CHAPTER 3

Instrumentation for atmospheric electrical research

3.1 Introduction

The three main atmospheric electrical parameters used for the study of atmospheric electricity at the EGRL are the potential gradient (PG), air-Earth conduction current density ($J_c$) and total air conductivity ($\sigma$). Details of all the instruments used to make these measurements will be given in this chapter. Electrometers used for these instruments designed by us at our electronics laboratory. Of these instruments for the measurement electric potential at a height of one meter, passive antenna system developed by us at EGRL. In this chapter long wire antenna for Maxwell current (long wire antenna), Field Mill (FM) and Electric Field Meter (EFM-100) for electric field, Passive antenna for potential gradient and Gerdian meter for conductivity measurement discussed. Same instruments used at polar station Mairti, Antarctica for this study. Apart from these instruments Wire antenna used for the measurement of air-earth current (conduction current ) at Maitri, Antarctica since November 2008.

3.2 Maxwell current (long wire antenna)

There are several methods available for the measurements of atmospheric electrical parameters. An important and the most informative parameter of the global electric circuit is the Maxwell current (Ruhnke, 1965). Ground-based measurements are valuable because they provide continuous long-term recordings. The common ground-based sensors used for current measurements are Wilson plate, the horizontal
long-wire antenna and the spherical shell in the form of two hollow hemispheres. The long-wire antenna is a good alternative since it allows for the suppression of local disturbances by averaging the vertical current over a large area (Tammet et al., 1996). By this technique, the contributions from the convection current can be made minimum. The horizontal long wire antenna, if placed in the atmosphere, will closely follow the electrical current variations of the atmosphere by collecting incoming charges from the atmosphere after the initial net charge on the antenna leaks off. When the antenna is shorted to the ground through a resistor, it will pick up a certain amount of current proportional to the Maxwell current. In the present work we use a long wire antenna of 144 m in length and 3 mm in diameter. The sensor is supported 1 m above the ground by means of masts that are electrically separated by teflon rods as shown in Fig. 3.1.

![Sketch diagram of Maxwell current experiment](image)

**Fig. 3.1. Sketch of the Maxwell current experiment.**

The electrometers were calibrated for their performance at the National Physical Laboratory, New Delhi, India. The calibration curve obtained from this
exercise is shown in Fig. 3.2. A simple linearity between the input current source and the electrometer output was observed as noticed in Fig. 3.2. The effective area of the present experimental setup using the Kasemir-Ruhnke model (Kasemir and Ruhnke, 1959) is 158.12 m² calculated from the formula \( S = \frac{hC}{\varepsilon_o} \), \( \varepsilon_o \) being the dielectric constant of air, \( C \) is the capacitance of the antenna and \( h \) is the height of the antenna above ground. As realized in the recent past, this effective area works well for the displacement current whereas the current flow lines representing the conduction current are not expected to match the electric field lines in the presence of inhomogeneities induced by space charges and convection currents. The static effective area proposed by Tammet et al. (1996), which is appropriate for determining conduction current density using long-wire antenna, involves polar conductivity and electric potential.

The sensor is connected to the electrometer (Model AD549) that has high input impedance of the order of \( 10^9 \) ohms and permits extremely low input bias current (\( 10^{-14} \)A). The electrometer converts the current into voltage. The electrometer measures the current in the range of a few picoamperes (pA) to a few nanoamperes (nA) with the high feedback resistance (\( 5 \times 10^9 \)) chosen for this experimental setup. A unity gain operational amplifier (LM308) is connected to the electrometer output signal. The output signals are filtered by a low pass filter with a cut-off period of 1 second (3dB) at the input of an analog-to-digital converter (ADC) that is 100 m away from the preamplifier. The filtered signal is fed to the 12 bit ADC (AD574) with 2.44 mV resolution which is mounted inside the personal computer (PC). The PC records the signal at a sampling interval of one second. The hourly averaging of the data
samples carried out during the analysis stage further eliminates any short-period variations in the measured current.

![Maxwell current electrometer (AD549) calibrated at NPL](image)

**Fig. 3.2 Electrometer model AD 549 calibration curve**

### 3.3 Wilson’s plate antenna (Conduction current)

We have developed an experimental set-up to measure the atmospheric air-earth current (conduction current). Data obtained with the continuous measurements of Wilson’s plate are used in the study of air-earth current density. There are only a few methods suitable for measuring atmospheric electric currents. The common ground-based sensors used for current measurements are Wilson’s plate, the horizontal long-wire antenna, and the spherical shell in the form of two hollow hemispheres (Raina, 2002). In the case of Wilson’s plate set-up, the current collector is in the form of a metal plate flush with the ground and isolated by an insulator supported by Teflon rods. As soon as the charged particles come in contact with the antenna, the electric field is
indicated by an electrometer with AD 549 which converts the current into a voltage. The electrometer measures the current in the range of Pico-amperes to a few nano-amperes with high feedback resistance. A buffer stage (LM308) is connected to the electrometer output. The output signals are filtered by a low pass filter (3 dB) at the input of an analog-to-digital converter (ADC) that is nearly 50 m away from the preamplifier.

![Circuit Diagram]

**Fig. 3.3. Circuit diagram of the Wilson’s plate experiment.**

The filtered signal is fed to a high-resolution Windows based data logging system. Averaging of the data samples were carried out during the analysis stage at 1-min and 30-min intervals, respectively. Wilson’s plate is exposed permanently to the atmosphere and kept flush with ground level (zero potential). The charge is accumulated on the plate by the air-earth current. The time-varying component passes through high 50 GΩ resistance (R2) and capacitance 18 nF (C1) that constitute the feedback loop of the current-to-voltage converter connected as a parallel combination, as shown in Fig. 3.3
The convection current through the surface of an antenna is inherently zero because air cannot pass through this surface. Thus, the total current collected by the plate antenna is the sum of two components (conduction current and displacement current).

![Photograph of Wilson’s Plate antenna](image)

**Fig. 3.4. Photograph of Wilson’s Plate antenna**

To obtain the conduction current component one has to eliminate the displacement current ($\mathbf{J}_d$); this is achieved by making the time constant of the electrometer, in current mode, equal to the relaxation time ($\varepsilon_0/\sigma$) of the atmosphere. The conductivity is $1.4 \times 10^{-14}$ to $1.6 \times 10^{-14}$ mhos/m close to ground level. Therefore, from the above given value, we take the polar conductivity to be half and $\varepsilon_0 = 8.85 \times 10^{-12}$ Fm$^{-1}$. Accordingly, the time constant of the electrometer has been set to nearly the atmospheric relaxation time. A significant contact potential exists between the ground and metal plate. Here, we have nearly 1 V of contact potential in between the Wilson plate and the ground. This potential also varies with the variation in soil moisture and causes a variable error in the measurement of conduction current.
density. In order to reduce the error due to the contact potential, the Wilson’s plate is made of stainless steel (which is supposed to have a minimum contact potential) which is shown in Fig. 3.4. The side wall and bottom of the pit are covered with the same stainless steel material and are properly earthed. This helps in suppressing the current from the ground due to radioactive sources.

Another improvement is in the shape and size of the plate. In the air-earth current receiver, a 1×1 m plate or 1 m² circular plates are being used as the air-earth current receiver (Price and Rind, 1992). In the improved design installed at EGRL, the plate is 1×4 m. To calculate the conduction current density the measured current has to be divided by the Area of the antenna. The length of the plate is also in the direction of the prevailing wind at the site, which reduces the effect of the convection current carried by the wind to the plate and, consequently, the signal-to-noise ratio is increased. This experiment is conducted during fair weather days and cloudy days and to avoid electrometer damages it is put off on lighting and rainy days. Very much care should be taken regularly for cleaning and maintenance to avoid contact potential and short circuit between ground and antenna.

3.4 Passive antenna for electric field

The vertical atmospheric electric field may be sensed by using a passive antenna, which is charged slowly by exchanging the charges in the atmosphere. The potential of the atmosphere is obtained by the measurement of potential difference between the antenna and earth’s surface, which is same as the atmospheric potential. In case of a passive antenna at 1m above the surface, the voltmeter system attached with the antenna system and it is operate over a typical input range of ±500V. This
voltage is generated by a floating voltage generator. The input bias current used in the system is of the order of nearly $10^{-14}$A with input resistance of $\sim 10^{15}$ $\Omega$. This combination must be considered in this circuit is to provide an appreciably higher resistance than atmospheric resistance. In this passive antenna system a high voltage guard is also desirable. The output is given to the ADC and thus the potential can be measured. This system can be operated at a remote place with minimum power consumption. Damages to the electrometer due to severe electrical storms can be cheaply repaired.

The antenna consists of 20m of 1mm diameter tined copper wire, suspended horizontally between short metal masts. At each end there are porcelain egg insulators, and PTFE fixing under steady compression at the masts. Sketch diagram of passive antenna shown in Fig 3.5. The insulators are regularly cleaned with isopropanol. A guard potential, which is close to the potential on the wire, is applied to the support wires at each end. This is to minimize the leakage through the insulators, which would occur if the support wires were merely grounded. As a precaution against the guard potential influencing the potential sensed by the antenna, the parallel cable that is carrying the guard signal to the far end of the antenna has an earthed screen.
The antenna is connected, with a short wire made of same material as that of the antenna, through a UHF male connector to operational amplifier LMC 6042, which is configured as a unity gain follower. LMC 6042 is a low input bias current operational amplifier, which is the input amplifier, and PO-97 is used as driver stage for the source amplifier. The input potential is connected, via a PTFE stand off, to the input of LMC 6042. A 9V battery powers LMC 6042, with the 0V reference set at 1.2 V above the battery negative supply by TC04. This ensures an adequate performance by LMC 6042 around 0 V. The data sheet of the LMC 6042 shows that for positive input voltages, the ultra low bias current is maintained which can otherwise increase for negative input voltage. Thus, by ensuring that the input voltages to LMC 6042 will always be positive at start-up, no large current will be drawn from the high-impedance source, which could otherwise lead to oscillation.

To provide a low impedance output to a voltmeter or logging system the operation potential of LMC 6042 is reduced by a 1/100. 100 MΩ potential divider.
(trimmed by high voltage transformer T1), and presented to the input of MAX 430, also a follower stage. MAX 430 is a chopper stabilized amplifier (with a 1pA input bias current) so that any additional dc error is minimized. A low pass filter (C210 and R211) protects MAX 430 from external short circuits. The negative supply of the output amplifier (MAX 430) is taken from a voltage inverter ICL 7661. This work by first accumulating charge in a bucket capacitor connected between pin 2 and 4 and then transfers it into reservoir capacitor connected between pin 5 and ground. A third power supply by-pass capacitor is recommended (0.1 µF to 10 µF).

An isolated, high-tension supply generates approximately ± 500V (designated +-HT), which is supplied to two high-voltage MOSFETS Q1 and Q2 as wired as a source follower, operated at constant current (generated by Q2) to improve the linearity. OP-97 is a unity gain driver stage, which has frequency compensated for phase shifts caused by driving the considerable input capacitances of Q1, and the capacitance of the cable to the antenna support wires (auxillary guard). OP-97 is powered from a transformer derived supply, but shares 0V connection with LMC 6042. At start up, the potential on LMC 6042 and the input of the supply can differ by the full bipolar HT voltage (1kV). This can cause damage to LMC 6042. And hence a series resistor of 100 MΩ is connected to LMC 6042 to restrict the input current under voltage overload. A stable voltage offset is generated by the circuitry around TC04-LM7555 (IC 201). By adjusting the potentiometer T2, the output at pin 1 of LMC 6042 can made to precisely track the input 5. This output can also used to provide a local guard (body of the UHF female connector) potential for LMC 6042 input connection.
The main power for the unit is supplied from two 12V (7AH) rechargeable batteries, from which a 9V (± 4.5) is obtained using a 9V fixed regulator and is given to LM 6042. 10.5V supply is derived from, such as load dump (60V), when the input voltage to the regulator exceed the specified maximum operating voltage (33V type), the regulator will automatically shut down to protect both internal circuits and the load. The LM 2931 cannot be harmed by temperature mirror-image insertion. The output of the output amplifier is connected to a PC based data logger with a 12 bit ADC to record the field variations continuously. From the circuit, the tracks are drawn using software called, PROTEL EASTEDIT 2.0. Print out were taken and from this printout the tracks is taken and from the printout the tracks are translated into the PCB using screening technique.

The insulators are regularly cleaned with isopropanol. A guard potential, which is close to the potential on the wire, is applied to the support wires at each end. This is to minimize the leakage through the insulators, which would occur if the support were merely grounded. As a precaution against the guard potential influencing the potential sensed by the antenna, the parallel cable that carries the guard signal to the far end of the antenna has an earthed screen. The antenna makes contact with a short wire made of same material as that of the antenna, which is connected to a voltage follower electrometer (LMC 6042) with the unity gain that permits ultra low input bias current of nearly 1 fA. The frequency response of the electrometer is shown in Fig. 3.6. The amplified signals are filtered by the low pass filter at the input of ADC, which is 100 m away from the preamplifier. The filtered signal is fed to the 12 bit ADC. The response of the passive antenna electrometer to specific input voltages is shown in Fig. 3.7.
Fig. 3. 6. Passive antenna frequency response curve.

Fig. 3. 7. Passive antenna input output voltage response curve.
3.5 Field Mill (FM)

The atmospheric electric field has been measured with a vertical ac field mill made out of nonmagnetic stainless steel to reduce the contact potentials (Willett and Bailey 1983). As constructed the mill consists of an upper rotor plate with four equal sectored plates which alternately cover and uncover two four bladed sets of stator plates. The total capacity between the rotor and stator set is ~500 pf and ~ 90pf. The dynamic capacity between the rotor and each set of stator plates is ~ 6pf. The specific capacitance between the plates is $2.4 \times 10^{-8}$ fm$^{-2}$. The induced current per plate set is given by

$$I_0 = \frac{d\varepsilon_o}{dt} = \varepsilon_o E_o \frac{dA}{dt} = \varepsilon_o E_o \hat{R} \omega$$

Where $\hat{R}$ is geometric function and $\omega$ is angular frequency in radsec$^{-1}$. A is the area of the plates. Dynamic range of the mill is 25kV m$^{-1}$. Calibration constant is 15.5mV/100Vm$^{-1}$. Non linearity is less than 0.570. Long term uncertainty is zero and the short term uncertainty is less than 3Vm$^{-1}$. In addition the field mill will reject common mode signals and D.C. component of non-transient contact potentials and the rejection time is less than 5 milliseconds but it will respond to transients less than 8 milliseconds. Photograph of the Field Mill (FM) shown in Fig. 3. 8.
Atmospheric electric field is measured with a field mill with its sensor plates kept flush with the ground. Field mill consists of two stators which are periodically exposed to and shielded from the atmospheric electric field with a rotor fixed on the shaft of an a. c. synchronous motor of 1400 rpm and 12W power. The diameter of rotor is 12 cm and it is made of nonmagnetic stainless steel. The rotor is grounded using a mercury cup at the other end of motor. Two stators are also made of the same material and of same diameter as the rotor. The stators are separated from each other by a distance of 0.5 cm with Teflon bushes. The stators are connected to the inverting inputs of two operational amplifiers (IC 8007). The magnitude of the charge induced on the stators is directly proportional to the intensity of the atmospheric electric field. The two amplified signals are $180^\circ$ out of phase with each other. These two signals, after amplification, are fed to a demodulator (IC 1456) for combination into a single wave. The reference signal for the demodulator is generated with a circular plate with

Fig. 3.8 Photograph of Field Mill installed at Maitri, Antarctica
sectors cut of the same shape as that of rotor and fixed at the other end of motor. This circular plate rotates through an opto-separater and generates a square wave signal of same frequency as that of input signals and exactly in phase with one of the two input signals. Neglecting charge separation on splashing, nontransient rain current, as seen by the field mill would depend on the plate area exposed. Since the rotor has constant angular velocity, it would result in the out-of-phase triangular voltages at the two current amplifier outputs. The differential action of the demodulator would then give the signal with zero d. c. level. It can measure electric field of ±12.5 kV m⁻¹ with response time of 0.1 s. Normally it can sense the lightning-induced electrostatic field changes of an average thunderstorm 20–25 km away from the observatory. The Field mill is calibrated directly by placing it in uniform electric field made by applying known voltages, V, across a parallel plate capacitor, separated by a known distance, d. Batteries are used as a power supply for calibration on the upper plate: the calibration uses the relation E=V/d. The maintenance of the instrument and calibration were carried out regularly. The calibration response curve of the Field Mill is shown in Fig. 3.9.

![Graph showing calibration response curve of Field mill](image_url)

**Fig. 3.9 shows the calibration response curve of Field mill**
The Field mill is calibrated directly by placing it in uniform electric field made by applying known voltages, V, across a parallel plate capacitor, separated by a known distance, d. Batteries are used as a power supply for calibration on the upper plate: the calibration uses the relation \( E = V/d \). The maintenance of the instrument and calibration were carried out regularly. The calibration response curve of the Field Mill is shown in Fig. 3.9.

3.6 Gerdien conductivity meter

In 1905 Gerdien developed a device which has become the standard instrument for measuring air conductivity. It is made of two coaxial electrodes, a hollow cylinder known as the outer electrode containing a thinner central electrode (which is frequently a solid ire). This configuration has a finite capacitance, which can be theoretically derived from Gauss’ Law, and is therefore frequently referred to as a "condenser" (Swann, 1914). If a potential is applied across the electrodes and the tube is ventilated, then air ions of the same sign as the voltage are repelled from the outer electrode and attracted to the central electrode. If they meet it, a small current flows, which is proportional to the ion concentration and electrical conductivity of the atmosphere. Schematic diagram of a Gerdien condenser is shown in Fig. 3.10.
Fig. 3.10 Schematic of a Gerdien condenser (single tube)

Early Gerdien were substantially proportioned, with linear dimensions of about 8 cm by 50 cm (Torreson, 1949). This was necessary in order for the output current to be large enough to be resolved by contemporary electrometers. In the 1950s smaller tubes were developed for radiosonde measurements, which were typically of order 5 cm in diameter and 30 cm in length. Attaching the Gerdien to a fixed potential, and allowing the voltage to decay through air permits a voltage to be measured rather than the current from the central electrode. This is preferential for conductivity measurement on radiosondes, because it is more straightforward to measure voltage than small currents, and immensely simplifies the issues associated with electrometry. The smaller sized tube was not problematic when ion currents did not have to be directly measured. Recent improvements in electronics have improved measurements of very small currents in the femto ampere range (Harrison, 1997a; Harrison and Aplin, 2000a).

The most common of the varied materials used to make Gerdien condensers has been brass (e.g. Higazi and Chalmers, 1966; Brownlee, 1973) probably following successful use of this material by early investigators (e.g. Rutherford, 1897). Gerdien
designed for use on radiosondes have necessarily been made of less dense materials such as aluminum or aluminized paper (Hatakayema et al, 1958; Venkiteshwaran, 1958). The tube material could be significant for two reasons: firstly that of its durability when used in the field, and secondly that of the effect of contact potential. Wählin (1986) discusses the effect of the material of the tube, opining that contact potentials cause offsets in the i-V response. This is credible, as two electrodes touching a fluid containing ions do make an electrochemical cell (e.g. Atkins, 1989), even if the electrolyte (air) is dilute. According to Wählin (1986), a Gerdi\nmen will measure a non-zero current when the bias voltage is zero, due to electrochemical potential at the surface of the tube. Wählin (1986) suggests that a steel tube has to be biased at about 0.4 V and the aluminum at 1 V to counteract this. However, he does not explain how the effects of tube material alone were distinguished in his experiments from the many other sources of offset associated with Gerdi\nmen condenser measurements. The effect of different tube materials has not been systematically investigated, but Hatakayema et al (1958) did apply an offset of -140 mV corresponding to the contact potential for their aluminum tube, though they do not explain how this quantity was obtained.

Fig. 3. 11. Diagram of a Gerdi\nmen condenser
Atmospheric electrical conductivity of both positive and negative polarities is measured simultaneously with gerdien condenser. The apparatus consists of two identical tubes of 10 cm diameter and 41 cm length joined by U-tube. Each tube has central electrode 20 cm long and 1 cm in diameter. The two central electrodes carry positive voltage of polarity to measure positive negative ions. Air is sucked through them with a single fan fixed at the end of the U-tube as shown in Fig. 3.11. To reduce the intensity of turbulent mixing, the ends of the inner electrodes that face the air stream are rounded smoothly. To reduce the effect of atmospheric wind in the condenser, the inner electrode is placed well inside the outer electrode away from the entrance, allowing the initial atmospheric turbulence to decrease considerably. A voltage of ±35 V is applied to one cylinder, known as the driving electrode, with respect to the other. This driving voltage repels ions of one polarity towards the other electrode, where ions get collected. For voltages that are sufficiently low, the collector current increases in proportion to the driving voltage. The collector current at these voltages is given by the equation

\[ i = \frac{-\sigma Q}{\varepsilon_0} \]

Where \( Q=CV \), \( V \) (35 V) is the applied driving voltage is the conductivity of the ambient air, \( \varepsilon_0 \) is the permittivity of free space and \( C \) is the capacitance of the condenser obtained from

\[ C = \frac{2\pi \varepsilon_0 L}{\ln \left( \frac{b}{a} \right)} \]
Where L is the length, a & b are the radii of the inner and outer electrodes, respectively. The collector current, which is proportional to the conductivity which amplified signals from Gerdien’s apparatus are fed through Teflon, insulated coaxial cables to a PC-based data acquisition system, which is 20m away from the field. The equipment is operated at a sampling interval of one second. The maintenance of the instruments, especially cleaning of their insulators, was done daily. The zero shifts are checked twice a day and are corrected if the deviations are appreciable (Deshpande and Kamra 2001).

3.6 Conduction current measurement

Wire antenna can be used for the measurement of Maxwell current as well as air-earth current (Conduction current). Maxwell current includes, (1) conduction current, (2) Displacement current, (3) convection current, (4) lightning current, (5) point discharge current and (6) precipitation current, etc., but in Conduction current measurement is has maximum part of conduction current and small portion of displacement current during fair-weather conditions. It depends on the RC (time constant) in the electronic circuit used for the measurement. Close to the ground the atmospheric relaxation time is about 5 to 40 minutes, 4 seconds near 18 km height and \(10^{-4}\) second near 70 km above the earth’s surface. Maxwell current has two components which is d.c component as well as a.c. The fluctuation part of the Maxwell current is displacement current (AC part) with time domains of 0.1 seconds to 10 minutes. Conduction current with frequency greater than 1Hz is a pure displacement current and at frequencies less than a millihertz is purely conduction current. For frequencies between 1 Hz to 1mHz the conduction current density contains both components as shown in the below equation.
\[ J_M = \Delta X H = \sigma E + \varepsilon_0 \frac{\partial E}{\partial t} \]

Where, \( J_M \) is the Maxwell current density, \( \sigma \) is the atmospheric conductivity and \( E \) is electric field in the atmosphere. It is of considerable interest to separate displacement current density from conduction current density. The determination of displacement current density will be useful studying global scale a.c., component of Maxwell current density. To separate the purely conduction current density and the displacement current density we have used the wire antenna. The Schematic diagram of the conduction current wire antenna is shown in Figure 3.12.

Fig. 3. 12 Schematic diagram of the conduction current wire antenna

The horizontal long wire antenna, if placed in the atmosphere, will closely follow the electrical current variations of the atmosphere after the initial net charge on the antenna leaks off. When the antenna is shorted to the ground through a resistor, it will generate a voltage that is proportional to the air-Earth current. In the present experimental setup, a long wire of length 20 m and thickness 3 mm is kept
horizontally stretched parallel to the ground at a height of 1. The wire is mechanically supported by means of masts. By using Teflon rods at their ends it is ensured that the antenna wire is electrically insulated from the supporting masts. The input is fed through the electrometer (Model AD 549) that has high input impedance and permits extremely low input bias current \(10^{-14} \text{A}\). The electrometer measures the current up to 1 nA (corresponding to the output voltages whose limit is \(\pm5 \text{ V}\)) with a feedback resistance of 50 \(\times 10^9 \Omega\). A unity gain operational amplifier (LM308) amplifies the electrometer output signal. The amplified signal is then taken in a shielded cable over a distance of 40 m to the control room where it is fed to a PC-based data logger. The sensitivity of the digitized signal is 2.44 mV that will correspond to a current of 0.5 pA. The data are recorded at a sampling interval of one second (Panneerselvam et al., 2003). The effective area of the experimental setup is 21.9 m\(^2\) calculated from the formula (Kasemir and Ruhnke, 1959; Tammet et al., 1996),

\[
S_d = \frac{2\pi LH}{\ln(2H/r_o)}
\]

L length of the antenna and H the height of the antenna above the ground and \(r_o\) is radius of the antenna wire. The current density can be estimated by dividing the measured current by the effective area of the antenna. RC (time constant) used in the electrometer circuit is 1000 seconds to eliminate other than conduction and displacement current.

3.7 Electric Field Meter (EFM-100)

There are different methods to measure atmospheric electric field like Field mill (Deshpande and Kamra 2001), passive antenna (panneerselvam et al., 2007). These instruments cannot be operated during bad weather conditions like heavy rain,
blizzards and etc., The above instruments needs 230 V a.c., and also more care has to taken during the operation conditions. Regular cleaning and maintenance is very much needed. The present one Electric Field Mill (EFM 100) can be operated in any weather conditions and also it can be operated in any remote place with 12 V d.c., where a.c., is not available. It measures the atmospheric electric field intensity of the atmosphere and the data can be operated with the sampling rate of as low as 0.5 seconds. Schematic diagram of EFM -100 is shown in Fig. 3. 13.

![Electric Field Mill](image)

**Fig. 3. 13. Schematic diagram of EFM -100**

Electric fields develop wherever there is a difference in electric potential. Electric field is measured in Volts per meter (1 meter = 3.28 feet.) The electric fields which accompany thunderstorms are normally measured in the thousands of Volts per meter, usually abbreviated to kV/m. Lightning can be detected as a sudden change in
the electric field. The electric charge contained in a thundercloud also generates an electric field. This field can be measured on the ground. For an accurate electric field reading the field mill needs to be mounted flush with the ground. Mounting the field mill flush with the ground is not practical however as water, dirt, insects, etc will collect around the sense electrodes and contaminate the electrode insulators. Mounting the electric field mill above the ground surface will enhance the electric field resulting in an incorrect high reading. Sensitivity Plugs are provided to reduce the sensitivity of our field mill and compensate for the higher field mill readings. The EFM-100’s electric field mill senses electric field by repeated exposing and shielding a series of sense electrodes. Field Mill Block Diagram shown in Fig. 3.14.

![Field Mill Block Diagram](image)

Fig. 3.14. Electric Field Meter Block Diagram.
An electric field mill uses a mechanical chopper to alternately shield and expose several sense plates to an electric field. When the sense plates are exposed to the electric field an electric charge is drawn from ground to the plates through a sense resistor. When the sense plates are shielded from the field the charge flows back to ground, again through the sense resistor. This moving charge is an electric current which is measured as an AC voltage across the sense resistor. The size of the voltage is proportional to the size of the electric field applied to the plates. Charge flowing onto and off of the sense electrodes will develop a voltage across the sense resistor. This voltage is amplified and then filtered with a low pass filter then, fed into an ADC. Finally the signal cable is connected to the Data logger or PC where the EFM-100 program installed. The signal from the EFM-100 carried by the Fiber optic cables, and to the EFA-10 Fiber Optic Adapter converts the optical data from the field mill to an electrical signal compatible with personal computer. Data is transmitted optically from the field mill at 9600 baud, 8 data bits, 1 stop bit, and no parity. There is a provision for sensitivity selection. Sensitivity plugs reduce the sensitivity to compensate for the enhanced electric field of a field mill mounted above the surface of the ground. Lower numbers represent lower sensitivities. For example, the 0.25X plug will reduce the sensitivity to ¼ of the field mills normal sensitivity. On a clear day simply choose the sensitivity jumper which produces field values closest to the normal fair-weather electric field of 0.1 kV/m\(^{-1}\). If electric field readings during thunderstorms routinely exceed 20 kV/m (the limit of the field mill) we should change to a lower value Sensitivity Plug. Grounding of EFM -100 is very important and separate grounding should be provided for the good quality of data collection. There is an option for the data storage in the computer software program, it can be stored in the Hard disk or any external disk with 0.5 seconds sampling rate. The EFM -100
suppliers also supplying the software for detecting the lightning and warning alarm
with sound system as well as with different colour option on the graphical display.
The EFM has the sensitivity to detect up to 30 kms of the radial distance from the
measuring site. There is an option for selecting the range of the measuring electric
field. The EFM-100 program creates a file in a day. More details are available in
info@boltek.com.