Calibration of Electronic Distance Measurement Instruments

Last updated April 2021

1. Introduction

An Electronic Distance Measurement (EDM) instrument is calibrated on a baseline to determine instrument constants and errors.

A series of measurements on a baseline can also be used to check the performance and reliability of the instrument and to assess its precision against the manufacturer's claims and specified minimum standards.

There are a number of sources of error inherent in EDM equipment. The three most influential systematic errors, which may occur in EDM instruments, are:

- zero constant or index error;
- scale error; and
- cyclic or short periodic error

It is beyond the scope of this procedure to identify all sources of error inherent in EDM equipment. Surveyors should be aware of the limitations of the equipment they use and ensure that it is well maintained and regularly checked by the manufacturer's agent.

2. Controlling Legislation

Matters relating to the calibration of measuring equipment are detailed in Regulation 20 of the Licensed Surveyors (General Surveying Practice) Regulation 1961.

3. Regulation 13 Certificate

A verifying authority is empowered to issue certificates under Regulation 13 of the National Measurement Act that attest to the calibration of a standard of measurement. Such a certificate is evidence of the matters stated in it and may be received as evidence in any court of law.

An increasing number of measurements are being made for regulatory purposes and these require traceability within the meaning of Section 10 of the National Measurement Act.
The Surveyor General of Western Australia is a verifying authority for length in this State. Surveyors and other clients requiring this service should contact Survey Services
Phone number: +61 (0)8 9273 7114
Email: geodesy@landgate.wa.gov.au

4. Calibration of Electronic Distance Measurement (EDM)

The following errors are determined by calibration:

4.1 Zero constant or index error

All distances measured by a particular EDM instrument and reflector combination are subject to a constant error; caused by three factors:

- electrical delays, geometrical detours and eccentricities in the instruments
- differences between the electronic centre and the mechanical centre of the instrument; and
- differences between the optical and mechanical centres of the reflector.

This error may vary with changes of reflector, or after jolts, or with different instrument mounting and after service. It is an algebraic constant to be applied directly to every measurement.

4.2 Scale Error

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

- internal frequency errors, including those caused by external temperature and instrument "warm up" effects;
- errors of measured temperature, pressure and humidity which affect the velocity of the signal; and
- non-homogeneous emissions/reception patterns from the emitting and receiving diodes (phase in-homogeneities).

4.3 Cyclic Error

The precision of an EDM instrument is dependent on the precision of the internal phase measurement.

Unwanted interference either through electronic/optical cross talk or multi-path effects of the transmitted signal onto the received signal causes cyclic error. The major form of the cyclic error is sinusoidal with a wavelength equal to the unit length of the instrument.

The unit length is the scale on which the EDM instrument measures the distance, and is derived from the fine measuring frequency. Unit length is equal to one half of the modulation wavelength (Reference Rueger 1984). The magnitude of the cyclic error can be of the order of 5 - 10 mm, but it will vary depending on the actual length measured.

5. Western Australian EDM Baselines

Landgate maintains three baselines in WA as well as the BaselineWA software which has been developed specifically for the calibration of EDM instruments over these baselines.

5.1 Curtin University Baseline

This baseline is situated on Curtin University property parallel to Kent Street, Bentley. The baseline is managed by Landgate. Refer to this plan for access details and pillar locations. The baseline consists of 12 co-linear pillars with the first 4 being closely spaced to the extent that for normal calibration operations only pillars 2 and 3 need be occupied.

The baseline is accessible by any vehicle at all times via the track alongside the length of the baseline. Permission is not necessary to use the baseline. Any conflict of usage should be decided on a first to occupy basis.

5.2 Kalgoorlie Baseline

This baseline is situated on the Department of Mines and Petroleum, Explosives Reserve in Piccadilly Street, Kalgoorlie. Refer to this plan for access details and pillar locations.

Access to the facility is by any vehicle (when dry) during normal business hours after first obtaining the required entry permission. Any conflict of usage should be decided on first to apply basis.

Contact Reserve Manager, on phone number +61 (0)8 9091 7590 to make appointments to access the reserve.

The following conditions will need to be met for continued access to the site.

- Requests for access, are made preferably at least one week in advance.
- The number of people coming onto the reserve to conduct calibration work is kept to an absolute minimum.
- People conducting the calibration must be accompanied at all times by a reserve officer while on the reserve.

The baseline consists of eight co-linear pillars.

5.3 Busselton Baseline

This baseline is situated on Reserve 44755. It runs parallel to and to the North of the Busselton Bypass Road, 1.3 Kilometres west of Redgum Way. The baseline is managed by Landgate. Refer to this plan for access details and pillar locations.

The baseline is accessible by any vehicle at all times via the track alongside the length of the baseline, with entry via the west end of the truck bay. Permission is not necessary to use the baseline. Any conflict of usage should be decided on a first to occupy basis.

The baseline consists of six co-linear pillars.

6. Minimum Standard for the Uncertainty of Calibration

The National Standards Commission now incorporated into the National Measurement Institute, states that the minimum standard for the uncertainty of calibrations of an EDM instrument used for cadastral surveys should be ± (4.0mm + 20ppm) at the 95% confidence level.

This recommendation means that an instrument correction is derived for an EDM/reflector combination from measurements on a certified EDM baseline and that the uncertainty (against the National Standard) of this instrument correction (IC) shall not exceed ± (4.0mm + 20ppm). Subsequent to a calibration, the derived instrument correction is applied to distance measurements, thus bringing the EDM readings in line with the National Standard of length. In terms of standard deviation, the instrument correction must be accurate to at least

± (2.0mm + 12ppm) [6.1].

Note that the uncertainty and standard deviations listed above refer to the accuracy of the instrument correction and not to the precision of a distance measurement. The expression at [6.1] does not relate in any way to the accuracy specification quoted by manufacturers for their instruments.

7. Calibration Procedures

Calibration will typically be undertaken when the equipment is to be used for precision survey work requiring an accuracy of distance measurement of greater than 1 part in 12,000 or as required by the controlling legislation.

Field Booking Sheets are available here:

Curtin University Baseline
Kalgoorlie Baseline
Busselton Baseline

Measurement procedure on baselines - Ascertain the unit length of the EDM (half of the modulation wavelength of the fine measurement) and record on the booking sheet. This length should be provided under the technical specifications for the instrument in the manufacturer's handbook.

Recommended sequence of measurements for calibration:

CURTIN UNIVERSITY BASELINE

Place EDM on pillar 2 and measure to pillars 4, 5, 6, 7, 8, 9, 10, 11B and 12 in turn. Then shift EDM to pillar 3 and measure to pillars 12, 11B, 10, 9, 8, 7, 6, 5 and 4 in turn. This sequence requires the reflector to be moved up and down the line only once.

KALGOORLIE BASELINE

Place EDM on pillar 1 and measure to pillars 3, 4, 5, 6, 7 and 8 in turn. Then shift EDM to pillar 2 and measure to pillars 8, 7, 6, 5, and 4 in turn. This sequence requires the reflector to be moved up and down the line only once.

BUSSELTON BASELINE

Place EDM on pillar 1 and measure to pillars 2, 3, 4, 5 and 6 in turn. Then shift EDM to pillar 2 and measure to pillars 6, 5, 4, 3 and 1 in turn. This sequence requires the reflector to be moved up and down the line only once.

If required, higher order calibrations can be obtained for EDMs by observing to more pillars, however this may require considerable time to complete. For more information, contact Survey Services:
Phone number: +61 (0)8 9273 7111
Email: geodesy@landgate.wa.gov.au

All calibration measurements can be taken in either daytime or nighttime but a mixture of day and night measurements is not acceptable.

EDM instruments, thermometer and barometer are to be shaded by an umbrella in sunny and rainy conditions. Only one thermometer and barometer will be needed. A psychrometer or hygrometer may be used to measure humidity for a more accurate determination of atmospheric correction.

It is recommended that the identification of the meteorological field equipment be recorded in the comments field of the observation sheet.

Measure all heights to the instrument and prism from the pillar plate accurately to +/- 1mm.

If possible the instrument should remain switched on during the whole calibration (instruments with own thermostatically controlled oscillators must remain switched on during the whole calibration).

The same reflector, reflector mounting and tribrach should be used for all measurements. The reflector must have a unique identification (serial number) which must be entered on the booking sheet.

On each line, four separate distance measurements should be taken as a minimum, with re-pointing after each measurement. Pointing can be performed optically or electronically as recommended by the manufacturer.

Atmospheric Correction Control - Atmospheric corrections using corrected observed temperature and pressure should preferably be entered into the EDM instrument. This is essential for Pulsed EDM instruments. Temperatures and pressure should be noted for every distance measured. Observers MUST note on the booking sheet whether the atmospheric correction control is set to zero, or has been set according to the prevailing temperature and pressure.

8. Calibration Software, Reduction and Interpretation

The BaselineWA EDM calibration software has been developed by Landgate for the calibration of EDM instruments against standard baselines. The calibration of EDM instruments is carried out to determine the instrument corrections to be applied to measurements and to ensure its reliability. On-line help provides the user with the instructions necessary to run this software application. The software can be freely downloaded here.

The calibration results and measurements for each EDM instrument and baseline are stored in a database for future reference and legal traceability. The Curtin, Kalgoorlie and Busselton baseline details have already been included in the database. A selection of EDM instruments and reflector makes and models is also included. When installing new versions of the baseline software, please install it in the same directory path as your existing version and your existing calibrations and instruments will be retained.

The instrument details, measured distances and observed meteorological details are entered interactively by the operator. After the observed data is reduced to obtain horizontal distances and their associated variances, a least square adjustment is performed. The adjustment is made as suggested by Dr J.M. Rueger (Rueger 1984) for modeling systematic errors in EDM measurements.

BaselineWA produces several reports for analysing an EDM instrument calibration and a certificate which summarises the results of an EDM instrument calibration.

To obtain a Regulation 13 Certificate in Western Australia for the purposes of legal traceability to the Commonwealth standard of length, the measuring instrument must be submitted to the National Measurement Institute (NMI). for calibration and certification. A charge for this service applies.

The minimum standards for the uncertainty of calibration are described in terms of Recommendation No.8 of the working party of the National Standards Commission (now NMI) on the calibration of EDM Equipment of 1 February 1983. All uncertainties are specified at the 95% confidence level.