CHAPTER 6 STATIC AND KINEMATIC POSITIONING

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6.1 Introduction

- Varieties of field survey techniques using one or other of basic observables exist depending on the capabilities of the receivers and the type of survey (Schoffield # 338, Ghilani and Wolf # 369)
- Some of the techniques currently being used are (Ghilani and Wolf # 369):
    1. Static
    2. Rapid Static
    3. Pseudo-kinematic
    4. Kinematic
    5. Stop-and-Go
    6. Real-time Kinematic
- All of these techniques employ relative positioning mode; i.e., 2 or more receivers occupying different receivers and simultaneously making observations to several satellites (Ghilani and Wolf # 369)
- The distance between receivers is called baseline and its coordinate difference components (ΔX, ΔY, ΔZ) in geocentric coordinate system are computed as a result of the observations (Ghilani and Wolf # 369).
- Using carrier phase observable in the differential mode produces accuracies of 1 ppm of the baseline length (Schoffield # 338)

6.2 Static Positioning

- In this technique, two or more receivers are employed (Ghilani and Wolf # 369)
- The process begins with one receiver (base) located on an existing control station (Ghilani and Wolf # 369)
- The remaining receivers (rovers) occupy stations with unknown coordinates (Ghilani and Wolf # 369)
- For the first observing session, simultaneous observations are made from all stations to 4 or more satellites for a period of 30 minutes to several hours (6+ hours usually) depending on the number of visible satellites, baseline length, accuracy required, etc., in order to resolve integer ambiguity between the satellite and the receiver upon completion of the session (Ghilani and Wolf # 369, NAVSTAR # 5-6)
- Any receiver from the first session now serves as the base station for the next session (Ghilani and Wolf # 369)

- ❖ Rest of the receivers can be moved to new stations and observations are made (Ghilani and Wolf # 369)
- ❖ The process is repeated until all the stations are occupied, and baselines form geometrically closed figure (Ghilani and Wolf # 369)
- ❖ For checking purposes, some repeat baseline observations should be made during the surveying process (Ghilani and Wolf # 369)

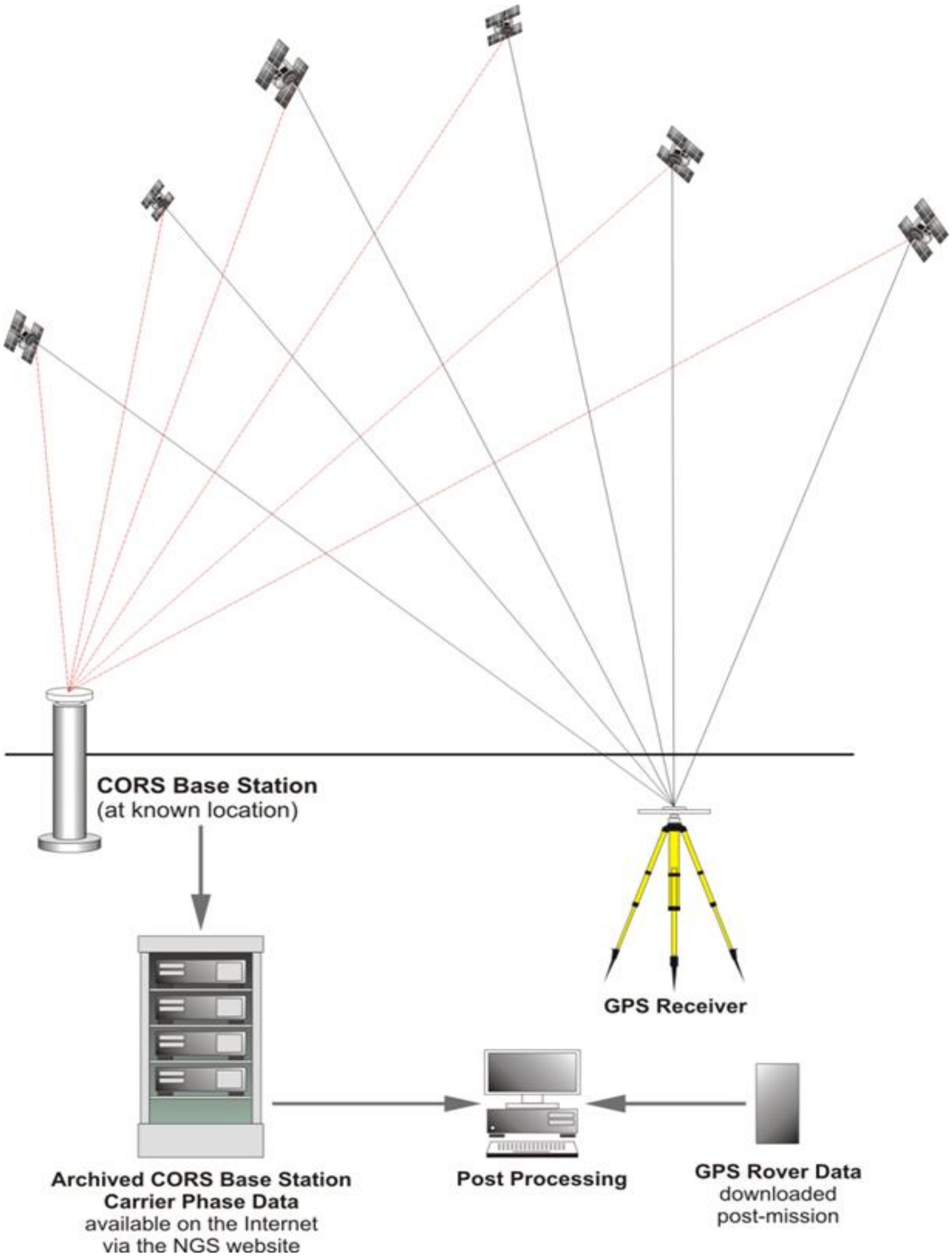


Figure 1: Static Positioning, Teunissen and Montenbruck # 1016

- ❖ The value of epoch rate in static survey must be same for all receivers during the session
- ❖ Typically, this rate is set to 15 sec to minimize the number of observations and thus the data storage requirements (Ghilani and Wolf # 369)
- ❖ Either single- or double frequency receivers may be used (NAVSTAR # 5-6)
- ❖ Most receivers either have internal memory capabilities or are connected to controllers that have internal memory for storing the observed data (Ghilani and Wolf # 370)
- ❖ After all observations are completed, data are transferred to a computer for post-processing (Ghilani and Wolf # 370)

- ❖ Accuracies with static positioning are about ±3 to 5 mm + 1 ppm (Ghilani and Wolf # 370)
- ❖ Static survey techniques are used where highest degree of accuracy in required (Ghilani and Wolf # 369)
- ❖ For example; precise control and geodetic surveying (NAVSTAR # 5-6)
- ❖ Apart from establishing control networks, it is used in control densification, measuring plate movement in crustal dynamics and oil rig monitoring (Schoffield # 339)

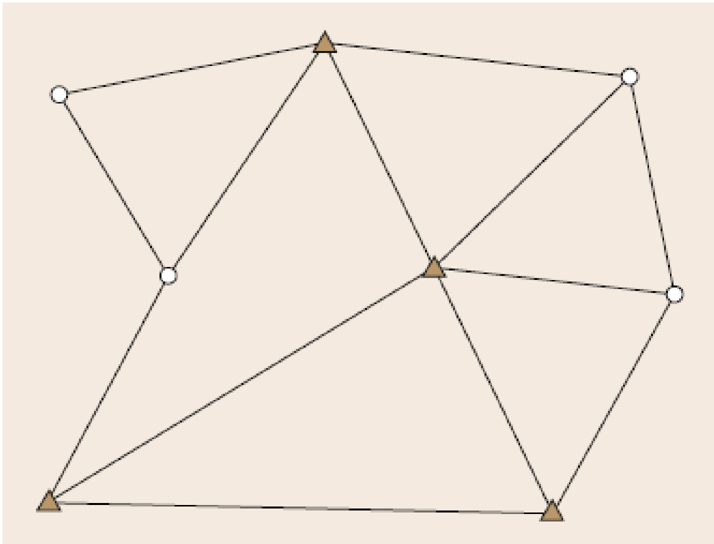
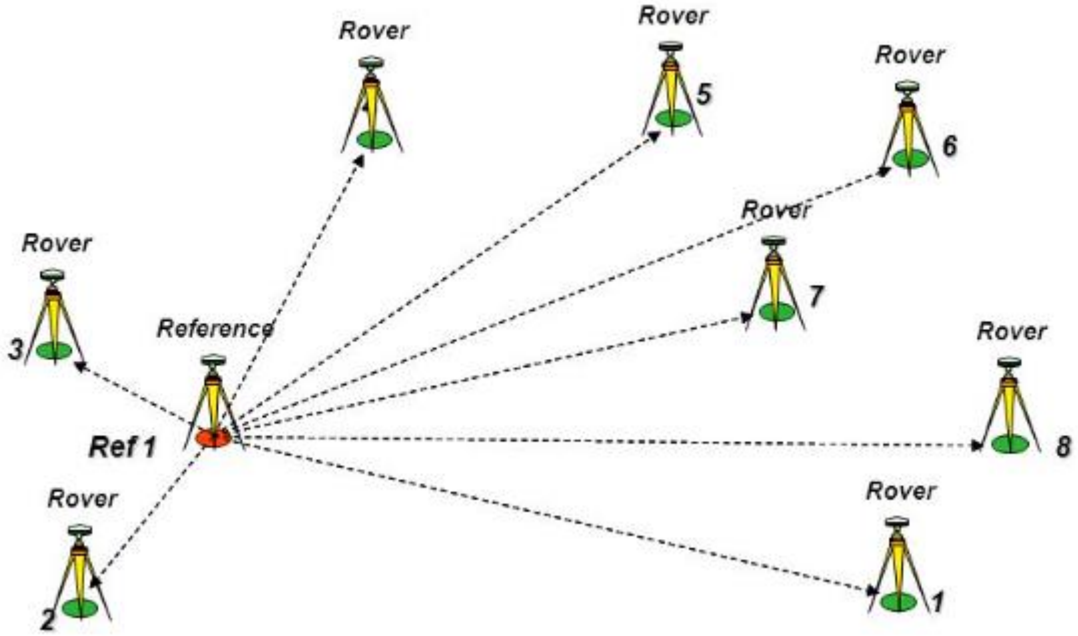


Figure 2: Network of coordinated points for static survey, source: Teunissen and Montenbruck # 1016

6.3 Rapid Static Positioning

- ❖ This technique is similar to static surveying, except that one receiver always remains on a control station while the others are moved progressively from one unknown point to the next (Ghilani and Wolf # 371)
- ❖ An observing session is conducted for each point, but the sessions are shorter than for the static method (Ghilani and Wolf # 371)
- ❖ The master or base receiver is set up on a reference point and continuously tracks all visible satellites throughout the duration of the survey (Schoffield # 339)
- ❖ The roving receiver visits each of the points to be surveyed, but stops for just a few minutes, typically 2 to 10 minutes (Schoffield # 339)
- ❖ Using difference algorithms, the integer ambiguity terms are quickly resolved and position relative to the reference point, obtained in sub-centimeter accuracy (Schoffield # 339)
- ❖ Each point is treated independently and as it is not necessary to maintain lock on the satellites, the roving receiver may be switched off whilst travelling between stations (Schoffield # 339)
- ❖ Apart from saving in power, the necessity to maintain lock, which is very troublesome in urban surveys is removed (Schoffield # 339)
- ❖ This method is accurate and economical where there are many points to be surveyed (Schoffield # 339)
- ❖ Rapid static positioning can yield accuracies on the order of about ±3 to 5 mm + 1 ppm, i.e., the same as static positioning (Ghilani and Wolf # 371)
- ❖ However, to achieve these accuracies, optimal satellite configurations (good DOP) and favourable ionospheric conditions must exist (Ghilani and Wolf # 371)
- ❖ As with static surveys, all receivers should be set to collect data at the same epoch rate of 2-10 sec, typically 5 sec with this method (Ghilani and Wolf # 371)

- ❖ It is ideally suited for short baselines where systematic errors (such as atmospheric, orbital, etc.) may be regarded as equal at all points and so differenced out (Schoffield # 339)
- ❖ Can be used for baselines upto 20 km in length under good observation conditions (Ghilani and Wolf # 371)
- ❖ In such a case, it may require to have longer observation periods due to the erratic behaviour of the ionosphere (Schoffield # 339)
- ❖ If observations are carried out at night when the ionosphere is more stable, observing times may be reduced (Schoffield # 339)



- ❖ Rapid static surveying is ideal for many engineering surveys and is halfway between static and kinematic procedures (Schoffield # 339)
- ❖ Ideal for small control surveys (Ghilani and Wolf # 371)
- ❖ As in static survey, either single or dual frequency receivers can be used (Ghilani and Wolf # 371)

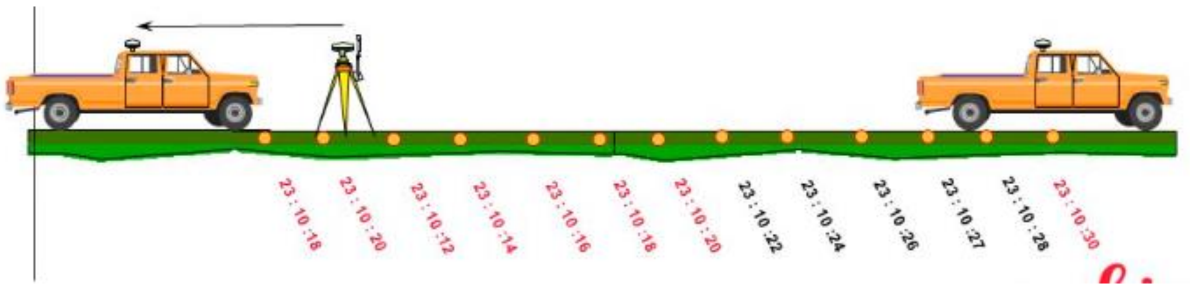
6.4 Pseudo-kinematic Survey

- ❖ Also known as the intermittent or reoccupation method and like previous static methods requires a minimum of two receivers (Ghilani and Wolf # 371)
- ❖ Base receiver always stays on a control station, while the rover goes to each point of unknown position (Ghilani and Wolf # 371)
- ❖ 2 relatively short observation sessions (around 5 to 10 min each in duration) are conducted with the rover on each station (Ghilani and Wolf # 371)
- ❖ After one or two hours, the roving receiver returns to the first unknown point and repeats the survey (Schoffield # 339)
- ❖ This produces an increase in the geometric strength of the observations due to the change in satellite geometry that occurs over the time period which is useful to resolve the integer ambiguities (Schoffield # 339, Ghilani and Wolf # 371)
- ❖ Accuracies approach those of static surveying (Ghilani and Wolf # 371)
- ❖ Using dual frequency receiver, the results are comparable with the rapid static technique (Schoffield # 339)

- ❖ Due to the method of changing the receiver/satellite geometry, it can be used with cheaper single frequency receivers (although extended measuring times are recommended) and a poorer satellite constellation (Schoffield # 339)
- ❖ A disadvantage of this method, compared to other static methods is the need to revisit the stations (Ghilani and Wolf # 371)
- ❖ Furthermore this procedure requires careful presurvey planning to ensure that sufficient time is available for site revisitation, and to achieve most efficient travel plan (Ghilani and Wolf # 371)
- ❖ This kind of survey is more appropriate where the points to be surveyed are along a road, and rapid movement from one site to another can be readily accomplished (Ghilani and Wolf # 371)
- ❖ During the movement from one site to another, the receiver can be turned off, i.e., loss of satellite lock is acceptable (Ghilani and Wolf # 371, NAVSTAR # 5-6)
- ❖ Appropriate for alignment surveys, photo-control surveys, lower order control surveys and mining surveys (Ghilani and Wolf # 371)
- ❖ Given the speed and accuracy of kinematic surveys, however, this survey procedure is seldom used in practice (Ghilani and Wolf # 371)

6.5 Kinematic Survey

- ❖ The major problem with static surveys is the time required for an appreciable change in the satellite/receiver geometry so that the initial integer ambiguities can be resolved (Schoffield # 340)
- ❖ However, if the integer ambiguities could be resolved (and constrained in a least squares solution) prior to the survey, then single epoch of data would be sufficient to obtain relative positioning to sub-centimetre accuracy (Schoffield # 340)
- ❖ This concept is the basis of kinematic survey (Schoffield # 340)
- ❖ In kinematic survey, a reference receiver is set up at a known station and as the name suggest, a rover traverses between the unknown points to be positioned, stopping briefly at the unknown points, or it can be in continuous motion as in aircraft, moving vehicles, boats, etc. (Ghilani and Wolf # 371, NAVSTAR # 5-6)
- ❖ The data is collected and processed (either in real-time of post-time) to obtain accurate positions to the centimetre level (NAVSTAR # 5-6)
- ❖ However, this method requires initialization to resolve the carrier phase ambiguities (NAVSTAR # 5-6)
- ❖ Once the initialization is completed, it is necessary to keep lock on these satellites whilst moving the antenna (Schoffield # 340)
- ❖ As the movement is continuous, the observations take place at pre-set time interval, often less than 1 sec (Schoffield # 340)
- ❖ Lock must be maintained to at least four satellites, or re-established when lock is lost (Schoffield # 340)



- In this technique, the trajectory (path) of the rover is surveyed and points are surveyed by time rather than position (Schoffield # 340)
- Hence linear detail such as roads, rivers, railways, etc., can be rapidly surveyed (Schoffield # 340)
- Antenna can be fitted to fast moving vehicles, or even bicycles, which can be driven along a road or path to obtain a 3D profile (Schoffield # 340)
- This is the most productive survey methods, but it is also the least accurate (Ghilani and Wolf # 371)
- The accuracy of a kinematic survey is typically in the range of ±1 to 2 cm + 2 ppm (Ghilani and Wolf # 371)
- This accuracy is sufficient for many types of surveys and thus is the most common method of surveying (Ghilani and Wolf # 371)
- Applicable for many type of survey that requires many points to be located, which makes it very appropriate for most topographic and construction surveys (Ghilani and Wolf # 371)
- It is also excellent for dynamic surveying, that is, where the rover station is in motion (Ghilani and Wolf # 371)
- The baseline length in a kinematic survey is limited to the broadcast range of the base radio (Ghilani and Wolf # 372)

6.6 Semi-kinematic Survey

- Also known as stop-and-go kinematic survey – characterized by alternatively stopping and moving the roving receiver to determine the positions of fixed points along the trajectory (Wellenhof # 142)
- The most important feature of this method is the increase in accuracy when several measurement epochs of the stop locations are accumulated and averaged (Wellenhof # 142, NAVSTAR # 5-6)
- This techniques is often referred to as simply kinematic survey (NAVSTAR # 5-6)
- Relative positional accuracies at eh centimetre level can be achieved for baselines upto 20 km (NAVSTAR # 5-6)
- The focus is on the stop points rather than the trajectory route, so data is collected only at those points (Schoffield # 340)
- Since multiple epochs of data are recorded at each point, the accuracy of this method is usually greater than that of kinematic mode
- After the period of initialization, satellite lock must be maintained though the data observed when moving is not necessarily recorded (Schoffield # 340, NAVSTAR # 5-6)
- If loss of satellite lock does occur, a new period of initialization must take place (NAVSTAR # 5-6)
- Can be performed with two fixed or known stations in order to provide redundancy and improve accuracy (NAVSTAR # 5-6)
- Ideal for construction and topographic surveys where increased accuracy is desired (Ghilani # 405, Schoffield # 340)

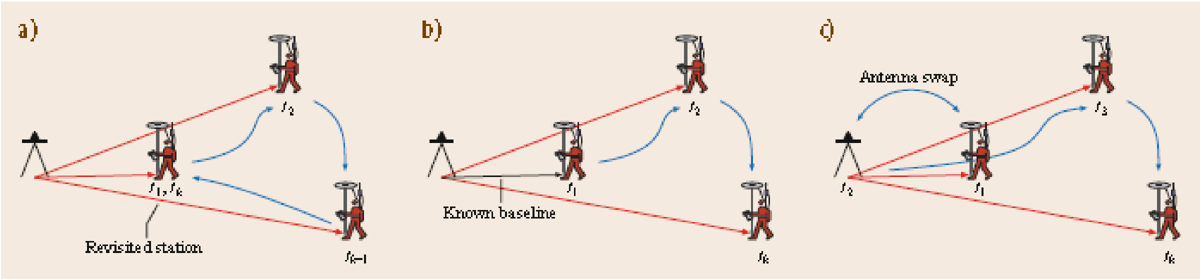


Figure 3: Semi-kinematic relative positioning strategies: (a) with revisiting of stations; (b) starting from a known baseline; (c) with antenna swap, source: Teunissen and Montenbruck

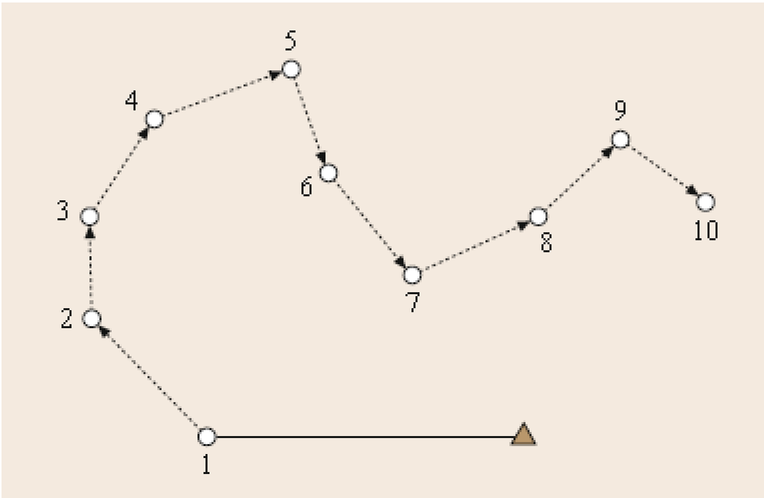


Figure 4: Progress of a stop-&-go GNSS survey, source: Teunissen and Montenbruck # 1019

6.7 Real-time Kinematic (RTK) Survey

- Provides relative position instantaneously (Schoffield # 340)
- Use of mobile data communication between base and rovers (Schoffield # 340)
- Lock to minimum number of satellites to be maintained (Schoffield # 340)
- Avoid working close to major obstructions (Schoffield # 340)
- Can be single of dual frequency receivers (Schoffield # 340)
- When lock is lost it can be regained by remaining static for short period of time over a point (Schoffield # 340)
- Advantage for engineering surveyors – used for setting out on site (Schoffield # 340)
- Application in construction, reference BM for land surveyors and robotic guidance (Schoffield # 340)
- Epoch rate 0.2 sec – typically 1 sec (Ghilani and Wolf # 405)

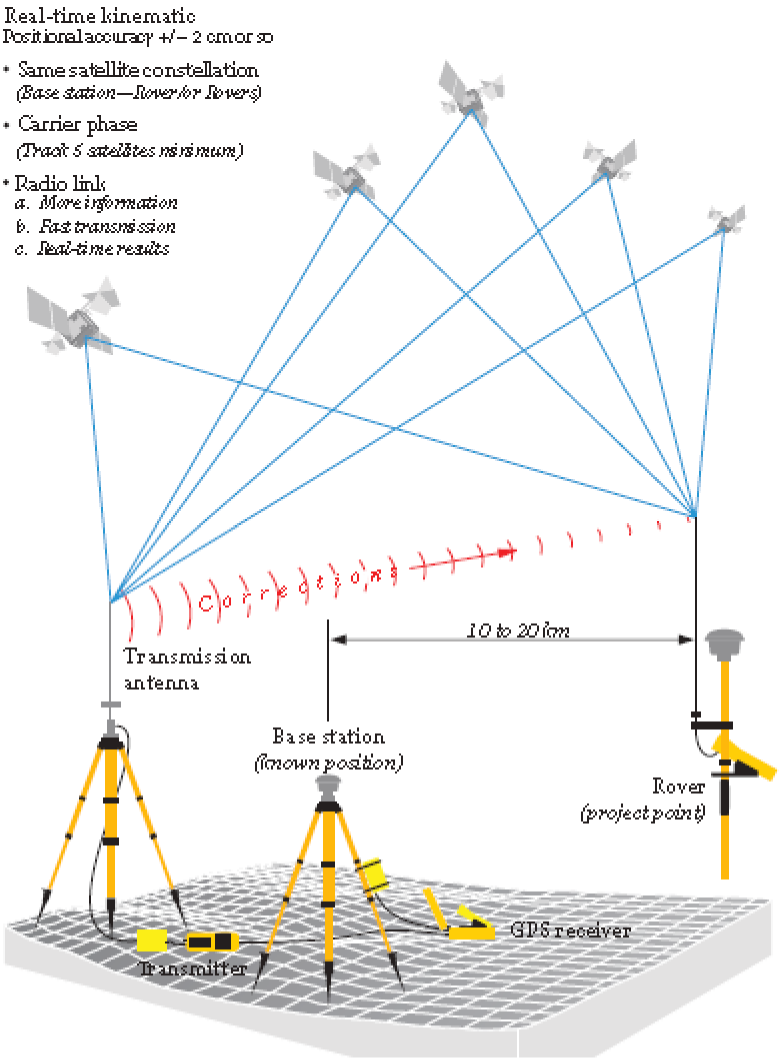


Figure 5: Real-time Kinematic Survey, GPS for Land Surveyors, Van Sickle # 248