Chapter 5
Summary, Conclusions and Recommendations

5.1 Summary

This thesis concerns with the geometrical factors which affect the accuracy of the GPS real time kinematics technique in order to get an accurate position determination using this technique of observation and to get accuracies comparable or nearly comparable with the static technique accuracy.

The geometrical factors of the study are: the cut off angle, the satellite altitudes, the number of base stations, the inter visibility between the base and the rover, the data transmission frequency from the base to the rover, the number of observations (number of Epochs), the number of satellites, the distance between the base and the rover and the azimuth of the base line.

To achieve the target of this research actual observations were made on about 26 points in two sample areas as following:

- 14 new points were selected and fixed in area number (1) of about 3 km in Masaken Sheratoon area at different distances, azimuths, levels and inter visibility …etc. from a known base station.

- Static observations were done for these new 14 points for about 1.5: 2 hours for each point, then the data were processed, adjusted and tabulated to get its final adjusted coordinates to be the reference with which RTK measurements can be compared.

- The study was made in the form of WGS84 coordinate system to neglect any influence may be caused by using any transformation parameters.

- The study was made for all RTK measurements using a wooden tripod not a pole to neglect any influence may be caused due to errors in centering and leveling.

- 4 dual frequency GPS receivers were used in the RTK and Static observations and 4 Satelline data link radios of 0.5 watt output power were used in the RTK measurements.

- Each factor was studied separately by fixing the other factors during measurements to neglect their effect on the measurements and data analysis.

- RTK observations were made in order to study the influence of each factor on the obtained accuracy by changing the values of each factor according to planed steps.

- All the results were listed in tables and represented in graphs as seen in chapter 4 through sections from 4-1 to 4-7 for the first 6 factors of the study.

- In order to study the influence of the distance between the base and the rover as well as the influence of the base line azimuth on the RTK results a new sample area number (2) was selected on an open area on the ring road with longitudinal shape in both east west and north south directions.

- A new point called BS2 was selected to be on the intersection of the two main east west and north south roads. Then, 12 new points was selected and fixed on the 2 roads at distances from about 300m to about 4700m (6 points on each direction).

- Static observations were done for the all 12 points for 1: 1.5 hours. Then, the data were processed, adjusted and had been listed in tables to be the reference with which the RTK measurements can be compared.

- RTK measurements were made in order to study the influence of each factor from the 2 factors on the obtained accuracy by changing the values of each factor according to planed steps.

- 2 dual frequency GPS receivers were used in the RTK and Static observations and 2 Satelline data link radios of 1 watt output power were used in the RTK measurements.

- All the results were listed in tables and represented in graphs as seen in chapter 4 through sections from (4-8) to (4-10).

5.2 Conclusions

The general conclusion which could be drawn from this study is that the accuracy of the Real Time Kinematics technique of observation can be improved if one takes into account some geometrical considerations. From the experiments and results represented in chapter 4 the following conclusions can be drawn:

1- It is clear from section (4-2) that the influence of the cut off angle values is clearly noticed as the accuracy was improved when increasing the cut off angle value but under condition that we still have sufficient number of satellites at good constellation. The best cut off angle that can be used is the maximum cut off angle value at which minimum 6 satellites at good constellation can be observed.

2- The number of base stations used in real time kinematics observations has a noticed effect on the obtained accuracy. It has been shown in section (4-3) from tables (4-10) and (4-11) and from figures (4-9) and (4-10) that the accuracy obtained using real time kinematics technique is improved when increasing the number of base stations which transmit correction to the RTK rover. Note that this improvement is expected to be to a certain level then it will be stopped.

3- The great effect of the inter visibility between the RTK base and the RTK rover can be noticed clearly in chapter 4 section (4-4) from tables (4-12),(4-13),(4-14) and (4-15) and from figures (4-12),(4-13) and (4-14). It can be noticed that the best accuracy obtained at the

rover points which have clear intervisibility with the used base station. For the rover points which have more obstructions such as solid big buildings between the point and the base station the accuracies obtained were so bad. The reason of the bad accuracy obtained through big obstructions refers to the radio signal characteristics as the successful radio transmission depends essentially on the radio field. Where the field strength is over a certain level the operational results are very good. Below this level, low field strength marginal areas may occur in which errors begin to be generated by noise and interference which will lead to loss of connection or cause a delay in the received corrections as a result of the multi path occurred. Whilst in an open space, the field strength is at its optimum level, although it will still be reduced by distance. Rough topography and buildings cause multi path and of course cause loss of energy through absorption and reflection of radio waves which cause a noise and delay in the data received by the rover which lead to bad accuracy.

4- The influence of the data transmission frequency can be clearly noticed from section (4-5). From tables (4-16) and (4-17) and from figures (4-15) and (4-16) it can be noticed that the best accuracies for RTK observations were obtained when using data transmission frequencies less than the observation rates of the rover. When using data transmission frequency equal or greater than the observation rates of the rover the obtained accuracies were worse.

5- The number of observations (number of epochs) effect in RTK observations is shown in section (4-6) from table (4-18) and figure

(4-17). The obtained accuracy is improved when increasing the number of observations to 30 epochs and more. The obtained accuracy is improved by increasing the number of observations.

6- It is clear from section (4-7) and from tables (4-19) and (4-20) and from figures (4-18) and (4-19) that the number of the observed satellites has an effect on the obtained real time kinematics observations. The obtained accuracy was improved when more than six satellites were observed in good satellite constellation as it appears from the corresponding obtained DOP values. The obtained was decreased when less than six satellites were observed in bad satellite constellation as it appears from the corresponding obtained DOP values. Increasing the number of satellites from 4,5,6,7, to 8 satellites improve the obtained accuracy.

7- The influence of the distance between the Base and the Rover (Base line length) can be clearly noticed in section (4-9) from tables (4-23) and (4-24) and from figures (4-22) and (4-23). Increasing the distance between the base and the rover caused decreasing in the obtained accuracy. The reason of the bad accuracy obtained through big distances refers to the radio signal characteristics as the successful radio transmission depends essentially on the radio field. Where the field strength is over a certain level the operational results are very good. Below this level, a low field strength marginal area may occur in which errors begin to be generated by noise and interference which will lead to loss of connection or cause a delay in the received corrections as a result of big distance although in open space as the field strength is reduced by distance increasing.

8- In section (4-10) from table (4-25) and figure (4-24) it can be noticed that the accuracies obtained from the group of points taking the north south direction is better than the accuracy obtained from the group of points which take the east west direction. The reason may be that the majority of the GPS satellites paths in the open sky on Egypt are directed to be in the north south direction nearly to be parallel to the base lines in that north south direction.

5.3 Recommendations

From the above conclusions the following recommendations could be drawn in order to get accurate position determination using the real time kinematics technique.

1- The best cut off angle can be used is the maximum cut off angle value at which minimum 6 satellites at good constellation can be observed.

2- It is better to use more than one reference station if possible and the rover can work in more accurate way in between.

3- The position of the base station(s) should be in the highest positions in the area wanted to be surveyed and it is preferred to be 100% intervisible with the all rover positions.

4- The used data transmission frequency between the base station and the rover must be the fastest as possible

5- It is recommended to take much more epochs ; at least 50 or 60 epochs should be observed using wooden tripod in static mode for control points observations if high accuracy is needed following the new "real time static technique".

6- The maximum possible number of satellites with good constellations is recommended to be used. So, the chosen positions for both the base and the rover should be in open sky positions or using modern receivers which have the ability to receive signals form more than one satellite constellation such as GPS and GLONASS. Also, Galileo and Compass constellations can be used in the future within the next two years.

7- It is recommended that not to work in real time at the maximum distance of the used radio data link where a low field strength marginal area may be exist.

8- It is preferred that to choose the position of the base station used as reference in real time kinematics technique to be in the north or the south of the area wanted to be surveyed in order to get the maximum of the base lines in the north south direction.

9- The recommendations for future studies are to study real time kinematics using GSM for maximum RTK range when this technology became permissible and to restudy the case again in the future using the coming new satellite constellations such as Galileo and Compass and the coming GPS new signal L5.