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Comparison of atmospheric electric field measurements by a pole mounted fieldmeter and by a horizontal wire antenna

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ABSTRACT

The studies reported show that measurements of atmospheric electric fields by pole mounted electrostatic fieldmeters can match measurements by a horizontal antenna wire. Some differences were experienced early in the tests that cannot yet be explained. The differences are tentatively attributed to tribocharging actions during initial set up of the antenna system and by wind blown airborne particulates at the antenna wire. Pole mounted fieldmeters provide opportunity for long term unattended measurements in quite adverse weather conditions with continuous checking of operational health against debris, spider's webs, etc.

Introduction

A horizontal wire antenna is a well established way of measuring atmospheric electric fields [1]. A pole mounted electrostatic fieldmeter provides an alternative approach [2]. Both approaches aim to establish the local voltage at the measurement height, so the electric field is derived by dividing this voltage by the height.

For the antenna system a horizontal wire is mounted from insulators with the voltage of the insulator mountings automatically adjusted by a current sensing circuit to maintain the observed current to zero [1]. The insulator mountings thus act as guard electrodes. With the pole mounted fieldmeter the local potential around the fieldmeter is derived from measurements with the fieldmeter at earth potential using the variation of fieldmeter response with applied voltage established during pre-test calibration [2].

Both methods of measurement appear sound in themselves, but there is need to check whether they provide identical values as expected. With this information it will be possible for researchers to select which method is appropriate for their needs and to be confident in the equivalence of measurements by the two systems.

The objective of the study reported in this paper was to make direct and simultaneous comparison by two methods for measuring ground level atmospheric electric fields and to comment on any differences identified.

Experimental arrangements

Pole mounted fieldmeter system

An electrostatic fieldmeter can be used as a probe of the local potential in its local environment [3]. If the potential of the fieldmeter is varied the observed electric field will be zero when the potential is the same as that of its surroundings. As the potential of the fieldmeter is varied the electric field varies linearly with voltage difference. Thus knowing the slope of this variation the voltage for zero field (i.e. the local space potential) can be calculated from the electric field observed when the fieldmeter is at earth potential [2,3].

The measurement of atmospheric electric fields with a pole mounted fieldmeter used the same arrangement as was used in previous studies [2]. This involved a fieldmeter (a JCI 140) mounted at the top of a slender pole and set with the sensing aperture 2 m above the level of the surrounding ground. The fieldmeter was mounted to be horizontal so observations would relate just to the potential difference between it and its surroundings and not be affected by the local ambient vertical atmospheric electric field. Previous studies [2] had confirmed that this influence was quite small, but it seemed sensible to avoid it.

Observations by the fieldmeter were displayed on a UNI-T UT58A digital multimeter and recorded manually.

Antenna measurement system

The approach used for measurements with the antenna system differed slightly from that used by Harrison [1]. Harrison used the

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maintenance of zero current to a sensing circuit in a servo feedback circuit to adjust the voltage of the mountings of the insulators supporting the antenna wire. For the present studies an electrostatic fieldmeter was used to sense the voltage difference between the antenna wire and the antenna mounting at one of its end insulators. The analogue output from the fieldmeter was measured and the output of a high voltage generator adjusted manually to null the voltage difference between the mountings of both insulators and the antenna wire. Essentially the fieldmeter was thus used as a nulling electrostatic voltmeter. The voltage of the antenna was thus that of the applied voltage plus any voltage difference observed by the antenna fieldmeter – so long as the leakage resistance is sufficiently high to prevent any significant current drain. The overall arrangement is shown schematically in Fig. 1. Because the output current capability of the HV generator was quite low a resistive voltage divider, between the voltage of the insulator mountings and earth, was used to provide the signal for measurement of the guard voltage. Digital multimeters were used to display the output of the antenna fieldmeter and of the divided applied high voltage.

The advantage of the above approach is that each aspect of the overall measurement can easily be checked independently: the leakage resistance of the insulator mountings and the voltage sensitivities of the fieldmeter and of the high voltage measurement.

The antenna was a 15 m long 1 mm diameter tinned copper wire stretched horizontally between the tops of two slender, guyed and earthed, support poles. The insulation at each of the antenna wire was PTFE and at the antenna fieldmeter end this was well shielded to avoid it affecting fieldmeter observations. The antenna wire was mounted with minimum sag about 2 m above level ground. The antenna fieldmeter and the high voltage generator were housed in a metal shielding box – as illustrated in Fig. 1. The level of the voltage was adjusted manually with a remotely connected multiturn potentiometer.

Performance testing

Calibration of pole mounted fieldmeter

For calibration of the fieldmeter, it and its mounting pole were insulated from ground. A range of voltages were applied up to and beyond the level at which the fieldmeter reading was zero.

Calibration measurements in August 2014 provided a figure of 1.420 ± 0.034 V of local potential around the fieldmeter for 1 mV of fieldmeter signal output. The accuracy of measurements by the pole mounted fieldmeter depends primarily on the accuracy of measurement of the slope of the variation of fieldmeter output with applied voltage.

The axis of the fieldmeter was mounted to be horizontal. This aimed to avoid the relatively small contribution to the fieldmeter signal output from the atmospheric electric field around the fieldmeter [2]. Thus the fieldmeter output related solely to the field generated by the difference in potential between the fieldmeter at its local surroundings.

Calibration of antenna system

The sensitivity of the antenna fieldmeter was measured to be 0.406 ± 0.003 mV output per volt difference between the shielding box and the antenna.

The signal from the resistive divider measuring the voltage of the shielding box relative to ground was 1.116 ± 0.013 mV per volt applied.

The leakage resistance from the antenna wire to the shielding box and to the guard electrode at the far end insulator mounting was measured, with the two mountings linked directly together, by the simple expedient of applying some charge to the link and observing, with the antenna fieldmeter, the rate of charge decay. With measurement of the capacitance involved the resistance is obtained from $R = \tau/C$. The capacitance involved was 15 pF. Thus the insulation resistance was around 5×10^{14} Ω. So long as the voltage difference across the antenna insulators was manually kept below 10 V the instrumental leakage current would be less than 2×10^{-14} A.

The frequency response of the antenna fieldmeter observations was limited by the UNI-T UN58A digital multimeter used to display the readings.

Test location and set up

Calibration of the pole mounted fieldmeter and preliminary testing of overall system operation was carried out in a domestic environment and garden. Practical tests were carried out in the middle of a rugby pitch at the local Leisure Centre. By testing in a large flat open area well away from structures such as buildings and trees the atmospheric electric field should be uniform over the whole test area and be the same for both measurement systems. The test situation is shown in Fig. 2.

The pole mounted fieldmeter was spaced about 10 m away from the middle of the antenna wire. Observations were made and

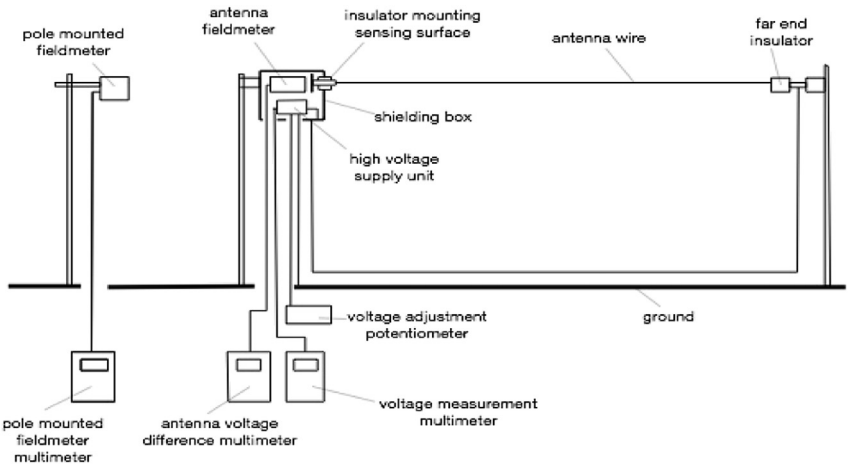

Fig. 1. Schematic diagram of antenna measurement system.