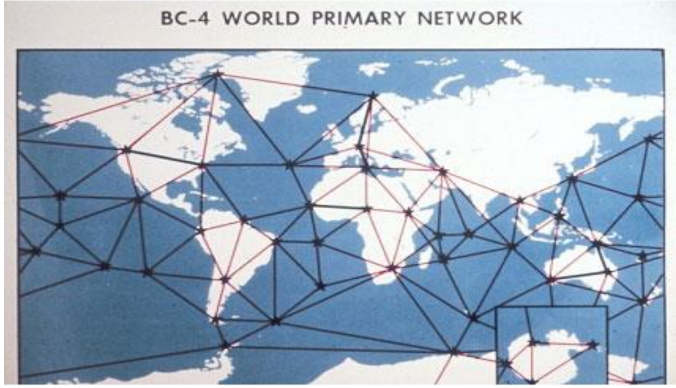
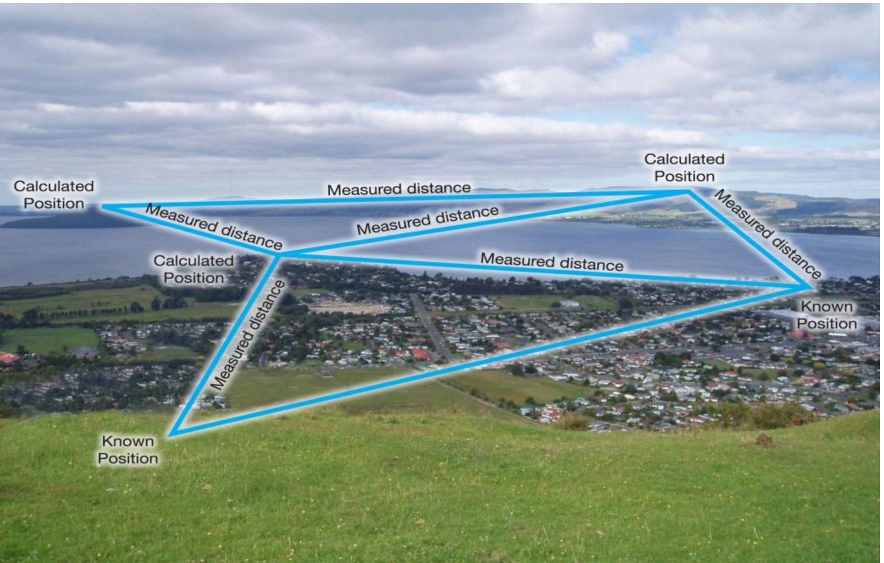


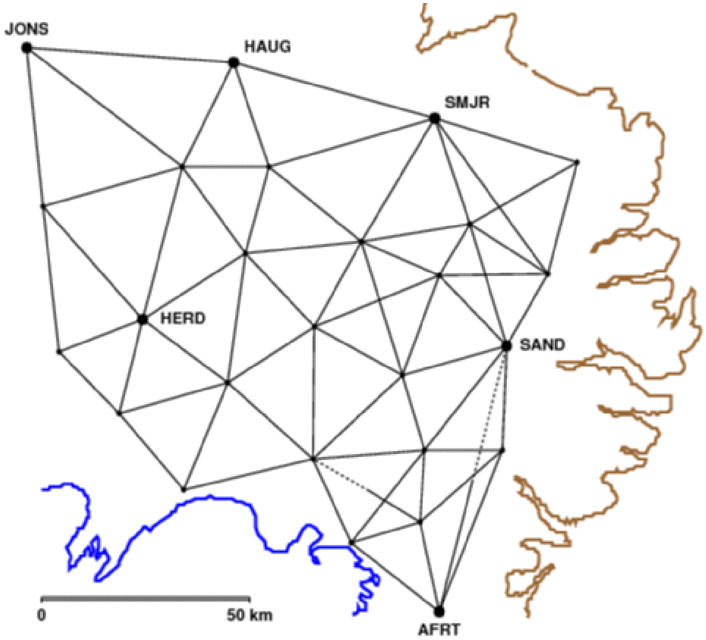
Triangulation

Lecture - 04



Triangulation

- Type of geodetic survey.
- Used for large areas.
- We form triangles by selecting suitable stations.



Principle of triangulation

- The method of surveying called *triangulation is based on the trigonometric proposition that if one side* and two angles of a triangle are known, the remaining sides can be computed. Furthermore, if the direction of one side is known, the directions of the remaining sides can be determined.
- A triangulation system consists of a series of joined or overlapping triangles in which an occasional side is measured and remaining sides are calculated from angles measured at the vertices of the triangles.

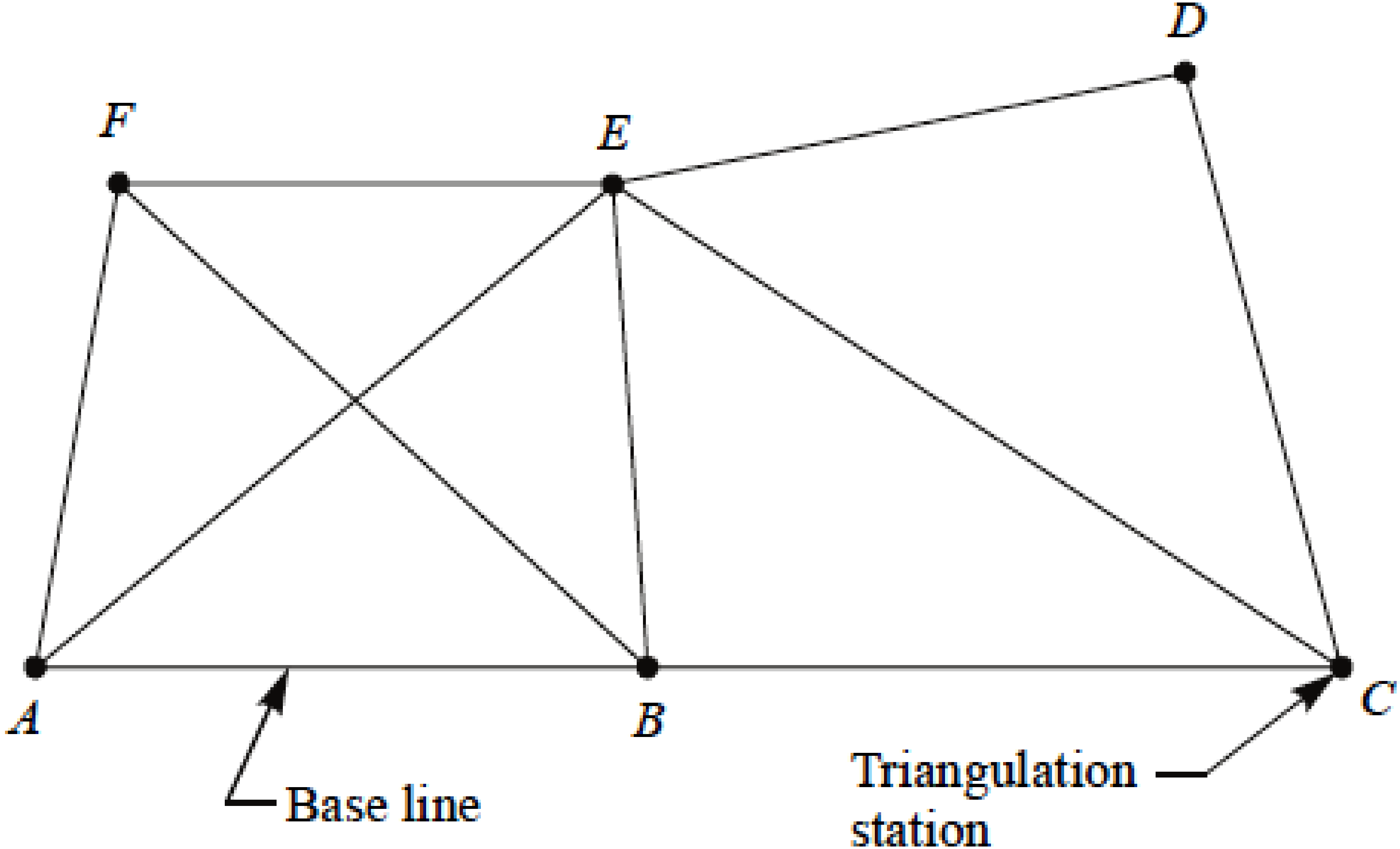


Fig. 1.1 Triangulation network

Forms of triangles

1. Single chain of triangles

- When the control points are required to be established in a narrow strip of terrain such as a valley between ridges, a layout consisting of single chain of triangles is generally used.
- This system is rapid and economical due to its simplicity of sighting only four other stations,

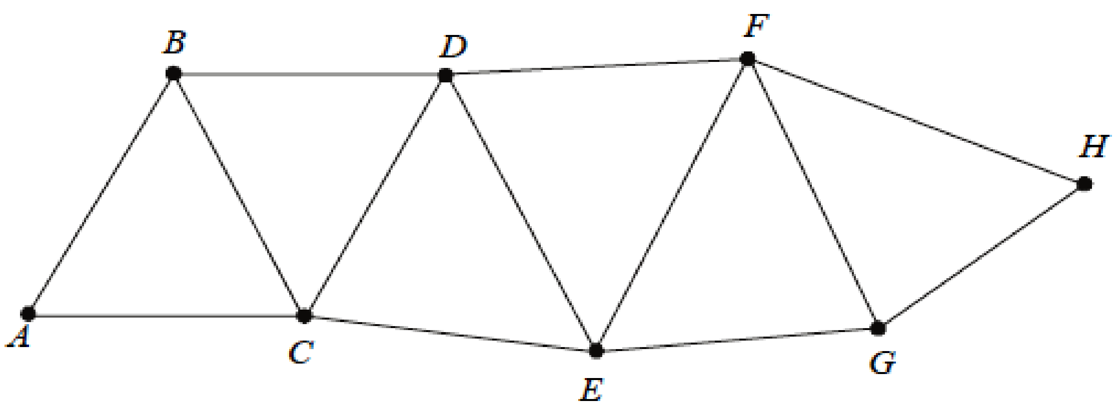


Fig. 1.4 Single of triangles

2. Double chain of triangles

- A layout of double chain of triangles is shown in Fig. 1.5. This arrangement is used for covering the larger width of a belt.

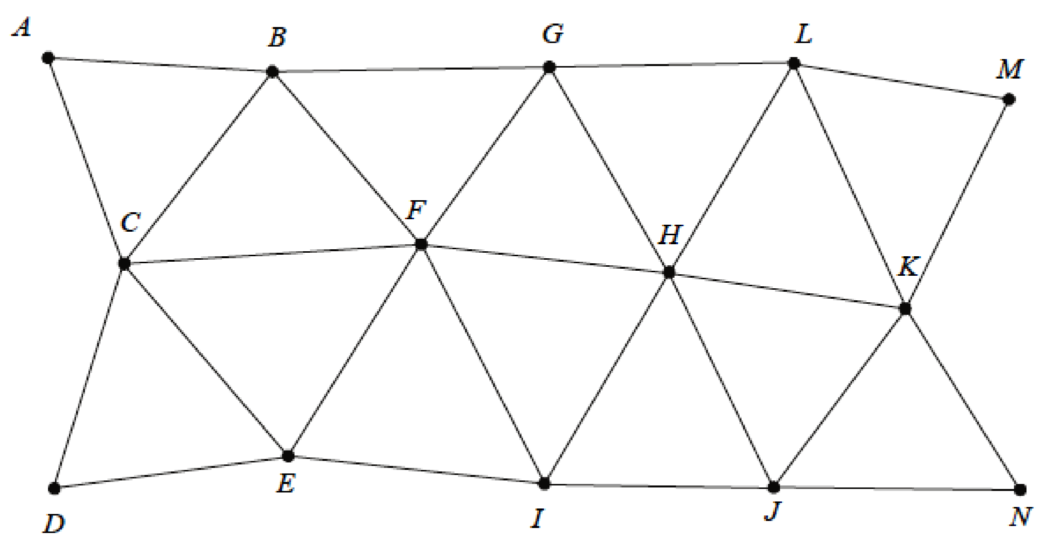


Fig. 1.5 Double chain of triangles

3. Chain of braced Quadrilaterals

- A triangulation system consisting of figures containing four corner stations and observed diagonals shown in Fig. 1.6, is known as a layout of braced quadrilaterals. In fact, braced quadrilateral consists of overlapping triangles. This system is treated to be the strongest and the best arrangement of triangles, and it provides a means of computing the lengths of the sides using different combinations of sides and angles.
- Most of the triangulation systems use this arrangement.

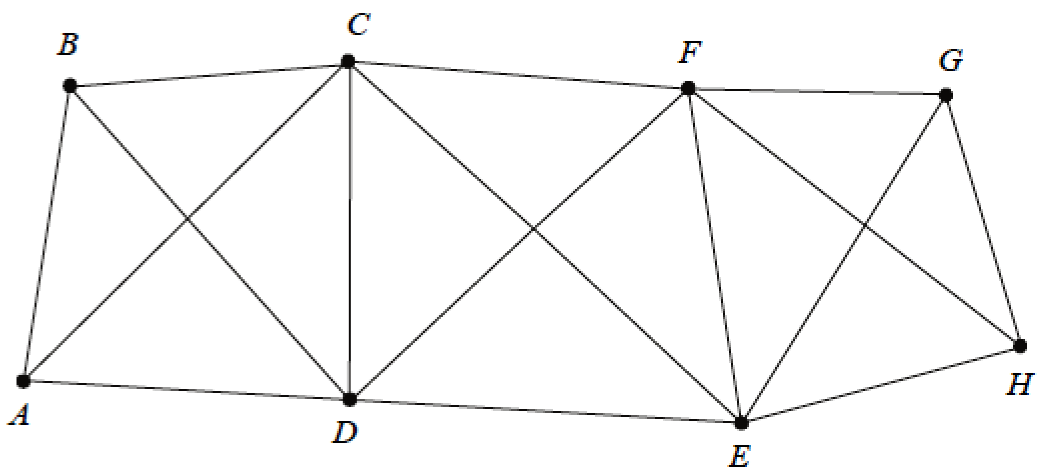


Fig. 1.6 Braced quadrilaterals

4. Chain of hexagons

- This layout in a triangulation system is generally used when vast area in all directions is required to be covered. The centered figures generally are quadrilaterals, pentagons, or hexagons with central stations.
- Though this system provides checks on the accuracy of the work, generally it is not as strong as the braced quadrilateral arrangement. Moreover, the progress of work is quite slow due to the fact that more settings of the instrument are required.

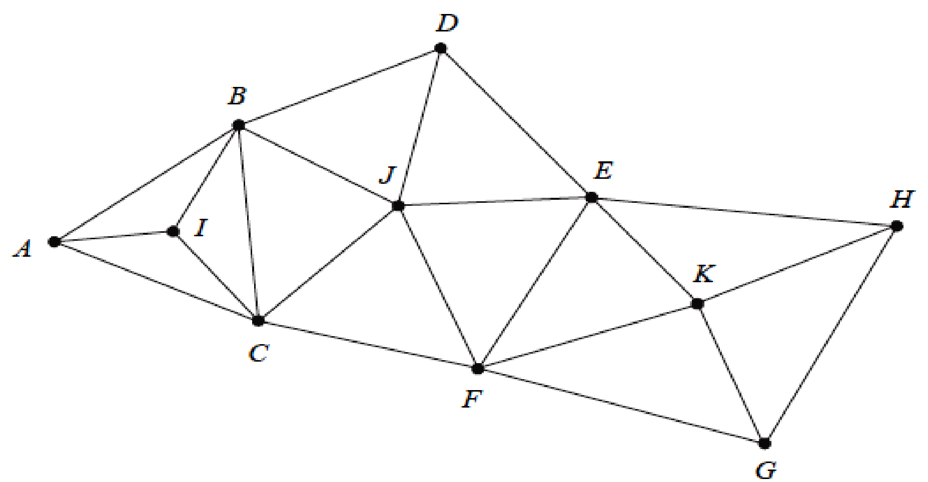


Fig. 1.7 Centered triangles and polygons

5. **Grid iron system**

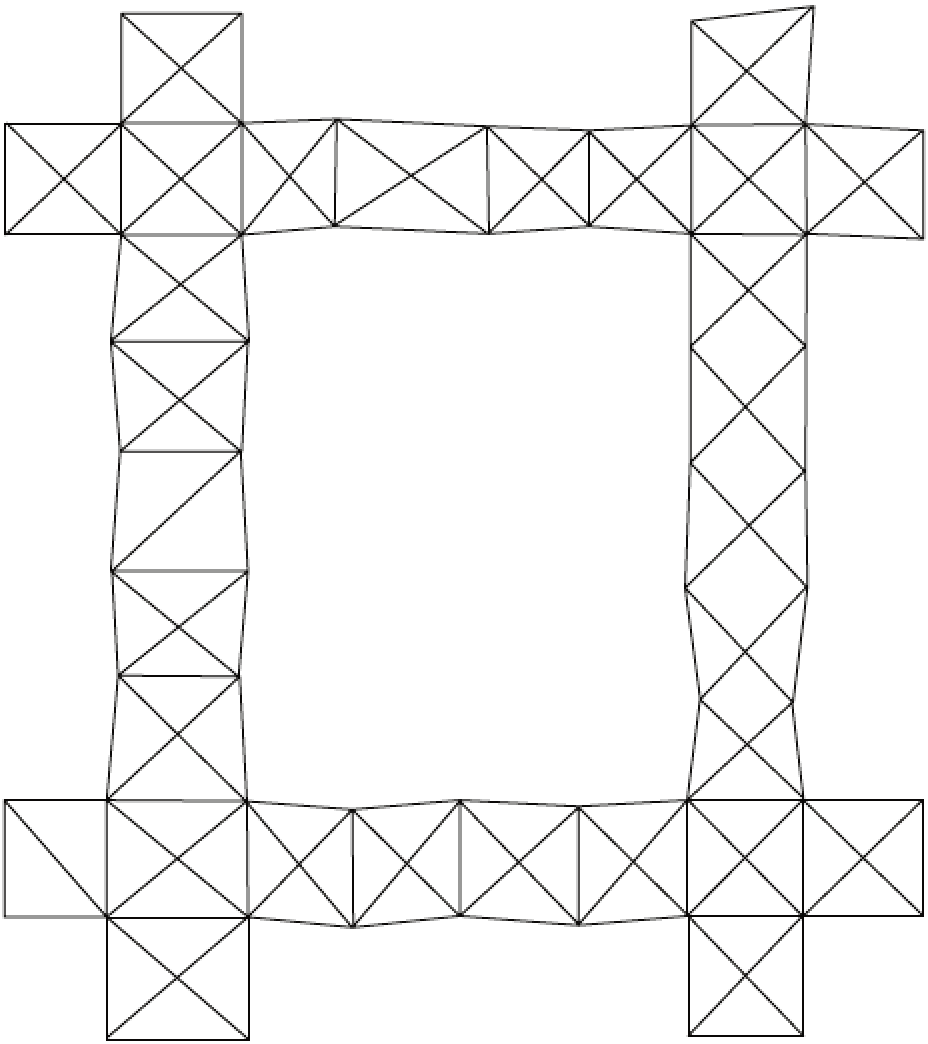


Fig. 1.8 Grid iron system of triangulation

- In this system, the primary triangulation is laid in series of chains of triangles, which usually runs roughly along meridians (north south) and along perpendiculars to the meridians (east-west), throughout the country (Fig. 1.8). The distance between two such chains may vary from 150 to 250 km. The area between the parallel and perpendicular series of primary triangulation, are filled by the secondary and tertiary triangulation systems.
- The method is expensive

6. Central system of triangles

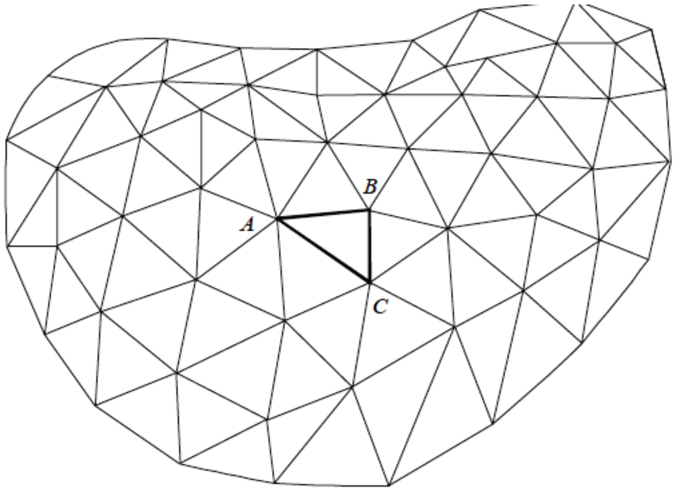
- In this system, the whole area is covered by a network of primary triangulation extending in all directions from the initial triangulation figure *ABC, which is generally laid at the centre of the country (Fig. 1.9).*

- A base line is set and triangles

are constructed all around it.

All the triangles in this type

Should be well conditioned.



Types of triangulation

- There are three types of triangulation.

1. Primary Triangulation
2. Secondary triangulation
3. Tertiary triangulation.

First Order or Primary Triangulation:

- The first order triangulation is of the highest order and is employed either to determine the earth’s figure or to furnish the most precise control points to which secondary triangulation may be connected.
- The primary triangulation system embraces the vast area (usually the whole of the country).

Secondary Order or Secondary Triangulation

- The secondary triangulation consists of a number of points fixed within the framework of primary triangulation.
- The stations are fixed at close intervals so that the sizes of the triangles formed are smaller than the primary triangulation.

Third Order or Tertiary Triangulation:

- The third-order triangulation consists of a number of points fixed within the framework of secondary triangulation, and forms the immediate control for detailed engineering and other surveys.

- The sizes of the triangles are small and instrument with moderate precision may be used.

S.No	Characteristics	Primary Triangulation	Secondary triangulation	Tertiary Triangulation
1.	Also called as	First order	Second order	Third order
2.	Length of the base line	5 to 15 km	1.5 to 4.5 Km	1 to 3 Km
3.	Length of sides	150 Km or more	8 to 60 Km	1 to 6 Km
4.	Error limit in Base Line	1:25000	1:10000	1:5000
5.	Error in length measure by trigonometry	1:50000	1:50000	-
6.	Average triangulation error (angle measurement)	Not more than 1”	8”	15”

Procedure for triangulation

1) Reconnaissance survey
2) Selection of stations
3) Erection of signals and towers
4) Measurement of angles
5) Measurement of Base line
6) Checking and correction of the work

Reconnaissance survey

1. Examination of terrain to be surveyed.
2. Selection of suitable sites for measurement of base lines.
3. Selection of suitable positions for triangulation stations.
4. Determination of intervisibility of triangulation stations.
5. Selection of conspicuous well-defined natural points to be used as intersected points.
6. Collection of miscellaneous information regarding:
   - (*a*) Access to various triangulation stations
   - (*b*) Transport facilities
   - (*c*) Availability of food, water, etc.
   - (*d*) Availability of labour
   - (*e*) Camping ground.

Selection of stations

Criteria for selection of triangulation stations

1. Triangulation stations should be intervisible. For this purpose the station points should be on the highest ground such as hill tops, house tops, etc.
2. Stations should be easily accessible with instruments.
3. Station should form well-conditioned triangles.
4. Stations should be so located that the lengths of sights are neither too small nor too long. Small sights cause errors of bisection and centering. Long sights too cause direction error as the signals become too indistinct for accurate bisection.
5. Stations should be at commanding positions so as to serve as control for subsidiary triangulation, and for possible extension of the main triangulation scheme.
6. Stations should be useful for providing intersected points and also for detail survey.
7. In wooded country, the stations should be selected such that the cost of clearing and cutting, and building towers, is minimum.
8. Grazing line of sights should be avoided, and no line of sight should pass over the industrial areas to avoid irregular atmospheric refraction.

Satellite station

- To secure well-conditioned triangles or to have good visibility, objects such as chimneys, church spires, flat poles, towers, lighthouse, etc., are selected as triangulation stations. Such stations can be sighted from other stations but it is not possible to occupy the station directly below such excellent targets for making the observations by setting up the instrument over the station point.
- Therefore additional stations are selected nearby such stations at a suitable distance .Such additional stations are called as satellite station.

Inter visibility

Inter visibility not obstructed by intervening ground

- If the intervening ground does not obstruct the indivisibility, the distance of visible horizon from the station of known elevation is calculated from the following formula:

$$h = 0.06735\, D^2$$

where

h = height of the station above datum,

D = distance of visible horizon,

In Fig. 1.17, the distance between two stations A and B of heights h_A and h_B, respectively, is D. If D_A and D_B are the distances of visible horizon from A and B, respectively, we have

$$D_A = \sqrt{\frac{h_A}{0.06735}} = 3.853\sqrt{h_A} \quad \text{...(1.15)}$$

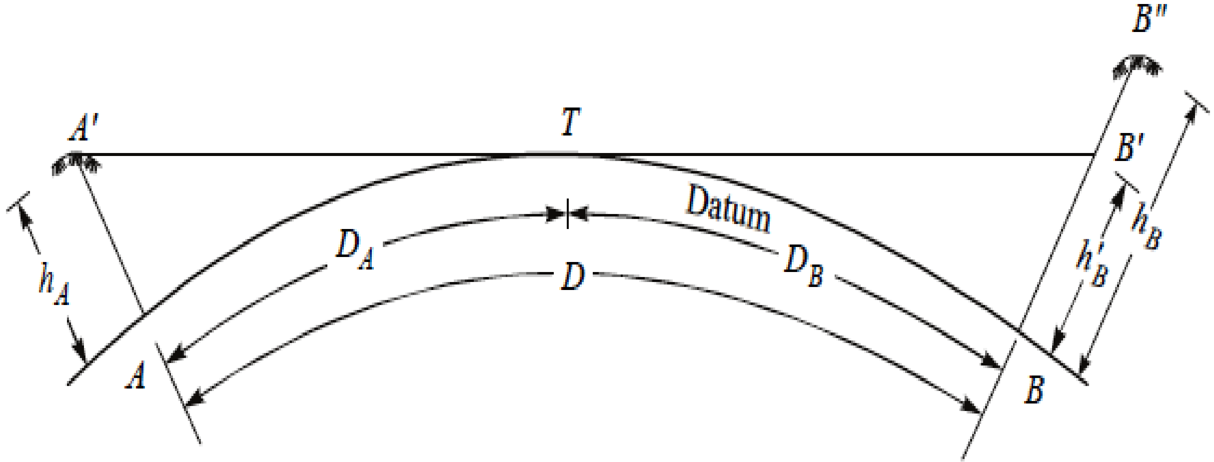


Fig. 1.17 Intervisibility not obstructed by intervening ground

We have $\quad D = D_A + D_B$

or $\quad D_B = D - D_A$

Inver visibility obstructed by intervening ground

- If there is a obstruction between two stations (hill, building etc) then following methods are used,
  - Similar triangles rule
  - Captain G.T. McCaw's method

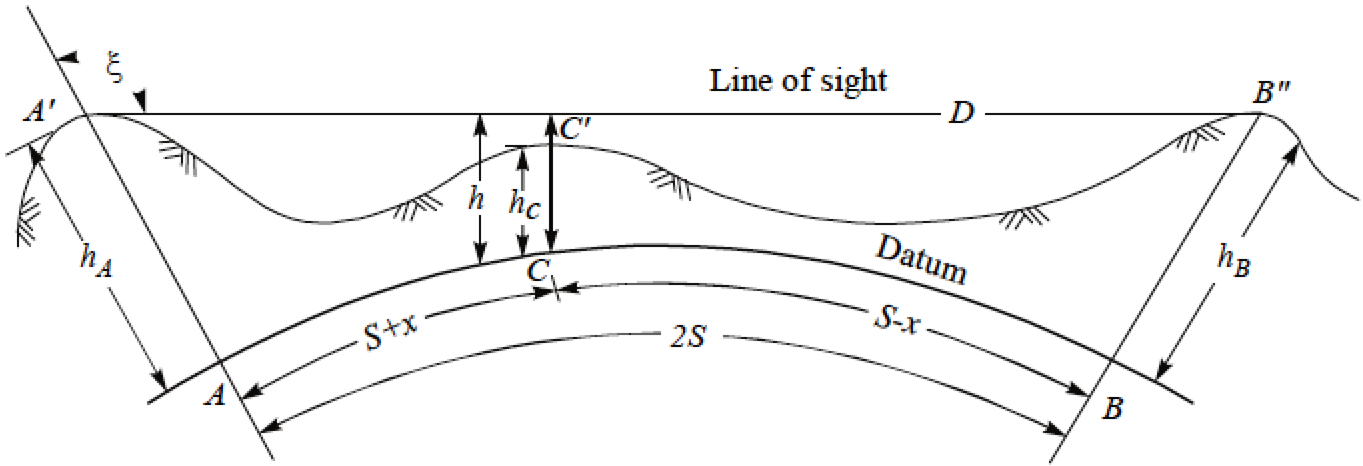


Fig. 1.20 Captain McCaw's method of ascertaining intervisibility

Signals

- Signals are centered vertically over the station mark, and the observations are made to these signals from other stations. The accuracy of triangulation is entirely dependent on the degree of accuracy of centering the signals. Therefore, it is very essential that the signals are truly vertical, and centered over the station mark. Greatest care of centering the transit over the station mark will be useless, unless some degree of care in centering the signal is impressed upon.

Classification of signals

1) **Non-luminous signals**

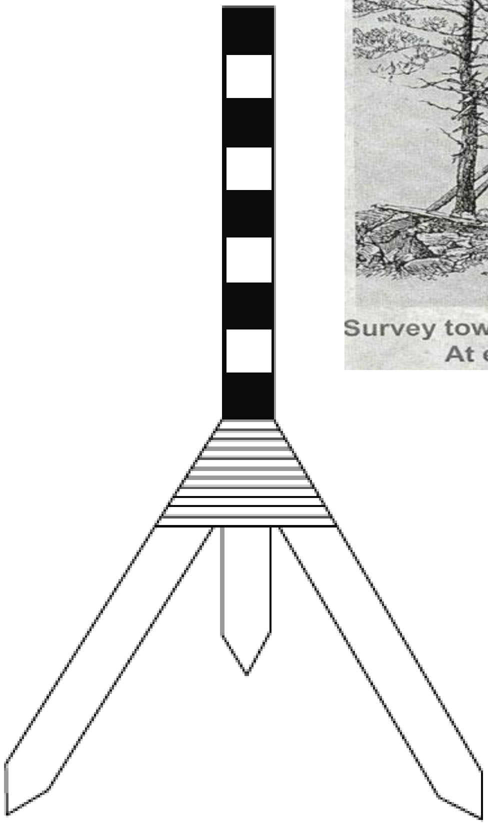
Non-luminous signals are used during day time and for short distances. These are of various types, and the most commonly used are of following types.

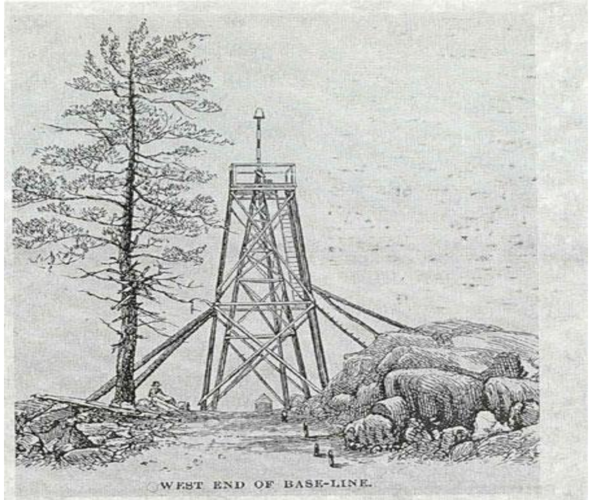
a) ***Pole signal*** *: It consists of a round pole painted black and white in alternate strips, and is supported vertically over the station mark, generally on a tripod.*

Pole signals are suitable up to a distance of about 6 km.

b) ***Target signal :*** *It consists of a pole carrying two squares or rectangular targets placed at right angles to each other. The targets are generally made of cloth stretched on wooden frames.*

Target signals are suitable up to a distance of 30 km.





Survey tower with signal pole and tin cone
At end of Epping Base Line

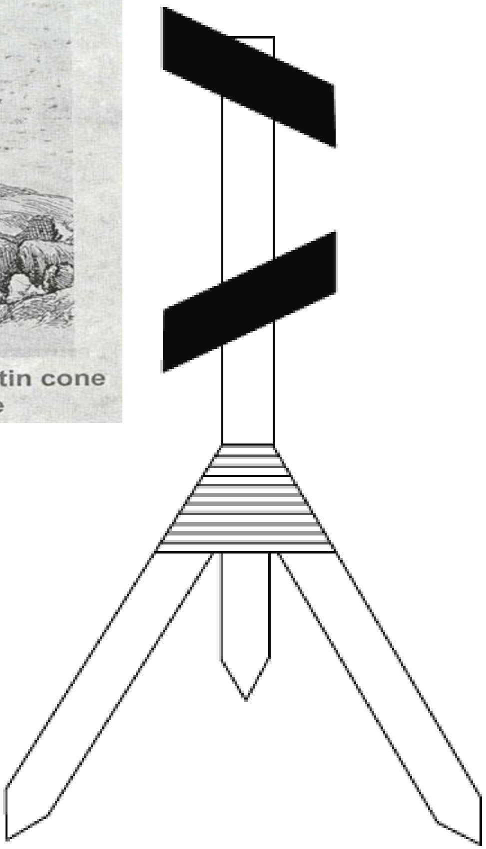


Fig. 1.24 Pole signal

Fig. 1.25 Target signal

2) Sun signals : Sun signals reflect the rays of the sun towards the station of observation, and are also known as heliotropes. Such signals can be used only in day time in clear weather.

3) Night signals: When the observations are required to be made at night, the night signals of following types may be used.

a. Various forms of oil lamps with parabolic reflectors for sights less than 80 km.
b. Acetylene lamp designed by Capt. McCaw for sights more than 80 km.
c. Magnesium lamp with parabolic reflectors for long sights.
d. Drummond's light consisting of a small ball of lime placed at the focus of the parabolic reflector, and raised to a very high temperature by impinging on it a stream of oxygen.
e. Electric lamps

Measuring angles

- Repetition method
- Reiteration method

Measuring Base line

- Most important in triangulation.
  - ➢ The accuracy of an entire triangulation system depends on that attained in the measurement of the base line.
- Length varies from 1 to 15 Km.

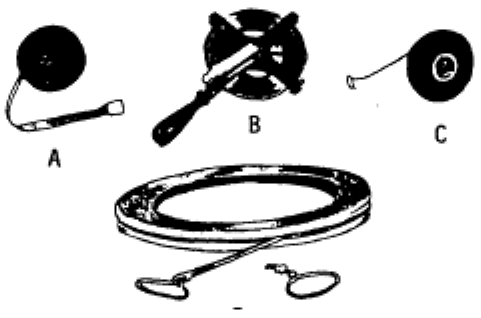
Selection of site for base line

Since the accuracy in the measurement of the base line depends upon the site conditions, the following points should be taken into consideration while selecting the site for a base line.

1) The site should be fairly level or gently undulating. If the ground is sloping, the slope should be uniform and gentle.
2) The site should be free from obstructions throughout the length of the base line.
3) The ground should be firm and smooth.
4) The two extremities of the base line should be inter visible.
5) The site should be such that well-conditioned triangles can be obtained while connecting extremities to the main triangulation stations.

Equipment for base line measurement

- Generally the following types of base measuring equipments are used:
  1. Invar tapes
  2. Straining devices
  3. Spring balance
  4. Six thermometers
  5. Pocket scale
  6. Marking tripod/stakes
  7. Supporting tripod/stakes



Extension of base line

- There are two methods
  1) Extension by prolongation
  2) Extension by double sighting.

Extension by prolongation

- Let suppose that AB is a short base line (Fig. 1.37) which is required to be extended by four times. The following steps are involved to extend AB.
    a. Select C and D two points on either side of AB such that the triangles BAC and BAD are well conditioned.
    b. Set up the theodolite over the station A, and prolong the line AB accurately to a point E which is visible from points C and D, ensuring that triangles AEC and AED are well-conditioned.
    c. In triangle ABC, side AB is measured. The length of AC and AD are computed using the measured angles of the triangles ABC and ABD, respectively.
    d. The length of AE is calculated using the measured angles of triangles ACE and ADE, and taking mean value.
    e. Length of BE is also computed in similar manner using the measured angles of the triangles BEC and BDE. The sum of lengths of AB and BE should agree with the length of AE obtained in step (iv).
    f. If found necessary, the base can be extended to H in the similar way.

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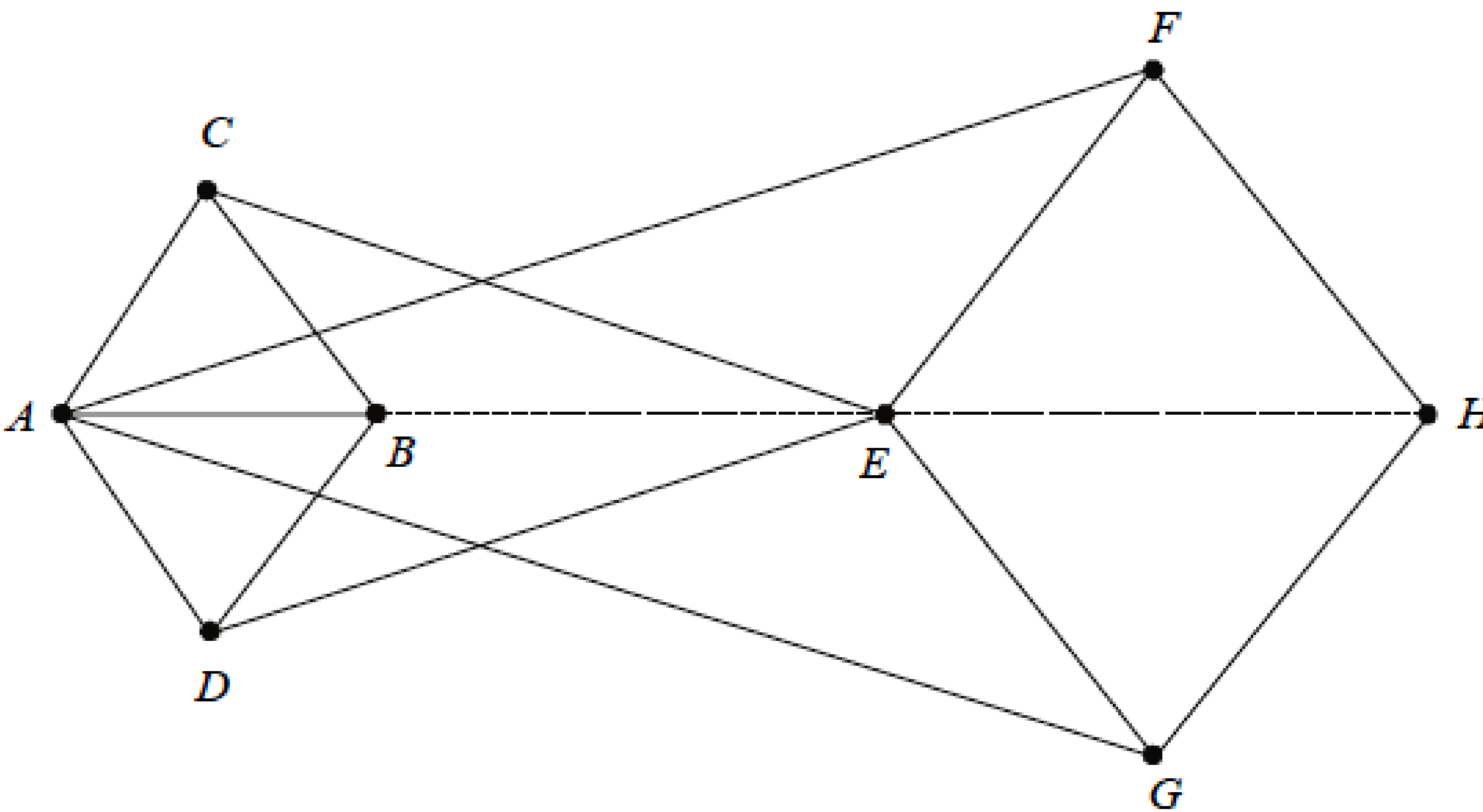

Fig. 1.37 Base extension by prolongation