sufficient for the kind of currents expected from the sensor. This part of the circuitry is essentially similar to the one used in the ground-based instrument. Output from all the three stages were available, and the appropriate one was selected for recording by the operator on board using a thumb-wheel switch (TWS). The inverter shown in Figure
Figure 5.3 Circuit diagram of the electronic circuitry used in the aircraft payload.
5.3 was used to maintain positive the polarity of the signal at the input to the modulator.

The output from the signal conditioning circuits was fed to a positive input fm modulator built around an 8038 which gave frequency output in the range from about 300 Hz to about 2500 Hz. Whenever the driving voltage polarity or the gain stage was changed, the proper polarity signal for the modulator was provided using the invertor and the switch SW 3 shown in Figure 5.3. The modulated signal was recorded on good quality C90 cassettes during flight. In order to facilitate the selection of the proper gain stage during flight, the modulator input was monitored on an analog meter. This also gave an indication that the system was functioning properly up to that point.

Complete calibration of the system was done before and after each flight by giving known currents from a pico ampere source (Keithley Instruments) to the collector of the sensor and recording the output on the cassette used for the flight. The cassette was played back through an fm demodulator and the data transferred to paper chart after the flight. Calibration of the entire system, from the sensor to the demodulator and the paper chart recorder, was taken and it shows very good linearity. Typical calibration curves are shown in Figure 5.4.

The sensor was mounted onto a strut of the aircraft using a simple clamp. The clamp also had provision to holds the current to voltage converter inside it. This eliminated the problems that a long cable running from the sensor to the amplifier could create. The total weight of the sensor with the clamp is about 1.7 kg.
5.3 GROUND SURVEYS

In order to test the instrument designed and fabricated for the aerial surveys, the sensor was mounted on a Maruti Gypsy, and a few surveys carried out. Due to the fact that these measurements were during the development of the instrument, data are available only over part of the distance covered, except in the case of a survey from Trivandrum to Manavalakkurichi. Some interesting results that have come out of these measurements are presented here.
Figure 5.5 gives the results from the survey from Trivandrum to Manavalakkurichi. In this survey, positive polar conductivity was measured during the onward journey and negative during the return journey. The vehicle maintained a more or less constant speed of about 60 kmph. At places where the vehicle had to slow down, the data have been rejected. The polar conductivities are large from around Karingal onwards up to the Kadayapatnam beach at Manavalakkurichy.

Another survey was conducted from Trivandrum up to and beyond Chavara. However, data were obtained only at intervals. This also

![Figure 5.5 Polar conductivity data from jeep-borne survey between Trivandrum and Manavalakkurichy.](image)
showed a peak at Chavara, falling off rapidly towards the north and the south.

In one test run along the MC Road from Trivandrum to Kottarakara, it was observed that conductivity values were high around a granite quarry near a place called Venjarammoodu. Figure 5.6 shows the portion of the chart corresponding to the location. The high values are probably due to the release of nuclear radiations and radon from the freshly exposed faces of the rock. Radioactive nuclei present in the freshly exposed surfaces of the rock, including that of small particles of rock released into the air, would provide an abundant source of radiation. Also, since the permeability of the rock is low, radon produced by the decay of radioactive nuclei in the rock would be locked up inside. When the rock is broken, whatever radon remains is released, adding to the ionization in the air.

5.4 RESULTS OF AERIAL SURVEYS

In order to investigate the extent of the influence of radioactivity on electrical conductivities, three surveys were conducted. Aerial surveys in both north-south and east-west directions, covering the regions having radioactive deposits, including a short distance into the sea were done. Initially, a test flight was conducted which was useful for understanding the problems and intricacies involved in such experiments. Three more successful flights were carried out, which helped to validate the technique and to demonstrate its utility in atmospheric electrical investigations. The flights were from Trivandrum to Kanyakumari and back, Trivandrum to Alleppey and back, and
Figure 5.6 Portion of the chart showing enhancement in conductivity near a quarry.
Trivandrum to Kottarakara to Chavara and back. The flight paths of these surveys are shown in Figure 5.7.

The results of the individual surveys are presented and discussed below. The data from each survey are shown in the form of a graph. Finally, the values from all the surveys are classified into ranges and presented together in a map along with the terrestrial radiation measurements of Sankaran et al (1986).

5.4.1 Survey 1: Trivandrum – Alleppey

A survey was carried out from Trivandrum to Alleppey along the coast to study the north-south extent of the radioactive deposits. The flight took off from Trivandrum at about 1150 hrs on 1.10.1992, reached Alleppey around 1300 hrs, and returned to Trivandrum at about 1400 hrs. The aircraft was maintained at an altitude of about 1000 feet (about 300 m) and at a distance of roughly 500 m from the coast.

Average readings for each minute were taken from the chart and reduced to conductivity values. The results obtained are plotted against distance from Trivandrum in Figure 5.8. Conductivity remains at about the same value up to a distance of about 45 km from Trivandrum. It is slightly higher there onwards up to about 10 km before Chavara. From here, conductivity increases rapidly, goes through a maximum at Chavara and then decreases. The region north of Chavara shows relatively lower conductivity compared to the southward portion. This is because the deposits of monazite sands are not found to the north of Chavara.
Figure 5.7 Map of the region showing the routes along which aerial surveys of polar conductivities were carried out. A location map of the region is given in the inset.
Figure 5.8 Conductivity variation along the coast from Trivandrum to Alleppey.

An interesting observation is the fluctuations seen between Chavara and Alleppey. The data show large fluctuations covering spatial distances from around one kilometre to several kilometres. A sample portion of the chart that shows these fluctuations is given in Figure 5.9. This can be caused by isolated convection cells that bring up air from near the ground which would have a much higher conductivity than the ambient air. These convection cells could be formed by the presence of large and small water bodies. The land regions between these water bodies would support convective motion whereas the water bodies would not. The region between Chavara and Alleppey has many water bodies, and rains a few days prior to the flight had created isolated water bodies in the coastal region.
Figure 5.9 Sample portion of the chart from the survey between Trivandrum and Alleppey showing the large fluctuations.
5.3.2 Survey 2: Trivandrum - Kanyakumari

Apart from the Chavara region of Kerala State, large deposits of monazite are present around Manavalakurichi in Tamil Nadu. A survey was therefore conducted southward along the coast almost up to Kanyakumari and back. The aircraft took off from Trivandrum at about 1625 hrs on 1.10.1992 and landed back at about 1745 hrs. This survey also was carried out at an altitude of about 330 m (1000 feet) and almost hugging the coastline. The results are plotted against the distance from Trivandrum in Figure 5.10. The values show two peaks one at about a few kilometres north of Kolachel and the other at Manavalakurichi.

Figure 5.10 Conductivity values obtained in the survey between Trivandrum and Kanyakumari.
5.3.3 Survey 3: Trivandrum - Kottarakara - Chavara

To study the east-west extent of the effect of the radioactive deposits on the atmospheric electrical conductivity the third survey was conducted. This survey started from Trivandrum, went up to Kottarakara, and then turned west, flew over Chavara and a short distance over the sea, and then returned along the same route. In this survey the aircraft was maintained at about 2000 feet (650 m). The flight took off around 1340 hrs on 30.9.1992, and landed back at about 1515 hrs.

Mean values for each minute of the flight are shown in Figure 5.11. The data show the conductivity decreasing towards Kottarakara,

![Figure 5.11 Conductivity data obtained in the survey between Trivandrum and Chavara via Kottarakara.](image-url)
where it reaches a minimum, and then increasing up to Chavara. Monazite is present all along the coastal region and a few kilometres inland. Near and around Kottarakara the radioactivity is low. This is reflected in the conductivity being low over Kottarakara.

As the aircraft moves towards the coast after crossing Kottarakara, the conductivity increases, and reaches a peak at Chavara. The peak value at Chavara is lower than the one seen in the first survey because this survey was conducted at a higher altitude. During the short flight over the sea, the conductivity is seen to decrease rather rapidly. However the effect is seen to persist for the distance the flight went over the sea, the conductivity being larger than typical marine values. This has to be due to the transport of radon from over the land. Normally one would expect the conductivity to be high to the east of Chavara and decrease rapidly towards the sea. Because sea breeze is normally expected to carry away the radon and bring in fresh air from the sea, conductivity even at the coast should be close to that of marine air. This is not seen here. The ground station located at Chavara has also shown that conductivity values were higher than that of marine air even during periods when strong monsoon winds from the seaward side were present.

At a distance of around 20 km from Trivandrum, the negative polar conductivity measured during the return journey is seen to be much higher than positive. This is because the aircraft had taken a slightly different route during its return journey, and flew over a hill towards the north of Trivandrum. This hill is about 160 m high and has a somewhat higher level of radioactivity compared to its surround-
ings. The high negative values seen are therefore due to the reduction in ground height of the aircraft as it flew over the hill and the higher level of radioactivity there.

In the survey to Alleppey and back the positive and negative conductivity values are comparable. In the other two surveys the negative conductivities are higher than the positive conductivities. One possible cause for this difference is that the two polar conductivities are not measured simultaneously. Therefore, any change in polar conductivities with time will be reflected in the data. It is known that the conductivities do show a diurnal variation. Another possibility is that it could be due to a charging of the aircraft, as mentioned earlier. But since the first survey to Alleppey does not show any difference between the two polar conductivities, either the aircraft did not get charged during that flight, or the two processes could have combined to neutralize the effect of each other. Since the flights were carried out on consecutive days, when the weather remained more or less uniform, it is difficult to understand why the aircraft did not get charged in one flight alone. Therefore, the difference in polar conductivities could be due to a combination of these two causes.

The results of the conductivity surveys are plotted on a map of the region in Figure 5.12. The positive conductivity values alone are plotted in four convenient ranges. The ranges are different for the Kottarakara-Chavara survey because this survey was carried out a different altitude from the other two. Over Chavara, therefore, polar conductivities have been obtained at two different altitudes, namely 1000 and 2000 feet, in addition to the data obtained at the surface. These
Figure 5.12 Map showing the positive polar conductivities obtained in the aerial surveys. The ranges are different for the Trivandrum-Kottarakara-Chavara survey because the aircraft flew at a different altitude.
measurements show that conductivity decreases with altitude in this region of the atmosphere. This is a direct result of the high radioactivity at the surface. In the horizontal plane, the higher conductivity is more or less confined to the region having the deposits.

The relationship between the polar conductivities at low altitudes and the presence of radioactive deposits at the surface points to the possibility of adapting this technique for preliminary surveys of radioactive deposits. The instrument is simple, light weight and inexpensive, and no special attachments or fixtures are needed on the aircraft. However, some more work has to be done to validate the technique and work out its feasibility.