EXPERIENCE WITH ELECTROSTATIC FIELDMETER INSTRUMENTS WITH NO EARTHING OF THE ROTATING CHOPPER[1]

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ABSTRACT

In 1990 two novel designs of 'field mill' fieldmeter were described [2] which do not use the traditional arrangement with an earthed rotating chopper. The instruments described were based on 'constant capacitance' and 'back to back' fieldmeter operation. This paper reports the experience gained since 1990 in the operation of commercial instruments based on both the above principles. Also included are comments on features required for high performance and reliable long term continuous operation.

Experience has been that although the 'back to back' fieldmeter approach appears more complex, both mechanically and electronically the complexities can be handled without difficulty so that the significant benefits can be realised. The main benefits from avoiding the need to earth the rotating chopper are:
1) *avoidance of wear of earthing brushes: which means long and quiet operational life, limited only by the motor drive and bearings*
2) *avoidance of drag of earthing brushes: which means easy operation at high rotational speeds so fast response fieldmeters are feasible*
3) *avoidance of the need for special precious metal alloys for the earthing brushes, the careful mechanical setting required and the progressive degradation of zero noise as brushes wear.*

To minimise the influence of contamination all surfaces within the sensing region need to be gold plated and gaps between surfaces need to be large to minimise the influence of dust and surface contamination and to avoid the risk of bridging by fibres. For operation in wet environments (for example for measurement of atmospheric electric fields) critical gaps need to be at least 6mm to avoid water bridging. Long surface insulation paths are needed.

1. INTRODUCTION

Traditionally fieldmeter instruments have been based on the use of an earthed rotating chopper to modulate the observed electric field at a sensing surface [1]. This approach works well, but has a number of limitations for practical and commercial instruments. Making a good low noise earthing contact to a rotating shaft is not easy. No lubrication can be used and the contact wears. Wear can be minimised by using a smooth shaft of small diameter, by keeping the rotational speed and the brush contact pressure down. The simple approach is a thin wire resting on the side of the rotating shaft. For low noise a precious metal earthing brush contact is needed. The earthing problems become significant for instruments needed for long continuous operation (over several months) and for fast response (below say 10ms). At the higher rotational speeds for fast response instruments a higher contact pressure is needed to avoid contact bounce – and this both exacerbates wear and increases the motor

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power required. It may not be easy to mount and adjust suitable earthing brushes in small scale instruments.

In 1990 two novel designs of ‘field mill’ fieldmeter were described [2] which did not use the traditional arrangement with an earthed rotating chopper. The two instruments described were based on ‘constant capacitance’ and ‘back to back’ fieldmeter operation. This paper reports the experience gained since 1990 in the operation of commercial instruments based on both the above principles. Also included are comments on features required for high performance and reliable long term operation.

2. GENERAL FIELDMETER INSTRUMENTS

The ‘constant capacitance’ fieldmeter approach is an arrangement of the rotor system that ensures the potential of the rotor assembly remains constant during rotation and is not affected by any nett charge on it. With this condition the signals observed and the sensing surface relate only to modulation of the observed external electric field by rotation of the rotor assembly. Achievement of a constant capacitance during rotation of the rotor requires very accurate setting of the counterbalancing capacitance. Critical to this is the absence of end float in the motor drive. Good mechanical stability of the whole sensing region is also important. Although over 100 compact handheld instruments were made with this mode of operation, it became clear that the approach was not well suited to easy and reliable manufacture. A change was hence made to the 'back to back fieldmeter' approach.

The ‘back to back’ fieldmeter approach is in principle two fieldmeters driven by the same motor with the two rotor assemblies electrically connected together. The ‘secondary’ fieldmeter is in a fully shielded enclosure. The signal arises just from any voltage on the rotor assembly. By backing off the signal of the primary fieldmeter by an appropriate fraction of the signal observed by the secondary fieldmeter signal it is possible to fully compensate for any nett charge held on the dual rotor assembly. A useful simplification for practical design is realisation that the function of the secondary fieldmeter is, in fact, just to observe the voltage variation of the rotor assemble arising from variations in capacitance of the rotor as it rotates. Figure 1 shows the basic arrangement for the rotor, sensing surfaces, motor drive and phase sensitive detection.

An original arrangement for a ‘back to back’ fieldmeter had the two sensing regions at either end of a motor with a double ended shaft. This worked, but the capacitance coupling of motor commutation noise signals to the shaft gave large common mode signals to the fieldmeter sensing circuits. These were difficult to null. By having the two rotors mounted together this assembly can be isolated from motor noise by insulation to radically reduce common mode commutation noise. Having the two rotor assemblies together is mechanically simpler and if arrangements are made to operate phase sensitive detection either from the motor or from the secondary chopper then single ended motors may be used – and this is convenient for compact instruments.

Infra red detectors are often, and conveniently, used for obtaining rotational information to drive phase sensitive detection circuits. Care needs to be taken, particularly with reflective opto detectors, to avoid interaction of such detectors with ambient radiation. This is only really a problem with strong illumination by tungsten lamps or from sunlight. Such interaction can upset operation of phase sensitive detection. To avoid the possibility of such problems a change was made to use of a reluctance magnetic pick-up.

The 'back to back' fieldmeter approach requires absence of end float in the rotor assembly drive, but is easier to set up and is more stable than the 'constant capacitance' approach. Immunity to charge on the rotor assembly is easily tested by adding charge to and then earthing the rotor assembly. This is used in both fieldmeter approaches for setting up instruments.

To minimise the influence of corrosion, and different electrochemical potentials, it is best to gold plate all surfaces in and around the sensing region. It is also advantageous to keep gaps between surfaces as large as compatible with other design requirements to minimise the influence of dust and surface contamination and to avoid the risk of bridging by debris and fibres.

Experience has been that although the 'back to back' fieldmeter approach appears more complex, both mechanically and electronically, than the traditional field mill with an earthed rotor the complexities can be handled without difficulty and significant benefits can be realised. The main benefits from avoiding the need to earth the rotating chopper are:

1) avoidance of wear of earthing brushes: which means long and quiet operational life, limited only by the motor drive and bearings
2) avoidance of drag of earthing brushes: which means easy operation at high rotational speeds - so fast response fieldmeters are feasible
3) avoidance of the need for special precious metal alloys for the earthing brushes, the careful mechanical setting required and the progressive degradation of zero noise as brushes wear.

In indication of the performance achieved, it is noted that a fieldmeter with a sensing aperture diameter of 25mm has a noise level and ability to measure electric fields to within 20V m^{-1} pk-pk with a response time around 50ms. This capability allows measurement of surface potentials to better than 1V at 100mm. Response times down to below 3ms can be achieved, and these enable observations to follow 50/60Hz fields.

3. FIELDMETERS FOR ADVERSE ENVIRONMENTS

For operation in wet environments (for example for measurement of atmospheric electric fields) critical gaps need to be at least 6mm to avoid water bridging between plane horizontal surfaces. This requires an appropriately large sensing aperture to achieve sensible coupling of the external electric field to the primary sensing surface. Insulation for the sensing surfaces needs to be provided with suitably long surface tracking paths and, of course, the signal processing circuits need to be well protected from the environment [3].

A fieldmeter for long term continuous measurement of atmospheric electric fields (for a lightning warning system on St Kilda) was built using a sensing aperture diameter of 95mm (in an overall diameter of 101mm) and a four sector chopper with the arrangement shown in Figure 1. For long operational life the chopper assembly was driven by an electronically commutated motor. A logic signal from this motor provided the basic reference to synchronise operation of the phase sensitive detection circuits.

This instrument provided the opportunity to measure electric fields up to 2000kV m^{-1} with noise around 1 Vm^{-1} on the most sensitive range. Calibration [4] remained very stable.

To justify confidence for observations in adverse conditions, such as long term monitoring of atmospheric electric fields, a system was developed for continuous operational health monitoring. This involved modulating the potential of the whole fieldmeter assembly, relative to the local earth, by a low amplitude square wave signal of known voltage excursion. The modulation of observations was compared with expectations, taking account of any general local slope of the variation of observations. Immunity to environmental conditions was shown by the ability to make continuous measurements through periods of heavy rain with an upward facing instrument. The utility of the operational health monitoring facility was demonstrated by detection of a fine spider's web across the sensing aperture during atmospheric electric field measurements!

4. CONCLUSIONS

Experience has shown that the 'back to back' design of fieldmeter, devised in 1990 and developed since then, is suitable for use in practical commercially manufactured instruments. It has proved an approach that offers good electric field measurement capability - in terms of low noise, stable zero, accurate measurement of electric field over a wide range and opportunity for fast response.

REFERENCES:

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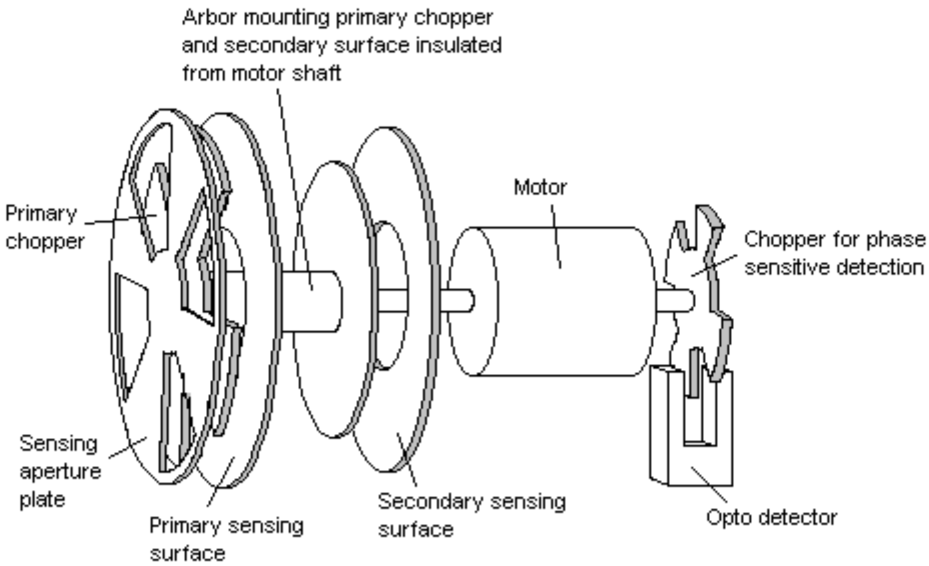

Figure 1: Basic arrangement for 'back to back' fieldmeter

"Experience with electrostatic fieldmeter instruments with no earthing of the rotating chopper" 'Electrostatics 1999' Conference in Cambridge. Article. Jan 1999. J.N. Chubb. View.Â The first design uses a second fieldmeter section to measure and compensate for the voltage on the rotor of the primary section; the second uses a constant-capacitance rotor arrangement with capacitive pick-up of the electric field modulated signal at the rotor. The two designs offer a measurement performance approaching conventional field mill instruments. The principles and features of the two new designs are described, and both avoid the need for earthing of the rotating chopper.