Electronic Distance Measurement (EDM)

INTRODUCTION

To obtain accuracy in surveying and speed up distance measurement, the electronic distance measuring (EDM) method was introduced.

The distance is measured with the help of electro-magnetic waves such as micro wave, infrared wave and other similar waves.

The electronic distance measuring equipment and a reflector are necessary to measure the distance.

The wave emitted from the electronic distance measuring equipment reaches the reflector and return back to the electronic distance measuring equipment.

Then the distance is measured with the help of time taken for the above process – time taken by the wave for the emission and return.

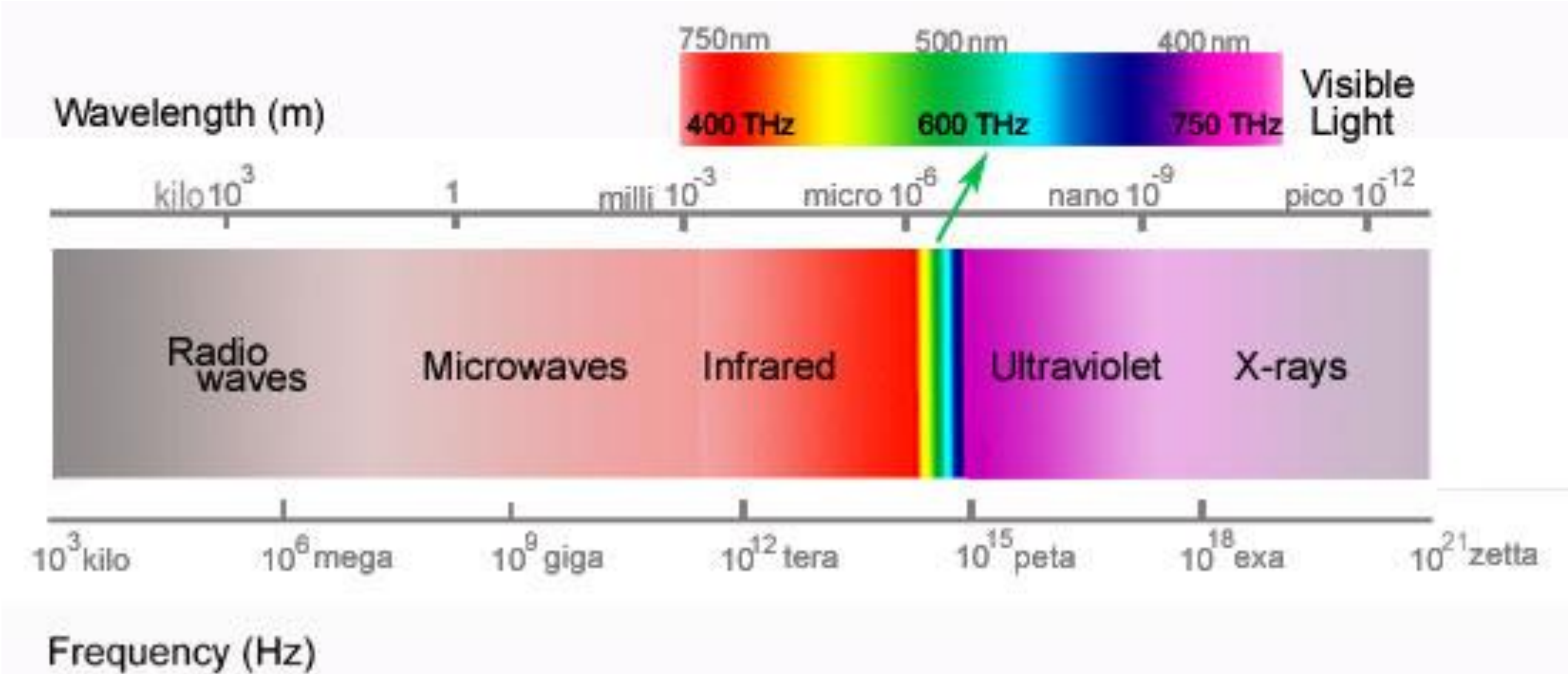
Distance = Time interval x speed

Electro Magnetic Waves

Electromagnetic Spectrum (Electromagnetic Radiation)

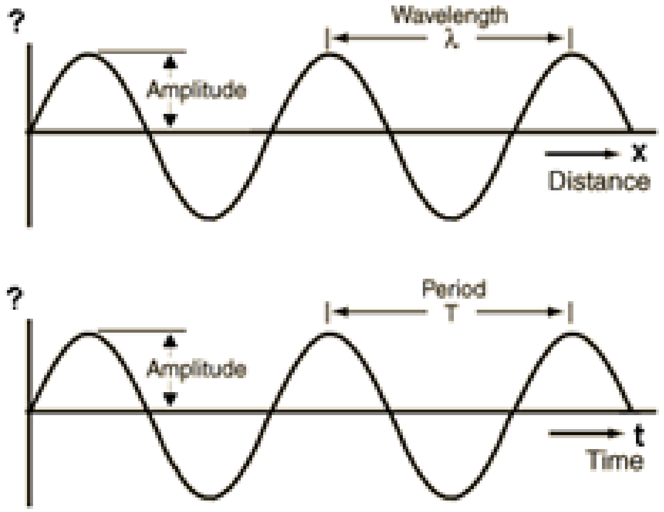
Electromagnetic radiation extends for a long spectrum: from very short wave length to very long wave length.

Two types of electronic distance meters (simply referred to as EDMs) are commonly used in ground surveying. They are the **electromagnetic** (**microwave**) instruments and the **electro-optical** (**light wave**) instruments.

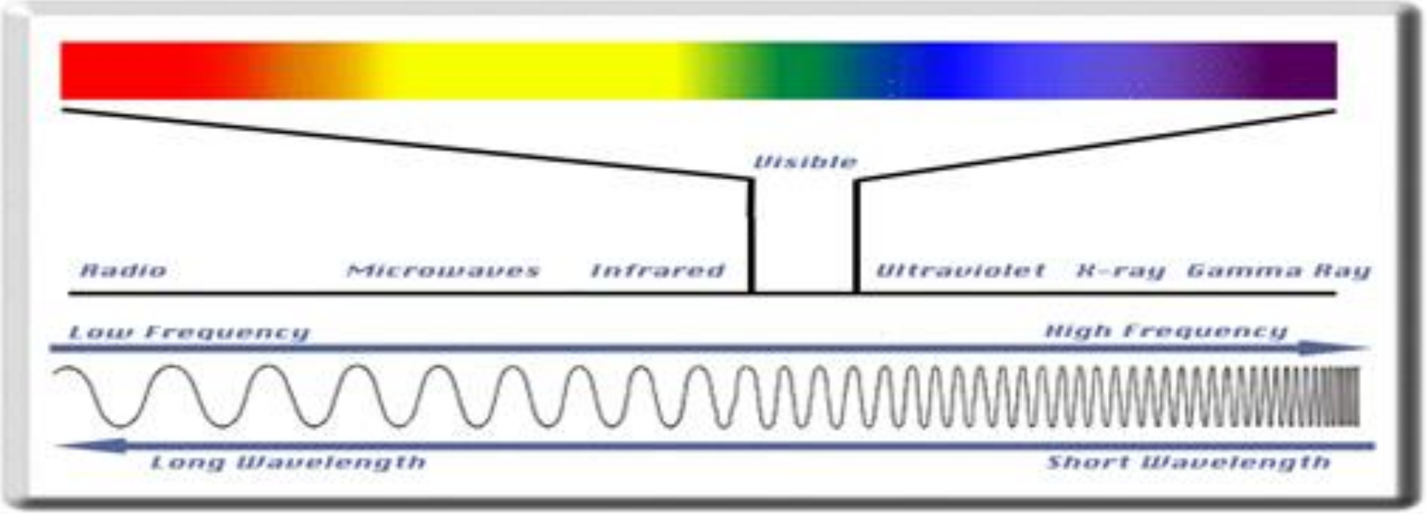


Electro Magnetic Waves

Electromagnetic Waves move in sinusoidal curve. Peak to peak is wave length, λ

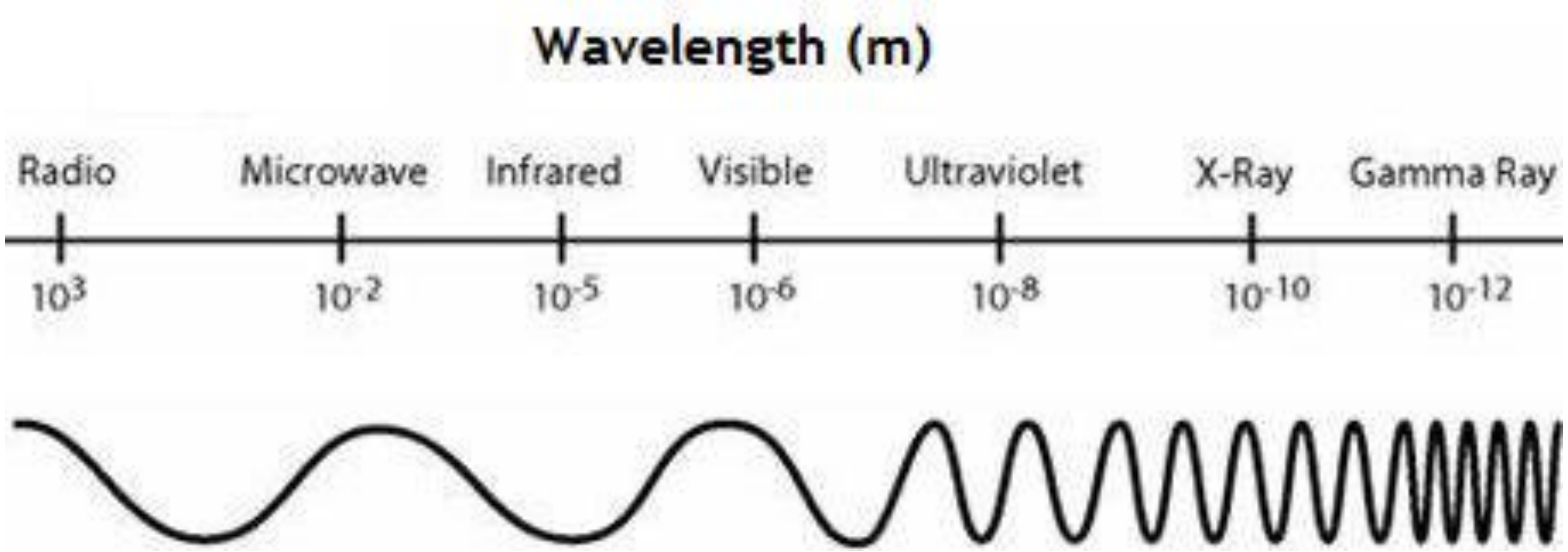


Micro waves have wave length frim 1mm to 30cm; Visible light has wave length between 0.4μm to 0.65μm



Spectrum

Wave length variation



Wave length Variation

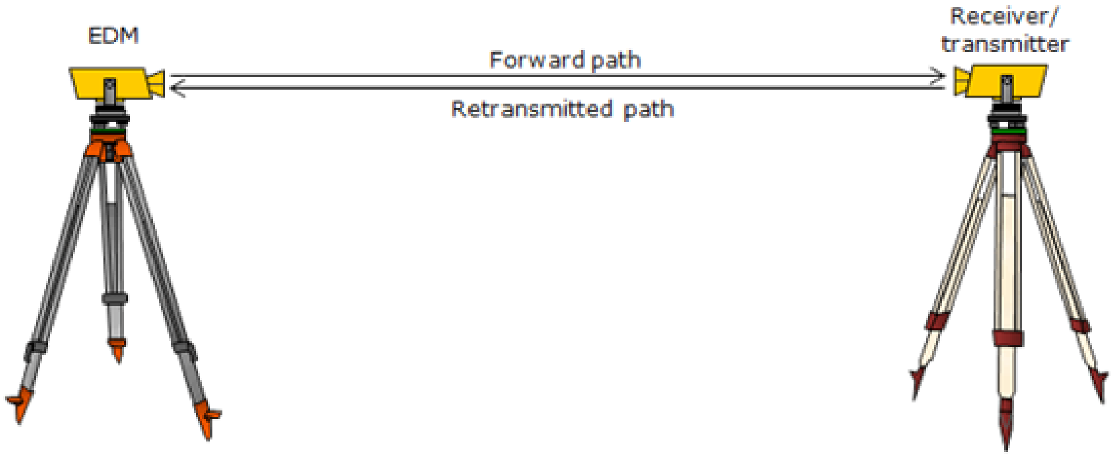
Following is the wavelength of the spectrum

Type of Radiation	Frequency Range (Hz)	Wavelength Range
gamma-rays	10^{20} - 10^{24}	< 10^{-12} m
x-rays	10^{17} - 10^{20}	1 nm - 1 pm
ultraviolet	10^{15} - 10^{17}	400 nm - 1 nm
visible	4 - $7.5*10^{14}$	750 nm - 400 nm
near-infrared	$1*10^{14}$ - $4*10^{14}$	2.5 μm - 750 nm
infrared	10^{13} - 10^{14}	25 μm - 2.5 μm
microwaves	$3*10^{11}$ - 10^{13}	1 mm - 25 μm
radio waves	< $3*10^{11}$	

Micro Wave EDM

Electromagnetic Microwave Instruments

Electromagnetic EDMs, first developed in the 1950s, use high-frequency radio waves. The first generation of this equipment was very precise for measuring long distances; however, it was too bulky and heavy for the practicing surveyor’s needs.



Microwave EDM Principle

Micro wave EDM

Microwave Distance Measurement

As illustrated before, the sending (**master**) instrument transmits a series of modulated radio waves to the receiving (**remote**) instrument.

The remote instrument interprets these signals and sends them back to the master unit that measures the time required for radio waves to make the round trip.

The distance is computed based on the velocity of the radio waves. Because this velocity is affected by atmospheric conditions, corrections for temperature and barometric pressure are applied according to the operating instructions provided with the equipment.

Optical Light EDM

Modern electro-optical EDMs are smaller, lighter, easier to use, and require less power. Modern short-range instruments have ranges from 0.5 km to 5 km. Long range instruments, using coherent laser light, have ranges from 10m to 15 km.

In general: **long range: 10 – 20 km, medium range: 3 – 10 km and short range: 0.5 – 3 km.**

To use an electro-optical EDM, you set up the instrument at one end of the line being measured and a reflector at the other end of the line.

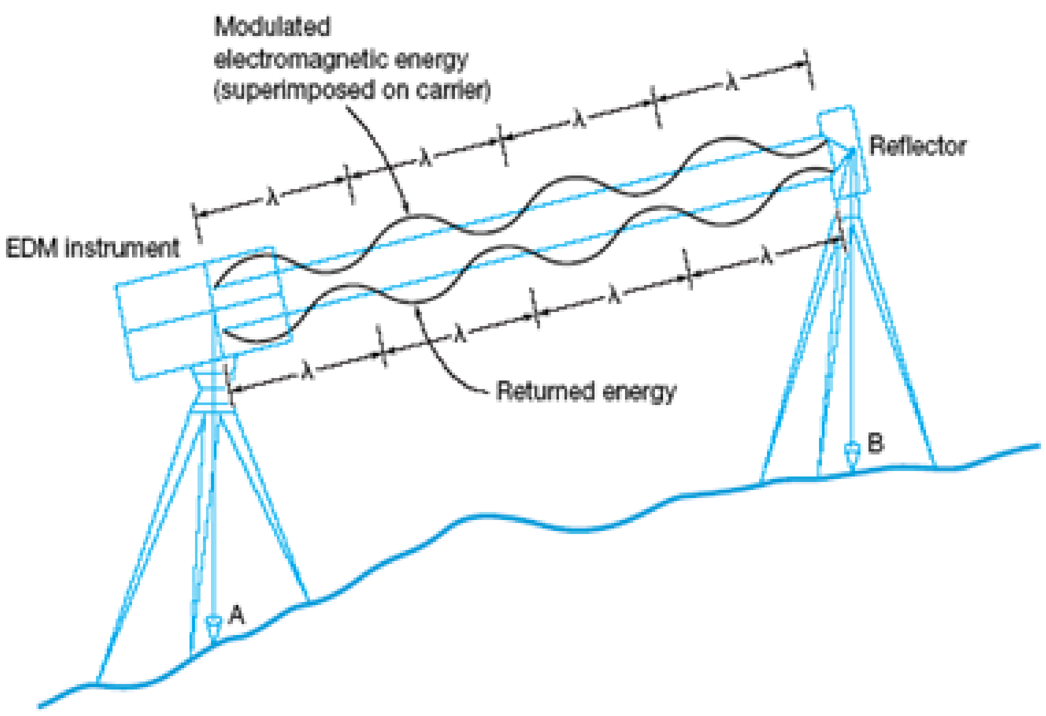


Figure 6–9 Generalized EDM procedure.

Optical Reflector

Comparison: Microwave and Optical EDM

Comparison between Electro Optical and Microwave EDMs

EM Type	Advantages	Disadvantages
Electro-optical	Less susceptible to atmospheric conditions. Less expensive: only a single transmitter needed.	Shorter range.
Microwave	Can penetrate fog and rain. Longer range. Transmitter at both ends allow voice communication.	Atmospheric affects are greater. Susceptible to ground reflected signals. More expensive: requires two transmitters.

EDM Principles

Electro Optical EDM are used to measure distances in land surveying and engineering applications.

<u>EDM Principle</u>: Electromagnetic waves run in sine wave shapes.

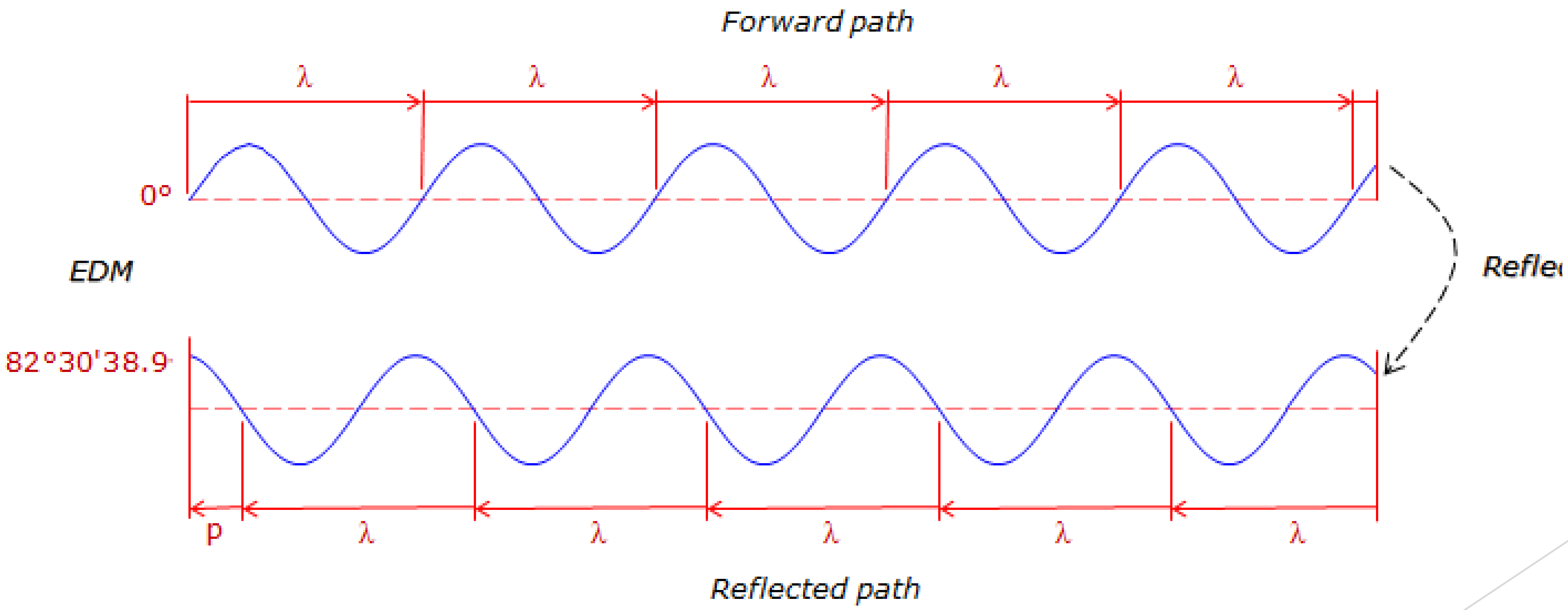


Fig. 14c. Electronic Phase Difference Measurement Principle

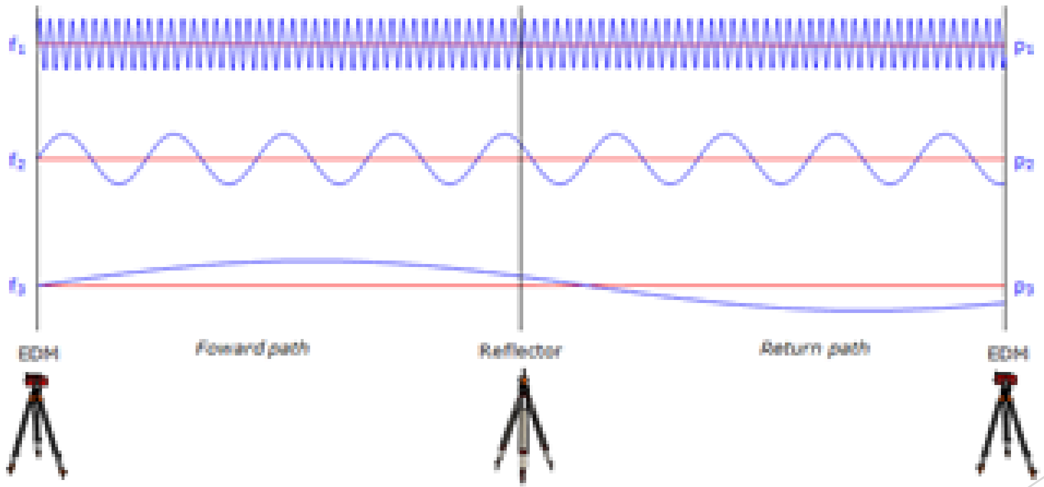
How to count number of wave length cycles

The EDM can't determine how many full wavelengths occurred along the distance, directly. So how does it resolve this dilemma?

Decreasing the frequency by a factor of 10 *increases* the wavelength by a like amount. The partial wavelength at this level will give the next higher distance digit.

This is repeated a number of times until the distance is resolved.

Three frequencies each folded out to show a continuous EDM-reflector-EDM path will allow finding number of wave lengths repeated to measure the distance.



Example

Resolving Embiguity

The following table shows the length of the last partial wave for each of 4 different wavelengths. What is the total distance? The digits in **bold** represent the digits added to the distance as a result of each partial wavelength.

λ, m	p, m	dist, m
10.00	3.69	3.69
100.0	53.7	53.69
1000.	454	453.69
10000	8450	8453.69

The *total* distance is 8453.69 m. The distance from the EDM to the reflector is 8453.69/2 = **4226.84 m**.

EDM Principles

Wavelength = wave speed / wave frequency or **$\lambda = c / f$.**

Measured distance = **$L = (n\lambda + p) / 2$,** where: n = whole number of wavelengths, **p** = partial wavelength measured from phase delay between transmitted and reflected wave.

The rate of change of the phase of a sinusoidal waveform is:

$d\phi / dt = 2\pi f$; $dt = d\phi / (2\pi f)$;

$P = c\, dt = c\, d\phi / (2\pi f) = [d\phi / 2\pi]\, \lambda$

The two-way distance is $(n\lambda + p) = [n\lambda + (d\phi / 2\pi)\, \lambda]$.

The EDM can very accurately determine the length of the last partial wavelength, **p,** from its phase difference measurement.

Example

Example

An EDM of modulated wave length 20m is used to measure a distance AB. Number of complete wave lengths is 10. Phase difference recorded was 82º 30’ 38.9”. Compute distance AB.

Solution:

The last partial wave, p is:

P = **[(82º 30’ 38.9”) / (360º 00’ 00”)] x 20.00 = 4.582m**

If n=10, then the total distance EDM-reflector-EDM is:
10 x 20.00 m + 4.582m = 204.582m

The distance between the EDM and reflector (AB) is half that:

204.582 m/2=102.291 m.

Errors in EDM

Errors in distance measurement using EDM include:

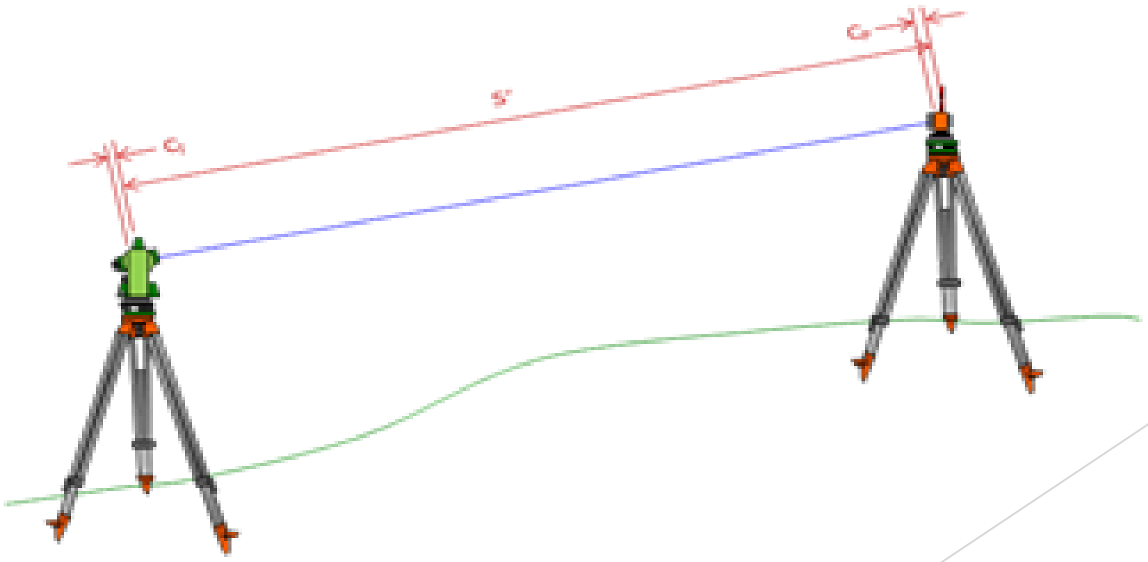
Instrumental Errors, Personal Errors and Natural Errors.

(1) Instrument constant Error

The points of signal origin and signal reflection may not be on the vertical axes used to orient the equipment over the ground points. Most surveyors are familiar with a prism offset and how it is affected by the mounting system, as seen below:

Instrument Constant

Error



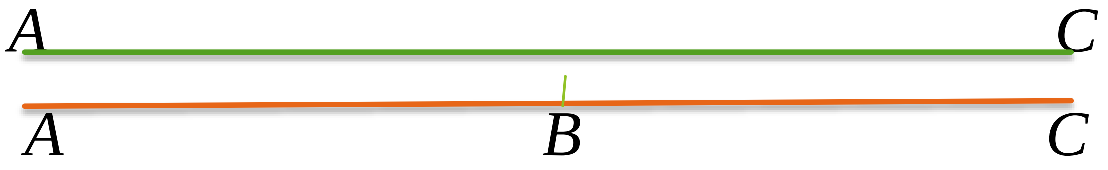
Errors in EDM

Check and Correction for ICE

A simple and accurate method for checking the combined constant is by setting up and measuring a three point baseline.

Step (1) Set the prism constant to 0 on the EDM and apply appropriate atmospheric settings before making any measurements.

Step (2) On open relatively flat terrain set three points (A, B, & C) on a straight line. The outer two points (A & C) should be 100 to 200 m apart; the inner point (B) should be near the midpoint of the line. Point B does not have to be at the exact midpoint but *all three points must be on a straight line*.



Step (3) set the EDM at point A and record distance AC

Errors in EDM

Step (4): Set instrument at station B, measure and record BA and BC.

Step (5) The combined constant, k, affects all three measurements. Since the EDM was set to a 0 prism constant we expect a disparity between the total distance AC and the sum of its parts BA+BC. k can be computed from:

$$AC + k = (BA + k) + (BC + k)$$

$$K = (BA + BC) - AC$$

Step (6) The calibration should be run a second time to check for consistency.

Step (7) When done, k should be used in place of the prism constant for that particular TSI and prism combination.

Errors in EDM

Natural Sources of Errors:

(2) Atmospheric Conditions

Electro-optical EM signals are affected by atmospheric pressure and temperature.

EDMs are generally standardized at a specific temperature and pressure. When measurement conditions deviate from either then a proportional correction must be applied.

This is normally done by the EDM once after operator provides it some necessary information (temp and press or the actual correction factor).

The velocity V of electromagnetic waves in air is a function of the speed of light in vacuum (**V_o = 299,792.5 Km / s**) and the **refractive index (n) of air**, and is given by: **$V = V_o / n$**

Errors in EDM
Atmospheric Refractive Index

The refractive indices of electromagnetic waves in air are functions of air temperature, atmospheric pressure and the partial pressure of water vapor. But, light waves and microwaves react somewhat differently to varying atmospheric conditions.

For **light wave**, the index of refraction n_g of **standard air** (i.e., for an atmosphere at 0^o C, 760 mm Hg pressure and 0.03 percent carbon dioxide) is given by Barrell and Sears Formula:

$$N_g = 1 + \left[287.604 + \frac{4.8864}{\lambda^2} + \frac{0.068}{\lambda^4}\right] x 10^{-6}$$

in which λ is the wavelength of the **carrier beam** of light in micrometers.

EDM Errors

Owing to changes in temperature pressure and humidity the refractive index of air becomes $\mathbf{n_a}$ given by

$$n_a = 1 + \frac{0.359474\,(n_g - 1)p}{273.1 + t} - \frac{1.5026\,e\,(10^{-5})}{273.2 + t}$$

Where p = atmospheric pressure in mm Hg, t = temperature in °C, e = vapor pressure, mmHg.

For **<u>microwave</u>**, the refractive index (n_r) of the atmosphere is

$$(n_r - 1)10^6 = \frac{103.49}{273.2 + t}(p - e) + \frac{86.26}{273.2 + t}\left(1 + \frac{5748}{273.2 + t}\right)e$$

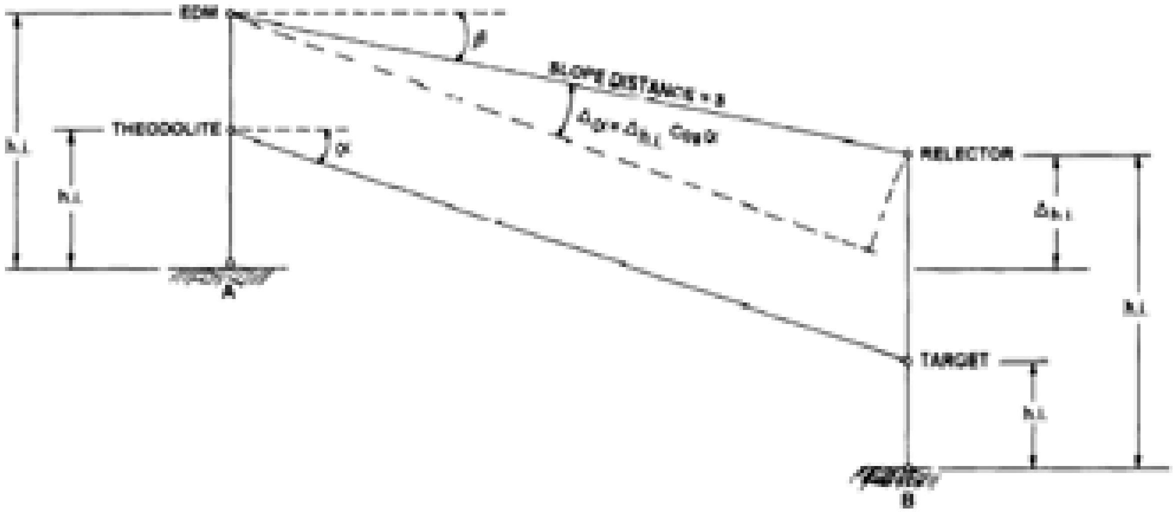
Where p = atmospheric pressure in mmHg, E = Vapor pressure in mmHg, t = temperature, °C

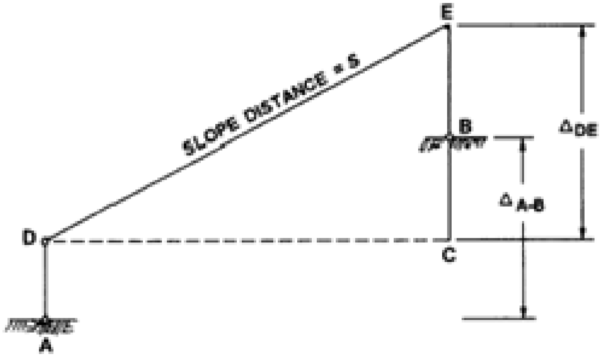
The velocity V of electromagnetic waves in air is $\mathbf{V = V_o / n_r}$

EDM Errors

(3) REDUCTION OF SLOPE DISTANCE

To reduce the slope distance of a line to horizontal distance, you need to know either the vertical angle of the line measured from the instrument or the difference in elevation between the ends of the line.





(a) EDM mounted on theodolite

$Dh = (h_{ref} - h_t) – (h_{EDM} – h_i)$

(b) Total Station

$\Delta_{DE} = \Delta_{AB} – h_i$ **of EDM** $+ h_r$ of reflector

Total Station

Introduction

The Total station is designed for measuring slant distances, horizontal and vertical angles and elevations in topographic and geodetic works, tachometric surveys, control survy as well as setting out in engineering projects.

Total station is composed of **Electromagnetic Distance Measuring Instrument** and Electronic Theodolite. It is also integrated with Microprocessor, Electronic Data Collector and Storage System.

The measurement results can be recorded into the internal memory and transferred to a personal computer interface.

Total Station Parts

Components of a Total Station

Total Station is a compact instrument which weighs around 50 N to 55 N. It consists of a distance measuring instrument (EDM), an angle measuring instrument (Theodolite) and a simple microprocessor. The components used in Total station surveying are as follows:

A **tripod** is used to hold the total station

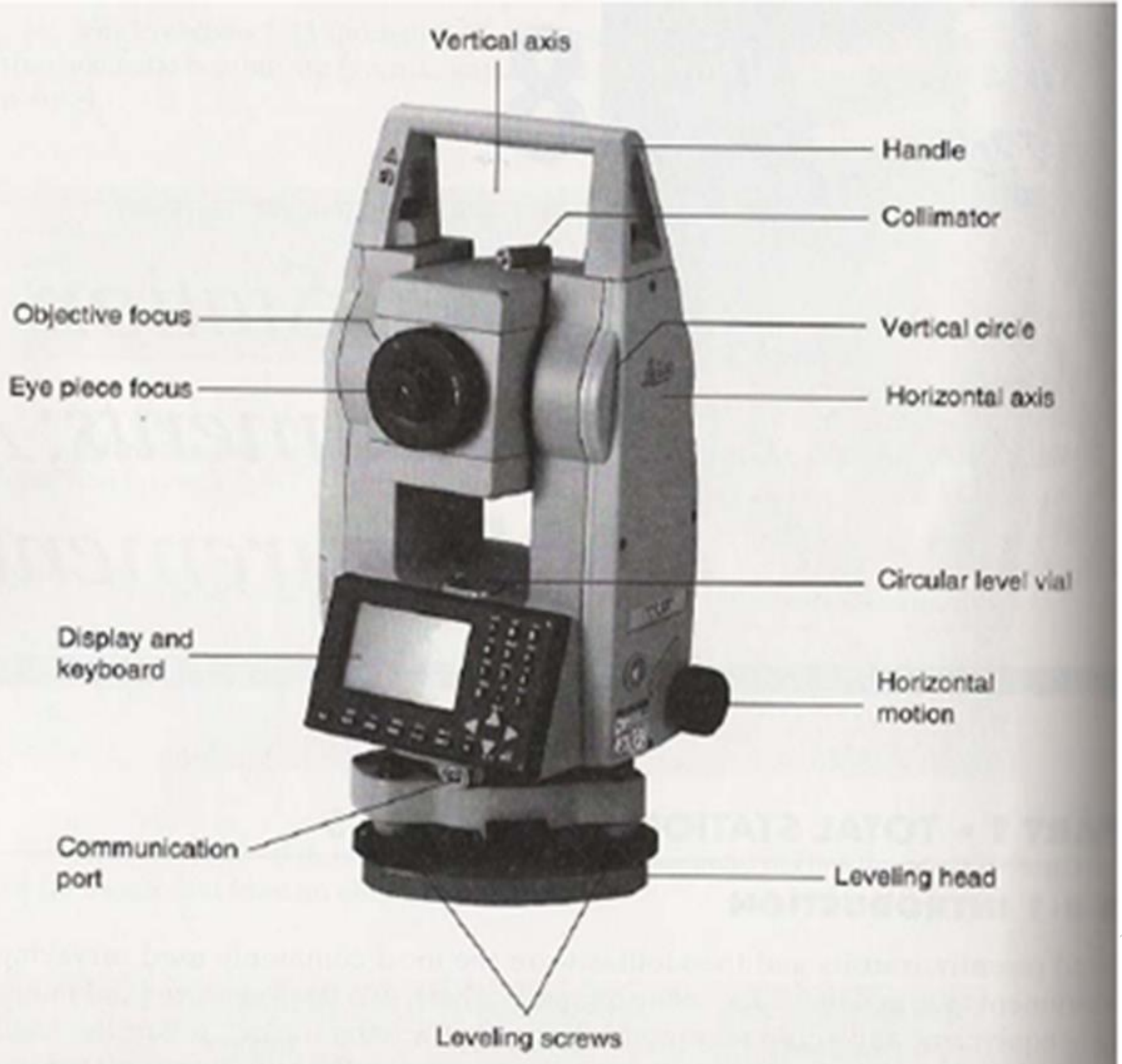
An **electronic notebook** used to record, calculate and even manipulate the field data

Prism and prism pole which can measure lengths up to 2 km and up to 6-7 km can be measured with triple prism

Battery

Total Station

Total Station Parts



Parts of a total station instrument, with view of eyepiece end of telescope. (Courtesy Leica Geosystems, Inc.)

Total Station

- Total Station Parts

Total Station

Basic Steps involved in Total station surveying

Step-1: Setting up of the instrument along with the tripod

Step-2: Levelling of the instrument approximately with the help of "bull's eye bubble" and then verifying the levelling electronically

Step-3: Adjustment of reticle focus and image.

Step-4: Recording all the measurements

Step-5: Data Processing

Total Station

Functions of Total-Station

Angle Measurement:

To measure horizontal and vertical angles, the **electronic theodolite** of the device is used with an accuracy of ***2-6 seconds***. For horizontal measurement of angles, any direction can be taken as reference. In case of vertical measurement of angles, upward direction is taken as reference.

Distance Measurement in Total Station:

To measure the distance, **Electronic Distance Measuring (EDM)** instrument of total station is used with an accuracy of ***5-10 mm per km***. The range of EDM varies from *2.8-4.2 km*.

Data Processing:

Computation of horizontal distances along with X, Y, Z coordinates is done by the instrument **Microprocessor**. Hence, if atmospheric temperature and pressure is applied, the microprocessor applies suitable correction to the measurements.

Total Station

Accuracy of a Total Station:

Accuracy depends upon the instrument and varies from instrument to instrument.

1.The angular accuracy varies from1″ to 20 ″.

2.Distance accuracy depends upon two factors.

a) Instrumental error which ranges from ± 1 to ± 10mm

b) Error due to atmospheric effects depending on the length of measurement.

It can be from ± 1mm per km (1 ppm) to ± 10mm per kilometer (10 ppm).

Range of measurement depend on reflector prisms:

1 prism: 2.5–2.7 km; 2 prisms: 5-7 km; 3 prisms: 10-12 km

Total Station

Advantages of Total Station

The first and foremost advantage of using a Total station is that it saves time of work on the field.

It understands and supports all the local languages.

Setting up of the instrument on the tripod can be done easily and quickly by laser plummet.

The accuracy of measurements is much higher in comparison to other conventional surveying instruments.

The computed data can be saved and simultaneously transferred to the computer. No writing or recording errors can be detected since everything is computerized.

With the help of data accumulated from Total-station, map making and contour plotting can also be done.

Total Station

Disadvantages of Total Station

The working conditions of the total station should be checked before hand by the surveyor before using it.

The cost price of the instrument is higher than the other land surveying instruments.

Checking for errors during the operation is slightly difficult for the surveyor.

Essentially, skilled surveyors are required to handle it since it is a sophisticated instrument to operate.

Total Station

Applications of Total station

- General purpose of angle and distance measurements.
- Data collections for contours plotting
- Data for detailed maps
- Setting out in construction engineering
- Carrying out control surveys
- Archaeologists use total station to record excavations
- Police use it in crime scene investigations to take measurements of the scene
- Used to fix the missing pillars of known ground coordinates
- Remote Distance Measurement (RDM)
- Missing Line Measurement (MLM)
- Remove Elevation Measurement (REM)

Total Station

Total station in construction site work