




CE331 Lab 3 : EDMI Calibration

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Objective

Lab Exercise 3 : Calibration of EDMI

For given EDMI determine the following errors:

- Cyclic error curve
- Reflector-instrument error
- Scale error

Equipment

- EDMI
- Tape
- Reflector
- Tripod
- Bipod

EDMI (Electronic Distance Measuring Instrument)

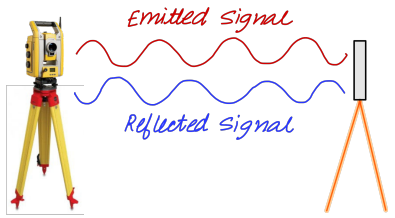
- Combines theodolite angle measurements with electronic distance measurement.
- Replaces taping, ensuring quick and accurate distance measurements regardless of terrain.
- Measures both horizontal and zenith (altitude) angle as well as sloping distance.
- Automatically calculates horizontal and vertical components from the slope distance.
- Distance measurement takes 1.5 to 3 seconds, repeated measurements improve accuracy.
- Commonly referred to as **Electronic Total Station (ETS)** or **Total Station**.
- Useful for
  - traversing
  - control networks
  - setting-out
  - photogrammetric control
  - deformation monitoring

Principal of Distance Measurement

Phase Comparison Method

- Measures the distance by comparing the phase shift of the reflected signal with the emitted signal.

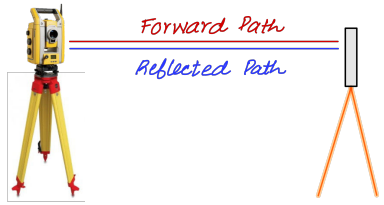
$$D = M(\lambda/2) + \frac{\phi}{2\pi}(\lambda/2)$$



Time of Flight Method

- Measures the distance based on the time taken for the signal to travel to the target and back.

$$D = c \cdot \Delta t/2$$



EDMI, Theodolite and Total Station

EDMI	*Theodolite*	*Total Station*
Distance measurement	Angle measurement	Distance + angle measurement (total surveying)
Laser technology	Optical technology	Integrated laser, optical, and digital technology



Parts of Total Station

Setting up the instrument

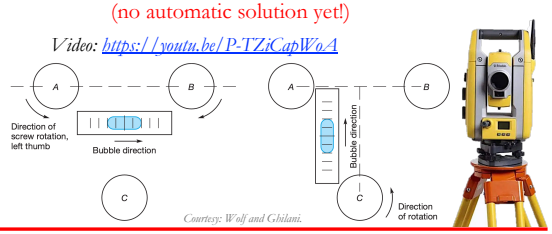
Tripod Adjustment

- Centering the Tripod:
  - Use a plumb bob to center the tripod over the survey point
  - Adjust legs radially and circumferentially
- Leveling the Tripod:
  - Adjust tripod legs to ensure the head is horizontal
  - Use built-in leveling bubble or device

Total Station Adjustment

- Centering:
  - Align optical axis over survey point using plumb bob or optical plummet
  - Rotate tripod legs for optimal centering
- Leveling:
  - Adjust foot screws to level instrument
  - Use trial and error method (no automatic solution yet!)

Video: https://youtu.be/P-TZiCapWoA



Prism Reflector

- Consist of a cube of glass cut across its corner to form three internal 90° faces.
- The signal enters, reflects off three internal faces, and returns along the same path it entered.
- Returns a signal to the EDM even if not perfectly aligned.
- Path length inside the prism remains constant, ensuring a coherent signal is returned.
- Looking through a prism shows your eye centered, regardless of rotation, demonstrating the reflective property.
- Height of a prism reflector in lab can be adjusted from 1.5 to 2.66 meters.

Calibration of EDMI

- Adjusts measurements to match true values by applying correction factors.
- Involves determining systematic errors and applying necessary corrections.
- Ensures instrument accuracy despite age or wear.

Calibration Errors in EDMI

Zero Error:

- Independent of distance, a constant offset in measurements.

Cyclic Error:

- Varies with distance, typically caused by internal instrument imperfections.

Scale Error:

- Proportional to distance, affects accuracy over long range distances.

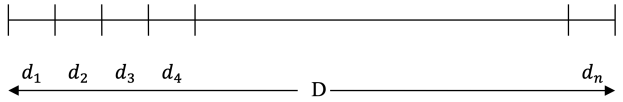
Zero Error (Reflector-Instrument Constant)

- Caused by changes in instrument/reflector constants due to aging or repairs.
- Independent of distance.

Zero Error Calculation:

- Divide a suitable distance D into n segments.
- Use the same EDMI and reflector for all measurements.
- Measure the total length D and each segment $(d_1, d_2, d_3, \dots)$.
- Calculate the reflector constant using:

$$K = \frac{\left(D - \sum d_i\right)}{(n-1)}$$

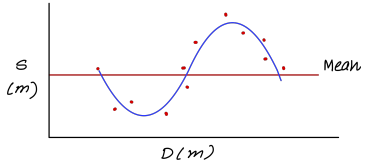


Cyclic Error

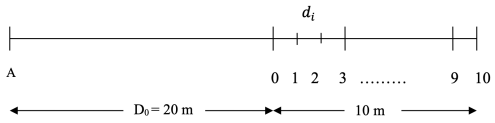
- Periodic error caused by phase difference in the signal.
- Sinusoidal curve over the measurement unit length and varies within $\pm\lambda/2$.
- Also known as period errors, resolver errors, non-linearity errors.

Cyclic Error Calculation:

- Divide a 30m line into segments: 20m and 10m.
- Further divide the 10m segment into 10 parts of 1m each.
- Measure each 1m part with tape and EDMI.

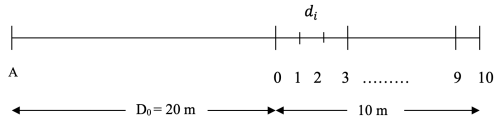


- Record measurements in columns (tape in column 2, EDMI in column 3).
- Measure a reference distance D_0 with EDM (e.g., 20.000m).
- Calculate error: $e_i = D_i - \left(D_0 + \sum d_i\right)$
- Compute correction: $c_i = -e_i + \frac{\sum e_i}{10}$



Cyclic Error

Observation Table



Station (1)	Taped dist. d_i, (m) (2)	EDMI dist. D_i, (m) (3)	$D_0 + \sum d_i$ (m) (4)	$e_i = D_i - (D_0 + \sum d_i)$ (m) (5)	$c_i = -e_i + \frac{\sum e_i}{10}$ (m) (6)
0	-	D_0 = 20 m			
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
				Average error = $e_{avg} = \frac{\sum e_i}{10}$	

Scale Error

- Proportional to distance, influenced by oscillator temperature and diode errors.
- Periodic deviation due to internal factors.

Scale Error Calculation:

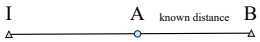
- Use a calibrated line of known length D_k.
- Measure the length using total station as D_m.
- Formula:

$$\text{Scale error (in ppm)} = \left(\frac{D_k - D_m}{D_k}\right) \times 10^6 = n \text{ ppm}$$

$$\text{Corrected distance} = D_m + n \times D_m$$

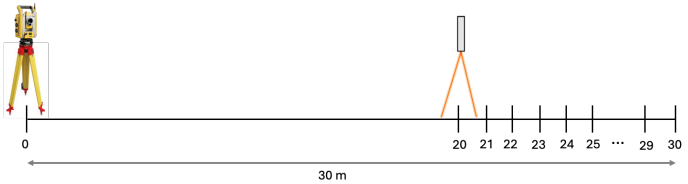
Note: Measure D_m as the difference between two measurements to eliminate zero error, since it is distance-independent.

$D_m = IB - IA$

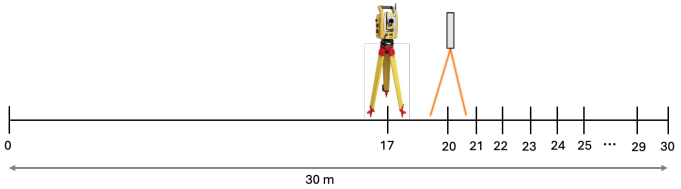


Field Readings

- Place the Total Station at 0 meters and record distance readings from 20 to 30 meters in 1-meter increments.



- Move the Total Station to 17 meters and repeat the distance readings from 20 to 30 meters in 1-meter increments (considering the minimum range of 3 meters).



Accuracy of EDMI

- Manufacturer after doing calibration report the quality of EDMI measurements as:

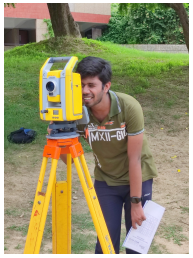
$$Accuracy = \pm(a\ mm + b\ ppm)$$

  - a: Distance independent error
  - b: Distance dependent error

- Standard deviation of observations:

$$\sigma_d = \sqrt{a^2 + b^2 d^2}$$

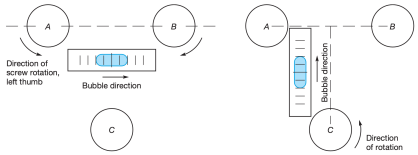
(a: mm, b: ppm, d: km)



- In GI Lab, Trimble S5 Robotic Total Station is used.

EDM Accuracy	Angular Accuracy	Minimum Range	Maximum Range	Features
1.0 mm + 2 ppm (Prism) / 2.0 mm + 2 ppm (DR)	1', 2', 3' or 5'	3 m	5500 m	Autolock, Magdrive, SurePoint

Source: Trimble S5 Spec sheet
https://trl.trimble.com/docushare/dsweb/Get/Document-751932/022516-153G_TrimbleS5_DS_USL_0121_LRsec.pdf



Thank you

Comments and Questions?
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