EDM CALIBRATION - INSTRUMENT CONSTANTS AND ERRORS

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Abstract: *An EDM instrument is calibrated on a base to determine instrument constants and errors. If significant, corrections should be applied to EDM measurements taken subsequent to the calibration. A series of measurements on a base can also be used to check the performance and reliability of the instrument over time and to assess its precision against the manufacturer's specifications.*

Keywords: *calibration, instrument’s constant, errors, correction.*

1. Introduction

This section presents the main types of errors that can occur during these geodetic measurements. It is good to keep this in mind and try as much as possible to correct both on the field and in laboratory environment.

The three distinct systematic errors that may occur in EDM instruments are:

- index (or zero) error;
- scale error; and
- cyclic or short periodic error.

1.1. Additive Constant (correction for zero or index error)

All distances measured by a particular EDM/reflector combination are subject to a constant error. It is caused by three factors:

- electrical delays, geometric detours, and eccentricities in the EDM;
- differences between the electronic centre and the mechanical centre of the EDM;
- and differences between the optical and mechanical centres of the reflector[1], [2].

This error may vary:

- with a change of reflectors;
- after receiving jolts;
- with different instrument mountings and after service. The additive constant or zero/index correction is an algebraic constant to be applied directly to every measured distance[4], [5].

1.2. Scale Error

Scale error is proportional to the length of the line measured and is caused by:

- the drift in frequency of the quartz crystal oscillator in the instrument;

errors in the measured temperature, pressure and humidity which affect the velocity of the propagation; and non-homogeneous emission/reception patterns from the emitting and receiving diodes (phase inhomogeneities). The scale frequency can be checked by:

- direct comparison against frequency testing apparatus; and measurement over a base of known distance[1], [6].

1.3. Cyclic Error (or Short Periodic Error)

Cyclic error is caused by the non-linearity in amplitude modulation of the carrier wave and phase measurement. This cyclic error varies across the modulated wavelength. For an instrument in good adjustment this error is normally small. However, its presence must be determined as an indication of the instrument's adjustment. Cyclic error is usually sinusoidal in nature with a wavelength equal to the unit length of the EDM.

The unit length is the scale on which the EDM measures the distance, and is derived from the fine measuring frequency. Unit length is equal to one half of the modulation wavelength of an EDM (Rüeger, 1990).

As cyclic error repeats itself for every unit length contained within a measured distance, its sign and magnitude varies depending on the length measured. The magnitude of the error could be in the order of 5-10 mm, however in modern EDM instruments it is usually less than 2 mm (negligible).

Cyclic error can increase in magnitude as an EDM's components age. Cyclic error can be derived by a series of check measurements made on EDM bases[1], [3], [5]. A series of measurements is made from the first pillar and then a second series is made from second pillar, which is at a distance (D) from the first pillar:

$$D = (x + 0.5)\ U \qquad (1)$$

where: U = the instrument's unit length (m), x = an integer representing a whole number of unit lengths, then cyclic error cancels out due to the errors affecting the distances being equal in magnitude but opposite in sign. The index error and scale error can then be determined independent of the cyclic error[2], [4], [7], [8].

2. Standard EDM Calibration-Booking Sheets or Recording Data

All observations shall be recorded on the EDM Calibration booking sheet at the time they are made. When mistakes occur, each mistake shall be crossed out, not erased or made illegible, and the correct value entered alongside.

All such alterations shall be signed or initialled by the person making the correction, and the date of change should also to be recorded. All details must be recorded and signed and dated by the operator. Units used are: metres (m) for distance, degrees Celsius (°C) for temperature and millibars (mb) for atmospheric pressure[6], [8], [9].

Note: 1 millibar (mb) = 100 pascals (Pa.)
= 1 hectopascal (hPa).
= 0.750 28 mmHg.
= 0.029 53 inHg.

2.1. Preparation of Equipment

Check the levelling bubbles on all tribrachs, reflectors and the theodolite, and if necessary, adjust before observing distances.

2.2. Set-up and Shade

Set the instrument on pillar 1. An umbrella must shade the instrument for the duration of the calibration observations as well as during the warm up period prior to the commencement of reading. To improve the accuracy of the calibration an umbrella may also be used shade the reflector[1], [5], [7].

2.3. Atmospheric Correction Control

Determine whether or not the EDM is a pulse distance meter. If not, then the atmospheric correction control (ppm) should be set to zero if possible. For instruments requiring meteorological observations to be input, enter the temperature and pressure for which the instrument is standardised (ie: ppm =0)[1], [5].

If the EDM is a pulse distance meter, then the ambient temperature and pressure must be entered into the EDM before observing each inter-pillar distance.

2.4. Index Error

Record the setting of the additive constant on the booking sheet. Set it to zero if possible. Attenuator or aperture settings must be set as prescribed in the manufacturer's instructions[1] ,[2], [3].

2.5. Power

The EDM battery should be fully charged prior to performing the calibration.

If possible the instrument should remain switched on during the whole calibration[8].

2.6. Height of Instrument

With the EDM instrument levelled, measure the height of the instrument (height of the trunnion axis) above the brass plate in the pillar. Record this height at each occupied pillar.

2.7. Reflector Mountings

The same reflector mounting and tribrach should be used for all measurements. If it is not possible to measure the longer distances with one reflector use a multiple reflector mounting. With this arrangement it will be necessary to remove or block out some reflectors for the short distances.

The height of the centre of the reflector prism above the brass plate must be measured and recorded at each pillar. If a multiple reflector arrangement is used, the reflector height in both the single and multiple configurations is recorded on the booking sheet.

The reflector must have a unique identification, which must be recorded on the booking sheet[1], [5] ,[6].

2.8. Theodolite Mounted Instruments

The axis of the beam must be adjusted according to the manufacturer's instructions and remain unaltered during the calibration.

It is necessary to record if the EDM is mounted in the "face left" or "face right" position of the theodolite as the additive constant may differ between face [1] ,[2], [6]

2.9. Meteorological Observations

Field equipment can be compared to standardised thermometers and barometers held by the Office of the Surveyor-General. Comparisons between field and standardised equipment will be recorded on the booking sheets. Temperature (°C) must be measured in the shade at both the instrument and reflector. Temperature is measured at instrument/reflector height and is to be observed for each inter-pillar interval. The atmospheric pressure (mb) must be measured in the shade at the instrument station for each inter-pillar distance.

To obtain a higher accuracy calibration, atmospheric pressure can also be observed in the shade at the reflector, for each inter-pillar interval.

Note: the typical atmospheric pressure readings at the EDM Base are between 930 – 970 mb.

The significance of errors in the meteorological observations on the EDM distance can be summarised as follows:

• An error in temperature of 1°C affects the distance by 1ppm.

• An error in pressure of 1hPa affects the distance by 0.3ppm.

Although humidity has only a small effect on EDM measurements, relative humidity (%), or wet bulb temperature observations can be taken to further improve the accuracy of the calibration[2], [4] ,[8] ,[9].

Standardised meteorological equipment will not be loaned out to users if inclement weather is forecast. Users will need to compare their own equipment to the standardised equipment before and after fieldwork.

3. EDM Specifications

Ascertain the unit length (m) of the instrument (half of the modulation wavelength of the fine measurement) as this influences the measuring procedure. This length is generally quoted in the technical specifications for the instrument in the manufacturer's handbook. Record the unit length on the booking sheet.

Likewise ascertain the frequency (Hz), carrier wave length (nm), and the manufacturer’s stated standard deviations of the EDM and record these on the booking sheet[1] ,[3], [5] ,[7].

3.1. Calibration Measurements

For each inter-pillar distance, a minimum of five (5) separate distance measurements are taken, re-pointing after each measurement. Pointing can be made optically or electronically as prescribed by the manufacturer. To improve the accuracy of the calibration, additional distances may be observed[1] ,[2].

3.2. Sequence

From pillar 1, measure distances to pillars 4 - 11 in turn. If the instrument has a unit length of 0.37, 2 or 10 m, shift to pillar 2. If the unit length is 1, 3 or 5m, shift to pillar 3.

Then measure to pillars 11 - 4 in turn. The sequence requires the "reflector man" to move up and down the line only once. For instruments with a unit length of 1.5m measure from pillar 1 to pillars 4- 11 and from pillar 4 to pillars 11 - 5, and 3 – 1 in turn.

For instruments with a unit length of 0.8m or 20m measure from pillar 1 to pillars 4 - 11 and from pillar 5 to pillars 11 - 6, and 4 - 1 in turn. Higher order calibrations will be obtained by setting up on all pillars and measuring to all other pillars (short distances between pillars 1, 2 and 3 are not read)[1] ,[3] ,[5] ,[8].

3.3. Comparison of Reflectors

Once all inter-pillar distances have been measured to the **one** uniquely identified reflector, compare this reflector with the remaining reflectors by measuring to each in turn. This should be performed on the shortest line (pillar 3 to pillar 4) by comparing the slope distances. However if reflectors vary in height, horizontal distances should be observed.

Where found to be significant, variations should be applied as corrections to the additive constant. It is for this reason that all reflectors should be uniquely numbered. Subsequent calibrations of the EDM should be performed using the same uniquely numbered reflector, in order to compile a calibration history for the instrument/reflector combination[6] ,[7] ,[8].

3.4. Reduction and Interpretation

The instrument details, measured distances and observed meteorological details are entered interactively by Office of the Surveyor-General staff. After the observed data is reduced to obtain horizontal distances and their associated standard deviations, a least squares adjustment is performed. This computes the instrument corrections and their associated uncertainties.

The adjustment is made as described in "*Introduction to Electronic Distance Measurement*" (Rüeger, 1990) for modelling systematic errors in EDM measurements.

The program generates an EDM Calibration Report, which includes baseline data, equipment details, observed data, adjusted observations, index correction, scale factor, cyclic error and variance factor. It also states the calculated uncertainty of the instrument correction at the 95% confidence level for standardised intervals.

The program also generates an abbreviated EDM Calibration Certificate. The Calibration Certificate contains the following:

Associated information including the surveyor's name, date of measurements, baseline details and details of the EDM and reflector are listed. The job identification name is also given.

The first velocity (atmospheric) correction formula used in the computation is given in full. The Instrument Correction (IC) equation. From this IC equation, a correction (in millimetres) can be calculated for any distance measured by the EDM in the range of the calibration. The instrument calibration parameters (index error, scale error and 4 terms describing the cyclic error), and their uncertainties at the 95% confidence level are listed.

The uncertainty of the instrument correction at the 95% confidence level is listed for various distances. Where the statistical analysis reveals the calibration to be outside tolerances, adherence to the test method, equipment settings and observation data is reviewed to determine the source of the inaccurate results.If changes are made, the calibration is re-run and further reviewed.

When the statistical analysis indicates that the calibration is within tolerance, the EDM Calibration Certificate can be signed by an Approved Signatory and supplied to the customer, along with the EDM Calibration Report and a copy of the booking sheets.

If the statistical analysis continues to fall outside of the tolerance, then the calibration is deemed to be nonconforming. In the event of a calibration found to be nonconforming, OSG staff shall determine the required course of action.

This may include the cessation of calibration activities or withholding of calibration reports and certificates, as necessary[1] ,[2] ,[3] ,[5].

4. Conclusion

EDM instrument calibration is very important for surveyors, surveyors and other users of land measuring instruments, especially topographic appliances is important that all users know the importance of permanent monitorisation of EDM instrument, meaning changes depending on the type parameter measurement performed and especially depending on environmental conditions.

This article aims to put it briefly users of these devices on some issues that should take into account before making topographic measurements, and especially make a contribution to the field calibration using a geodesic based on pilasters. This is useful because you can calibrate the accuracy and distance measurement error with some popular benchmarks.

5. References

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