UNIT- 3

Modern Field Survey Systems

Unit Specifics

Through this unit we have discussed the following aspects:

- Principle of Electronic Distance Measurement (EDM)
- Types of EDMs and their working
- Utility of EDMs
- Various components and parts of a Total Station
- Types of Total Stations and their working
- Taking measurements from Total Stations
- GPS and its components
- Working with GPS/GNSS
- Various methods used in GPS/GNSS survey
- Various applications of GPS

In addition to the basic principle of EDM, Total Stations, and GPS/GNSS, their working has been explained. The practical applications of these modern surveying equipment are presented for generating further curiosity and creativity as well as improving working in field data collection. These modern surveying equipment not only save time but they need less manpower in the fieled to collect ground data. Questions of short and long answer types are given following lower and higher order of Bloom's taxonomy, and a list of references and suggested readings are given in the unit so that one can go through them for additional readings.

Rationale

This unit provides principle and theory of using EDM, Total Stations and GPS/GNSS so that the students get familiar about the use of these modern equipment. It explains various components of each of these devices. Working with these instruments are also explained. The advantages and disadvantages of using EDM, Total Station and GPS/GNSS are given to offer students a wide spectrum of uses. Various methods used in the field and accuracies achieved are also given. Various sources of errors and their minimisation are discussed so that the users can minimise the errors from field data. Various applications given in this unit will further enhance the understanding of these equipment.

Pre-Requisite

Mathematics: geometry and trigonometry; Surveying: Theodolite and distance measuring instruments. Electro-magnetic waves.

Unit Outcomes

List of outcomes of this unit is as follows:

U3-O1: Describe various types of EDMs, Total Stations, and GPS/GNSS

U3-O2: Explain the essential components and characteristics of EDMs, Total Stations, and GPS/GNSS

U3-O3: Realize the role of EDMs, Total Stations, and GPS/GNSS for field data collection

U3-O4: Describe various methods of using EDMs, Total Stations, and GPS/GNSS

U3-O5: Apply the parameters collected in the field for various applications

Unit-3 Outcomes	Expected Mapping with Programme Outcomes *(1- Weak correlation; 2- Medium correlation; 3- Strong correlation)*					
	CO-1	**CO-2**	**CO-3**	**CO-4**	**CO-5**	**CO-6**
U3-O1	2	3	2	2	1	2
U3-O2	2	1	3	1	2	-
U3-O3	2	2	2	3	-	3
U3-O4	3	3	2	1	2	-
U3-O5	2	3	2	1	-	2

3.1 Introduction

Long distance measurements on the ground by conventional method has always been a problem in surveying. The use of electronics in modern surveying equipment has ease the process. Electronic Distance Measuring (EDM) device can be used for measuring the long distances (slope distances) with higher accuracy, thus saving a lot of time (Garg, 2021). The triangulation and trilateration surveys require accurate measurement of long distances. With the advent of EDMs, it has become easy and fast to measure the long distances. Early EDM instruments were large, bulky, complicated and expensive, but the improvements in electronics over a period of time have made them lighter, portable, simpler, and affordable. These EDMs can be mounted on tribrach or standard units or theodolites, and can be used with theodolites (both digital and optical) or as an independent unit (Subramanian, 2012). They provide slope distance, and once the slope distance is known, horizontal distance can be computed trigonometrically by using the vertical angle measured from the theodolite.

Total Station equipment, which is a combination of digital theodolite, an EDM and a small processor to process the data, can be used for taking multiple observations in the field, and thus this equipment eliminates the need of taking several surveying equipment in the field, such as theodolite, level, tacheometer, tape, etc. With the advent of Total Station, angular measurements, distance measurement and height measurements have become quick, easy and accurate (Gopi et.al., 2017). This equipment can be used to measure the horizontal angles, vertical angles, slope distances, and to determine horizontal distances, elevations, coordinates of the points using these measurements. The Total Station has made a revolution in surveying for digital data collection and data analysis, and subsequently creating a digital map.

The Global Positioning System (GPS) traditionally refers to the North American global positioning system, or satellite positioning system. Originally known as Navigation Satellite Timing and Ranging (NAVSTAR), GPS was developed by the US Department of Defense for military use in the 1970s. The Global Navigation Satellite System (GNSS) term refers to the international multi-constellation satellite system, and typically includes GPS, GLONASS, Baidu, Galileo, QZSS, NAVIC, or and any other constellation system. With the advent of Europe's Galileo system and China's BeiDou, users can now use a broader range of signals and get greater reliability as more satellites are available at any given time, greater precision as combinations of signals and frequencies can help to mitigate effects such as atmospheric interference on GNSS precision.

The GNSS based receivers are modern surveying device which are used to collect field data for mapping from all available satellite systems. The multi-GNSS receivers are now very common as they accurately determine their own location by measuring the distance to four or more satellites. The output from the GNSS receivers is 3D coordinates of the point (x, y and z) (Latitude, Longitude and Elevation) as well as time (Garg, 2021). For mapping purpose, we need only 3-D coordinates of various points. The availability of GNSS receivers has further simplified and speeded-up the survey work as there is no need to take angular or linear measurements (unlike Total Station) to compute the 3D coordinates, which are obtained directly as output. The measurements from GNSS can be taken day and night anywhere on the Earth.

The availability of EDM, Total Station and GNSS has eased the data collection and mapping work, and considerable reduced the cost and time to complete the survey work, as compared to conventional surveying equipment (Gopi et. al., 2017). However, today Total Station equipment, which has an in-built EDM, can be used to measure the long distances. So, now-a-days, there is no need to buy the EDM system separately. But Total Station and GNSS are complimentary to each other, so it is better to take both the equipment in the field while taking several observations. Total Station requires horizontal clearance of line of sight and GNSS needs vertical clearance of satellite signals, so field measurement work is not hampered if one of the clearance is not available (Garg, 2019). Looking at the potential use of both (Total Station and GNSS), a combination of both has emerged in the market, called a *Smart Station*. A Smart Station is an instrument which can be used as a Total Station or as a GNSS or in combination on the same system, so instead of carrying two equipment in the field, the surveyor can carry the Smart Station and perform the survey data collection work much faster.

This module will cover the details and working of EDMs, Total Station and GNSS. These electronic devices used for field survey measurements are dependent on the velocity of Electro-magnetic (EM) wave, and the time of travel of wave. Some advantages and disadvantages of each equipment are also given.

3.2 Electronic Distance Measurement (EDM) Devices

The EDM is an electronic distance measuring device, which measures the distance from the instrument to its target through electromagnetic waves (Garg, 2021). The EDM instruments are highly reliable and convenient, and can be used to measure distances of up to 100 km. Such long distance measurement can be done by instruments, like *geodimeter, tellurometer* or *distomat* etc. The first EDM instrument called '*geodimeter'* was developed in Sweden in the year 1948. It is geodetic distance meter developed based on a modulated light beam (Figure 3.1). The second instrument for EDM was designed and developed in Africa in the year 1957, named '*tellurometer'*. This instrument employs the modulated microwaves. As the technology improved, the EDMs became smaller and light-weight which measure slope distances in digital form and compute horizontal distances.

Figure 3.1 Old version of a Geodimeter (Source: https://www.aga-museum.nl/aga-geodimeter-3-8)

The method of direct distance measurement (e.g., Tape) can't be implemented in difficult terrains or for large distances or where large amount of obstructions exists. The direct method is limited to 15 to 150 m with an accuracy range of 1 in 1000 to 1 in 10000, whereas the EDM with an accuracy of 1 in 10^5 have a distance range of up to 100 km (Gopi, et.al., 2017).

3.2.1 Principle of EDM

The measurement of distances requires the EDM unit (called transmitter) which transmits Electro-magnetic (EM) wave, and a reflecting prism (called receiver/reflecting unit). The slope distance is determined between the points on the ground where these two units can be kept apart (Garg, 2021). The EDM is kept at a point known as *master station* and reflecting prism at another point called *remote station*. The general principle used in EDM is that a modulated EM beam is transmitted from a transmitter kept at the master station to a reflector which is kept at the remote station, and receiving the beam back at the master station. The instrument measures the travel time of EM wave from transmitter to receiver and back to transmitter. The slope distance between transmitter and receiver is computed by taking half of travel time multiplied by the velocity of EM wave (i.e., the velocity of light). Since measurement of time requires very precise observation, so in modern EDMs, the distance is determined by modulating the continuous carrier waves at different frequencies, and then measuring the phase difference at the master station between the outgoing and the incoming signals.

The EM wave, generated by the EDM, travels through the atmosphere in a sine wave form, and ultimately strikes to the prism and reflects back to EDM device, as shown in Figure 3.2a. The distance is measured as a function of speed of light and the elapsed time. Frequencies generated within an EDM are used to determine the elapsed travel time of its signal (EDM to prism and prism to EDM). The distance is calculated as:

Distance (D) = (elapsed time/2) x velocity of light (3.1)

However, since the travel time is too small, measuring the precise time by an EDM is a difficult task. The modern EDMs therefore use the phase difference approach where the number of completed waves and incomplete wave is measured. It basically measures the phase changes that occur as wave travels from one end to the other end of a line and returns back (Figure 3.2b). The EDMs that use the phase-shift principle carry out the measurements several times in order to resolve the ambiguity of phase difference.

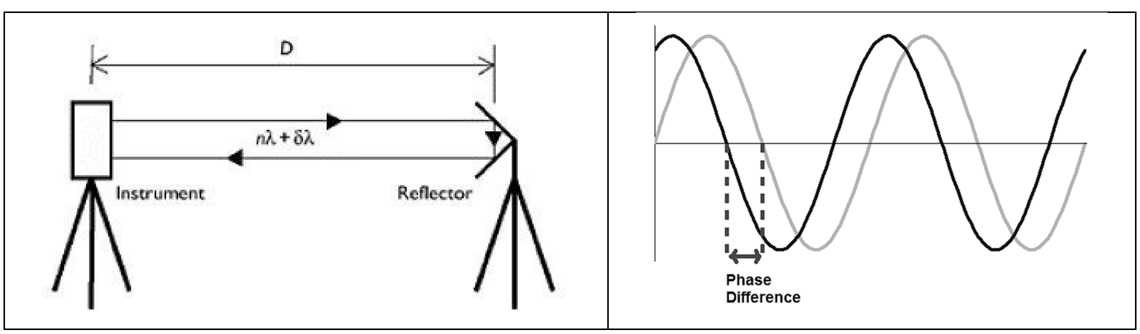

Figure 3.2 Measurement of (a) time, and (ii) phase difference

The phase shift method is considered to be the most accurate one as it allows a very narrow beam, but its measuring range is limited. Phase shift is typically measured in degrees where a complete cycle is 360º, and the wave form repeats every 360°. As, the EM wave travels in a sinusoidal wave form, the distance between two wave form peak is known as the *wavelength* (λ). The number of cycles a wave completes in per unit time is known as its *frequency* (*f*). The wave leaves the EDM at 0° phase, goes through *n* number of full phases on its path towards the reflector (prism), and returns to the EDM at some angle between 0° and 360°, creating a partial wavelength *p*. The partial wavelength is the difference between the phasing of the emitted and the received signal. When two waves reach at different phase angle at different times, they are out of phase or phase shifted. The EDM compares the phase angle of the returning signal to that of a replica of the transmitted signal to determine the phase shift.

The distance (D) is then determined as one-half of the sum of the number of wavelengths (*n*) in the double path distance multiplied by the wavelength (*λ*) plus the partial wavelength (*p*) represented by the phase difference. The distance is determined by the equation:

$$D = \frac{1}{2} (n \lambda + p) \quad (3.2)$$

The EDM can very accurately determine the length of the last partial wavelength from its phase. The total EDM to reflector to EDM distance is computed as per example given below:

The wavelength in Figure 3.3 is 6.1 m, and there are 10 full wavelengths before the last partial one.

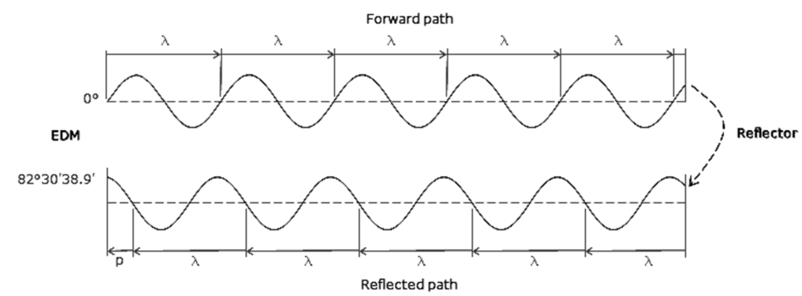

Figure 3.3 Representation of phase shift

The last partial wave (p) = (82°30'39.9" / 360°00'00") x 6.1 m = 1.40 m. The total distance EDM to reflector to EDM (10 full wavelengths and last partial wave) = 10 x 6.1 m + 1.40 m = 62.40 m. So, the distance between the EDM and reflector is half that 62.40 / 2 = 31.20 m.

In fact, while the EDM can accurately measure the last partial wavelength (*p*), it doesn't know the number (*n*) of full wavelengths occurred before it. This is resolved by decreasing the frequency (*f*) by a factor of 10 or increasing the wavelength (*λ*) by a factor of 10, and repeating the process of distance measurement. This is repeated a number of times for three or four different frequencies to get the correct value of *n* or the total distance.

Table 3.1 shows the last partial wavelength (*p*) given by the EDM for each of 4 corresponding different wavelengths to measure the distance between two fixed points. The digits in bold represent the digits which will be added to the distance as a result of each partial wavelength (*p*) to get the correct distance.

Table 3.1 Phase shift with different frequencies

***λ* (m)**	***p* (m)**	**Distance (m)**
10	**3.68**	3.68
100	**5**3.70	53.68
1,000	**4**54	453.68
10,000	**8**450	8453.68

The total distance is 8453.68 m, and the EDM-reflector distance is 8453.68/2 = 4226.84 m

3.2.2 EDMs classification based on range

The EDMs are also classified on the basis of their range of electro-magnetic (EM) waves (Subramanian, 2012), as:

(a) **High range-** radio wave equipment for ranges up to 100 km
(b) **Medium range-** microwave equipment with frequency modulation for ranges up to 25 km
(c) **Short range-** electro-optical equipment using amplitude modulated infra-red or visible light for ranges up to 5 km

Sun light or electromagnetic spectrum consists of different wavelengths at different frequency. Various wavelength regions of EM waves are shown in Figure 3.4. The EDMs are now-a-days incorporated in electronic theodolites (or Total Stations) that can automatically measure vertical angle to compute horizontal and vertical distances. The present EDM instruments have several other useful features; laser plummet, 30x magnification, high resolution LCD display, upload and transfer of data, data editing and exchange, and bluetooth connectivity.

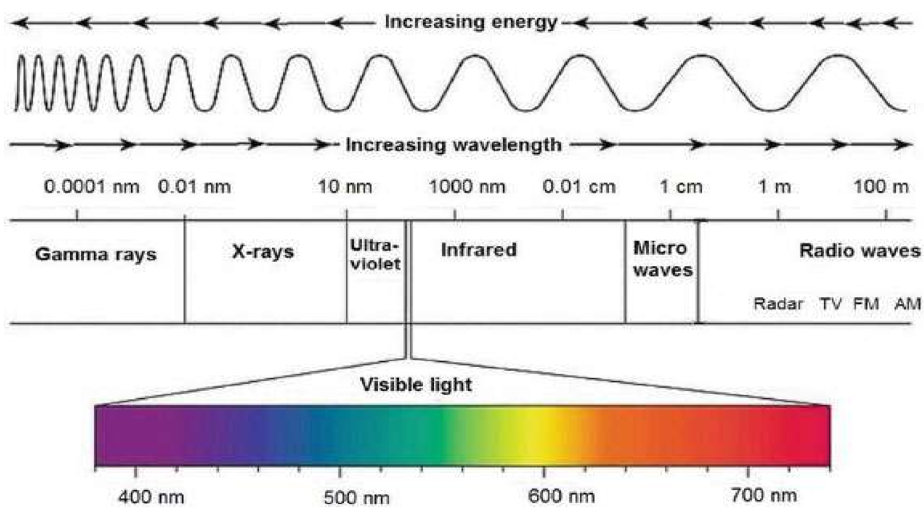

Figure 3.4 An electromagnetic spectrum (Garg, 2019)

The microwave-based EDMs make use of microwaves, such as Tellurometers, in the wavelength from 10 cm and 3 cm. The range of these instruments is up to 100 km with an error of ±5 to 15 mm/km. They can also be used in night and in adverse weather conditions. They consist of two identical units; where one unit is used as master unit and the other as remote unit. The master unit can be converted into a remote unit and a remote unit into a master unit, if required. Each unit is kept at two ends of a line to determine the distance. For long distance measurement, a communication facility is provided with each unit to interact with survey team members during the measurements.

Visible light or infrared wave-based EDMs rely on propagation of modulated waves, such as Geodimeter or Distomat (Gopi et.al., 2017). The instrument is kept at one end and the reflecting prism at the other end of a line. These instruments are light and economical, and can also be mounted on the top of a theodolite. Such EDMs are very useful for civil engineering project, as the accuracy of these of measurements varies from 0.2 mm/km to 1 mm/km distance. They can be used to measure distance up to 5 km.

3.2.3 Reflecting prisms

Reflecting prisms, also known as reflectors, reflect the EM wave back to the Total Station or EDM for computing the distance (Figure 3.5). Prisms are either mounted on a prism pole, or on the top of a tripod. They are used in single or in combination (of 3 or 6 etc.) making a pyramid shape. Large number of prisms are used to get increased accuracy when the distance to be measured is very large. The centre of the prism is bisected with the centre of the diaphragm of the telescope of EDM before taking the measurements. The prisms on top of the tripod are used for back-sighting purposes as well as to get the better accuracy (Garg, 2021).

While procuring a surveying prism, the offset, the thread size, the optics and the size of the prism are to be considered. Relevant factors are the prism construction (glass quality, geometry, coatings), the prism alignment with respect to the line of sight of an instrument and the EDM unit used. There are two main factors for good range measurement: prism diameter and beam deviation. The application requiring high accuracy demands to use circular prisms (Lackner and Lienhart, 2016). For stake out work, mini-prisms which are smaller in diameter, allows the users to get close to a wall or building to get the shot or stake out.

Figure 3.5 Reflecting prisms (Source: https://www.nsscanada.com/product-category/leica-geosystems/survey-accessories/prisms-reflectors)

3.2.4 Distance measurement

The EDM instruments generate the EM waves which are modulated and propagated. The EDM is kept at one point and the reflecting prism at the other point whose distance is to measured. The EDM is set up properly with temporary adjustment as has been explained for other equipment in Module 1. Many EDMs have optical plummet for accurate centering and auto levelling facility which levels the base within a certain small range. The optical plummet and auto-levelling facility save lot of time in the field for temporary adjustment of EDM. The diaphragm is properly focussed. Now, the prism is bisected accurately at its centre before taking the distance measurements from EDM.

The EDM sends out a laser or infrared beam which is reflected back from prism to the instrument, and the instrument calculates the distance travelled by the beam. Some EDM instruments use pulsed laser emissions, and these instruments determine the distance by measuring the time taken between the transmission of the signal and the reception of the reflected signal, by taking advantage of the pulsed laser beam.

3.2.5 Errors in EDM measurements

The errors in EDM measurements could be due to- Personal errors, Instrumental errors, and Natural errors. A good description of errors in EDM measurements is given by Rajput (2020). Some of these are-

(a) Inaccuracy in initial setup of EDMs and the reflectors over the stations
(b) Instrument and reflector measurements going wrong
(c) Atmospheric pressures, humidity, and temperature errors
(d) Atmospheric variations in temperature, pressure as well as humidity, as microwave-based EDMs are more susceptible to these parameters.
(e) Calibration errors
(f) Errors shown by the reflectors
(g) Multiple refraction of the signals
(h) Zero error (Additive Constant) in distance measurement which is caused by electrical delays, geometric detours, and eccentricities in the EDM. The additive constant or zero/index correction is added to the measured distances to correct for these differences.
(i) Differences between the electronic centre and the mechanical centre of the EDM
(j) Differences between the optical and mechanical centres of the reflector. This error may vary with changes of reflector, so only one reflector should be used for EDM calibration.
(k) Scale errors are linearly proportional to the measured distance, and can arise from both internal and external sources. Internal sources are ageing, drift and temperature effects (e.g., insufficient warm-up time) of the oscillator (Staiger, 2007).
(l) Internal frequency errors, including those caused by external temperature and instrument ‘warm-up’ effects
(m) Non-homogeneous emission/reception patterns from the emitting and receiving diodes (Phase in homogeneities).
(n) Cyclic error (Short Periodic error) which is a function of the actual phase difference measurement by the EDM (Staiger, 2007). Phase measurement error is caused by unwanted feed through the transmitted signal onto the received signal (Tulloch, 2012). Cyclic error is usually sinusoidal in nature with a wavelength equal to the unit length of the EDM. The unit length is the scale on which the EDM measures the distance, and is derived from the fine measuring frequency. The stability of the EDM internal electronics can also vary with age, therefore, the cyclic error can change significantly over time. Cyclic error is inversely proportional to the strength of the returned signal, so its effects will increase with increasing distance (i.e., low signal return strength). Calibration procedures exist to determine the EDM cyclic error that consist of taking bench marks measurements through one full EDM modulation wavelength, and then comparing these values to known distances and modeling any cyclic trends found in the discrepancies.

3.3 Total Stations

This instrument is an integrated version of an electronic Theodolite and an EDM, as shown in Figure 3.6. It also has a small micro-processor, electronic data collector and storage system. A Total Station is an electronic/optical instrument used to measure sloping distance of object to the instrument, horizontal angles and vertical angles (Garg, 2021). Micro-processor in Total Station processes the collected data to compute the average of multiple angles measured, average of multiple distance measured, horizontal distance, elevation of ground, and 3-D coordinates of the observed points. These data can be stored in the system itself but each Total Station has a limited storage space. The data can be transferred to a laptop and desktop later for its processing.

Figure 3.6 Total Station (Source: https://www.directindustry.com/prod/south-surveying-mapping-instrument-co-ltd/product-160571-1650628.html)

The Total Station sends out infrared waves that are reflected by the prism kept at the object. By taking measurements of the prism, the Total Station computes the prism's coordinates as well as reduced level of the ground point. Some of the major advantages of using Total Station over the conventional surveying instruments are; saving in time, ease in working, increase in accuracy, and facility to use computer for storing, processing the data and derive the final result in a desired format (Gopi et.al., 2017).

3.3.1 Various components of a Total Station

Total Station consists of a distance measuring instrument (EDM), an angle measuring instrument (Theodolite) and a simple micro-processor (Figure 3.7). It is a compact instrument, and one person can easily carry it to the field from one point to another. Total Stations with different accuracy, in angle measurement and different range of measurements, are available in the market. The components of a Total Station are as follows:

1. A **tripod** which is used to hold the Total Station
2. A **mainframe device** which is used to record, calculate and even manipulate the field data. Various parts of a Total Station are shown in Figure 3.8.
3. **Prism and prism pole/tripod** which can be used to measure distances up to 6-7 km with triple prism
4. **Battery** is required to provide power source to the instrument.

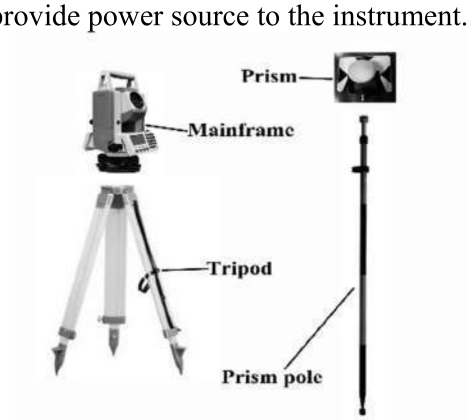

Figure 3.7 Components of a Total Station

Figure 3.8 Parts of a Total Station (Source: https://surveyforbeginners.wordpress.com/2019/01/01/total-station)

3.3.2 Steps involved in Total Station surveying

(a) Fix the instrument on the tripod that has been firmly kept on the ground (Figure 3.9a).
(b) Fix the instrument on the tripod with the help of a given screw in tripod (Figure 3.9b).
(c) Set up the instrument on the ground point. Some instruments have optical plummet which consists of a sharp laser beam and may be used for centering purpose (Figure 3.9c).
(d) Levelling of the instrument approximately with the help of "bull's eye bubble" using eye judgement (Figure 3.9d). Use the standard procedure for levelling (Figures 3.9e & f), and then correct the levelling precisely electronically (Figure 3.9g).
(e) Focus the diaphragm (Figure 3.9h).
(f) Fix the prism on the prism rod at a known height. Since, the prism rod is graduated so height of the prism is known.
(g) Measure the height of instrument with the help of a tape.
(h) Set up the working unit in the instrument. Enter the height of prism pole, height of instrument, coordinates of point where instrument is kept (if known), temperature and atmospheric pressure at the site (if known).
(i) Focus the prism kept at the other point.
(j) Bisect the centre of reflecting prism and with the help of appropriate functional buttons in the instrument. The measurement will be displayed on the display panel. Store all the measurements in the instrument itself.
(k) Compute the other data from measured observations.
(l) To speed up the work, more than one prism set is used the field. Various persons can set up the prisms at respective locations and observer from the same location of instrument can take observations all around. It saves lot of time in data collection.
(m) Transfer the field data into desktop or laptop and process it using the related software.

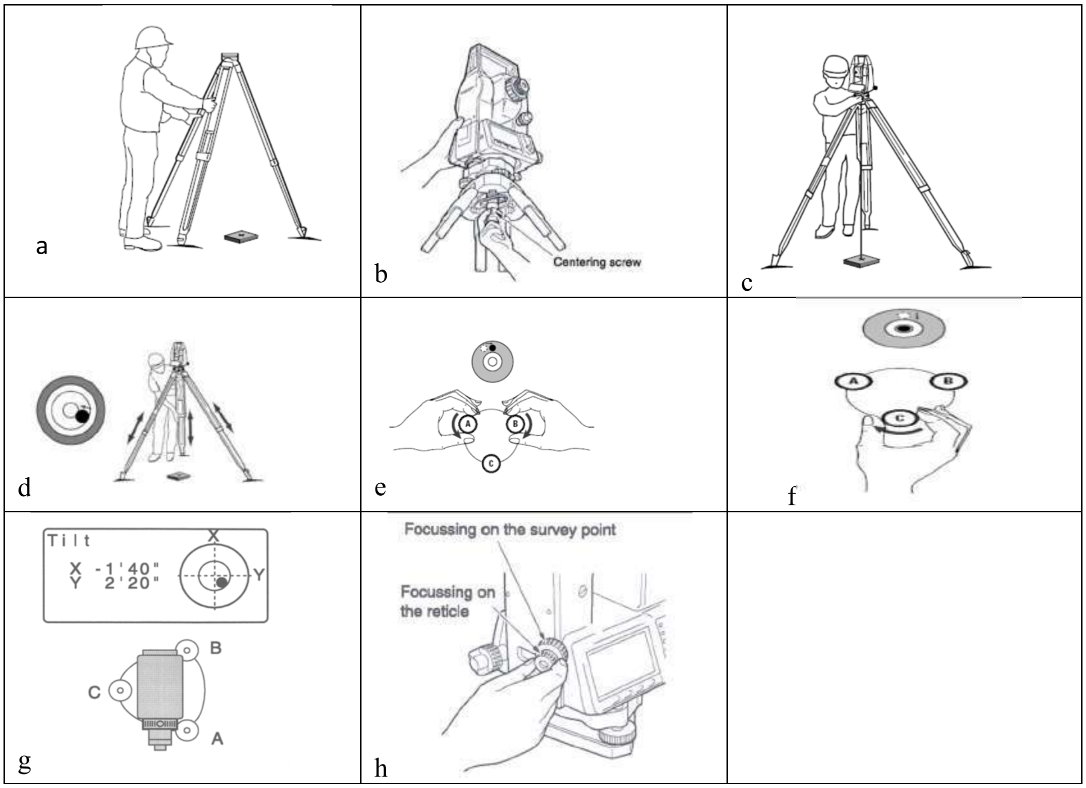

Figure 3.9 Various steps of Total Station (Sources: https://www.onlinecivilforum.com/site/setting-total-station/ and https://www.southalabama.edu/geography/allison/GY301/Total%20Station%20Setup%20and%20Operation.pdf)

3.3.3 Functions of Total Station

Most Total Stations have a distance measuring accuracy of 2-3 mm at short ranges, which will decrease to about 4-5 mm at 1 km (Mishra, 2014). Although angles and distances can be measured and used separately, the most common applications for Total Stations occur when these are combined to define the position in control surveys.

1. Angle measurement:

To measure horizontal and vertical angles, the Total Station is used with an accuracy of better than one seconds. For horizontal measurement of angles, any direction can be taken as reference. In case of vertical measurement of angles, horizontal direction is taken as reference.

2. Distance measurement:

The EDM is a major part of Total Station. To measure the distance, EDM instrument of Total Station is used with an accuracy of 5-10 mm per km or better. The accuracy varies with each Total Station equipment. They are also available to be used in Robotic mode, with automatic target recognizer. The distance measured is always sloping distance from instrument to the object.

3. Keyboard and display:

Total Station is activated through its control panel, which consists of a keyboard and multiple line LCD (Figure 3.10). A number of instruments have two control panels; one on each face, which makes them easier to use from either side or while changing the face of the instrument. In addition to controlling the Total Station, the keyboard is often used to code the data generated by the instrument; this code will be used to identify the object being measured. In some Total Stations, it is possible to detach the keyboard and interchange them with other Total

Stations or GNSS receivers. This is called *integrated surveying*. Electronic display unit is capable of displaying various values when respective key is pressed. The unit is capable of displaying horizontal distance, vertical distance, horizontal and vertical angles, difference in elevations of two observed points and the 3-D coordinates of the observed points. It also displays the graphical figures of the area covered as well as geographical distribution of data points collected in the field.

4. Electronic book:

Each point data can be stored in an electronic note book or stored in a pen drive. The capacity of electronic note book varies up to 10000 data points, depending on the model of instrument. The data from note book can be unload to a computer, and the note book is again empty to re-use in the field.

5. Data processing:

The instrument is provided with an inbuilt microprocessor. The microprocessor averages out the multiple observations. Computation of horizontal distances along with X, Y, Z coordinates is done by the microprocessor of instrument. Hence, if atmospheric temperature and pressure are to be applied, the microprocessor applies suitable corrections to the measurements.

6. Software:

Various softwares are available in the market which can be used to post-process the data from the Total Station. Usually, manufacturers provide their own customised software which allows to export the survey results into other formats. Thus, output can be imported to CAD application or software, like MX Roads, GIS software. Software, like Auto civil and Auto plotter clubbed with AutoCAD can be used for plotting contours at any specified interval and plotting cross-sections along any specified line. Normal survey task, such as traversing, mapping, area, volume, contouring., all are now available in software modules.

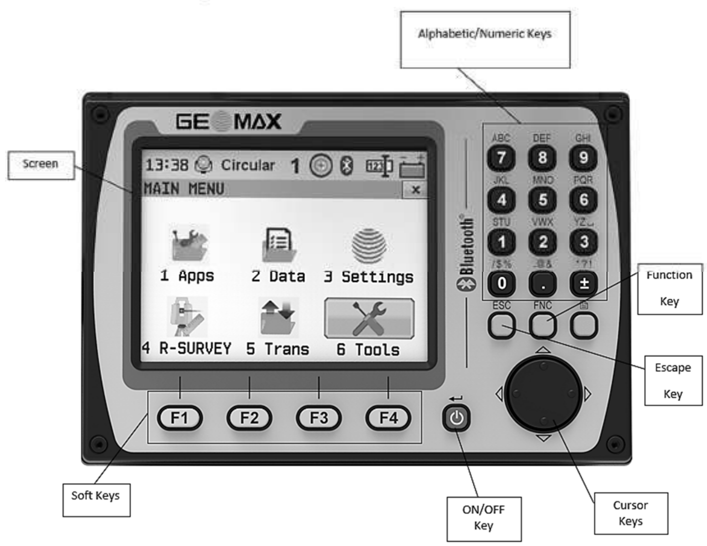

Figure 3.10 Keyboard and display unit (Source:https://surveyforbeginners.wordpress.com/2019/01/01/total-station)

3.3.4 Reflectorless Total Stations

There are two methods of measuring the distance; (i) With reflector and (ii) Reflectorless or prismless modes. The prism method uses a reflective prism at the measurement point, and the non-prism or reflectorless method does not require a reflective prism. Both the methods have been widely used in engineering and industrial surveying systems to measure the distances and angles automatically (Xia et al, 2006). At a small scale and a local coordinate system, the survey by Total Station is more superior and precise as compared to other surveying methods.

However, in order to obtain accurate and reliable results, it is necessary to check and adjust the instrument regularly.

With the reflectorless method, the instrument works with a laser (Light Amplification by Stimulated Emission of Radiation) beam (Figure 3.11). The instrument is placed at the measurement point, and the distance is measured using a laser beam (Beshr and Elnaga, 2011). With this method, it is possible to survey the areas of impossible reach, such as disaster areas (e.g., affected by landslides), snow-covered areas, nuclear waste sites, forest fire, etc., safely and efficiently. The laser beam based Total Station can be used in night or underground survey or those locations where it is not possible to keep the prism, such as bottom of the bridge deck, or there is danger to human life to keep the prism. The area to be surveyed may have safety concerns, underground mines, detail surveys of busy road intersections where traffic control is impossible. The main advantage of reflectorless Total Station is the ability to measure inaccessible points to collect data with increasing speed and accuracy.

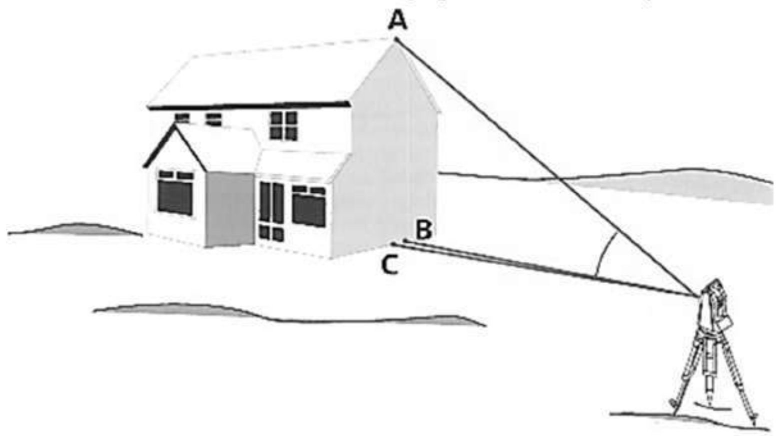

Figure 3.11 Use of a reflectorless Total Station

Modern Total Stations have the ability to measure inaccessible or hard to reach targets up to 2 km without reflector with an accuracy of 3 mm. It provides the additional advantage of requiring less labour and time as second person is not required to hold the prism at the target point. For example, when surveying busy roads, traffic puts the restrictions to work with a reflective prism. So, the decision to use the prism method or reflectorless method is taken according to the conditions at the survey site. Reflectorless Total Stations are used now-a-days for several applications in geodetic engineering due to their highly accurate and fast measurements in an automated measuring process (Garg, 2021). Structure deformation can also be measured with reflectroless Total Station instrument.

In reflectorless Total Station, the accuracy of measured slope distance for a white surface is higher than the accuracy of any other surface colour; hence this surface has the strongest reflectivity for reflectorless Total Station ray as compared with any other surface. Similarly, the surface of black target has a very low reflectivity, so it absorbs more energy. Increasing the inclination angle of reflecting surface leads to increase in the errors of slope distance measured by the reflectorless Total Station. The reflectorless measurements may have serious errors if the signals have reflected from any surface present in the line between the instrument and the target. For example, the signal may be reflected by a leaf present in between the line of sight. Because the laser pulses reflect-off different surfaces, precaution must be taken when pointing the instrument. This is especially critical when there are multiple surfaces at various orientations near the measurement point. Most reflectorless instruments can also be used with a prism as a conventional Total Station. giving them a greater flexibility of working.

Other main concern with the accuracy of reflectorless Total Stations is divergence of laser beam. The beam divergence of an EM beam is an angular measure of the increase in beam diameter or radius with distance from the optical opening or antenna opening from which the EM beam emerges. As the size of the laser spot increases with distance from the instrument, so the accuracy of the measurement becomes less reliable. The size of the laser beam depends on the distance from the EDM system; the greater the distance, the larger the laser spot size.

3.3.5 Robotic Total Stations

Another advancement in Total Station is the emergence of Robotic Total Station (RTS) which is able to follow a prism horizontally and vertically through servomotor in the instrument. These RTSs are expensive as they have more sensors in the device as well as prism. These sensors make the instrument to work in robotic mode. The servomotor automatically rotates the instrument, as it communicates with an Advanced Tracking Sensor (ATS) fitted in the prism for tracking the movement of the prism (Garg, 2021). A communication link between the RTS and prism allows, controlling the RTS from the prism pole side with a remote controller (Figure 3.12). With this instrument, just one person is required to carry out the entire survey.

Figure 3.12 Robotic Total Station and prism with remote control unit (Source: https://lasersurvey.com.au/product-category/surveying-equipment/total-stations/robotic-total-stations)

Modern Total Stations require only one surveyor to take the field measurements, thus saving time and money. They provide high accuracy, even under low visibility (night) condition. Total Stations are used to increase the productivity for topographic surveying, to set out bridges, dams, canal, houses or boundaries. The RTSs are also used by archaeologists, police, crime scene investigators, insurance companies, for automated guidance of dozers, graders, excavators, harvesters, tractors and scrapers, and for deformation studies, such as dams, towers and plant chimneys. There are many applications of automatic or RTs, such as a stakeout of points, deformation monitoring, cadastral surveys, tunnelling, volume calculations and construction. Its function for automatic tracking survey is very useful especially in the field of dynamic surveying.