Modern Surveying Instruments

RCI4C001 SURVEYING

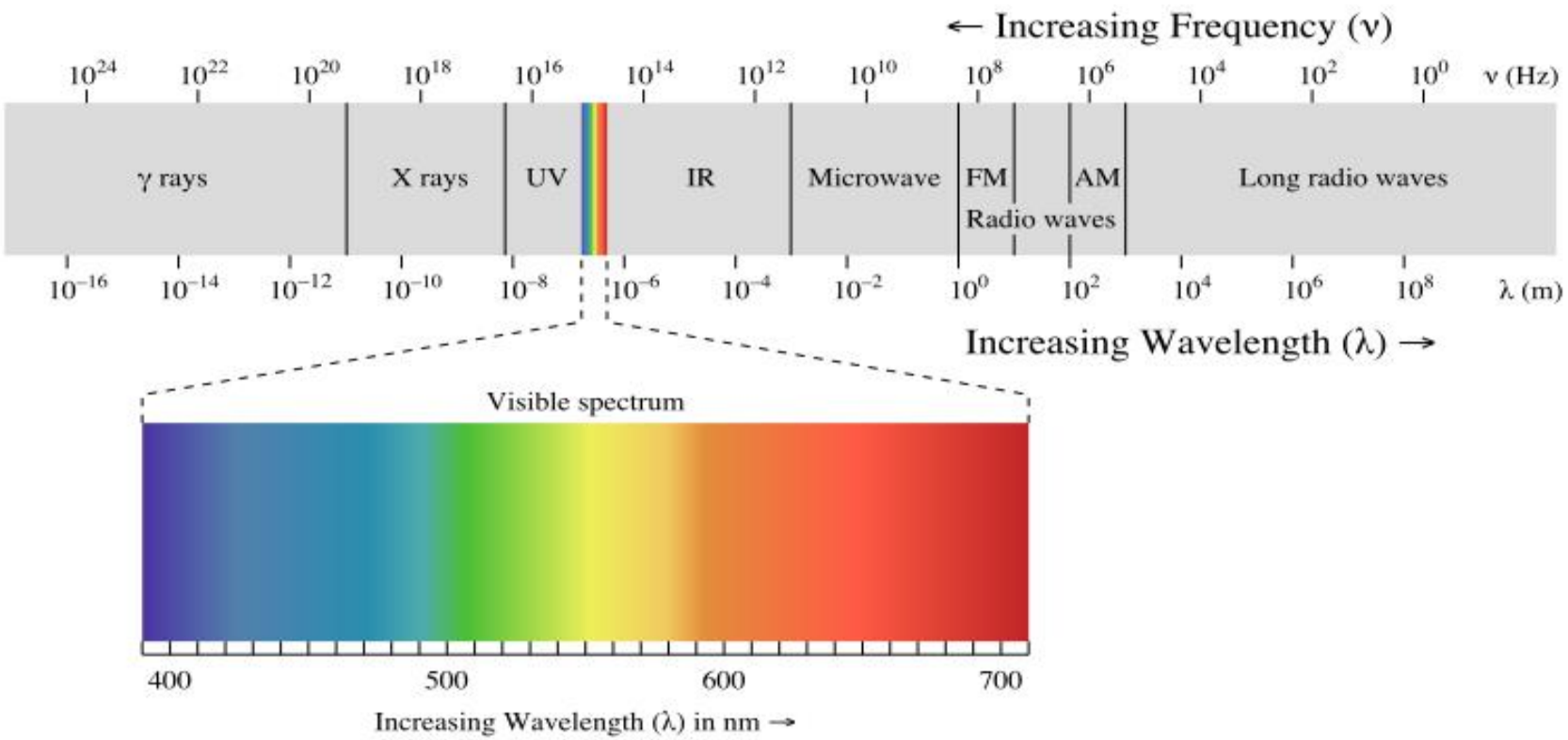
Module V

Modern Surveying Instruments – Electromagnetic Spectrum, Radar, Electronic Distance Measurement, EDM Equipment, Corrections to measurement, Digital Theodolite, Total Stations, Introduction to Remote Sensing and GIS

Mr. Saujanya Kumar Sahu
Assistant Professor
Department of Civil Engineering
Government College of Engineering, Kalahandi
Email : **saujanyaks@gmail.com**

ELECTROMAGNETIC SPECTRUM

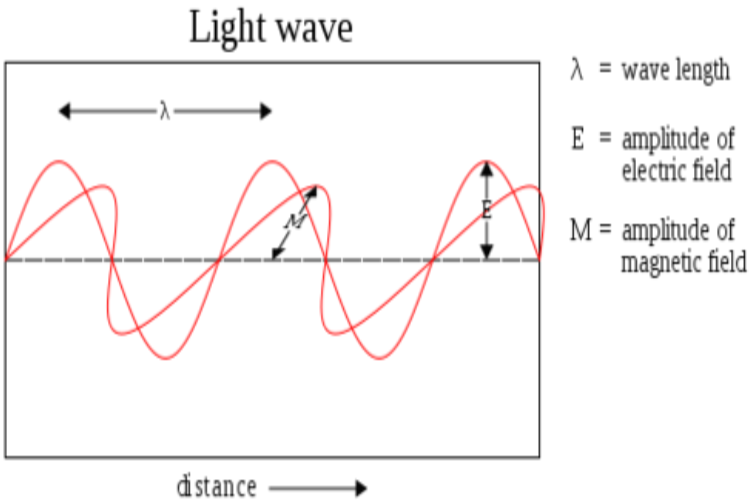
The EM spectrum is the ENTIRE range of EM waves in order of increasing frequency and decreasing wavelength.



ELECTROMAGNETIC SPECTRUM

Electromagnetic radiation is one of the many ways that energy travels through space.

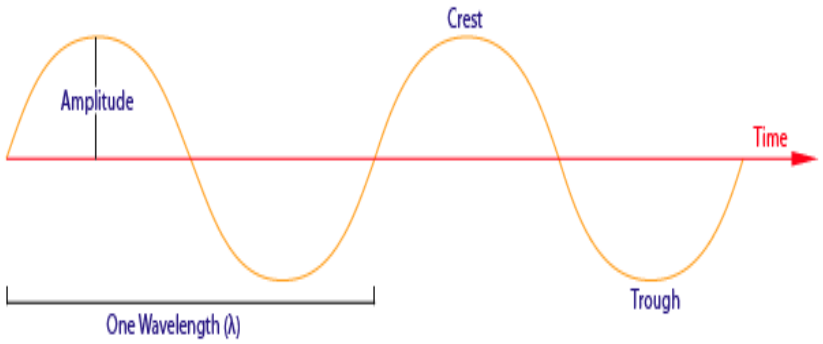
Electromagnetic waves consist of 2 waves oscillating perpendicular to one another. One of the waves is an oscillating magnetic field; the other is an oscillating electric field.



Basic properties of waves

A wave has a *trough* (lowest point) and a *crest* (highest point). The vertical distance between the tip of a crest and the wave's central axis is known as its ***amplitude***. This is the property associated with the brightness, or intensity, of the wave.

The horizontal distance between two consecutive troughs or crests is known as the ***wavelength*** of the wave



ELECTROMAGNETIC SPECTRUM

Wave's *frequency* refers to the number of full wavelengths that pass by a given point in space every second; the SI unit for frequency is Hertz (Hz)

Wavelength and frequency are inversely proportional: that is, the shorter the wavelength, the higher the frequency, and vice versa. This relationship is given by the following equation:

$$c = \lambda\nu$$

Their product is the constant c, the speed of light, which is equal to 3.00×10^8 m/s
This relationship reflects an important fact: all electromagnetic radiation, regardless of wavelength or frequency, travels at the speed of light.

A **wave's period** is the length of time it takes for one wavelength to pass by a given point in space. Mathematically, the period (T) is simply the reciprocal of the wave's frequency (f)

$$T = \frac{1}{f}$$

ELECTROMAGNETIC SPECTRUM

Planck found that the electromagnetic radiation emitted by blackbodies could not be explained by classical physics, which postulated that matter could absorb or emit any quantity of electromagnetic radiation.
Planck observed that matter actually absorbed or emitted energy only in whole-number multiples of the value $h\nu$, where h is Planck's constant $=6.626\times10^{-34}$ J/s and ν, is the frequency of the light absorbed or emitted

When an atom or molecule loses energy, it emits a photon that carries an energy exactly equal to the loss in energy of the atom or molecule. This change in energy is directly proportional to the frequency of photon emitted or absorbed. This relationship is given by **Planck's famous equation** $E = h\nu$

ELECTROMAGNETIC SPECTRUM

Different Types Of Electromagnetic Waves

Type	Wavelength range	Frequency range (Hz)	Production	Detection
Radio wave	> 0.1 m	3×10^3 to 3×10^8	Rapid acceleration and deceleration of electrons in aerials.	Receiver's aerials
Microwave	0.1 m to 1 mm	3×10^8 to 3×10^{11}	Klystron valve or magnetron valve.	Point contact diodes
Infrared wave	1 mm to 700 nm	3×10^{11} to 4×10^{14}	Vibration of atoms and molecules.	Thermopile, Bolomet infrared photographi film
Light	700 nm to 400 nm	4×10^{14} to 8×10^{14}	Electrons in atoms emit light when they move from one energy level to a lower energy level.	The eye, photocells, photographic film
Ultraviolet rays	400 nm to 1 nm	8×10^{14} to 8×10^{16}	Inner shell electrons in atoms moving from one energy level to a lower level.	Photocells, photographic film
X-rays	1 nm to 10^{-3} nm	1×10^{16} to 3×10^{21}	X-ray tubes or inner shell electrons.	Photographic film Geiger tubes
γ-rays	$< 10^{-3}$ nm	5×10^{18} to 5×10^{22}	Radioactive decay of the nucleus.	Photographic film, ionisation chamber

ELECTROMAGNETIC SPECTRUM

EM waves Characterisitcs:

•The higher the frequency, the more energy the wave has.

•Do not require media in which to travel or move.

•considered to be transverse waves because they are made of vibrating electric and magnetic fields at right angles to each other, and to the direction the waves are traveling.

• Inverse relationship between wave size and frequency: as wavelengths get smaller, frequencies get higher.

RADAR

Radar is a contraction of the words **Radio Detection And Ranging.**

Radar is an electromagnetic system for the detection and location of objects. It operates by transmitting a particular type of waveform, a pulse-modulated sine wave for example, and detects the nature of the echo signal.

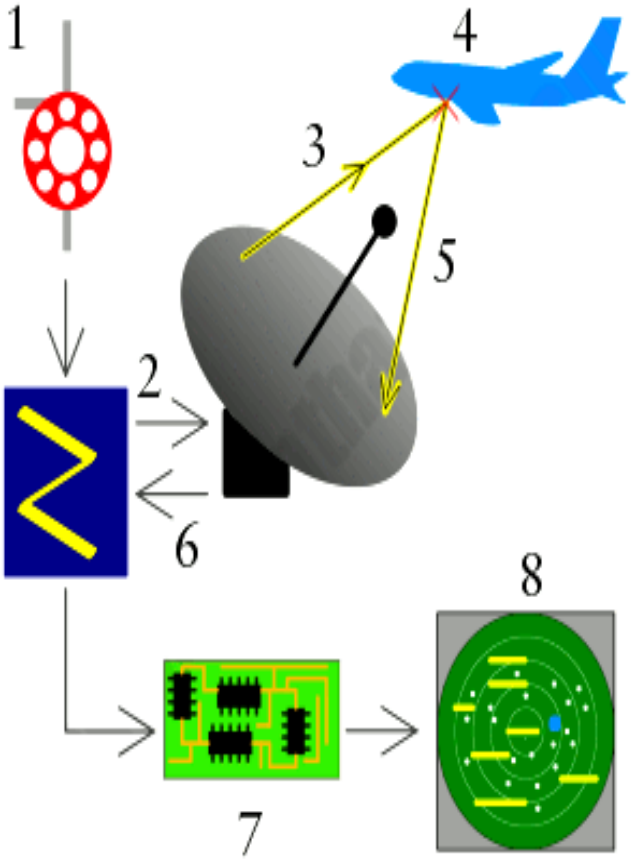
Radar can see through conditions such as darkness, haze, fog, rain, and snow which is not possible for human vision. In addition, radar has the advantage that it can measure the distance or range to the object.

.

RADAR

How does radar work?

1. Magnetron generates high-frequency radio waves.
2. Duplexer switches magnetron through to antenna.
3. Antenna acts as transmitter, sending narrow beam of radio waves through the air.
4. Radio waves hit enemy airplane and reflect back.
5. Antenna picks up reflected waves during a break between transmissions. Note that the same antenna acts as both transmitter and receiver, alternately sending out radio waves and receiving them.
6. Duplexer switches antenna through to receiver unit.
7. Computer in receiver unit processes reflected waves and draws them on a TV screen.
8. Enemy plane shows up on TV radar display with any other nearby targets



RADAR

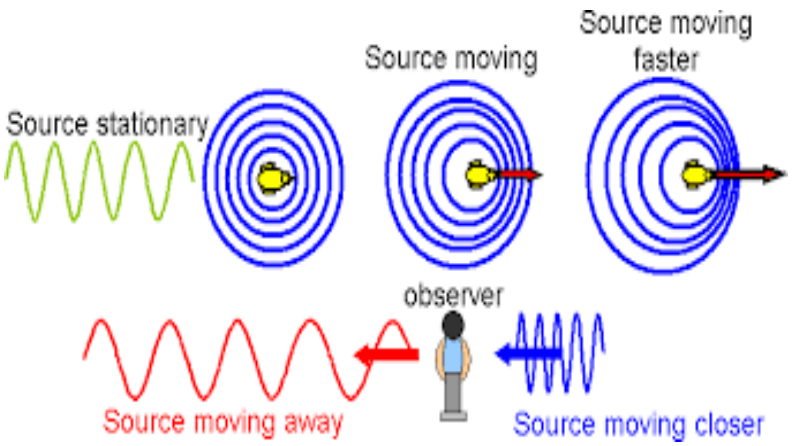
Doppler Effect in Radar Systems.

If the target is not stationary, then there will be a change in the frequency of the signal that is transmitted from the Radar and that is received by the Radar. This effect is known as the **Doppler effect.*(frequency shift)***

According to the Doppler effect, two possible cases –

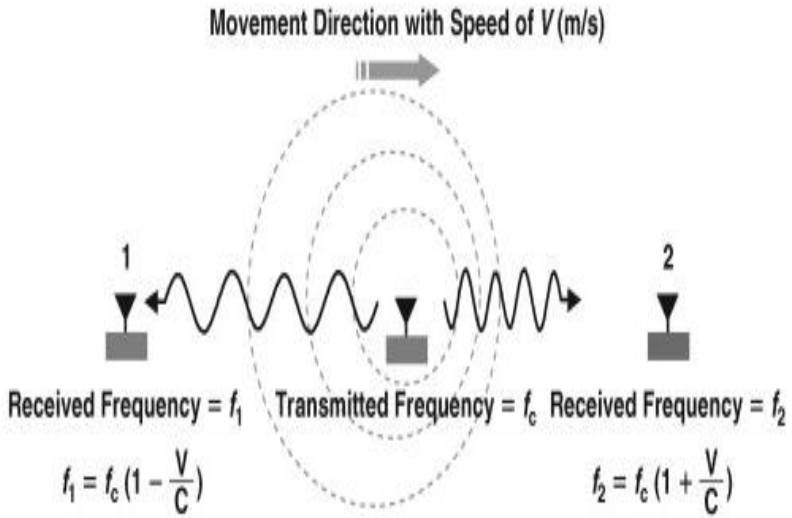
The **frequency** of the received signal will **increase,** when the target moves towards direction of Radar.

The **frequency** of the received signal will **decrease,** when the target moves away from the Radar.



Use of principle:

A stationary transmitter shoots waves at a moving object. The waves hit the object and bounce back. The transmitter (now a receiver) detects the frequency of the returned waves. Based on the amount of the Doppler shift, the speed of the object can be determined.



RADAR

- An elementary form of radar consists of a transmitting antenna emitting electromagnetic radiation generated by an oscillator of some sort, a receiving antenna, and a signal receiver.
- A portion of the transmitted signal is intercepted by a reflecting object (target) and is reradiated in all directions.
- The receiving antenna collects the returned signal and delivers it to a receiver, where it is processed to detect presence of target and to extract its location and relative velocity.
- The distance to the target is determined by measuring the time taken for the Radar signal to travel to the target and back.
- The direction, or angular position, of the target is determined from the direction of arrival of the reflected wave front.
- The usual method of measuring the direction of arrival is with narrow antenna beams.
- If relative motion exists between target and radar, the shift in the carrier frequency of the reflected wave (Doppler Effect) is a measure of the target's relative (radial) velocity and may be used to distinguish moving targets from stationary objects.
- In radars which continuously track the movement of a target, a continuous indication of the rate of change of target position is also available

RADAR

It was first developed as a detection device to warn the approach of hostile aircraft and for directing antiaircraft weapons. A well designed modern radar can extract more information from the target signal than merely range.

Measurement of Range:

The most common radar waveform is a train of narrow, rectangular-shape pulses modulating a sine wave carrier.

The distance, or range, to the target is determined by measuring the time TR taken by the pulse to travel to the target and return.

Since electromagnetic energy propagates at the speed of light c (3 x 108 m/s) the range R is given by : R= cTR /2 The factor 2 appears in the denominator because of the two-way propagation of radar.

With the range R in kilometers or nautical miles, and TR in microseconds, the above relation becomes: **R(km) = 0.15 X TR (μS)**

RADAR

Maximum unambiguous range:

Once the transmitter pulse is emitted by the radar, sufficient time must elapse to allow any echo signals to return and be detected before the next pulse is transmitted.

Therefore, the rate at which the pulses may be transmitted is determined by the longest range at which targets are expected. If the pulse repetition frequency is too high, echo signals from some targets might arrive after the transmission of the next pulse, and ambiguities in measuring range might result

The range beyond which targets appear as second-time-around echoes (or the farthest target range that can be detected by a Radar without ambiguity) is called the maximum unambiguous range and is given by: **R unambig. = C/2fp**

Where fp = pulse repetition frequency, in Hz. (PRF)

RADAR

Simple form of Radar Equation:

If the power of the radar transmitter is denoted by Pt and if an isotropic antenna is used (one which radiates uniformly in all directions) the **power density** (watts per unit area) at a distance R from the radar is equal to the transmitter power divided by **the surface area 4πR2of an imaginary sphe**re of radius R with radar at its centre.

The **gain G** of an antenna is a measure of the increased power radiated in the direction of the target as compared with the power that would have been radiated from an isotropic antenna. It may be defined as the *ratio of the maximum radiation intensity from the given antenna to the radiation intensity from a lossless, isotropic antenna with the same power input.*

The radar cross section σ has units of area. It is a characteristic of the particular target and is a measure of its size as seen by the radar. The radar antenna captures a portion of the echo power. If the effective area of the receiving antenna is denoted as Ae , then the power Pr .received by the radar is given by $P_r = (P_t . G/4\pi R^2).(\sigma/4\pi R^2). A_e$

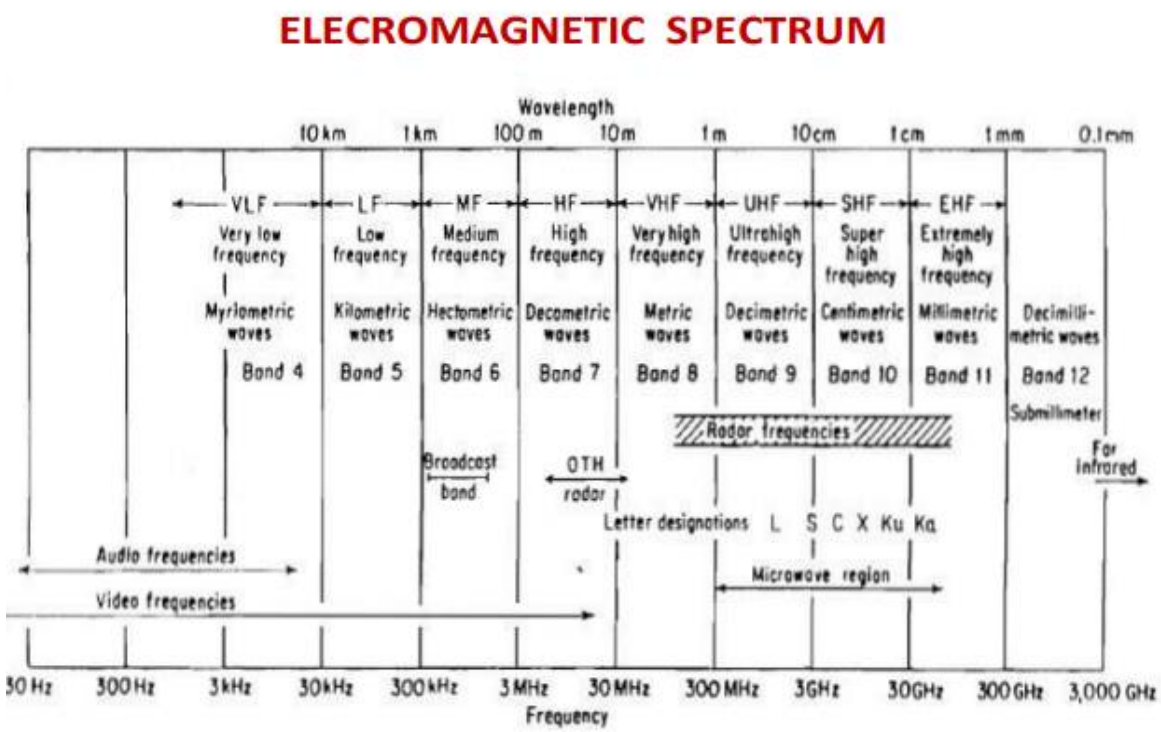
RADAR

The **maximum radar range Rmax** is the distance beyond which the target cannot be detected. It occurs when the received echo signal power Pr just equals the **minimum detectable signal Smin.**

$$R_{max} = [(P_t . G . A_e . \sigma) / (4\pi)^2 . S_{min}]^{1/4}$$

The important antenna parameters are the transmitting gain and the receiving effective area

Radar frequencies:
Conventional radars are operated at frequencies extending from about 220 MHz to 35 GHz, a spread of more than seven octaves. These are not necessarily the limits, since radars can be, and have been, operated at frequencies outside either end of this range.
The place of radar frequencies in the electromagnetic spectrum is shown in the figure



RADAR

Letter code designation of Radar frequencies:
Early in the development of radar, a letter code such as S, X, L, etc., was employed to designate Radar frequency bands.

Although it's original purpose was to guard military secrecy, the designations were maintained, probably out of habit as well as the need for some convenient short nomenclature.

This usage has continued and is now an accepted practice of radar engineers. The table below lists the radar-frequency letter-band nomenclature adopted by the **IEEE**

: Standard radar-frequency letter-band nomenclature

Band designation	Nominal frequency range	Specific radiolocation (radar) bands based on ITU assignments for region 2
HF	3–30 MHz	
VHF	30–300 MHz	138–144 MHz 216–225
UHF	300–1000 MHz	420–450 MHz 890–942
L	1000–2000 MHz	1215–1400 MHz
S	2000–4000 MHz	2300–2500 MHz 2700–3700
C	4000–8000 MHz	5250–5925 MHz
X	8000–12,000 MHz	8500–10,680 MHz
K_u	12.0–18 GHz	13.4–14.0 GHz 15.7–17.7
K	18–27 GHz	24.05–24.25 GHz
K_a	27–40 GHz	33.4–36.0 GHz
mm	40–300 GHz	

RADAR

Applications of Radar:

1. Military Use: Initial and important user of Radar

(i)Early warning of intruding enemy aircraft & missiles (ii)Tracking hostile targets and providing location information to Air Defense systems consisting of Tracking Radars controlling guns and missiles. (iii)Battle field surveillance (iv)Information Friend or Foe IFF (v)Navigation of ships, aircraft, helicopter etc.

2. Civilian Use:

(i)Air Traffic Control (ATC) All airports are equipped with ATC Radars, for safe landing and take-off and guiding of aircraft in bad weather and poor visibility conditions. (ii)Aircraft Navigation (a) All aircrafts fitted with weather avoidance radars. These Radars give warning information to pilot about storms, snow precipitation etc. lying ahead of aircraft's path. (b) Radar is used as an altimeter to indicate the height of the aircraft or helicopter.

3. Maritime ship's safety and Navigation: (i)Radar used to avoid collision of ships during poor visibility conditions (storms, cyclones etc.) (ii)Guide ships into seaports safely.

4. Meteorological Radar: Used for weather warnings and forecasting.

Electronic Distance Measuring Instruments (EDMIs)

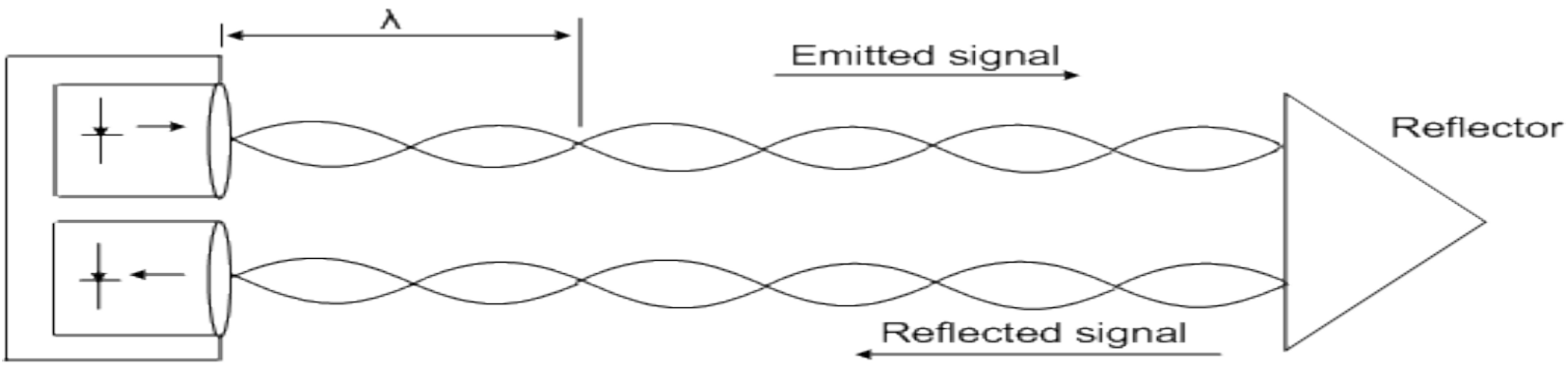
Introduction

EDMIs were first introduced in 1950's by Geodimeter Inc. Early instruments were large, heavy, complicated and expensive. Improvements in electronics have given lighter, simpler, and less expensive instruments. EDMIs can be manufactured for use with theodolites (both digital and optical) or as an independent unit. These can be mounted on standard units or theodolites or can also be tribrach mounted.

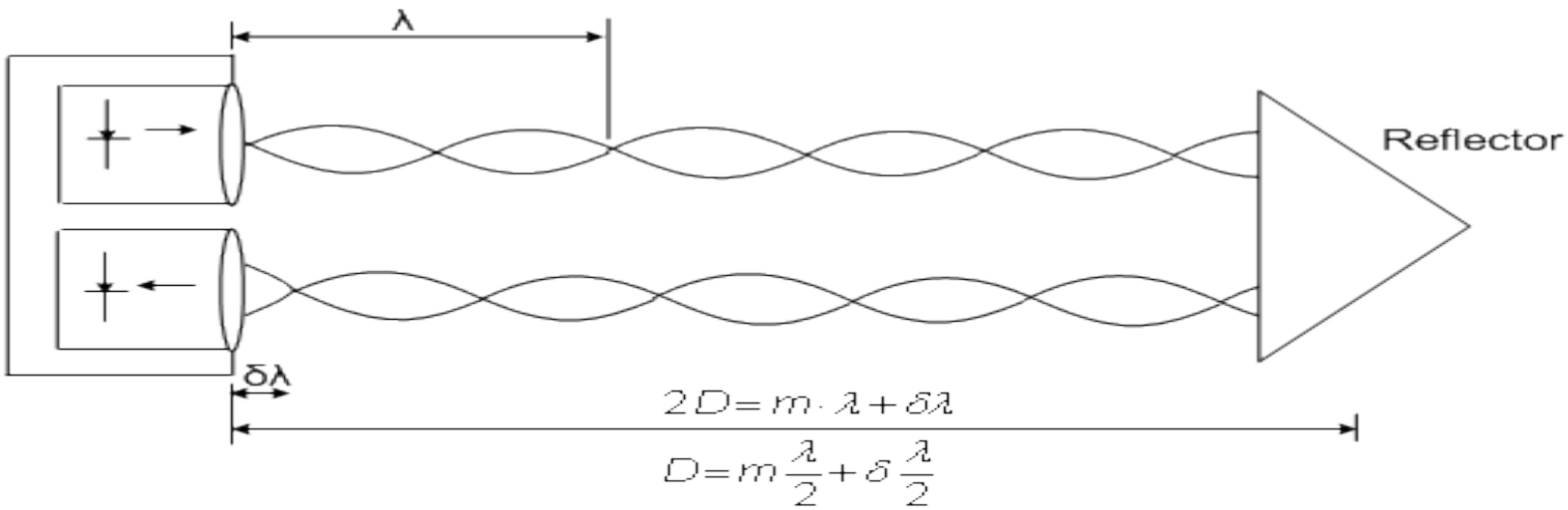
The electronic methods depend on the value of velocity of Electromagnetic radiation (EMR), which itself is dependent upon measurement of distance and time. Hence, there is no inherent improvement in absolute accuracy by these methods.

The advantage is mainly functional - precise linear measurement can now be used for longer base lines, field operations can be simplified and trilateration can replace or augment triangulation.

Electronic Distance Measuring Instruments (EDMIs)



(a) Signal in phase



(b) Signal out of phase

Electronic Distance Measurement

Principle of EDMI

The general principle involves sending a modulated Electro-magnetic (EM) beam from one transmitter at the master station to a reflector at the remote station and receiving it back at the master station.

The instrument measures slope distance between transmitter and receiver by modulating the continuous carrier wave at different frequencies, and then measuring the phase difference at the master station between the outgoing and the incoming signals.

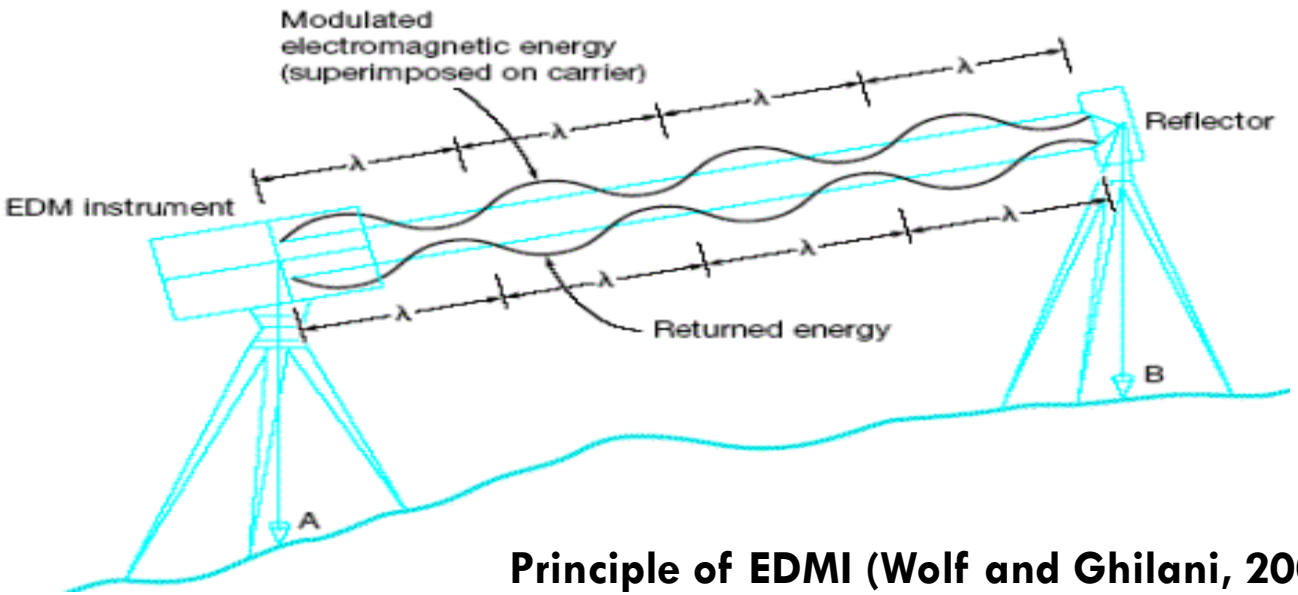
This establishes the following relationship for a double distance (2D):

$$2D = m\lambda + \frac{\phi}{2\pi}\lambda + k$$

Where *m* is unknown integer number of complete wavelengths contained within double distance, Φ; is the measured phase difference and λ is modulation wavelength, and *k* is constant. Multiple modulation frequencies are used to evaluate *m* , the ambiguity .

.

Electronic Distance Measurement



Principle of EDMI (Wolf and Ghilani, 2002)

Various EDMIs in use are based on two methods:

1. using timed pulse techniques such as those used in variety of radar instruments.
2. using measurements of a phase difference which may be equated to one part of a cycle expressed in units of time or length.

Pulse methods have advantages over the phase difference methods but their weight and power requirement is such that they cannot be classed lightweight portable instruments

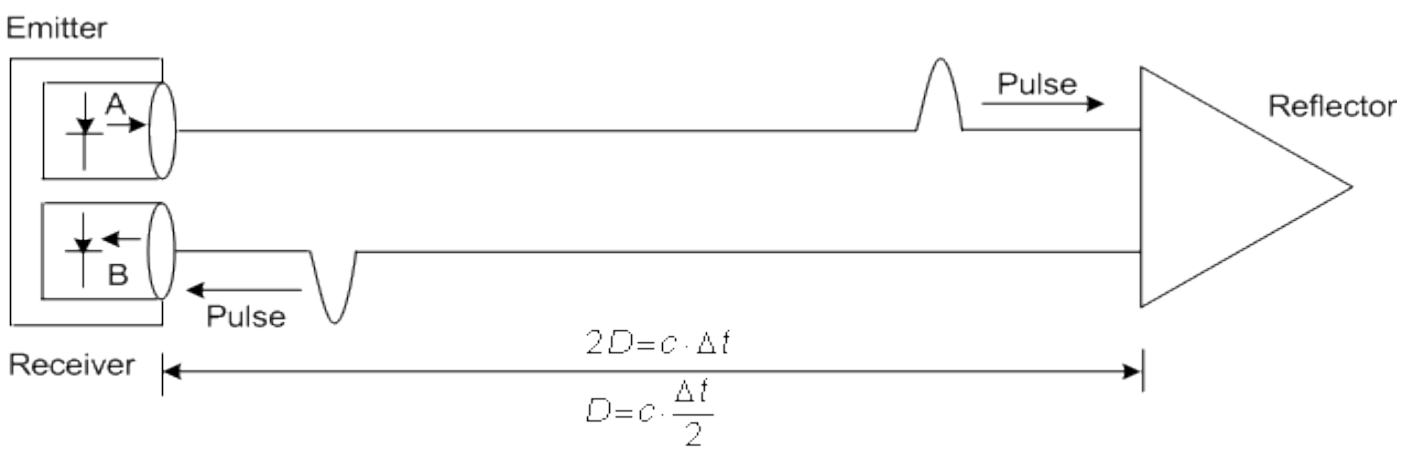
Electronic Distance Measurement

i) Pulse techniques

All such measurements incorporate a very precise measurement of time usually expressed in units of nanoseconds (1×10^{-9} s), which a EM wave takes to travel from one station to another.

In this method, a short, intensive pulse radiation is transmitted to a reflector target, which is immediately transmitted back to the receiver.

As shown in Figure, the distance (D) is computed as the velocity of light (V) multiplied by half the time ($\Delta t/2$) the pulse took to travel back to the receiver ($D = V \times \Delta t/2$).



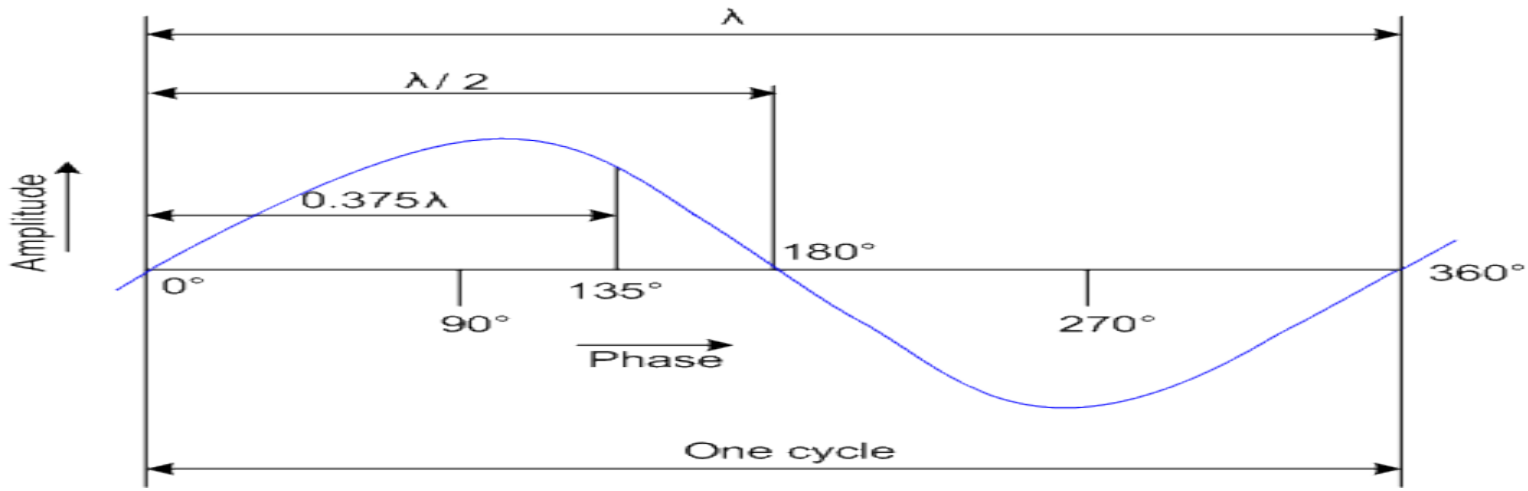
Principle of EDMI based on pulse measurement (Schoffield, 2002)

Electronic Distance Measurement

(ii) Phase difference techniques

The relationship between wavelength and associated phase difference shows that for a given complete cycle of EM wave, the phase difference can be expressed both in terms of angular (degrees) and linear (fraction of wavelengths) units.

In phase difference method used by majority of EDMI, the instrument measures the amount δλ by which the reflected signal is out of phase with the emitted signal



Relationship between Wavelength and phase difference (Wolf and Ghilani, 2002)

EDM EQUIPMENT

Classification of EDMI

EDMI can be classified on the basis of three parameters (Schoffield, 2001; Kavanagh, 2003)

:(i) wavelength used

(ii) working range

(iii) achievable accuracy

(i) Classification on the basis of wavelength

Present generation EDMIs use the following types of wavelengths (Schoffield, 2001):

(a) infrared

(b) laser

(c) microwaves

The first two types of systems are also known as electro-optical whereas the third category is also called the electronic system.

EDM EQUIPMENT

Electro-optical Systems

Infrared: Systems employing these frequencies allow use of optical corner reflectors (special type of reflectors to return the signal, explained later) but need optically clear path between two stations. These systems use transmitter at one end of line and a reflecting prism or target at the other end.

Laser: These systems also use transmitter at one end of line and may or may not use a reflecting prism or target at the other end. However, the reflectorless laser instruments are used for short distances (100 m to 350 m). These use light reflected off the feature to be measured (say a wall).

Electronic System

Microwave

These systems have receiver/transmitter at both ends of measured line. Microwave instruments are often used for hydrographic surveys normally up to 100 km.

These can be used in adverse weather conditions (such as fog and rain) unlike infrared and laser systems. However, uncertainties caused by varying humidity over measurement length may result in lower accuracy and prevent a more reliable estimate of probable accuracy.

EDM EQUIPMENT

(ii) Classification on the basis of range

EDMIs are also available as:

- long range radio wave equipment for ranges up to 100 km
- medium range microwave equipment with frequency modulation for ranges up to 25 km
- short range electro-optical equipment using amplitude modulated infra-red or visible light for ranges up to 5 km

iii) Classification on the basis of accuracy

Accuracy of EDMI is generally stated in terms of constant instruments error and measuring error proportional to the distance being measured: $\pm$ (a mm + b ppm).

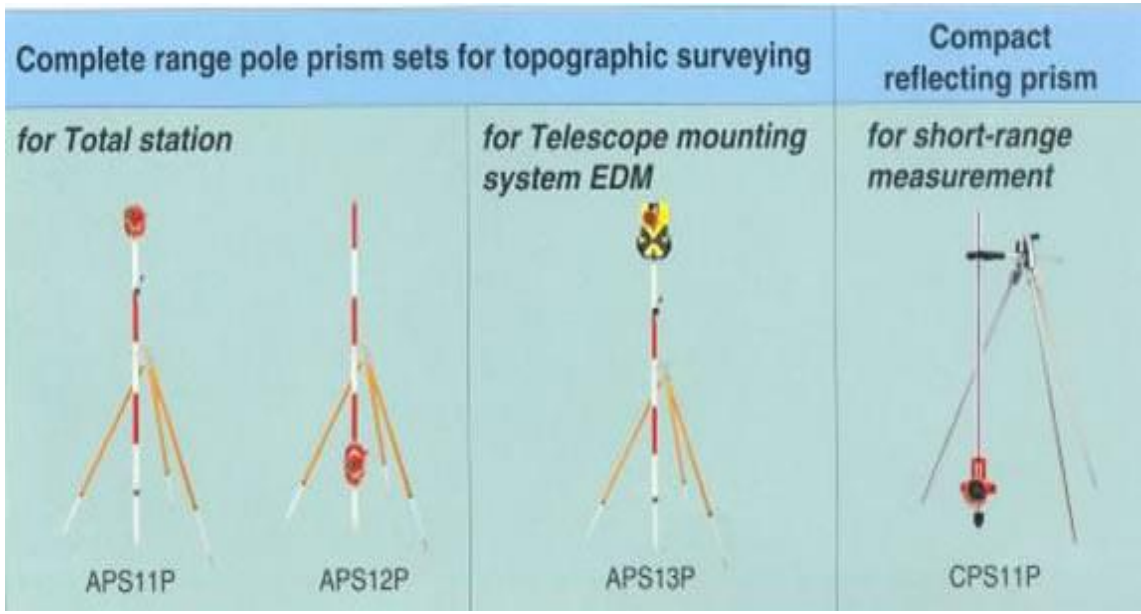
The first part in this expression indicates a constant instrument error that is independent of the length of the line measured.

The second component is the distance related error.

Here, a is a result of errors in phase measurements (θ) and zero error (z), whereas b results from error in modulation frequency (f) and the group refractive index (n_g). σ indicates the standard error.

Most EDMI have accuracy levels from $\pm$ (3 mm + 1 ppm) to $\pm$ (10 mm + 10 ppm). For short distances, part a is more significant; for long distances b will have large contribution.

EDM EQUIPMENT



EDM EQUIPMENT

Components of EDMI

major components constitututing a typical EDMI (Wolf and Ghilani, 2001):

- carrier signal
- modulation signals and modulator
- signal transmitter and signal receiver
- beam splitter
- reflector
- filter
- amplifier
- phase discriminator
- display unit

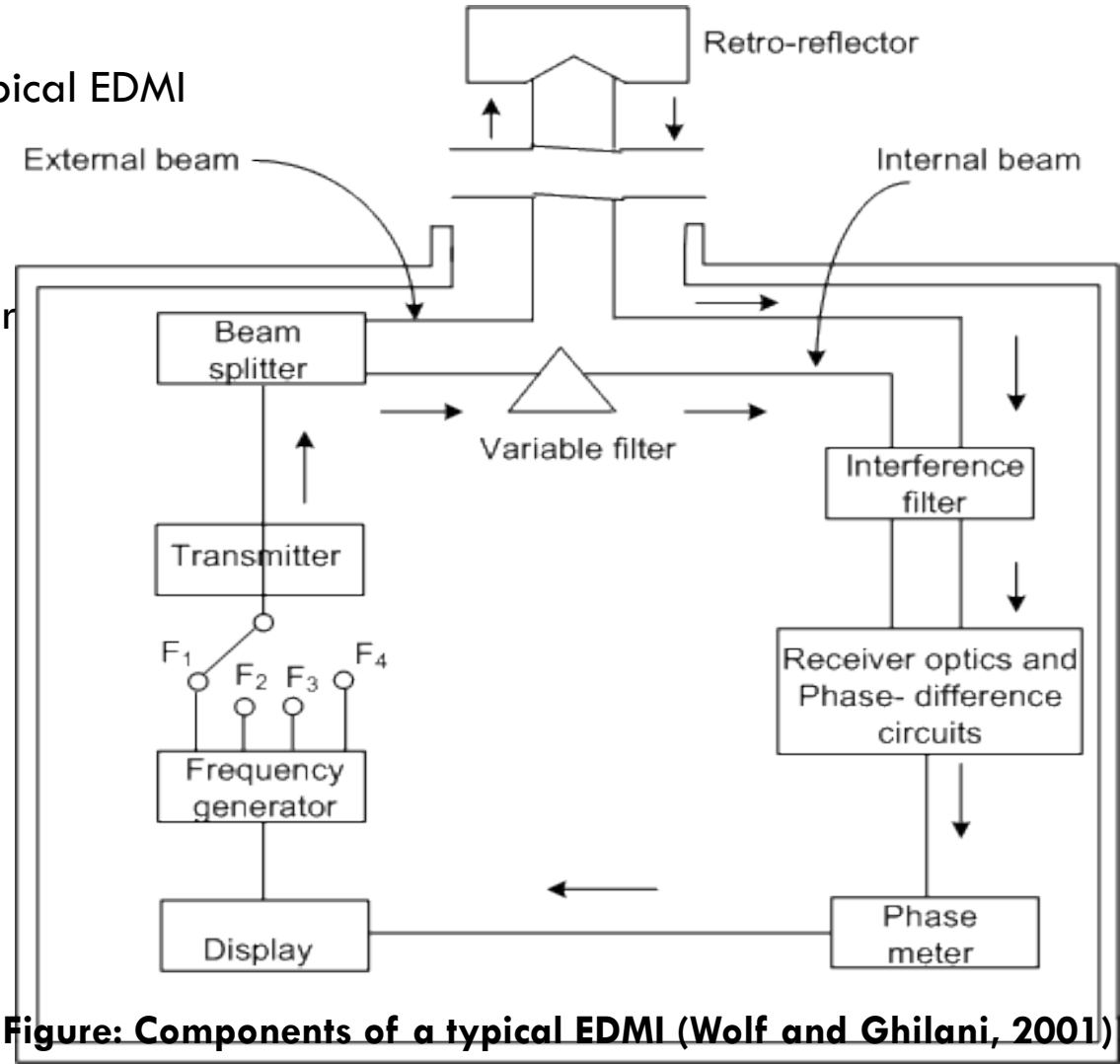


Figure: Components of a typical EDMI (Wolf and Ghilani, 2001)

EDM EQUIPMENT

(i) Carrier Signal

Three very distinct types of frequencies are used giving rise to three groups of instruments.

(a) Long wavelength instruments

These work over longest ranges and are used mainly for navigational purposes for ships and aircrafts, oceanographic and hydrographic surveys - employing ground wave mode of propagation. These instruments have lower accuracy compared to other methods mainly due to uncertainties in the value of the phase lag at the earth's surface.The unique characteristic of this category of instruments is that an unmodulated signal is used.

(b) Microwave instruments

These use the direct path and unless airborne are limited to intervisible rays on the ground. Lines up to 100 km have been measured successfully with these instruments.

(c) Instruments using visible or infrared radiation

These have a very short range of 1 to 2 km under favourable atmospheric conditions.. These instruments use a system of mirrors and lenses to produce narrow collimated beam usually with divergence of about 1/4o. Because the light path through the instrument and reflector (usually prism type) is well defined the results are very accurate

EDM EQUIPMENT

(ii) Modulator and modulation signals ✓ ***(IMPORTANT)***

Modulation is defined as the process of varying the amplitude (amplitude modulation), frequency (frequency modulation), phase (phase modulation) or the polarization (polarization modulation) of a carrier wave in accordance with other signals.

The long wave instruments are unmodulated and the carrier signal itself is the measurement signal.

For microwave instruments, the carrier signal is generated by a reflex Klystron which is more suitable for frequency modulation.

Two main reasons for modulation with microwave instruments are:

- since these use short wavelength (10 or 3 cm), there would be some ambiguities in resolving the integer *m* at long working ranges.
- at long distances it is doubtful whether the phase of the signal would be stable at the end of long path through the atmosphere. The modulation signal is, therefore, of much longer wavelength than the carrier.

EDM EQUIPMENT

✓ *(IMPORTANT)*

Amplitude modulation (AM): The amplitude of carrier wave is varied in direct proportion to the amplitude of the modulating (measuring) wave, the frequency remaining constant.

Frequency modulation (FM): The frequency of carrier wave is varied in direct proportion to the frequency of the modulating wave, the amplitude remaining constant.

Pulse modulation: This modulation is used in RADAR. In this a high frequency pulses of a few microseconds duration are imposed on a higher-frequency carrier wave at sufficiently large time intervals. of the order of a milliseconds, to allow the pulses to reach the distant object and be received back.

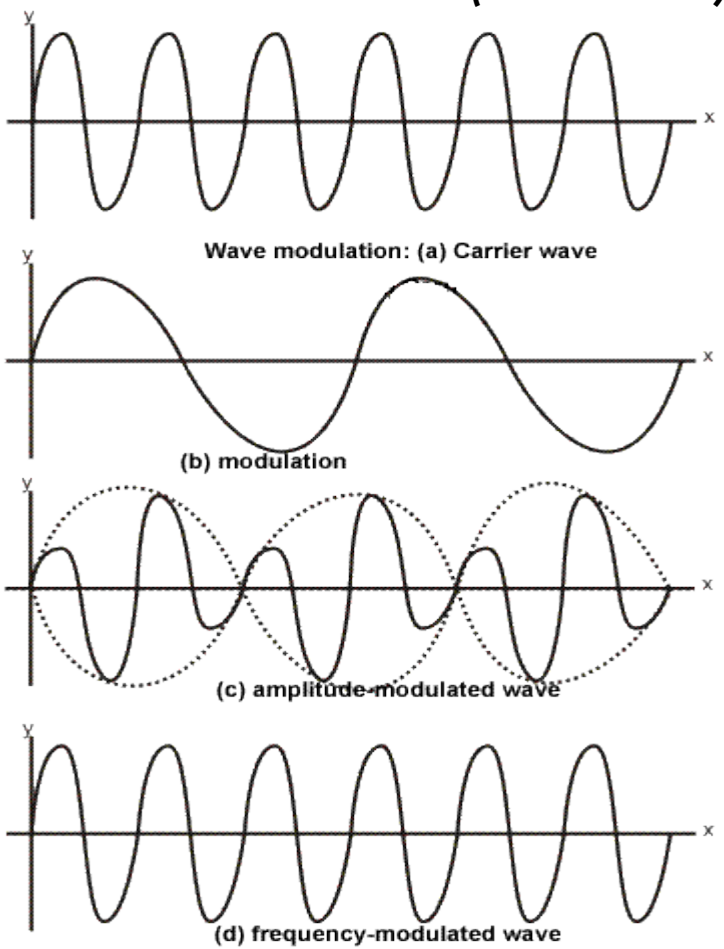


Figure : Carrier and modulation signal (Clendinning and Olliver, 1969)

EDM EQUIPMENT

iii) Signal transmitter and receiver

For long waves the most efficient radiator is a straight vertical wire of effective length $\lambda/4$ operating as one half of a dipole. In case of microwave, the signals can be radiated by dipoles of the appropriate dimensions. For visible spectrum wavelength, high degree of collimation is achieved making use of optical lens system.

(iv) Beam splitter

It divides the light emitted from the diode into two signals: an external measurement beam and an internal reference beam. By means of telescope mounted on EDMI, the external beam is targeted to a retro-reflector

(v) Reflector

Reflectors are required to return the signal to the point of comparison (at the master station) and have different requirements

EDM EQUIPMENT

vi) Filter

The internal beam passes through a variable-density filter and is reduced in intensity to a level equal to that of the returned external signal which enables a more accurate measurement. Both internal and external signals pass through an interference filter, which eliminates undesirable energy.

(vii) Amplifier

These filtered signals are converted to electrical energy while maintaining the phase-difference. These signal are weak and are amplified by an amplifier.

(viii) Phase discriminator

Phase discrimination is carried out by this component. A phase meter converts the phase difference into direct current with magnitude proportional to the differential phase which is subsequently displayed as the distance measured.

(ix) Display unit

The display unit provides results of range measurement on LCD panel.

EDM EQUIPMENT

Operations with EDMI

Measurement with EDMI involves four basic steps:

Setting up:

The instrument is centered over a station by means of tribrach or by mounting over a compatible theodolite. Reflector prisms are set over the remote station either on tribrach or on a prism pole. Observations related to height or instrument and prism are recorded. These are usually kept the same to avoid any additional corrections.

Aiming:

The instrument is aimed at prisms by using sighting devices or theodolite telescope. Slow motion screws are used to intersect the prism centre. Some kind of electronic sound or beeping signal helps the user to indicate the status of centering.

Measurement:

The operator presses the measure button to record the slope distance which is displayed on LCD panel.

Recording:

The information on LCD panel can be recored manually or automatically. All meteorological parameters are also recorded.

ERRORS & CORRECTIONS IN EDM

Error sources in EDMI
(Kennie and Petrie, 1990):

(i) Instrument operation errors
One has to be careful for precise centering at the master and slave station pointing/sighting of reflector entry of correct values of prevailing atmospheric conditions

(ii) Atmospheric errors
Meteorological conditions (temperature, pressure, humidity, etc.) have to be taken into account. These errors can be removed by applying an appropriate atmospheric correction model that takes care of different meteorological parameters from the standard (nominal) one.

(iii) Instrument error:
Consists of three components - scale error, zero error and cyclic error. These are systematic in nature.

ERRORS & CORRECTIONS IN EDM

The fundamental distance measured by EDMI can be put into the following generalized form:

$$D = m\left(\frac{\lambda}{2}\right) + \frac{\phi}{2\pi}\left(\frac{\lambda}{2}\right) + (K_1 + K_2 + K_3)$$

$$D = m\left(\frac{V_o}{2n_g f}\right) + \frac{\phi}{2\pi}\left(\frac{V_o}{2n_g f}\right) + (K_1 + K_2 + K_3)$$

m integer ambiguity
λ wavelength of modulation wave
Φ measured phase difference
n_g group refractive index
V_0 velocity of EMR in vacuum
K_1 scale error
K_2 zero error
K_3cyclic error

ERRORS & CORRECTIONS IN EDM

Measured distance *D* is given as $D = V \times t$, where *V* is the velocity along travel path and *t* is time taken to travel this distance. Three types of corrections are required to reduce this distance to correct one

1. **Calibration or standardization**

   Three types of errors (systematic in nature) are removed as a part of calibration process which should be carried out regularly to account for aging and wear and tear of equipment :

Scale error (K_1): It accounts for difference in the modulation frequency and the nominal or design frequency and is proportional to distance being measured.

Zero error (K_2): Also termed the additive constant error, index error, or reflector/prism offset. It is independent of distance measured. It occurs due the fact that the internal measurement centers of the instrument/reflector do not coincide with the physical centers of the instrument/reflector.

ERRORS & CORRECTIONS IN EDM

It consists of two components. The first component arises from the fact that the physical center of the instrument which is plumbed over the survey station does not coincide with the position within the instrument to which measurements are made.

The second component has similar interpretation for reflector which absorbs changes in velocity of light while moving from air to reflector glass prism and light path itself through the reflector.

Cyclic error (K_3): Also termed period errors, resolver errors or non-linearity errors and varies with distance. These errors are caused by internal electronic contamination between transmitter and receiver circuitry. Their effect is minimized by the manufacturer by electrical isolation and shielding of instrument components.

2. Velocity correction

It is applied to account for atmospheric effects since:

1. signal is not traveling in vacuum but some medium which reduces the speed of EMR.
2. waves follow a curved rather than a straight line path between the transmitter and receiver.

ERRORS & CORRECTIONS IN EDM

Propagating EM waves (at low or high frequencies) other than direct wave are results of reflection, refraction, or diffraction of the wave caused by variations in the refractive index (RI) of the atmosphere (*n*).

The RI is given as:

$$n = \frac{\text{Velocity in vacuum}}{\text{Velocity in medium}} = \frac{V_o}{V}$$

V is less than V_0 depending u = 299792458 ± 1.2 m/s as accepted at XVIth General Assembly of the International Union of Geodesy and Geophysics in 1975).

Two types of velocity corrections known as the first and second velocity corrections

(i) The first velocity correction:

Let the distance measured by EDMI be D after applying calibration often referred as the instrument distance. The corrected distance D_1 is given as $D_1 = D / n_g$ The first velocity correction is given as

$$\delta_1 = D_1 - D = \frac{D}{n_g} - D$$

$$= D\left(\frac{1}{n_g} - 1\right) = D\left(\frac{1 - n_g}{n_g}\right)$$

$$= D(1 - n_g) \because n_g \approx 1.0$$

ERRORS & CORRECTIONS IN EDM

(ii) The second velocity correction:

It compensates for the difference in radius of curvature of signal path and the spheroid (or atmospheric layer)

$$\delta_2 = -(K - K^2)\frac{D^3}{12R^2}$$

$$K = \frac{\text{Curvature of signal path}}{\text{Curvature of spheroid}} = \frac{1/r}{1/R} = \frac{R}{r}$$

K = coefficient of refraction (K = 0.125 and 0.25 for light and microwave respectively

R = mean radius of curvature of spheroid in the direction (a) of measured line

r = radius of curvature of signal path (r ≈ 8R for light waves and r ≈ 4R for microwaves)

3. iii)Geometric correction

It is applied to reduce the measured distance (corrected for refractive index) to the equivalent distance on the spheroidal surface.

ERRORS & CORRECTIONS IN EDM

It can be applied in following steps (Schoffield, 2001):

1.Reduction from D_1 to D_2 :

$$D_2 = D_1 + \delta_3$$

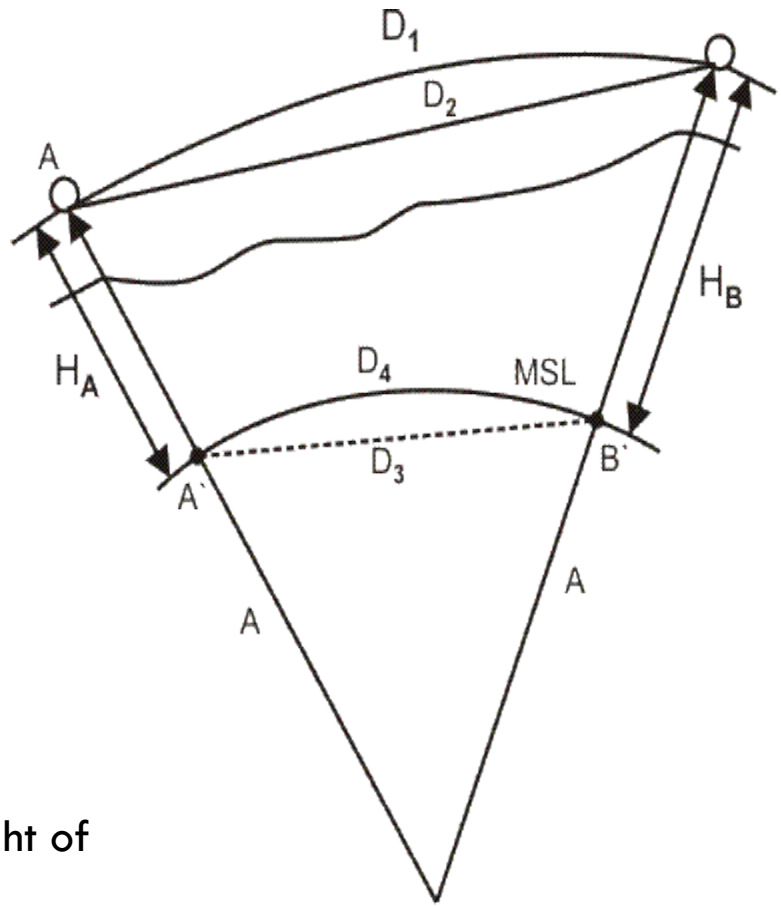
$$\delta_3 = -\frac{D_1^3 K^2}{24R^2}$$

2. Reduction from D_2 to D_3

$$D_3 = \left[\frac{D_2^3 - (H_B - H_A)^2}{\left(1+\frac{H_A}{R}\right)\left(1+\frac{H_B}{R}\right)}\right]^{1/2}$$

3. Reduction from D_3 to D_4

$$D_4 = D_3 + \frac{D_3^3}{24R^2}$$



H_A and H_B are height of instrument center and height of target center above ellipsoid (or MSL) respectively

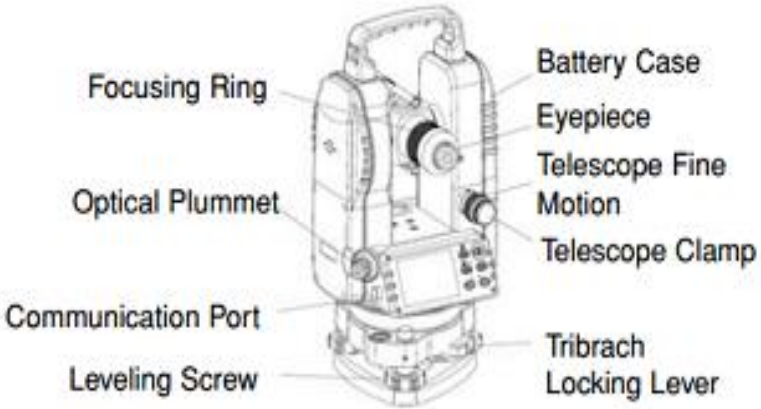
DIGITAL THEODOLITE

Electronic Theodolite

Theodolites or transits are used to measure horizontal angles. These have evolved as follows:

- Vernier theodolite (open face and Vernier equipped instruments)
- Optical theodolite (enclosed with optical readouts with direct digital readouts or micrometer equipped readouts)
- Electronic theodolites (enclosed with electronic readouts)

Electronic theodolites operate like any optical theodolite with one major difference that these instruments have only one motion (upper) and hence have only one horizontal clamp and slow motion screws.



DIGITAL THEODOLITE

Characteristics of electronic theodolites

✓Angle least count can be 1" with precision ranging from 0.5" to 20"

✓Digital readouts eliminate the personal error associated with reading and interpolation of scale and micrometer settings.

✓Display window/unit for horizontal and vertical angles available at either one or both ends.

✓Some digital theodolites have modular arrangement where they can be upgraded to be a total station or have an EDMI attached for distance measurements.

✓Vertical circles can be set to zero for horizon or zenith along with the status of battery shown in the display window.

Typical specifications for digital theodolites are generally given as follows:

- Magnification: 26X to 30X
- Field of view (FOV) 1.5^0.
- Shortest viewing distance 1.0 m
- Angle readouts, direct 5" to 20"
- Level sensitivity: plate level vial 40"/2 mm, circular level vial 10"/2 mm

)

DIGITAL THEODOLITE

An example :specifications for Nikon electronic theodolite (NE-202/203):

•Digital angle display is user-switchable from 5"/10" to 1"/5"

•Built-in vertical axis compensator automatically compensates for instrument inclination within ± 3' (NE-203)

•Accuracy is 5" in 5" display mode.

•Large, dot-matrix dual-line LCD screen displays both vertical and horizontal angles simultaneously.

•LCD screen and keyboard are placed on both sides of the alidade for easier operation

•Telescope magnification of 30X with a 45 mm objective aperture diameter.

•Employs a unique linear focusing mechanism to simplify focusing at both short and long distances. Minimum focusing distance of 0.7 m.

•Repeat horizontal angle measurement possible up to ±1999°59'55"

•Continuous operation for up to 48 hours with fresh alkaline-manganese batteries (NE-202)

Figure : Sokkia Electronic theodolite

TOTAL STATION

Total Station (TS) can record horizontal and vertical angles together with slope distance and can be considered ***as combined EDM plus electronic theodolite.***

The microprocessor in TS can perform various mathematical operations such as averaging, multiple angle and distance measurements, horizontal and vertical distances, X, Y, Z coordinates, distance between observed points and corrections for atmospheric and instrumental corrections.

Due to the versatility and the lower cost of electronic components, future field instruments will be more like total stations that measure angle and distance simultaneously having:

- ✓all capabilities of theodolites
- ✓electronic recording of horizontal and vertical angles
- ✓storage capabilities of all relevant measurements (spatial and non-spatial attribute data) for manipulation with computer.

Nowadays can be used in an integrated manner with Global Positioning System (GPS).

TOTAL STATION

Pentax R300 TS

Pentax Reflector prism

Example of Total Station

TOTAL STATION

Generally following **types of total stations** are available in the market:

Mechanical/manual TS:
The conventional multipurpose manual TS are used for routine works with powerful built-in applications program and are cheaper

Motorized TS:
Equipped with servo to allow for fast, smooth and accurate aiming. This increases the productivity by about 30%. The servo technology enables automated measurement.

Autolock TS:
In this case the instrument searches for an active remote positioning target (RMT), locks to it and follows the target as it moves to different points. Autolock technology eliminates the need for time-consuming error prone focusing and work effectively in low visibility environment. It improves the time efficiency by up to 50%.

Automatic/Robotic TS:
In this TS, the control unit can be taken to the prism to record measurements and collect other data. Generally a radio communication is used between TS and the prism.

TOTAL STATION

The control unit, battery, antenna and radio modem are integrated to allow full control over instrument and its operation. The prism used may be omni-directional .It improves the time efficiency by up to 80%.

A typical TS has the following characteristics:

Graphic display:
All commands for survey operation as well as results are displayed on graphic LCD using alphanumeric keyboard. Using built in software with menu and edit facilities, they automatically reduce angular and linear observations to three dimensional coordinates of the vector observed

Dual axis compensation :
The dual axis tilt sensor monitors any inclination of the standing axis in both X- and Y-directions. Consequently horizontal and vertical angle readings are free from error due to any deviation of the standing axis from the perpendicular

Levelling and centering:
Electronic display for levelling operation enabling rapid and precise leveling. The electronic levelling also eliminates errors caused by direct sunlight on plate bubbles.

TOTAL STATION

Laser plummet are replacing the optical plummet. A clearly visible laser dot is projected on to the ground that helps in quick centering of the instrument

Storage :
Most TS have on-board storage of records using PCMCIA memory cards of different capacity. The card memory unit can be connected to any external computer or to a special card reader for data transfer

Friction clutch and endless drive:
This eliminates the need for horizontal and vertical circle clamps plus the problem of running out of thread on slow motion screws.

Guide light or Lumi-guide tracking light :
This arrangement is fitted above the telescope objective lens and enables the target operator to maintain alignment when setting-out points. This system emits two visible beams of coherent red light, one steady and one blinking, enabling the rodman to locate the correct line quickly and easily by finding the position where both are visible

TOTAL STATION

Measurement modes :
Variety of measurement modes are available with TS such as *precise*, *accurate*, and *fast tracking*, etc. Depending up on accuracy levels required and measurement times, the surveyor can choose an appropriate measurement mode

Automatic target recognition (ATR):
This facility ensures that the instrument will lock on to the active target (by using RMT: remote measurement target).

Reflectorless or direct reflex measurement:
Distance measurement without prism is also available on many instruments, typically using two different coaxial red laser systems.

Remote control systems :
This arrangement allows truly one-person surveying capability. It is particularly useful for mass point surveys, cadastral surveys, staking out and machine guidance. Control of operation is transferred to the surveyor at the survey point where all functions can be called up

TOTAL STATION

Field techniques with TS:

Various field operations in TS are in the form of wide variety of programs integrated with microprocessor and implemented with the help of data collector.

All these programs need that the instrument station and at least one reference station be identified so that all subsequent stations can be identified in terms of (X, Y, Z).

Typical programs include the following functions:

- ✓Point location
- ✓Slope reduction
- ✓Missing line measurement (MLM)
- ✓Resection
- ✓Azimuth calculation
- ✓Remote distance and elevation measurement
- ✓Offset measurements
- ✓Layout or setting out operation
- ✓Area computation
- ✓Tracking
- ✓Stakeout

REMOTE SENSING

various definitions of remote sensing

- Technique of acquiring data about an object without touching it.

- The non-contact recording of information from various spectral regions of electromagnetic spectrum (ultraviolet, visible, infrared, and microwave regions) by means of various instruments (camera, scanners, lasers, linear arrays, and/or frame arrays) which are located on platforms such as ground, aircraft or spacecraft, and the analysis of acquired information by means of visual and digital image processing.

- Science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand and Kiefer, 2000)

- Photogrammetry and remote sensing are the art, science, and technology of obtaining reliable information about physical objects and the environment, through the process of recording, measuring, and interpreting imagery and digital representations of energy pattern derived from non-contact sensor systems

REMOTE SENSING

Remote sensing system

A typical remote sensing system consists of the following sub-systems:
(a) scene
(b) sensor
(c) processing (ground) segment

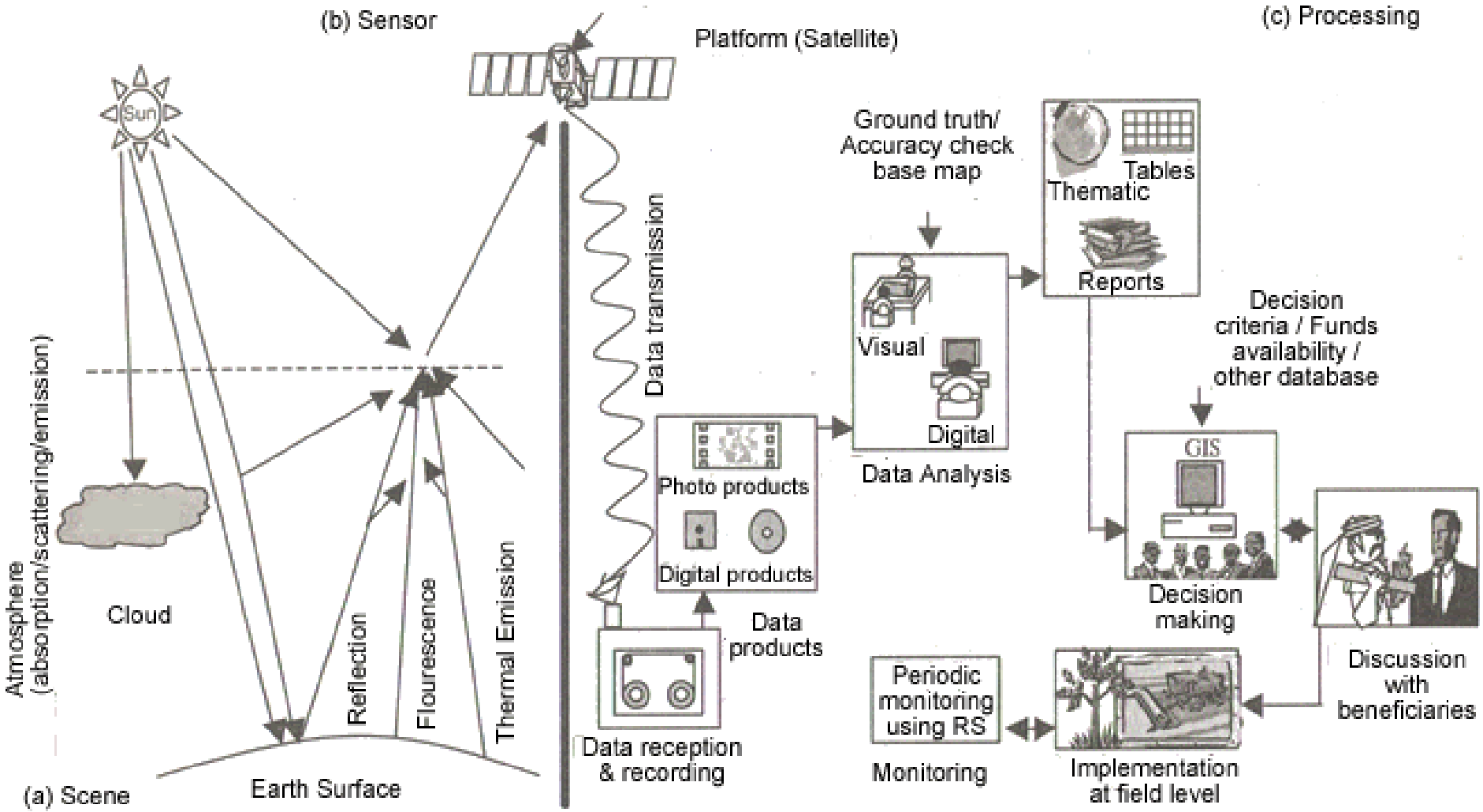
REMOTE SENSING

Various stages in these sub-systems

The electro-magnetic (EM) energy forms the fundamental component of a RS system. The following steps indicate how remotely sensed data gets converted into useful information:

1. Source of EM energy (sun/self emission: transmitter onboard sensor).
2. Transmission of energy from the source to the surface of the earth and its interaction with the atmosphere (absorption/scattering).
3. Interaction of EMR with the earth surface (reflection, absorption, transmission) or re-emission/self emission.
4. Transmission of reflected/emitted energy from the surface to the remote sensor through the intervening atmosphere.
5. Recording of EMR at the sensor and transmission of the recorded information (sensor data output) to the ground.
6. Preprocessing, processing, analysis and interpretation of sensor data.
7. Integration of interpreted data with other data sources for deriving management alternatives and applications.

REMOTE SENSING



Remote sensing system (Joseph, 2003)

REMOTE SENSING

The following four properties are used for interpretation of RS information:

1. Spectral wavelength or frequency, refractive or emissive properties of objects during interaction of EMR
2. Spatial viewing angle of sensor, shape & size of the object, position, site, distribution, texture
3. Temporal changes in time and position which affect spectral and spatial properties
4. Polarization object effects in relation to the polarization conditions of the transmitter and receiver

Multi-concept in RS

The multiple approach, considered to be the main strength of RS, could be described as follows:

Multi-stage : Recording of information from various distances (altitudes: ground, air, and space)

Multi-sensor : Variety of sensors are used to record information, e.g. MSS, TM, LISS, aerial photography, etc.

Multi-temporal :Sequence of RS observations with different acquisition dates or times.

Multi-spectral : Use of different wavelength bands (visible, infrared, microwave regions) and combination of different look angles

Multi-polarization : Use of differently polarized microwave data.

Multi-discipline : Experts from different disciplines collaborate

M**ulti-enhancement :** Combination of multi-stage, multi-spectral, multi-sensor, multi-temporal, and multi-polarization images to enhance interpretation capabilities for information extraction

REMOTE SENSING

Comparison of RS with other techniques(Buiten and Clevers, 1993):

- facilitates observation of the environment with EMR even outside the visible part of the EM
- produces measurable physical data.
- gives position-bound thematic information connected with the parameters what, where, when and
- how, allowing for improvement and completion of existing maps.
- offers flexible approaches in the form of a variety of RS observation techniques and digital imag processing (DIP) algorithms for optimum approach to information extraction.
- RS data can be reproduced at any time
- In comparison with the human eye, RS instruments offer the possibility of selection, so as to view
- objects in more detail and contrast, under a different angle of incidence & from various distances.
- provides the unparalleled synoptic view of a region as whole.
- provides area-wise information making the traditional way of point-wise sampling of the earth's surface more selective.
- Allows for an image recording of large area in a short time.with a high degree of reality
- Data disclose processes on the earth's surface both with regard to an instantaneous reproduction as well as change detection. Hence, RS can be considered dynamical/temporal.
- Satellite images may open up inaccessible regions
- RS as source of information may repeat, alter and improve the analysis of the images of the observed objects can be stored and compared with more recent images at later time.

REMOTE SENSING

A typical RS assignment consists of many linked steps for the successful interpretation and analysis. (Buiten and Clevers, 1993):

1. Knowledge of RS recording techniques
2. Understanding of physical relationship and interactions between object and EMR
3. Physical/mathematical modeling regarding the RS of the object concerned
4. Geometric and positioning aspects: matching of images to one another; registration of images to the geometry of a map projection, called geocoding;
5. Preprocessing methods of acquired analogue or digital data: interactive digital image processing and pattern recognition; contribution of private professional knowledge concerning the objects;
6. Combination techniques with data from other sources: integration with GIS to update the GIS database by means of the RS results.

REMOTE SENSING

Remote sensing in India

India, one of the leading nations in space science, has directed its efforts in three main areas (Reference):

- ✓Development of remote sensing satellites under Indian Remote Sensing Satellite (IRS) series
- ✓Development of communication and meteorological satellites under INSAT series
- ✓Development of different types of launch vehicles to put the satellites in proper orbits.

In India, Department of Space with ISRO (headquarter at Bangalore) as the nodal agency is responsible for coordinating all efforts in space technology. National Remote Sensing Agency (NRSA at Hyderabad) is responsible for satellite data dissemination to the user community.

So far nine IRS satellites have been launched: IRS-1A, IRS-1B, IRS-1C, IRS-1D, IRS-P3 and IRS-P4 (OCEANSAT), and Technology Experiment Satellite (TES), and IRS-P6 (RESOURCESAT), CARTOSAT-1.

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Definition of GIS

GIS -Geographic Information System or a particular information system applied to geographical data

***(Information System** -set of processes, executed on raw data, to produce information useful in decision-making. Uses both geographically referenced data as well as non-spatial data)*

Or it is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.

Why is GIS Important?

By putting maps and other kind of spatial information into digital form, connections between activities based on geographic proximity can be made. Looking at data geographically can often suggest new insights, explanations.

GIS has been called an "***enabling technology" because of the potential it offers for the wide variety of disciplines which must deal with spatial data***

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Major Areas of Application

- Land (parcels) (LIS)
- Facilities Management (FIS)
- Natural Resource & Environment
- Infrastructure Networking

The 4 main ideas of Geographic Information Systems (GIS) are:
Create geographic data.
Manage it in a database.
Analyze and find patterns.
Visualize it on a map.

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Components of Geographic Information Systems

The 3 main components of Geographic Information Systems are:

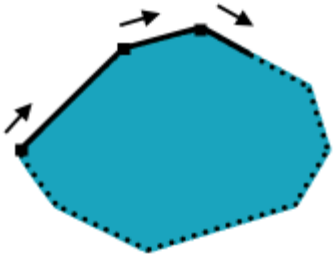
1. **DATA:** GIS stores location data as thematic layers. Each data set has an attribute table that stores information about the feature. The two main types of GIS data are

RASTER

Raster look like grids because they store data in rows and columns. They can be discrete or continuous. For example, we often represent land cover, temperature data and imagery as raster data.

VECTOR

Vectors are points, lines and polygons with vertices. For example, fire hydrants, contours and administrative boundaries are often vectors.

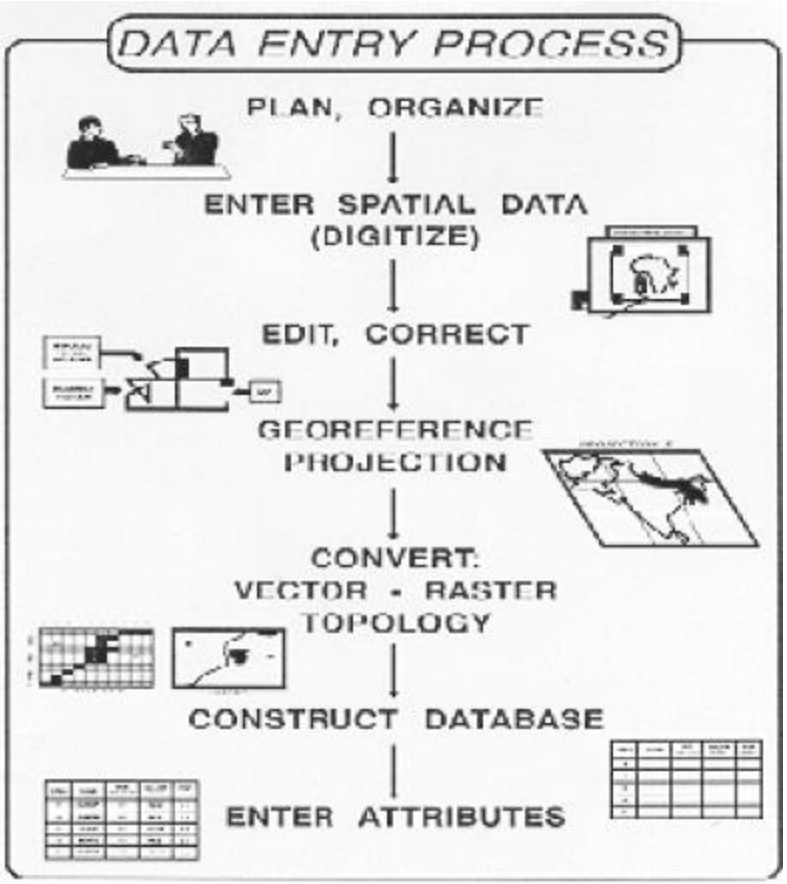


2. HARDWARE: Hardware runs GIS software. It could be anything from powerful servers, mobile phones or a personal **GIS workstation**.

3. SOFTWARE: ArcGIS and QGIS are the leaders in **GIS software**. GIS software specialize in spatial analysis by using math in maps. It blends geography with modern technology to measure, quantify and understand our world.

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

GIS PROCESS



Global Navigation Satellite System (GNSS)

Global Navigation Satellite System (GNSS)

• On February 22, 1978, the first GPS prototype satellite was launched into orbit by United States, starting a new era in satellite navigation.

• Four and a half years later on October 12, 1982, the first GLONASS satellites were places in orbit by Soviet union.

• Since then the two satellite navigation systems have been built up slowly. Now the world will have two separate and independent tool for navigation and positioning

The four global GNSS systems are – **GPS** (US), GLONASS (Russia), Galileo (EU), BeiDou (China). Additionally, there are two regional systems – QZSS (Japan) and IRNSS or NavIC (India).

NAVSTAR GPS

• **NAVigation by Satellite Timing And Ranging (NAVSTAR)**

• The United States Department of Defense (DoD) has developed the Navstar GPS, which is an all-weather, space based navigation system to meet the needs of the USA military forces and accurately determine their position, velocity, and time in a common reference system, any where on or near the Earth on a continuous basis (Wooden, 1985).

• Started in February 22, 1978. Initially developed as a military navigation system to assist US military, later extended to civilian users.

• 24 Satellites orbiting the earth & OneWay communication

Global Positioning System (GPS)

Segments of GPS

- Space segment: The Space Segment of the system consists of the GPS satellites; These space vehicles (SVs) send radio signals from space.

-Control segment: The Control Segment consists of a system of tracking stations located around the world.

-User segment: The GPS User Segment consists of the GPS receivers and the user community. GPS receivers convert space vehicle (SV) signals into position, velocity, and time estimates.

Global Positioning System (GPS)

1. Space segment

Satellite orbits

- Four GPS satellite will be unevenly distributed in each of six orbital planes.
- These planes are inclined to equator by 55°, separated from each other by 60° in longitude.
- The satellite's orbit are circular with a radius of about 26,500 kilometres.
- Kepler's third law relates the orbital radius to orbital period, the time needed by satellite to travel full circle in its plane.
- GPS orbital period is exactly one half of a sidereal day. (A sidereal day is rotation period of the earth, and is equal to a calendar day minus four minutes).
- Therefore, after one sidereal day the geometric relationship between fixed spots on the earth and the satellites repeats.
- For an observer on the earth, all GPS satellite reappear in same part of the sky day after day, always four minutes earlier each day.

Satellite signal

- The GPS user equipment receives the sum of the signals broadcast by all visible satellites. A particular signal can be tracked with a radio frequency channel in the GPS receiver by looking for the satellite's unique pseudo random noise (PRN) codes modulation, thereby rejecting all signals with a different code.

Global Positioning System (GPS)

- The procedure of separating the total incoming signals into the components transmitted by different satellites is called **code division multiple access (CDMA).**
- In order to decode the signal, the receiver must be aware of the PRN codes for each satellite.

A GPS signal contains three types of data

- **Unique pseudorandom noise (PRN) codes:**

The pseudorandom code is simply an I.D. code that identifies which satellite is transmitting information.

- **Satellite ephemerides data :**

which is constantly transmitted by each satellite, contains important information about the status of the satellite (healthy or unhealthy), current date and time. This part of the signal is essential for determining a position.

- **Almanac data :**

The almanac data tells the GPS receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits almanac data showing the orbital information for that satellite and for every other satellite in the system.

Global Positioning System (GPS)

GPS Datum

Datum is a set of parameters (translations, rotations, and scale) used to establish the position of a reference ellipsoid with respect to points on the Earth's crust.

From these, users can compute ECEF coordinates of the satellite for a particular measurement time using well-known equations. The resulting ECEF coordinates are referenced to the World Geodetic System 1984 (WGS-84).

2. Control Segment: US DoD Monitoring

Global Positioning System (GPS) Master Control and Monitor Station Network

Global Positioning System (GPS)

The control segment consists of five Monitoring Stations (Hawaii, Kwajalein [West Pacific], Ascension Island [South Atlantic], Diego Garcia [Indian Ocean], Colorado Springs), three Ground Antennas (Ascension Island, Diego Garcia, Kwajalein).

User Segment

- It consists of receivers that decode the signals from the satellites.
- The receiver performs following tasks:

- Selecting one or more satellites
- Acquiring GPS signals
- Measuring and tracking
- Recovering navigation data

Global Positioning System (GPS)

GPS Principles

1. *At least four (4) satellites are required to solve four (4) unknown parameters: Latitude, Longitude, Height and Receiver time offset* (difference between the receiver clock's indicated time
2. *a well-defined time scale reference* such as UTC (Coordinated Universal Time), TAI (International Atomic Time) or GPST (GPS Time))

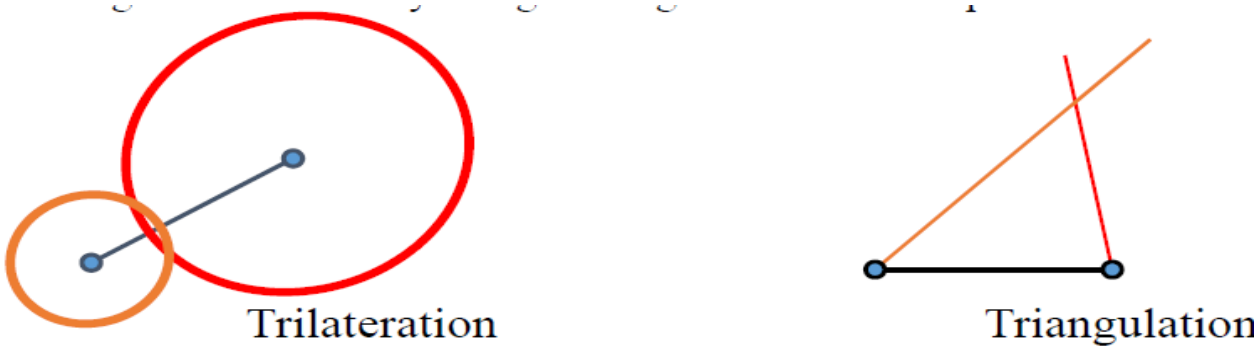
The following 5 basic steps are required to obtain these coordinates:

1. All GPS satellites have synchronized atomic clocks as time keepers.
2. The coordinates of all satellites, acting as moving control stations, are known precisely with the help of system control.
3. Satellite coordinates and time signals are transmitted to ground receiver.
4. These signals reach the ground delayed by distance traveled.
5. Making use of simple resection principle and the range information to each satellites, the receiver computes its coordinates

Global Positioning System (GPS)

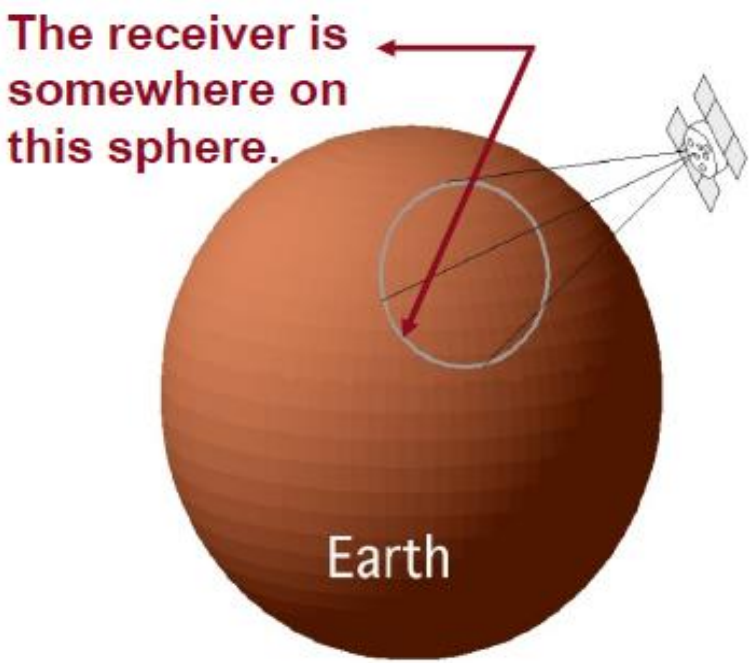
GPS Receiver : Basic Principle

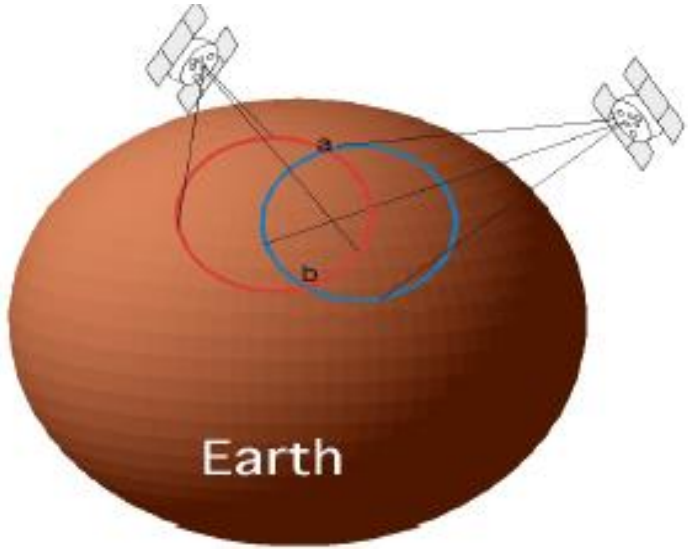
- The receiver collects, decodes and processes the satellite signals.
- The basic receiver does not include a transmitter.
- The receiver determines its location by trilateration.
- Trilateration works by using the distance from known positions.
- Triangulation works by using the angles from known positions.



Global Positioning System (GPS)

When the receiver knows its distance from only one satellite, its location could be anywhere on the Represented by the earths surface that is an equal distance from the satellite.

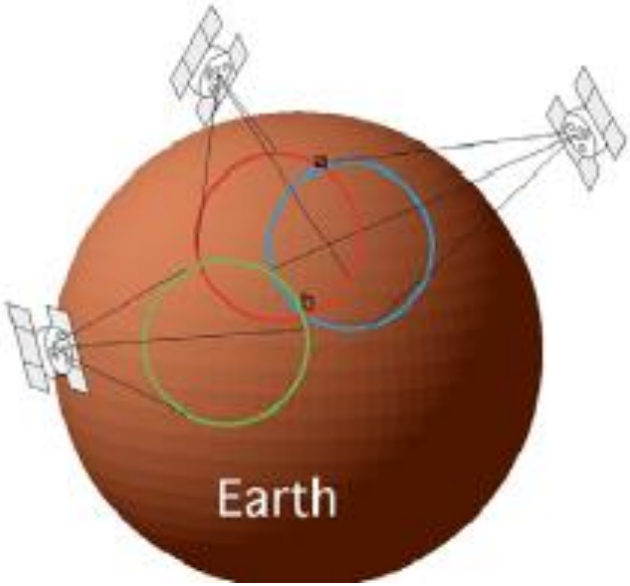


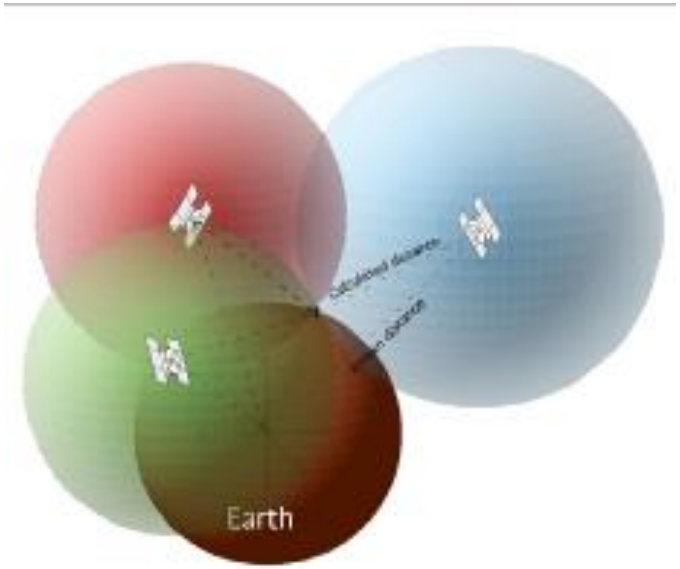


With signals from two satellites, the receiver can narrow down its location to just two points on the earths surface.

Global Positioning System (GPS)

Knowing its distance from three satellites, the receiver can determine its location because there is only two possible combinations and one of them is out in space.





A fourth satellite must be applied correction to compensate for the difference between the satellite and receiver clocks

Global Positioning System (GPS)

During GPS based positioning, the following steps are followed (Enge and Misra, 1999):

- **Basic navigation point position** can be calculated like a resection in which satellites are the orbiting control stations .
- **Range vectors** are measured to each of the satellites using a time dependent code based on the times of transmission and receipt of the signals.
- Since these times are biased by a common amount due to **offset between the satellite and receiver clocks** ; they are called pseudoranges .
- **Pseudorange measurements** from four satellites are needed to estimate the user position and the corresponding receiver clock bias.

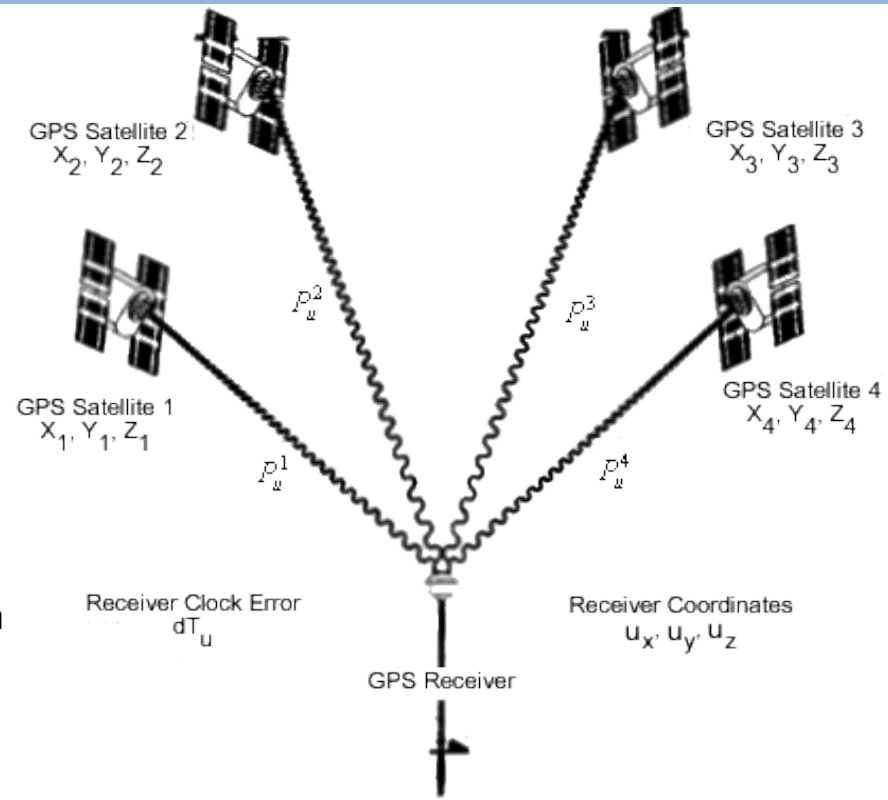
Global Positioning System (GPS)

The above principle is explained in Figure where 4 known GPS satellite coordinates are shown as (*Xi, Yi, Zi*).

The unknown coordinates of GPS receiver **u**=(*Ux, Uy, Uz*) are calculated by solving 4 range (or pseudorange P) equations.

A minimum of four equations are needed to solve for four unknowns- three unknown position coordinates (*Ux, Uy, Uz*) and to account for the fact that atomic clocks onboard GPS satellites and quartz clocks in GPS receivers are not synchronized.

This unknown time variable is called **receiver time offset or bias** (*dTu*).



P_u^i = Pseudorange from receiver u to satellite i

$\boldsymbol{u} \equiv (u_x, u_y, u_z)$ = Receiver coordinates

$(X_i,\ Y_i,\ Z_i)$ = Coordinates of satellite i

c = velocity of light

dTu = Satellite-receiver clock bias (Sickle, 2001)

Global Positioning System (GPS)

Background for Coordinate System

Well-defined coordinate systems are required for positioning points in 2D or 3D space on surface of earth. However, one needs to represent or idealize earth in a manner suitable for proper representation of position. Several idealizations have been proposed for the shape of earth.

For example, the first approximation to shape of earth is **Geoid**, the theoretical shape of earth. Differences in the density of the earth cause variation in the strength of the gravitational pull, in turn causing regions to dip or bulge above or below a mathematical reference surface called ellipsoid. This undulating shape is the Geoid

A rotational ellipsoid is another mathematical approximation to earth's shape. It is an imaginary, regular and smooth mathematical surface over which computation of coordinates becomes very easy. An ellipsoidal surface can be further approximated by a sphere.

GPS: GEOREFERENCING

Geodetic datums define the size and shape of the earth and the origin and orientation of the coordinate systems used to map the earth

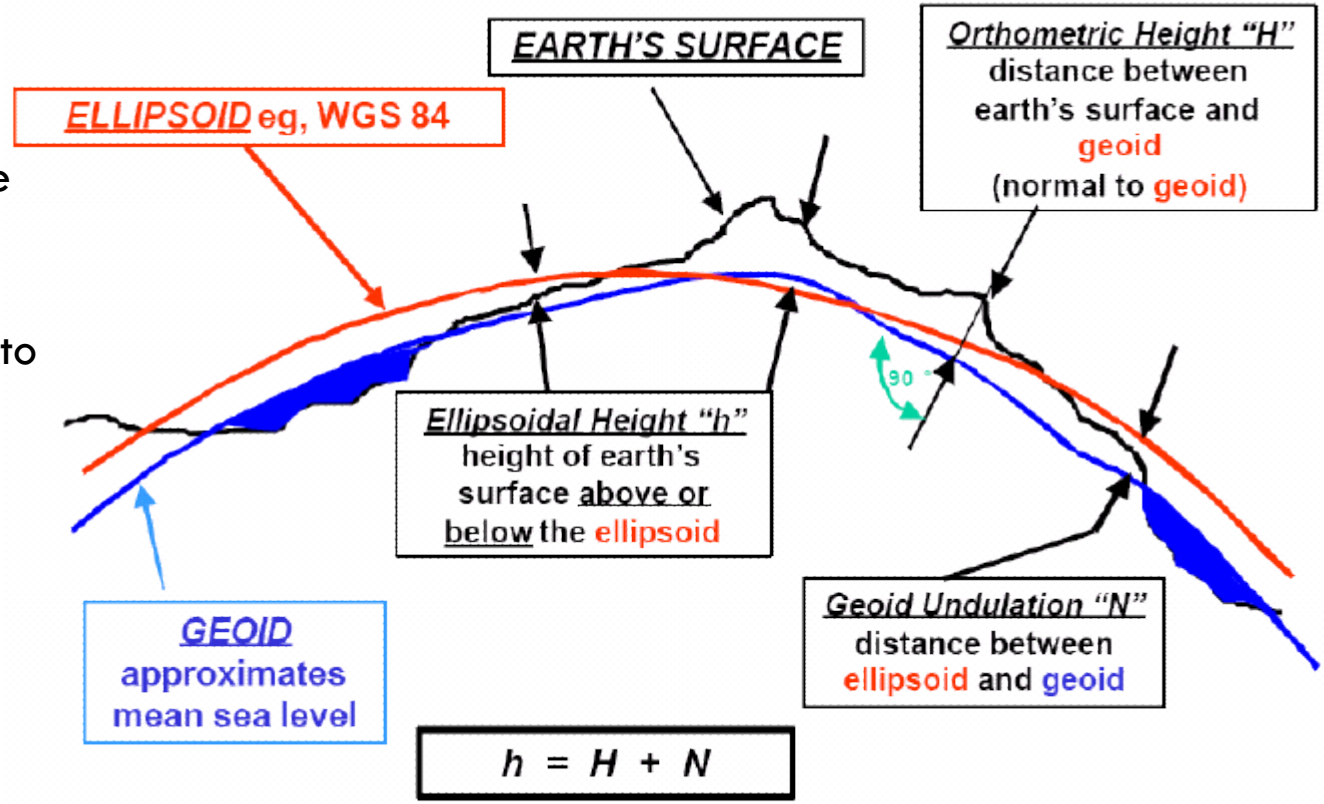
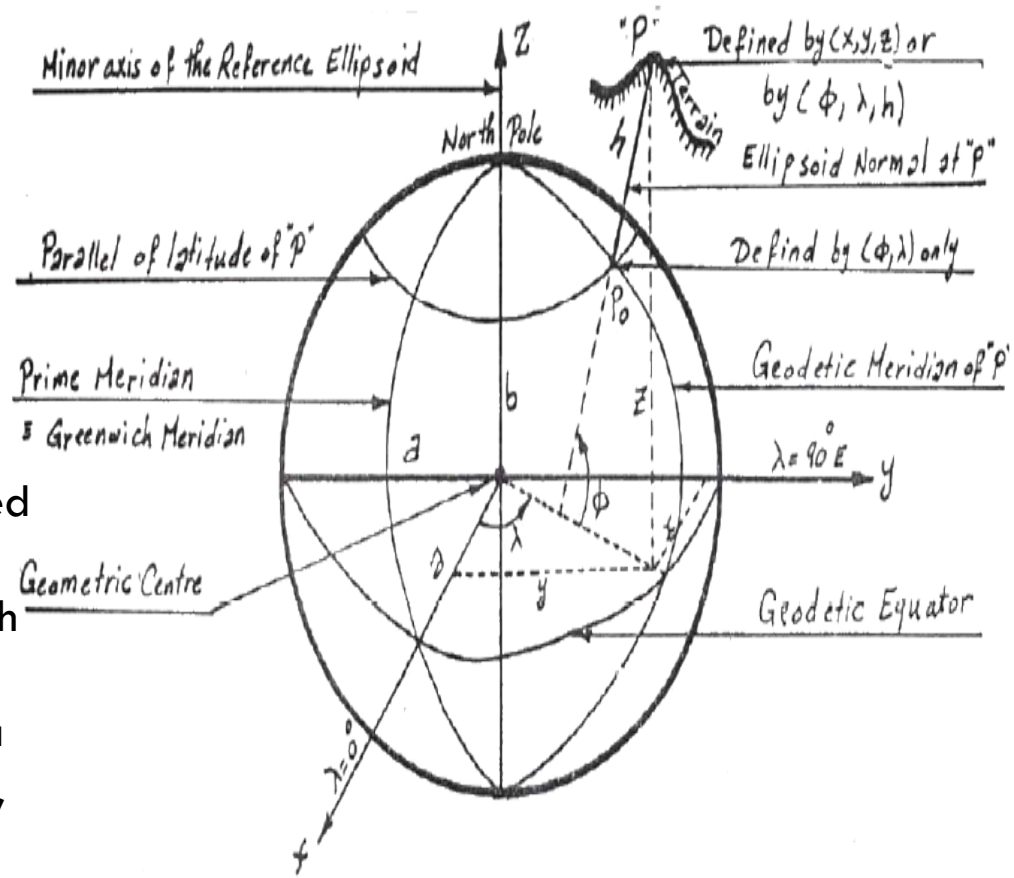


Figure : Important surfaces for positioning

GPS: GEOREFERENCING

The coordinates of a point P in this system can be expressed in two ways - curvilinear (longitude: l , Latitude: f , Geodetic height: h) and rectangular (x, y, z)



The ellipsoidal systems can be geocentric or non-geocentric.

The geocentric systems have their z-axis aligned either

(a) with the instantaneous spin axis of the earth (instantaneous terrestrial system, ITS)

(b) with a hypothetical spin axis adopted by a convention (conventional terrestrial systems, CTS). The World Geodetic System-84 (WGS-84) is one such

The non-geocentric systems are used for local work (observations) in which case their origin would be located at a point on the surface of the earth

GPS: GEOREFERENCING

Indian Geodetic Datum

The Indian system is a topocentric system which is realized by

- Choosing an initial point (origin)
- Specifying, the latitude and longitude of the initial point
- Azimuth of a line from this point
- Two parameters of a reference surface (ellipsoid):
  - Components of deflection of vertical
  - Geoidal undulation at the initial point

Indian Geodetic datum, using Everest spheroid is a local geodetic datum, which best fits to certain extent the Indian subcontinent. It is non-geocentric ellipsoid, and its origin is far away from the geocentre (C. G. of the Earth). The geodetic coordinates based on Everest spheroid differ considerably (in many cases even hundreds of meters) as compared to WGS 84 and other International ellipsoids.

Origin (Initial Point)	Kalyanpur
Latitude of Origin	24° 07' 11".26
Longitude of Origin	77 ° 39' 17".57
Meridional deflection of vertical	-0".29
Prime vertical deflection of vertical	2".89
Semi major axis of Everest Spheroid	6,377,301 meters
Flattening of Everest Spheroid	1/300.8017
Geoidal undulation	0 meters
Azimuth to Surantal	190 ° 27'06".39

Details of the Indian topocentric system (Agrawal, 2004)

GPS SURVEYING

Advantages

- Unlike conventional surveying procedures, no need for intervisibility between stations.
- Independent of weather conditions as a result of using radio frequencies to transmit the signals.
- Use of same field and data reduction procedures results in position accuracy which are independent of network shape or geometry and are primarily a function of inter-station distance.
- provides homogeneous accuracy. The points can be established wherever they are required and need.
- more efficient, more flexible and less time consuming positioning technique
- obtain high accuracy three dimensional (3D) information, anywhere and any time with relatively little effort on a global datum .
- GPS instrumentation and the data processing software do not radically change even if very high or moderately high accuracies are required (from 1 part in 10^4 to 1 part in 10^6).

GPS SURVEYING

Current Limitations of GPS

- GPS requires clear opening to sky without any obstruction signals by overhanging branches or structures ; limited applications in densely settled urban areas .
- needs careful advanced planning to realize true potential of GPS.
- may not be useful for conventional surveys due to intervisibility, shape and geometry requirements.
- Two intervisible stations would have to established by GPS in order to satisfy the requirement for azimuth data for use by conventional (line-of-sight) survey methods.
- reliable coordinate transformation schemes required for transforming GPS coordinates into a local geodetic system for their integration with results from conventional surveys.(Since GPS coordinates are available in global WGS-84 datum,)
- GPS heights have to be reduced to a sea level datum by suitable transformation.(Since GPS vertical information is not available in universally acceptable geoid based height system)
- GPS instrumentation is still comparatively expensive.
- require skilled personnel for operations.