Distance Measuring Techniques

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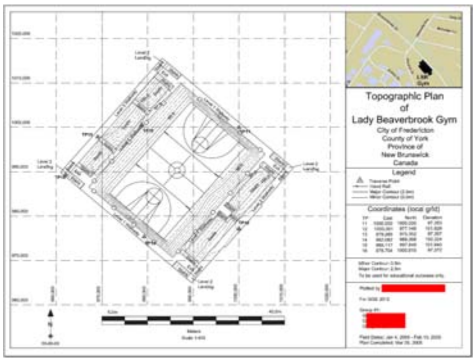
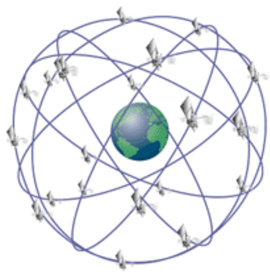




Distance Measuring Techniques

- accomplished by EDM (electronic distance measurement) or GNSS instrument in field (modern)
- or tape (e.g. steel tape) (conventional)
- distances between points can be determined by geometric or trigonometric computation with angles and slope distances measurement

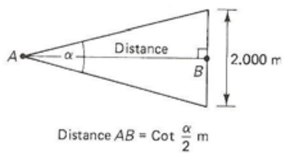
Techniques

1. Pacing
2. Tape (fiberglass, cloth, steel tapes), Subtense bar, Clinometer etc.
3. Odometer
   - traffic investigation to measure the distances at an accident.
   - improved application: some of the recent researches with GPS?
4. EDM
5. GPS, or VLBI

Distance Measuring Techniques

Quick Overview

- Subtense bar: a tripod-mounted bar having the target precisely 2m apart



(Kavanagh, B., 2006)

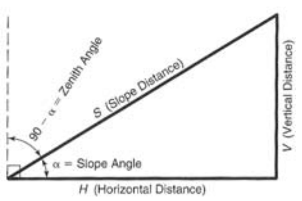
- Taping
  - fiberglass and cloth tapes
  - steel tapes (most common is 30m)

(steel tape, hand-level and clinometer)

Distance Measuring Techniques

- standard condition for steel tapes
  - temperature 20 deg. C
  - under tension 50 N (Newtons); 1 lb=4.448N
    → 50N = 11.24lb

- horizontal distances from slope measurement



(geometry)

(ex. slope distance is 20m and the zenith angle is 60 deg.. What's the corresponding horizontal and vertical distances?)

Distance Measuring Techniques

- Temperature corrections
  - standard in 20 deg. Celcius
  - need consideration of thermal environment
  - thermal coefficient of expansion of steel

$$C_t = k(T - T_o)L$$

k: expansion coefficient, T: temperature
T_o: nominal temperature (= 20 ^oC)
L: measured distances in metres

  - usually disregarded, but have to be very careful for the detailed work (1:15,000 or higher)
  - invar tape (specifically designed for reducing lower coefficient of thermal expansion)

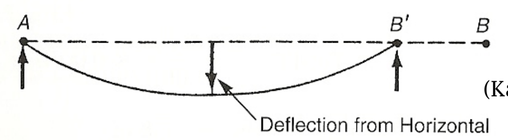
[**Quiz**] We measured the distance using steel bar and got 359.425m. When the measured temperature was 26 deg., what is the final distance corrected for temperature? (Assumption: standard temp. for the tape = 20 deg. C, and k, expansion coeff. is 0.000012)

Distance Measuring Techniques

- Tension Error (C_p) and Sag Error (C_s)

$$C_p = \frac{(P - P_s)L}{AE} \qquad C_s = -\left(\frac{W^2 L}{24P^2}\right) = -\frac{L}{24}\left(\frac{wl}{P}\right)^2$$

C_p : correction due to tension per tape length (m)
P : applied tension (N)
P_s : standard tension (standard steel tape = 50N)
L : total length (m), l=interval length between two supports
A : cross sectional area (m^2) from manufacturer
E : elasticity (steel tape = $20 \cdot 10^{10}$ N/m^2)
(invar tape = $14.5 \cdot 10^{10}$ N/m^2)
W: w·l (w= the weight of the tape per unit length, kg/cm)



(Kavanagh, B., 2006)

EDM

- **introduced in 1950s**, principles World War II **with RADAR tech.**
- In 1949, Dr. Erik Bergstrand of Sweden introduced Geodimeter (100 kg net weight) [W2-3]
- **indirect way** (as it determines the distance by deducing after having the phase delays between transmitted and received signals. uses the infrared or laser light)
- **accuracy depends** on the measurement of time sequence between transmission and reception of the laser signal. ***GPS** has the same principle, but different signals.*
- range of 200m with **accuracies from 1.3 mm to 3 mm.** (short 0.5~2km, medium 3~10km, long 10~20km coverage)
- **reflectless EDM** (e.g. pulsed laser emissions) reflect the light directly off the feature being measured.

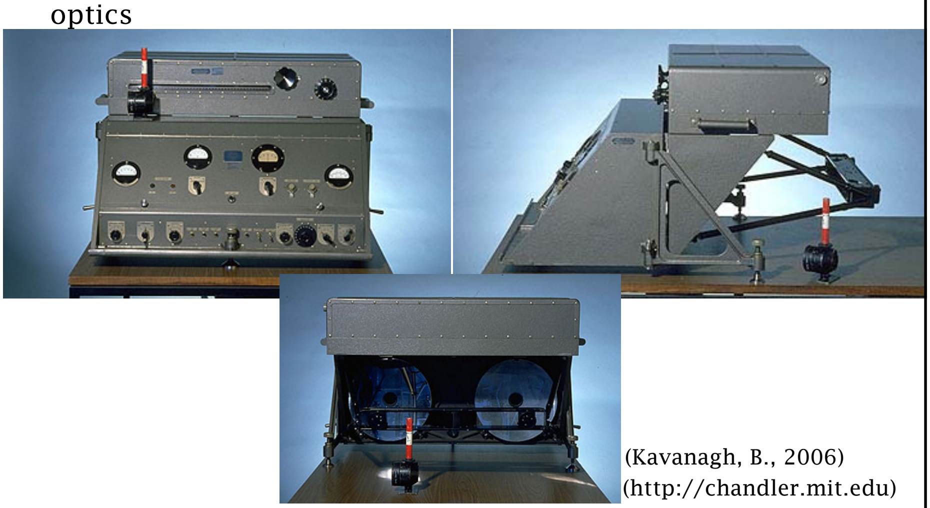
[Q] Does it reflect the light from all colored surfaces being observed or an uneven condition of the surfaces? Lab. (white → 100%, most → 18%)

- EDM + theodolite → horizontal, vertical, slope: **Total Station**

EDM

◆ First model of Geodimeter

- First units circa 1959 (50 kg each for measurement unit and optics

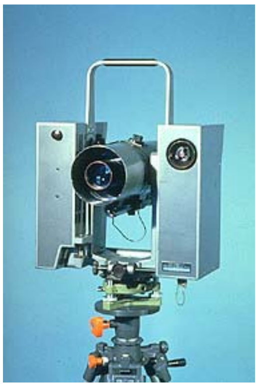


(Kavanagh, B., 2006)
(http://chandler.mit.edu)

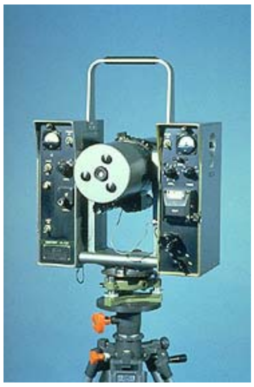
EDM

Later model of Geodimeter

- circa 1966



(front view)



(back view)

(http://chandler.mit.edu)

EDM

modern EDM instruments

- NIKON, Trimble, Leica (available UNB GGE, pulse laser and Infra-red devices)

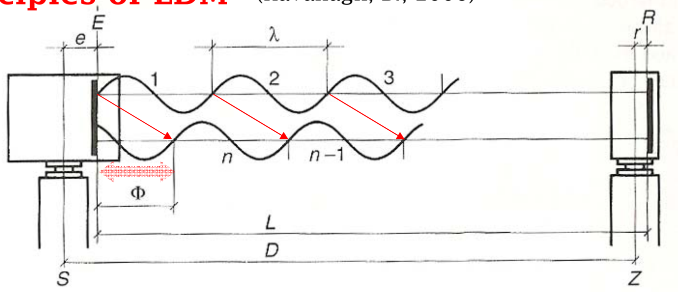
NIKON NPL-302

TRMBLE 5600

LEICA TC-400

EDM

◆ Principles of EDM (Kavanagh, B., 2006)



S Station
Z Target
E Reference plane within the distance meter for phase comparison between transmitted and received wave
R Reference plane for the reflection of the wave transmmitted by the distance meter
a Addition constant
e Distance meter component of addition constant
r Reflector component of addition constant
λ Modulation wavelength
Φ Fraction to be measured of a whole wavelength of modulation (Δ λ)
L The distance between the reference planes of the instrument and reflecting prism
D The distance between the instrument station and the prism station, i.e., the distance *L* corrected for the off-center constants at the instrument and at the prism

The addition constant *a* applies to a measuring equipment consisting of a distance meter and reflector. The components *e* and *r* are only auxiliary quantities.

$$2L = n \cdot \lambda + \Phi$$

- modulated EM wave from EDM device and reflected back to EDM
- partial wavelength can be determined by matching. *How "n" can be determined then?*

EDM

◆ How "n" can be determined?

$$2L = n \cdot \lambda + \Phi$$

- same problem happens in GPS (or GNSS) positioning.
- Phase difference between outgoing and incoming reflected tells something about distance. If distance is less than 1 wavelength then unique answer. But if more than 1 wavelength, then we need to know number of integer cycles. [How? Stochastic approach. This won't be covered here. This is GPS (GNSS) case.]

- For surveying instruments that make this type of measurement, *make phase difference measurements at multiple frequencies.*

EDM

◆ Example

- A typical example would be: Measure distances to 10 km using wavelengths of 20 km, 1 km, 200 m, 10 m, 0.5 m

Wavelength	Cycles	Resolved	Distance (m)
20km	**0.59**	**0.59**	**11,800.000**
1km	**0.79**	**11.79**	**11,790.000**
200m	**0.93**	**58.93**	**11,786.000**
10m	**0.54**	**1178.54**	**11,785.400**
0.5m	**0.70**	**23570.70**	**11,785.350**

(http://chandler.mit.edu)

- True distance 11 785.351 m

→ Error-Free? No. Why?

EDM

◆ Errors of EDM

- temperature
- atmospheric pressure
- water vapor

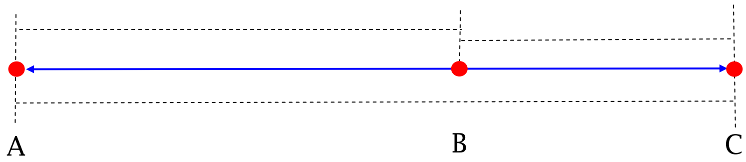
: temperature and pressure can be corrected on-board processor or manually corrected
: atmospheric conditions are not significant in short range, but long range (very important in microwave)

[ex.] Errors in 1 mmHg → -0.05ppm at 20 °C for light wave
→ +7 ppm at 20 °C for microwave
→ +17ppm at 45 °C for microwave

EDM

cf. Prism

: has to determine the **prism constant** by the flatness of the surface



AC – (AB + BC) = instrument/prism constant

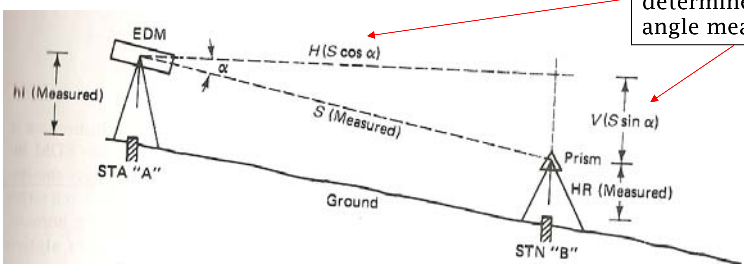
cf. Forced Centering Setup

: setup prisms with tribrachs, and interchange instruments, not tribrachs, each other to speed up the control survey work
: Only one tripod moves per station change
: what's the precaution in order to safely use this method?

EDM

Geometry of EDM

Unknowns: determined by the angle measured



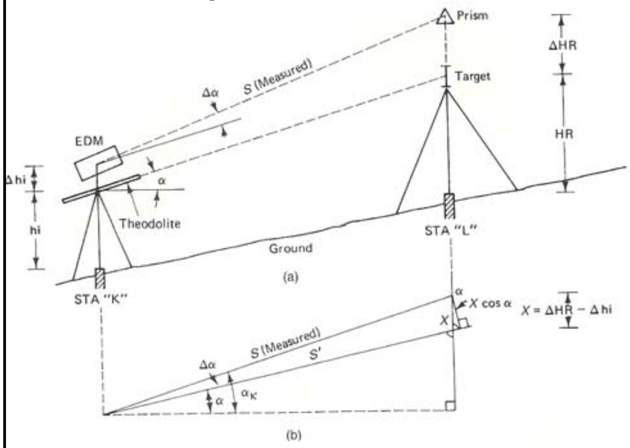
(in case of the same height btw. the optical target and reflecting prism)

$$Ele.B = Ele.A + hi - HR \pm V$$

(Kavanagh, B., 2006)

EDM

Geometry of EDM (Kavanagh, B., 2006)



$$\frac{X\cos\alpha}{S} = \sin(\Delta\alpha)$$

$$\alpha_k = \alpha + \Delta\alpha$$

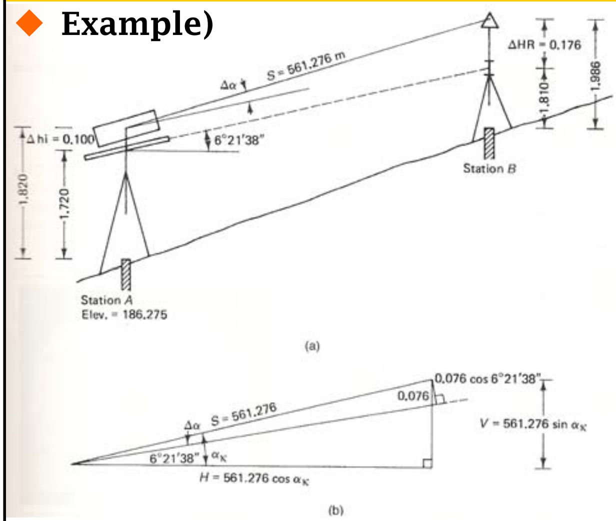
$$H_h = S \cdot \cos(\alpha_k)$$

(in case of the different height btw. the optical target and reflecting prism)

$$\text{Ele.L} = \text{Ele.K} + (hi + \Delta hi) - (HR + \Delta HR) + H_v\,(= S\sin(\alpha_k))$$

EDM

Example)



(Kavanagh, B., 2006)

$$X = \Delta HR - \Delta hi$$

$$\frac{X\cos\alpha}{S} = \sin(\Delta\alpha)$$

$$\alpha_k = \alpha + \Delta\alpha$$

$$H_h = S \cdot \cos(\alpha_k) = ?$$

$$\text{Ele.B} = \text{Ele.A} + (hi + \Delta hi) - (HR + \Delta HR) + H_v\,(= S\sin(\alpha_k)) = ?$$