Fundamental Surveying
(MSS 220)

Chapter (2)

DISTANCES MEASUREMENT

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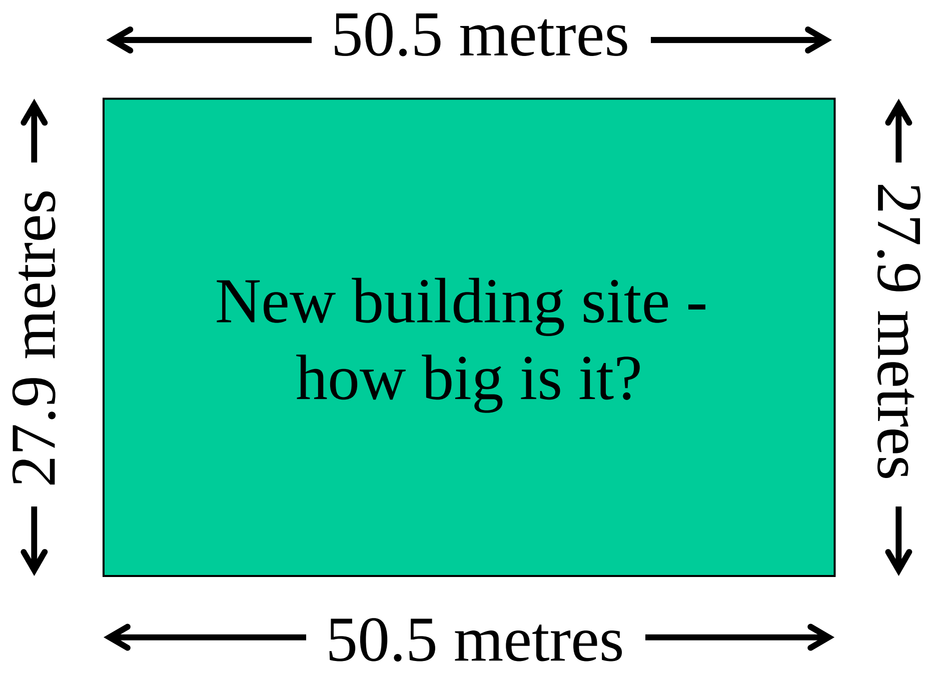
Distances Measurement

- In these lectures we will cover :
  - The role of linear measurements
  - Equipments
  - Procedures and rules
  - Errors
  - Applications of linear measurements

What is linear measurement?

- Simply the measurement of distance :



Distance measuring equipment and typical accuracies

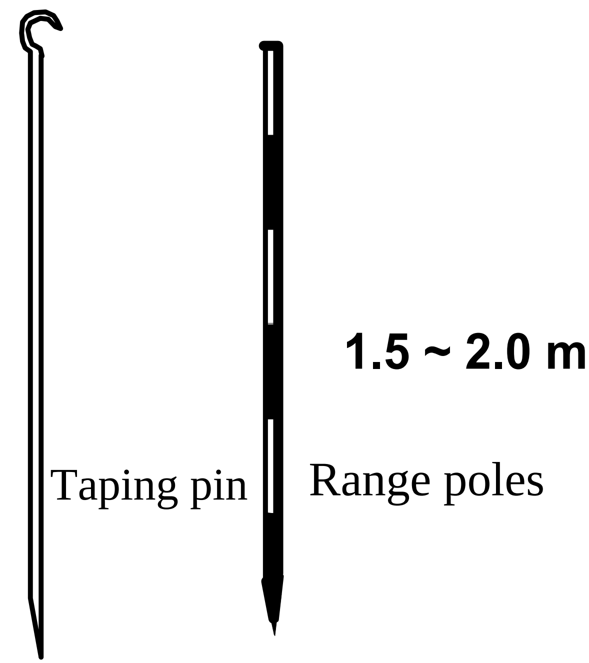
- Pacing (1:100)
- Taping or chaining (1:10,000)
- Optical range finder (1:300)
- Stadia tacheometry (1:1000)
- Electronic distance measurement (1:50,000)

Some things to note…

- Equipment is fairly cheap (except EDM)
- Equipment is easy to maintain and adjust
- Distances are easy to measure
- Very accurate results can be achieved
- Measurement line needs to be unobstructed
- Errors occur and need to be managed or minimised

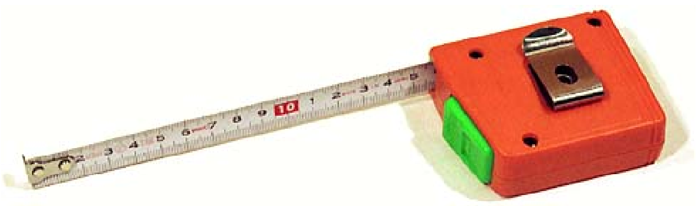
Taping procedures

- Tape must always be **straight**
- Tape must not be twisted
- Use **chaining arrows** for intermediate points
- Tape horizontally if possible
- Tape on the ground if possible
- Slope taping needs to be *reduced*
- **Catenary** (sag) taping requires *correction*
- **Step taping** suits some applications



Offset Tape

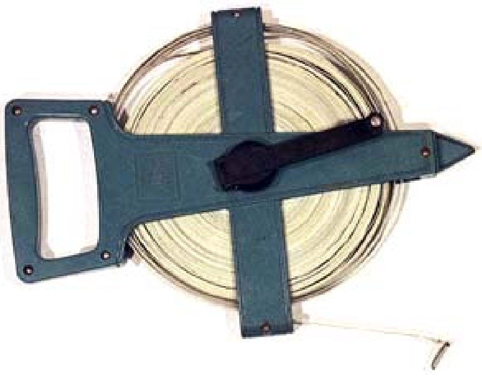
- **Examples Of Usage**
- Offset Tape can be used for:
- Measuring offsets to an object from a chain line for detail mapping.
- Determining the height of an instrument, for example a theodolite or a total station, above a ground mark.
- Measuring the dimensions of objects in a detail survey, such as the width of a path.



- **Factors Which Influence The Use Of Offset Tape**
- Measured distances are limited to the length of the tape, usually 2 or 5 meters.
- Clear paths of travel.
- **Survey Methods Used For**
- Tapes are used for the measurement of linear distance.

Stylon Tape

- A Stylon tape is made of plastic-coated steel, giving both stability and durability.
- **Examples Of Usage**
- Measuring distances for a variety of survey purposes, such as the length of a base line between two survey stations.
- Setting out a chain line as part of a chain and offset survey to carry out, for example, detail mapping.
- **Factors Which Influence the Use of Stylon Tape**
- Measured distances are limited to the length of the tape, usually 30 or 50 meters.
- Clear paths of travel.
- Large undulations in ground level can make chaining difficult.
- Distance accuracy is dependent on correct field procedures and often the application of corrections for various factors.
- **Survey Methods Used For**
- Tapes are used for the measurement of linear distance.



Chain

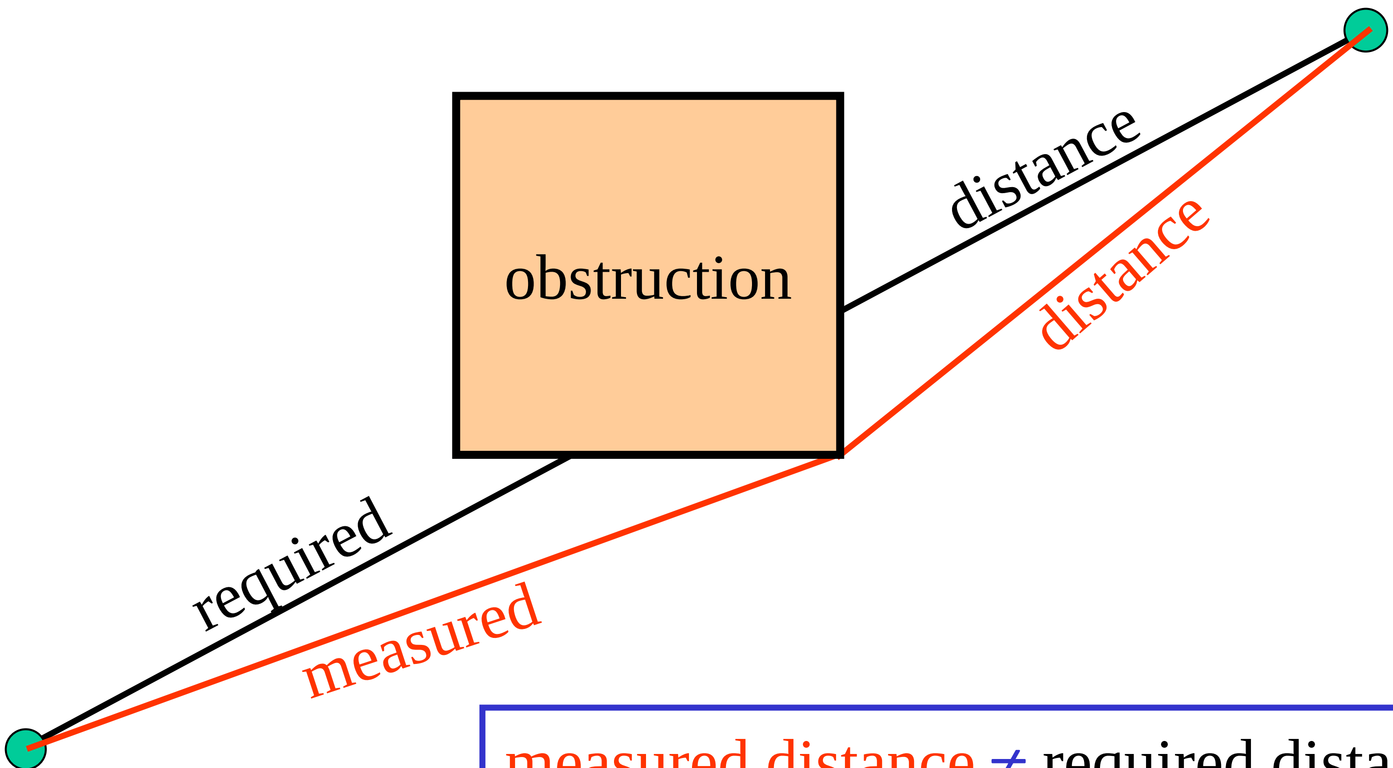
- A chain is made of steel, which has good stability and less bulk than a Stylon reel, but is more prone to damage and wear.

- **Examples of Usage**
- Measuring distances for a variety of survey purposes, such as the length of a baseline between two survey stations.
- Setting out a chain line as part of a chain and offset survey to carry out, for example, detail mapping.

- **Factors Which Influence the Use of Chains**
- Measured distances are limited to the length of the chain, usually 50 or 100 meters.
- Clear paths of travel, are needed between the end points of the distance.
- Large undulations in ground level can make chaining difficult.
- Distance accuracy is dependent on correct field procedures and often the application of corrections for various factors.

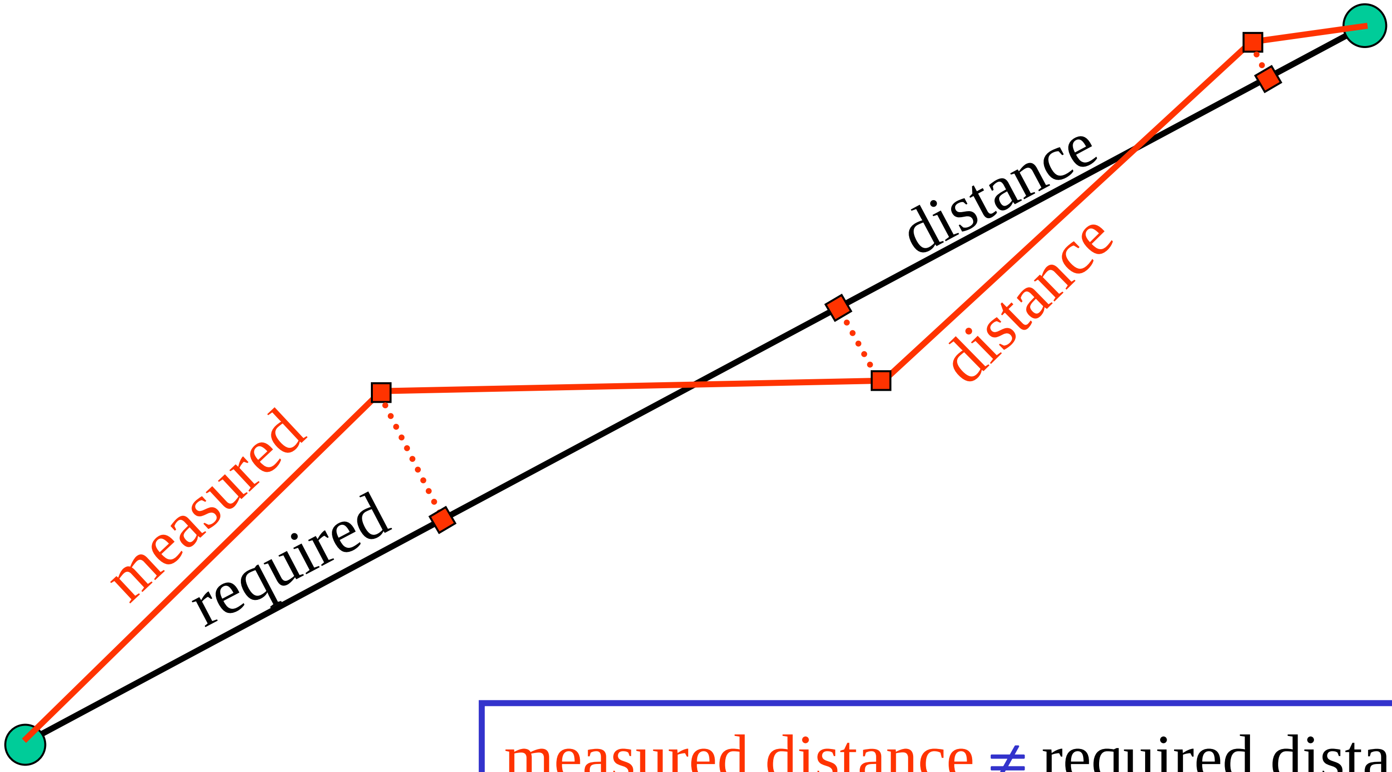
- **Survey Methods Used For**
- Chains are used for the measurement of linear distance.

Tape must be straight…



measured distance ≠ required distance

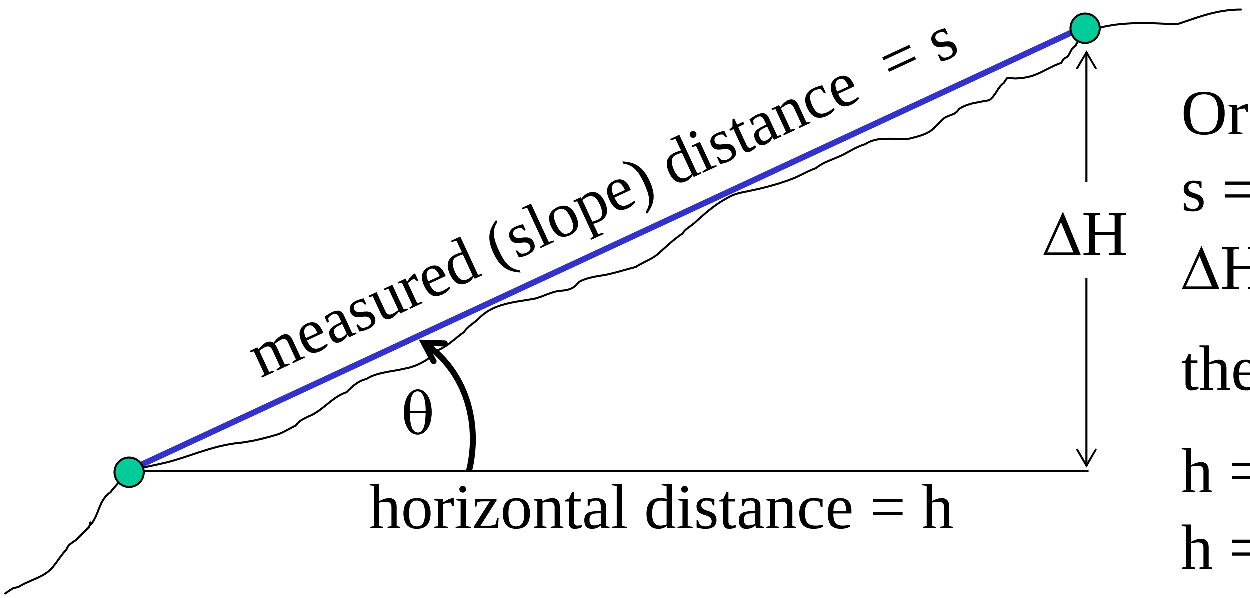
Use chaining arrows…



measured distance ≠ required distance

Tape Corrections

1- Slope correction…



Or….

$s = 30.589$ m

$\Delta H = 1.334$ m

then

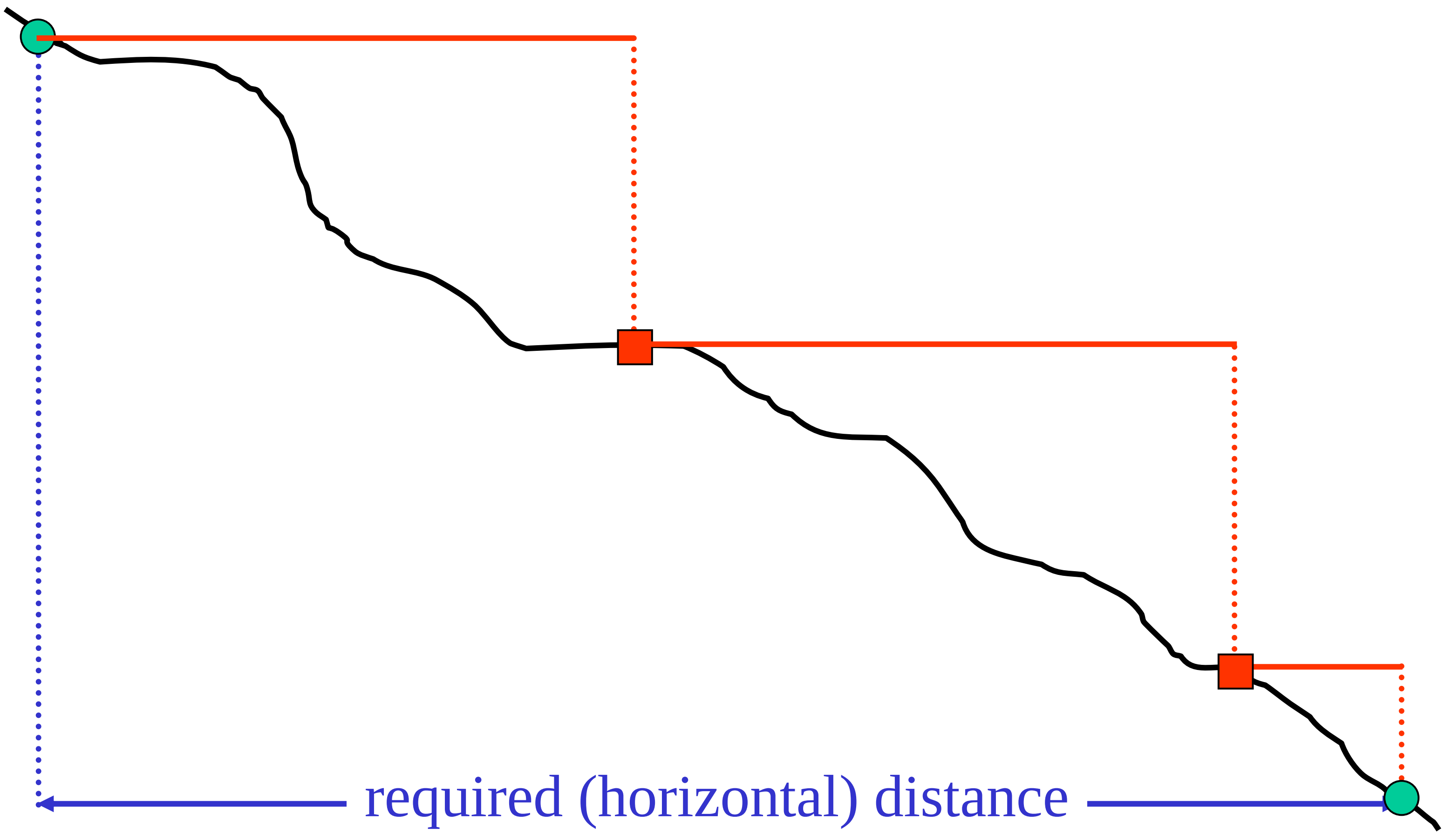
$h = (30.589^2 - 1.334^2)^{1/2}$

$h = 30.560$ m

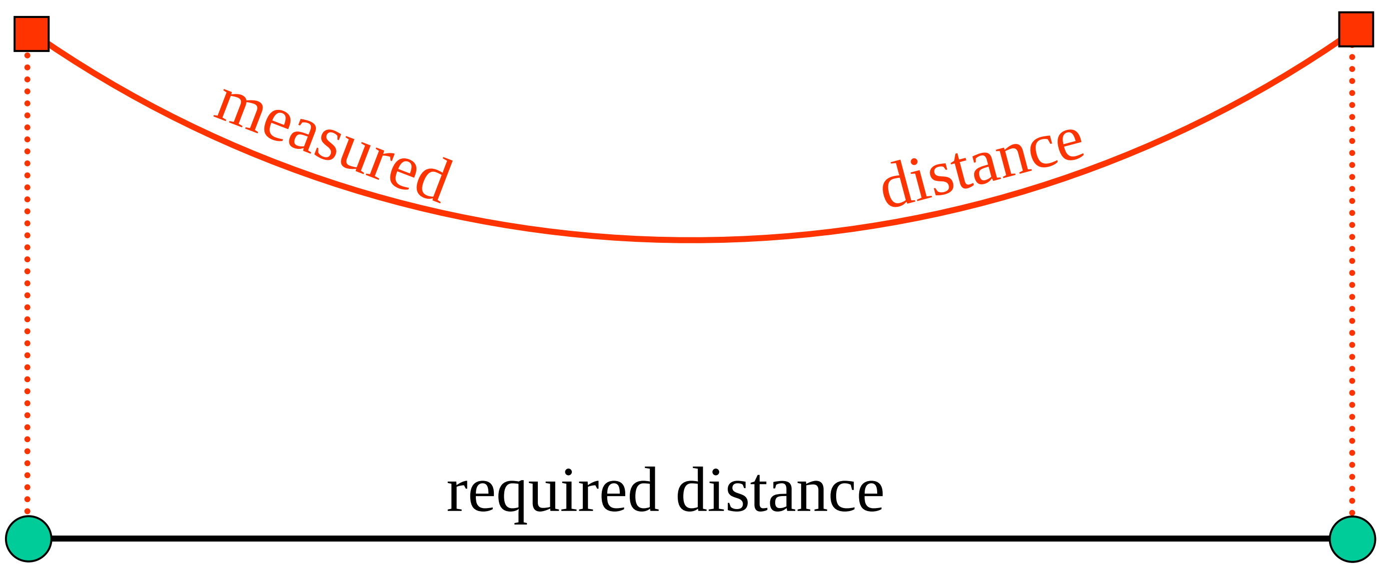
To calculate the *horizontal* distance :

$$\boxed{\mathbf{h = s\cos\theta} \quad \text{or} \quad \mathbf{h = (s^2 - \Delta H^2)^{1/2}}}$$

Step taping…



Catenary taping…



measured distance ≠ required distance

Types of errors

- **Blunders**
  - mistakes and gross errors
- **Systematic errors**
  - repeated size and sign
  - affect accuracy
- **Random errors**
  - small and usually undetectable (noise)
  - affect precision

These error types apply to <u>any</u> measurement technique used in surveying…

Accuracy and precision

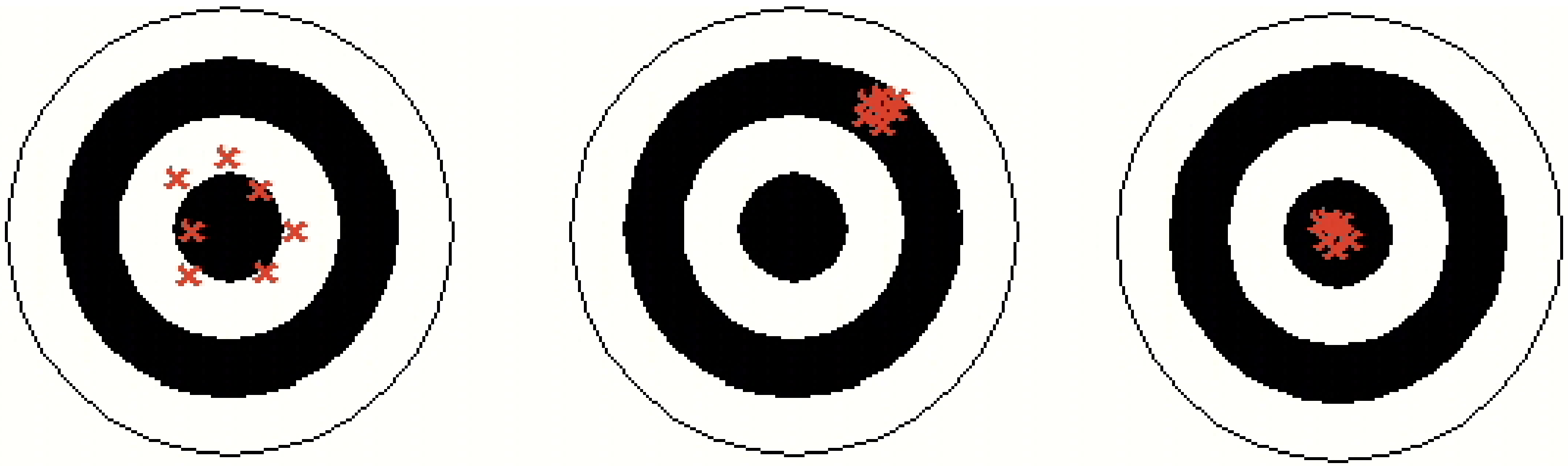


Figure 1(a)
Accurate but not precise

Figure 1(b)
Precise but not accurate

Figure 1(c)
Accurate and precise

Sources of error in taping

- **Temperature correction**

$$\boxed{L' = L + L.c.\Delta T}$$

where :

L'	is the corrected distance
L	is the measured distance
$c =$	1.15×10^{-5} m/°C (for a steel band)
$\Delta T =$	$T_{actual} - T_{standard}$

Example:

- If it "T" (standard) =20°C (usual), changed to "T" (actual) =37°C (hot!), and L = measured distance = 79.984
- Then the corrected measured distance will be:
- $L' = 79.984 + 79.984 \times c \times \Delta T =$

  $= 79.984 + 79.984 \times 1.15 \times 10^{-5} \times 17 = 80.00\text{m}$

Sources of error in taping

- **Standardisation**
  - The tape is not of "true" length

$$\boxed{L' = L \times \frac{measured \quad length}{assumed \quad length}}$$

Example:

If the measured distance L=226.20, assumed tape length = 30.00m, and the actual tape length = 30.005 m

Then:

The actual distance = $226.20 \times \frac{30.005}{30.00}$ = 226.238 m

Sources of error in taping

- **Catenary (sag)**
  - A suspended tape will measure too long

$$\boxed{L' = L - \frac{(Mg)^2 L^3}{24T^2}\cos^2\beta}$$

where :

M is the mass per unit length (0.011 kg/metre)

g is gravity (9.8 metre/sec^2)

T is the tension (50 Newton)

β is the slope angle

Example:

- For example, for a catenary of 30m, a tension of 50N and a mass per unit length of 0.011kg/m; Slop angle = 45°

- Then:
- $L' = 30 - \frac{(0.011 \times 9.8)^2 \times 30^3 \times \cos^2(45)}{(24 \times 50^2)} =$

  $=29.9975$ m

General Example for Tape corrections:

A 30-m steel tape standardized at 20°C and supported throughout under a tension of 5.45kg was found to be 30.012m long. The tape had a cross-sectional area of 0.050 cm^2 and a weight of 0.03967 kg/m. This tape was held horizontal, supported at the ends only, with a constant tension of 9.09 kg, to measure a line from A to B in three segments. The data listed in the following table were recorded. Apply corrections for tape length, temperature, and sag to determine the correct length of the line.

Section	Distance (m)	Temperature (C°)
A-1	30.00	14
1-2	30.00	15
2-B	21.151	16

Solution:

(a) The tape length correction is:

$$C_L = [30.0 + 30.0 + 21.151] \frac{[30.012 - 30.00]}{30.00} = +0.0324 \text{ m}$$

(b) Temperature correction:

$$C_{T1} = 1.15 \times 10^{-5} \times 30(14 - 20) = -0.0026\text{m}$$
$$C_{T2} = 1.15 \times 10^{-5} \times 30(15 - 20) = -0.0017\text{m}$$
$$C_{T3} = 1.15 \times 10^{-5} \times 21.151(16 - 20) = -0.0010\text{m}$$

$$\boxed{\Sigma C_T = -0.0053 \text{ m}}$$

(c) The sag correction:

$$C_{S1} = \frac{-2[(0.0397)^2 (30.00)^3]}{(24 \times 9.09^2)} = -0.0429 \text{ m}$$

$$C_{S2} = \frac{-[(0.0397)^2 (21.151)^3]}{(24 \times 9.09^2)} = -0.0075 \text{ m}$$

$$\boxed{\Sigma C_s = -0.0504 \text{ m}}$$

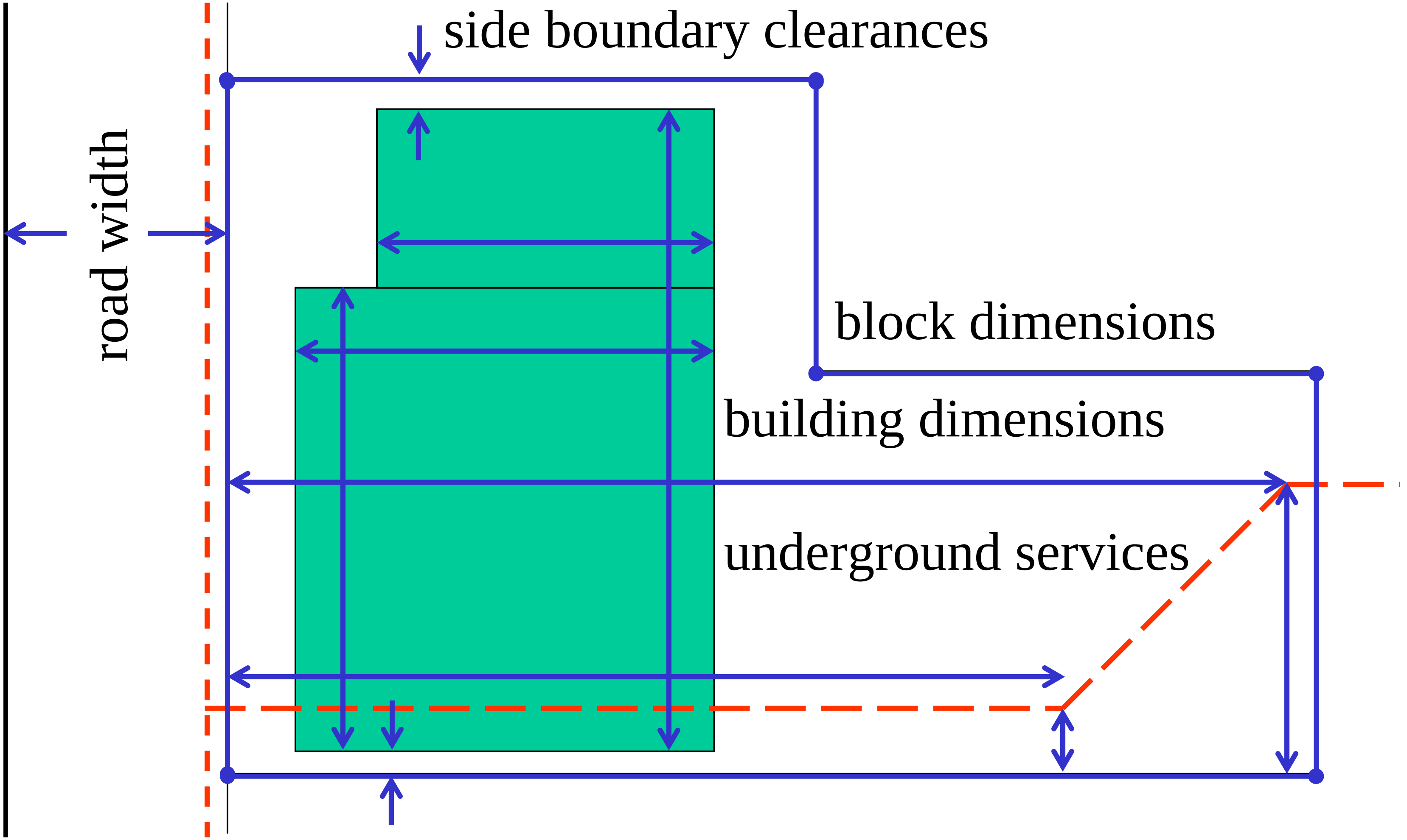
(d) Finally, corrected distance AB is obtained by adding all correction to the measured distance, or

$$L_{AB} = 81.151 + 0.0324 - 0.0053 - 0.0504 = 81.131 \text{ m}$$

Applications

- Dimensions of building features
- Block dimensions
- Location and size of site features
- Setting out for construction
- Clearances and tolerances

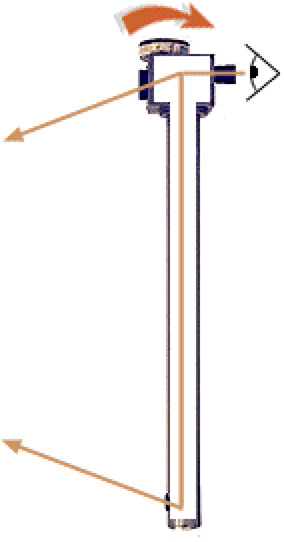
An example



side boundary clearances
road width
block dimensions
building dimensions
underground services

Range Finder

This is an optical instrument similar to the focusing system on a range finder camera. An eyepiece gives the user two images of the object being measured; when these are brought into coincidence the distance can be read off the scale on the adjustment lever or control. The scale is calibrated to read distance but is in fact a measure of the amount of movement needed to turn a prism or mirror, mounted on the end of a fixed base, to overlap the two images.



- **Examples Of Usage**
- Measuring distances for a variety of survey purposes, such as the length of a base line between two survey stations.
- As range finders have relatively poor accuracy, they are typically used for reconnaissance surveys.

- **Survey Methods Used For**
- Range Finders are used for the measurement of linear distance.

Electromagnetic Distance Meter (EDM)

How it works?

- EDM instruments are available to measure distance using light and radio waves. The distance is calculated either from the time difference between a transmitted pulse and a return pulse or the phase difference between a transmitted and a reflected beam of radiation.

EDM

How EDM Works? (Cont'd)

Components of EDM

1- Light source

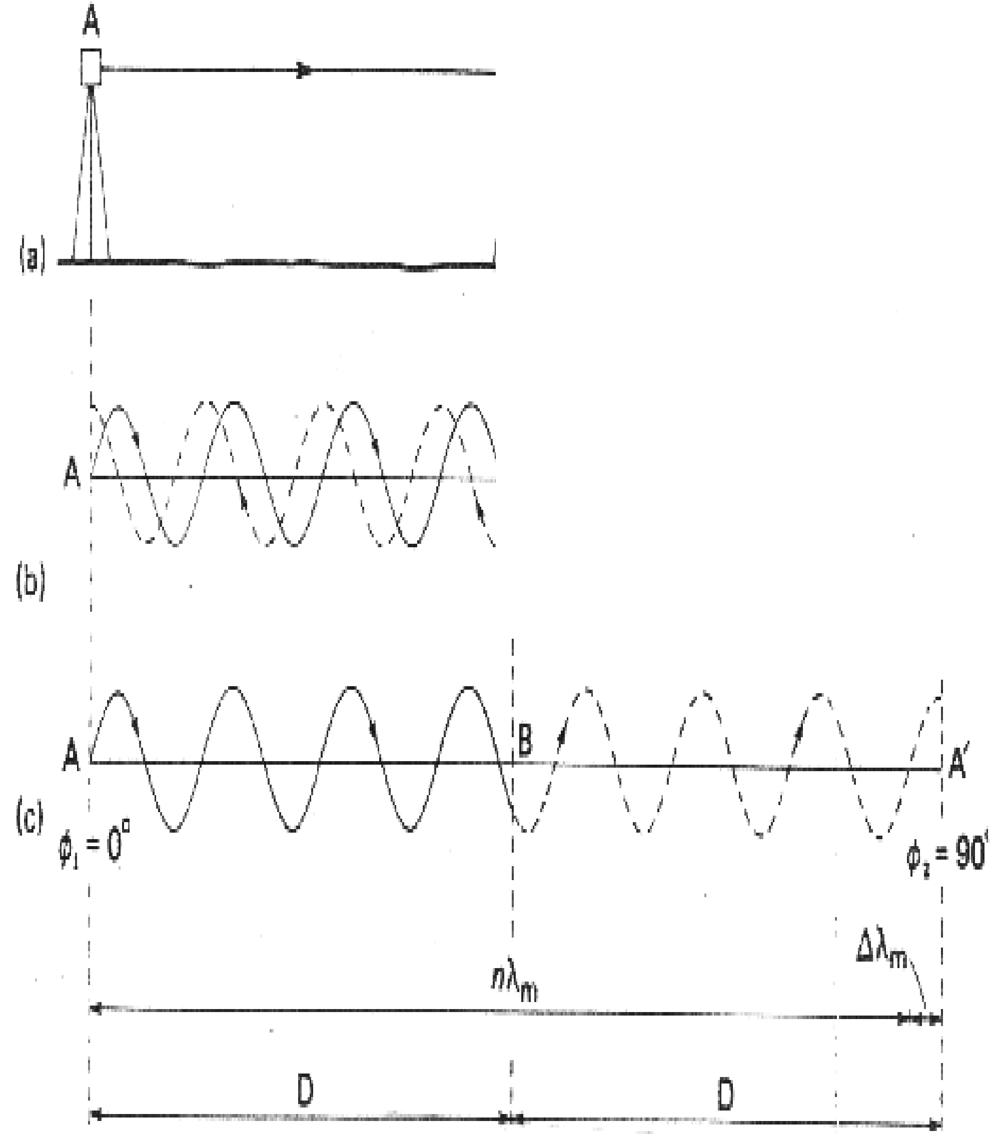
For transferring the electromagnetic waves.

2- Light Modulation

Change the light to Electromagnetic waves.

3- Phase Difference system

4- Mini PC or Calculator



EDM Systems

Electromagnetic distance measuring equipment use three different wavelength bands:

Microwave systems:

1- Range up to 150 km

2- Wavelength 3 cm

3- Unaffected by visibility

Light wave systems

1- Range up to 5 km

2- Visible light, lasers

3- distance reduced by visibility

Infra red systems

1- Range up to 3 km

2- limited to line of sight

3- limited by rain, fog, and other airborne particles.

EDM and electronic theodolite

The accuracy of the measurement varies from type to type but is usually in the range from ±(1.0 mm + 1.0 ppm) to ±(10.0 mm + 5 ppm).

Propagation of Electromagnetic Energy

Velocity of EM energy, $\mathbf{V = \mathit{f}\,\lambda}$

f is the frequency in hertz (cycles/second), λ is the wavelength.

Principle of EDM

If an object moves at a constant speed of V over a straight distance **L** in a time interval $\mathbf{\Delta t}$, then

$$\mathbf{L = V \times \Delta t}$$

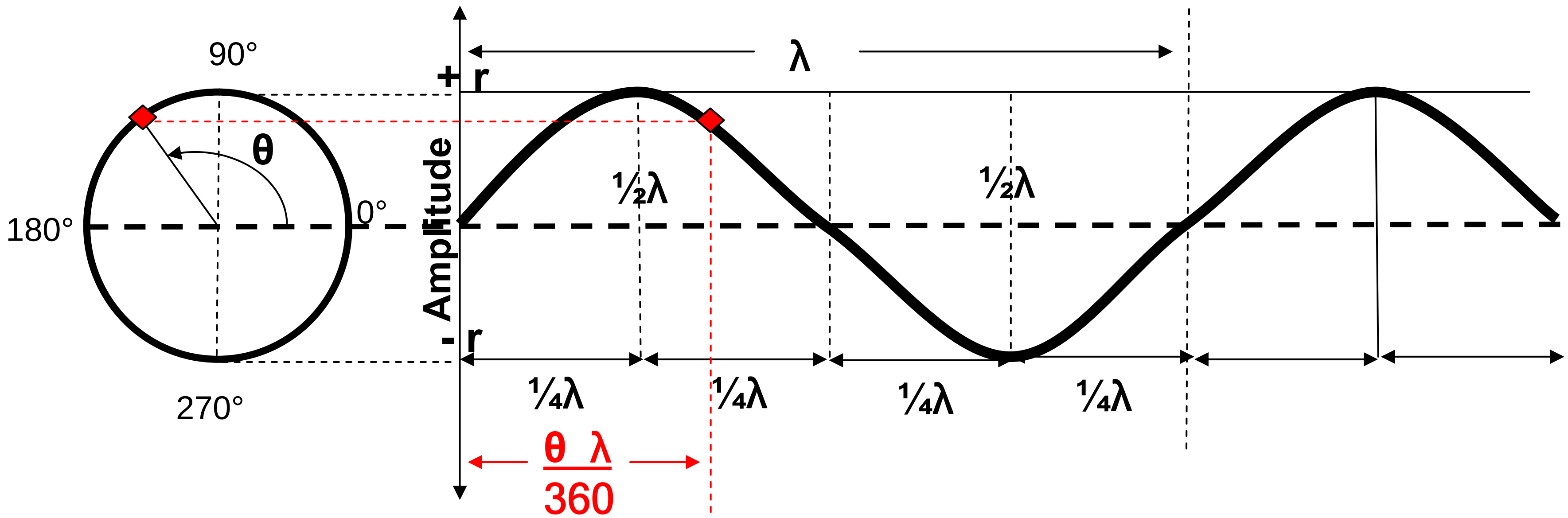
Knowing the speed of light **V** and being able to determine the time interval $\mathbf{\Delta t}$ it takes for an electromagnetic wave to move from **A** to **B** to determine the distance L between **A** and **B**.

But the **V** , the speed of light, is very high (about 300,000 km/sec), the time interval $\mathbf{\Delta t}$ would need to be measured extremely accurately. Instead, the principle of EDM is based on the following relationship:

$$\mathbf{L = 0.5(m + p)\,\lambda}$$

m is an integer number of whole wavelengths, **p** is a fraction of a wavelength (is measured by EDM). Thus, **L** can be determined from **λ, m, p.**

THE FRACTION OF A WAVELENGTH AND THE PHASE ANGLE



A fraction of a wavelength can be determined from a corresponding <u>phase angle</u> θ

<u>Note:</u>

For θ = 0° the fraction is 0

For θ = 90° the fraction is ¼

For θ = 180° the fraction is ½

For θ = 270° the fraction is ¾

For θ = 360° the fraction is 1

<u>EDM INSTRUMENTS CAN MEASURE PHASE ANGLES</u>

Example: Propagation of Electromagnetic Energy

- The fractional length is determined by EDM instrument from measurements of phase angle of returned signal.
- Assume that the wavelength was precisely 20.000m. Number of the full wavelengths is 9. Assume also that phase angle of retuned signal was 115.7° in which case length p would be (115.7/360)×20.000=6.428m.

Then:

- $\mathbf{L = 0.5} \times (\mathbf{9} \times 20.000 + 6.428) = 93.214$ m

Example

- Find the wavelength of a EDM instrument if the frequency of it is 37.474 MHz. If this instrument used to measure a distance in the range from 37 ~ 40 m and the phase angle was 165°. Then, calculate the adjusted value of this distance (assume the light speed is 299792 km/sec).

Solution:

$$\mathbf{V = f\,\lambda}$$

$$\mathbf{299792 \times 1000 = 37.474 \times 10^{6}\,\lambda}$$

$$\mathbf{\lambda = 8.0\ m}$$

$$\mathbf{L = 0.5(m + p)\,\lambda = 0.5(m + 165/360) \times 8}$$

$$\mathbf{L = 4m + 1.833}$$

Since the L is the range from the 37 ~ 40 m

Then $\mathbf{L = 4 \times 9 + 1.833 = 37.833\ m}$

Total Stations

- A Total Station integrates the functions of a theodolite for measuring angles, an EDM for measuring distances, digital data and information recording. Examples of Total Stations are the Sokkia Set4C , Tippecanoe, and Geodimeter 400 series.

Examples of Usage

- **General purpose angle and distance measurements.**
- **Provision of control surveys, Contour and detail mapping, Setting out and construction work**

- **Factors Which Influence the Use Of Total Stations**
- **A clear line of sight between the instrument and the measured points is essential.**
- **A well defined measurement point or target/prism is required to obtain the maximum accuracy.**

Topcon

Nikon DTM-801

Prism

- A corner-cube or reflective prism is essential for most Total Stations and EDM. The prism is used to return the transmitted beam to the instrument to allow a distance to be determined by time of flight or phase comparison.

- **Total stations allow for the direct input of temperature and pressure and automatic application of meteorological corrections.**

- **Most of the current EDM instruments use LASER beams and reflectors.**

- **The latest models provide for reflector-less measurements, thus improving efficiency for certain applications drastically.**

Prisms

One prism

Three prisms

Nine prisms

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