Calibration of Electronic Distance Measurement Instruments

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 surveying equipment. This procedure concentrates on those found in EDM equipment. The three distinct 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 surveying equipment. Surveyors should be aware of the limitations of the equipment they use and ensure that it is well maintained and regularly checked.

2. Controlling Legislation

Matters relating to the accuracy of surveys are detailed in Regulation 5 of the Licensed Surveyors (Guidance of Surveyors) Regulation 1961 that states:

"The necessity for the greatest practical accuracy cannot be too strongly impressed upon surveyors. In many instances no means exists by which errors can be immediately detected. If therefore, it is found that a Surveyor's work is not up to the necessary standard of accuracy, or is generally unreliable, or that he has in other respects neglected to comply with these regulations, he will be dealt with under Section 21 of the Act".

3. Regulation 13 Certificate

A verifying authority is empowered to issue certificates under Regulation 13 of the National Measurement Act that attest to the verification 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, for example, EDMs and Surveyor's tapes.

The Surveyor General of Western Australia is the verifying authority for length in this State. Surveyors and other clients requiring this service should contact the Registration Services Branch of Landgate.

4. Verification of Electronic Distance Measurement (EDM)

The following errors are determined by a verification:

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 propagation; and
- non-homogeneous emissions/reception patterns from the emitting and receiving diodes (phase inhomogeneities).

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 (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

5.1 Curtin University Baseline

In 1995 the Surveyor General reconditioned a 10 pillar baseline at Curtin University which had been in use for approximately ten years. Renovation included the placement of two additional collinear pillars making the baseline a twelve pillar base. New stainless steel pillar plate tops have been provided to all pillars, with a 5/8" whitworth threaded bolt at the centre of each pillar top. In 2005 a replacement Pillar 11A was established following the destruction of Pillar 11.

This baseline is situated on Curtin University property parallel to Kent Street, Bentley. The baseline is managed by Landgate.

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.

A software program [BaselineWA Version 2009.10.26.0] has been developed specifically for the verification of EDM instruments over the baseline.

5.2 Kalgoorlie Baseline

This EDM calibration baseline is situated on the Department of Mines and Petroleum, Explosives Reserve in Piccadilly Street, Kalgoorlie.

Access to the facility is available during normal business hours after obtaining the required entry permission. Any conflict of usage should be decided on first to apply basis.

Contact Reserve Manager, on 9091 7590 to make appointments to go onto 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 pillars set out such that all pillars are collinear.

The baseline is readily accessible to 2WD vehicles when dry.

A software program [BaselineWA Version 2009.10.26.0] has been developed for the verification of EDM instruments over the baseline.

5.2 Busselton Baseline

This baseline was completed in 2009 and is situated on Reserve 44755. It runs parallel to and to the North side of the Busselton Bypass Road, 1.3 Kilometres west of Redgum Way. The baseline is managed by Landgate.

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 concrete pillars set out such that all pillars are collinear.

A software program [BaselineWA Version 2009.10.26.0] has been developed specifically for the verification of EDM instruments over the baseline.

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) (5.1)

at the 95% confidence level. This recommendation means that an instrument correction is derived for a distance meter/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 distance meter 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) (5.2)

It is important to realise 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 (5.2) does not relate in any way with the accuracy specification quoted by manufacturers for their instruments.

7. Verification Method

The verification method involves the measurement of a set of segments on the EDM base to determine the existence and magnitude of any errors present. This level of verification 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.

8. Verification Procedures

8.1 Booking Sheets

- Curtin University Baseline
- Kalgoorlie Baseline
- Busselton Baseline

8.2 Measurement Procedure on Baselines

Ascertain the unit length of the instrument (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.

8.3 Sequence of measurements for a complete verification.

- CURTIN UNIVERSITY BASELINE

  Place EDM on pillar 2 and measure to pillars 5, 6, 7, 8, 9, 10, 11A and 12 in turn. Then shift EDM to pillar 3 and measure to pillars 12, 11A, 10, 9, 8, 7, 6 and 5 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. These require several hours to complete the observations. Please contact the Manager of Geodetic Survey, Landgate for more information.

8.4 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.

8.5 Level EDM instrument and reflector carefully on all stations. Start with all foot screws in the mid position. The stainless steel pillar tops have been set level on pillars.

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

8.7 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).

8.8 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.

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

8.10 Meteorological field equipment will have current calibration status.

8.11 On each line, four separate distance measurements should be taken as a minimum, with repointing after each measurement. Pointing can be optically or electronically performed as prescribed by the manufacturers.

8.12 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.

9. Reduction and Interpretation

An EDM Calibration software program [BaselineWA Version 2009.10.26.0] 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 from the Landgate Website.

The calibration results and measurements for each EDM instrument and baseline are stored in a database for future reference and legal traceability. The CurtinA, Kalgoorlie and Busselton baseline details have already been included in the database. A selection of EDM instruments and reflector makes and models are also included.

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.

The program produces several reports for analysing an EDM instrument calibration and for analyzing a calibration of a baseline. A certificate which summarises the results of an EDM instrument calibration is also produced.

To obtain in Western Australia a Regulation 13 Certificate for the purposes of legal traceability to the Commonwealth standard of length, the instrument must be submitted to Geodetic Survey at Landgate for verification and certification.

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.