

CHAPTER 6

INSTRUMENTATION AND MEASUREMENTS

6.1 MEASUREMENTS

Atmospheric electricity is a field that is very easy to get into because it does not require a large capital investment for measuring equipment. It is a difficult field, however, when it comes to the understanding and interpretation of the various measurements. For example, despite vast data collected over two centuries, there is still no agreement on how thunderclouds charge or how the earth-atmosphere fairweather field is maintained.

Today's advanced technology offers eloquent and accurate instruments with fast response time. It is now possible to construct simple electrometers and electromagnetic radiation detectors using chip circuitry. Video recording equipment is becoming a household item that also has great potential for lightning research, making it possible to view flights of lightning bolts in micro-second intervals.

6.2 ELECTRIC FIELD MEASUREMENTS

Most common are measurements of the electric field at or near the earth's surface. The potential gradient at the earth's surface varies in many ways but usually averages about +100 volts per metre during

fine weather in the absence of clouds. Except for the normal diurnal variations of the fairweather field (see sec. 2.2), strong rapid changes are often registered which might be due to electrically charged dust or heavy pollution. Marked changes in the fairweather field have been observed before the onset of fog or during temperature inversions in the lower atmosphere. Many of the above field effects and their causes are still not fully understood. The electric field below thunderclouds are usually very strong and easy to detect. Rapid field changes occur during lightning discharges and field reversals are common. Field measurements below thunderclouds reveal such features as charging rates, electric polarity and discharge rates to

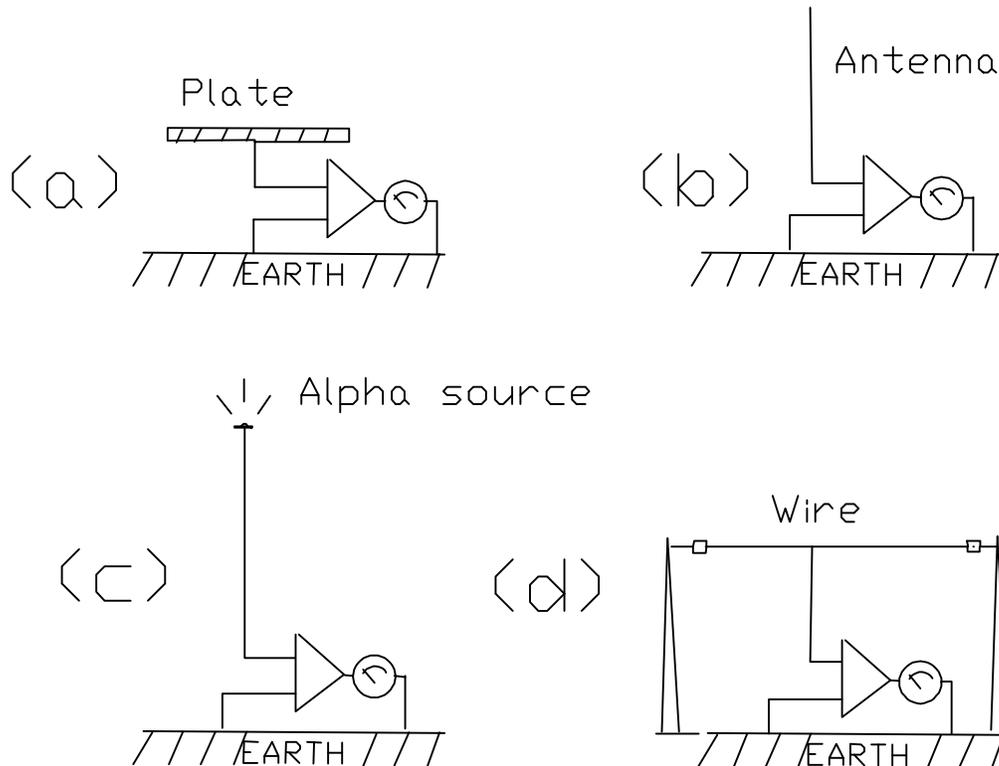


Fig. 43 Different antenna configurations for electric field measurements in the atmosphere. (a) Disc antenna. (b) Whip antenna. (c) Whip antenna with radioactive probe. (d) Long wire antenna.

mention a few. There are several ways one can measure the electric field in the atmosphere. A simple approach is to connect an electrometer to an antenna of some sort such as shown in Fig. 43. The antenna can be a conducting disc placed at a predetermined height

above ground (Fig. 43a). The disc will charge and reach a potential which is equal to or very near the potential of the atmosphere at that height. The diagram in Fig. 43b shows an electrometer connected to a short whip antenna which gives voltage readings that are difficult to calibrate since the antenna whip will protrude through many levels of electric potential. An ion-producing radioactive alpha source at the tip of the whip antenna, see Fig. 43c, will increase the electric conductivity in the air near the tip and ensure a better accuracy of potential measurement as a function of height. A long wire, suspended above ground at predetermined levels, will give accurate readings of atmospheric potentials as a function of height, see Fig. 43d.

6.3 THE ELECTROMETER

There are many excellent electrometers commercially available, but since the electronic market of today can offer a variety of sophisticated integrated circuits, it makes simple home made devices nearly as

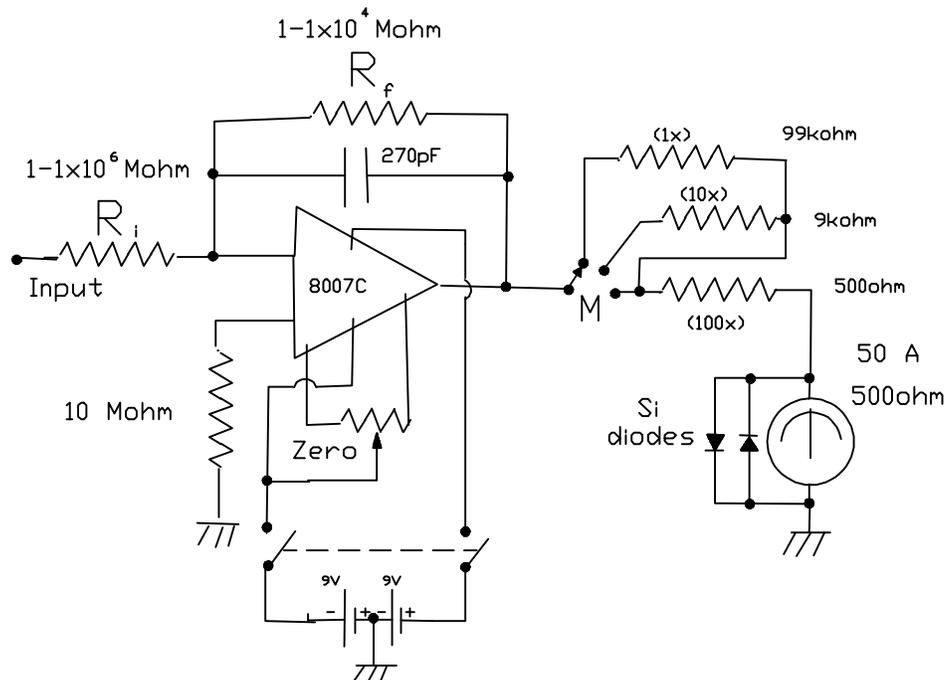


Fig. 44 Electrometer circuit.

effective. For example, the circuit in Fig. 44 has been used by the author in many experiments including the Gerdien cylinder measurements described in section 2.1. It uses two 9 volt batteries and is portable, which makes it convenient for experiments in the field. The electrometer is mounted in an electrically shielded metal box.

Measuring electric fields and field changes during thunderstorms will produce many interesting results. Lightning discharges cause rapid field changes and polarity reversals which can be registered on a chart recorder. The recovery time of the electric regeneration process in clouds is also a very interesting feature that can be studied with the help of a recorder. During thunderstorm measurements it is recommended that the electrometer in Fig. 44 be fitted with an RC network which increases the time constant of the circuit to several seconds. Because of the strong fields produced by thunderstorms, it is also advisable to decrease the sensitivity of the circuit, by changing R_i and R_f . A typical circuit modification for thunderstorm measurements is shown in Fig. 45.

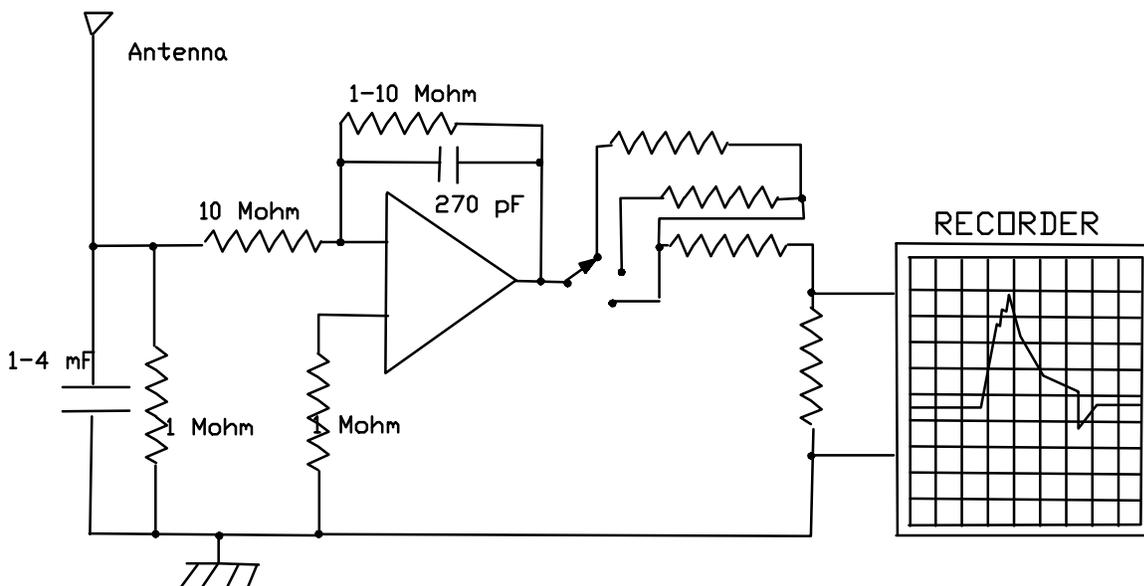


Fig. 45 Circuit for electric field measurements of thunderclouds

6.4 THE FIELD MILL

The electric field mill is a device based on electrostatic induction. It consists of one or two electrodes which either rotate in an electrostatic field or become periodically exposed to a field by rotating vanes. Fig. 46 illustrates a cylindrical field mill which consists of two cylinder

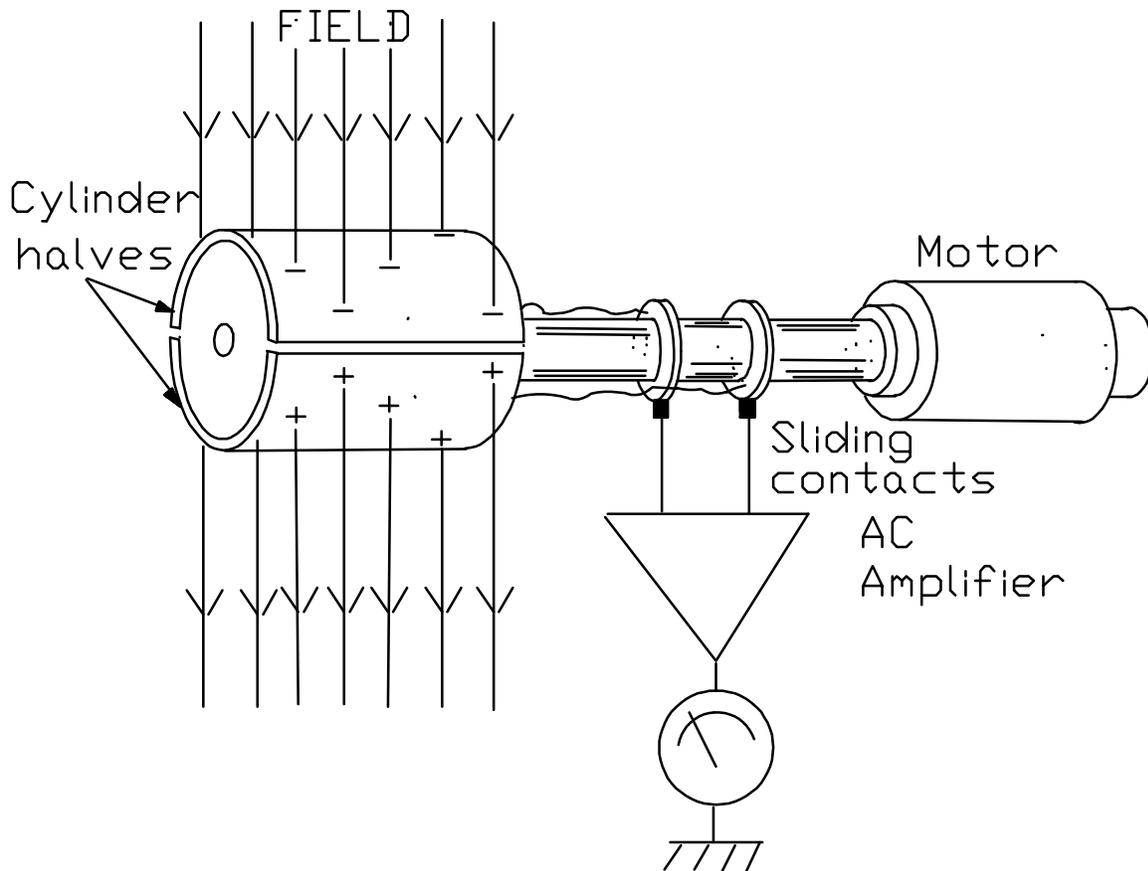


Fig. 46 Cylindrical electric field mill.

halves that are electrically insulated from each other. An electric motor rotates the two halves in the electric field to be measured so that they become alternately exposed to both the positive and negative direction of the field. The result is that an alternating (ac) signal is generated across the two halves which can be easily amplified. The rotating shutter field mill, on the other hand, comprises a stationary electrode, which becomes periodically exposed to the external electric field through a rotating grounded disc (see Fig. 47). A variation on this type of field mill is a stationary grounded cover plate with a rotating

disc electrode. Although not commonly used, the cylindrical field mill has the advantage that when mounted in a fixed position it can also indicate the direction of the field. This is accomplished by measuring the phase shift of the ac signal relative to the orientation of electric fields need to be measured. The rotating

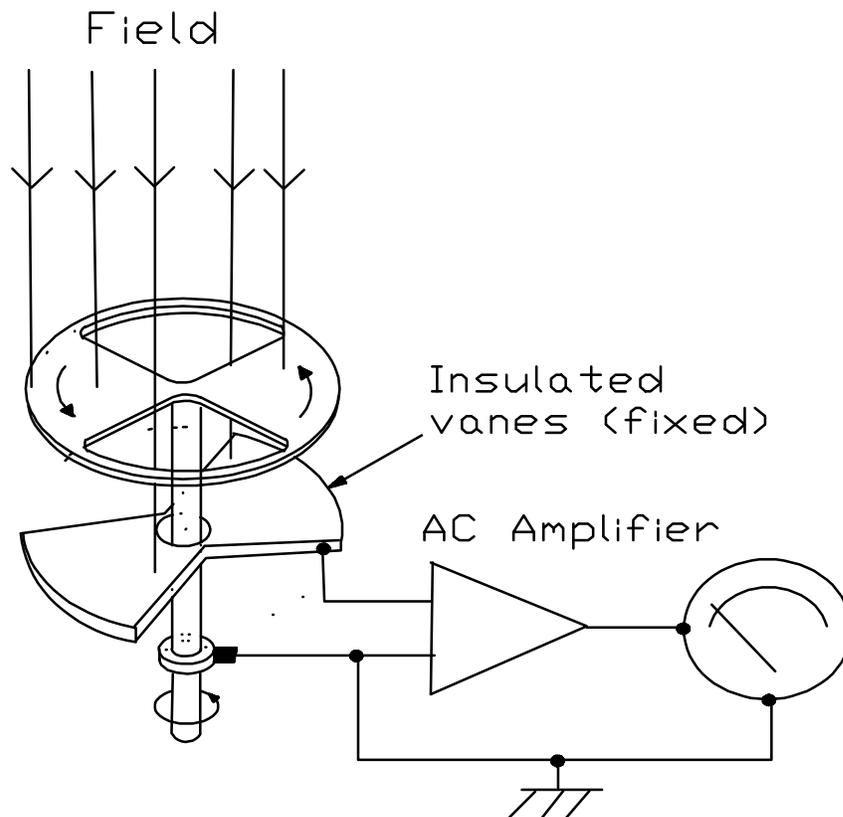


Fig. 47 Rotating shutter electric field mill.

shutter type field mill has to be pointed towards the source of the field in order to obtain a maximum reading. This feature is useful when searching for static charges that might cause problems in the laboratory or industrial plant. The rotating shutter field mill is commercially available in several countries.

6.5 ELECTROMAGNETIC DETECTION

The crackling sound of atmospheric generated by lightning is familiar to everyone who listens to radio. "Sferics" interference is usually

stronger in the low frequency band (10 - 500 kHz) were the electromagnetic energy spectrum of lightning is most powerful. There is also an interest in the higher frequency bands of lightning radiation, around 10 - 30 MHz, relating to corona discharges and fast field changes. An attractive feature of atmospheric is that it enables long distance detection of lightning storms. Radio receivers with directional antennae are used to determine the position and movement of thunderstorms. Several stations can accurately pin-point storms by triangulation. Loop or frame antennae, such as seen on ships, are used and a typical electric block diagram is shown in Fig. 48. Experience has shown that the shape of electromagnetic pulses received from lightning changes with distance, which makes it possible to estimate the distance from the antenna to the discharge. Some aircraft are fitted with "stormscopes" utilizing the above principles to determine the direction and distance of nearby intracloud discharges in order to avoid dangerous confrontation with lightning. Radar echoes of lightning bolts can be seen as reflections superimposed on echoes of heavy precipitation in clouds. It is believed that the ionized channel, produced by lightning, is large enough to cause reflection of radio waves. Radar observations of

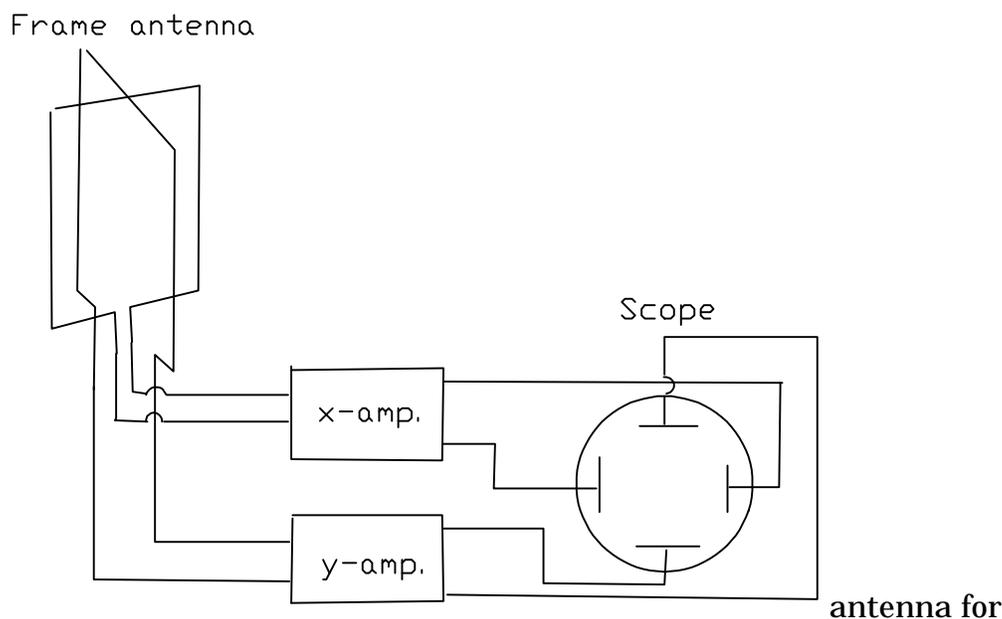


Fig. 48 Loop or frame lightning detection.

thunderstorms bring out many interesting features which might aid in the understanding of the physical processes at work in clouds. For example, radar reflections from precipitation appear several minutes before any visible electrical activity. The radar reflections rise at first together with the cloud top but start to descend as soon as lightning occurs. At the same time lightning commences, precipitation becomes visible and starts to fall out of the cloud. One question often asked is whether lightning induces gushes of precipitation; or vice versa.

6.6 THE FUTURE

There are still many problems outstanding in the field of atmospheric electrostatics. New and better measuring devices will help solve some of the problems still at large, but equally important is the development of new ideas and techniques.

Electrostatic fields and ions in the atmosphere and their effect on our well being is still an open question. There are no conclusive results yet available and more research is needed. It is known, however, that both positive and negative ions reduce the life of bacteria (*Serratia marsecens*) residing in aerosols and that high negative ion concentrations seem to offer relief to persons suffering from bronchial disorders.

Static electricity in the atmosphere might not offer much practical value but it has intrigued many of the best theoreticians and experimentalists throughout time. There is no shortage of thunderstorms and lightning but the problem is how to safely penetrate a cloud and study its micro structure. One alternative is to use large cloud chambers capable of producing convective clouds. Some of the problems might be solved with the aid of orbiting space laboratories or unmanned satellites. The world wide thunderstorm activity and lightning distribution can be monitored from space and correlated with electric field measurements at earth. This could help

settle the very important question whether or not the fairweather field is generated by thunderstorms. Another approach to the above problem is the use of computer modelling techniques. Electric field plots of thunderclouds could determine the amount of current, if any, delivered to the ionosphere. The number of field lines that extend from the top of a cloud to the ionosphere, compared to the number that reaches ground, indicates the fraction of current delivered by the cloud to the fairweather circuit. The previous title in this series *Computer Modelling in Electrostatics* by D. McAllister, J.R. Smith and N.J. Diserens deals in detail with such modelling techniques.

