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Integration And Calibration Factor By Practical Comparison Of GPS And Total Station Measurements In Sudan

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Abstract: There is some rate of distortion in the projected plane coordinates obtained by GPS. The coordinates obtained using terrestrial devices such as Total Station depends on the direct angular observations and distances measurements on the surface of the earth assumed as plane surface. Using different observation systems (terrestrial survey and GPS survey) yields discrepancies in the obtained results for the same location due to the variation of the observation sources and the technology used by each system. The discrepancy that exists in the measured results must be removed to obtain conformity of them by deriving *scale factor* which is the main objective of this study. This paper covers the procedure of integration between the Electronic Total Station and the Global Positioning System (GPS) and their use in surveying engineering projects. In this paper the author used Total Station and the Global Positioning System (GPS) commonly using observations of common points with the two systems (Total Station and the GPS receivers) to get the horizontal position difference and the scale factor between the Total Station and the GPS coordinates. The results showed that the difference as a distant scale factor for the considered area in Sudan is typical to the published international scale factor.

Keywords: *GPS, Total station, Scale factor, Pseudo-range, DGPS-RTK.*

1. INTRODUCTION

The theodolite was developed in the 16th century and the modern Total Station Theodolite is its latest incarnation. On a Total Station the angles and distance to surveyed points are recorded digitally and in this way the Total Station locates each point measured relative to itself. As the data are captured digitally, they can readily be passed to a computer with software designed to calculate the *x*, *y* and *z* coordinates of each point and to present the survey as a 2-dimensional (2-D) or 3-dimensional (3-D) drawing. The Total Station is perfectly capable of delivering highly accurate surveys in almost any terrain but is now used increasingly in combination with survey-grade satellite receivers. Satellite receivers fix positions using information broadcast by constellations of navigation satellites, most commonly those forming the American Global Positioning System (GPS) and Russian Global Orbiting Navigation Satellite System (GLONASS). These and other constellations of navigational satellites are known collectively as Global Navigation Satellite Systems (GNSS) although GPS is commonly used as the standard generic term (Ainsworth and Thomason 2003). The use of GPS receivers is entirely dependent upon the strength and quality of satellite reception and usually also on the maintenance of a radio or mobile phone link to a base receiver. Satellite receivers therefore may not work in some locations, such as steep-sided valleys, among trees or close to buildings. In such environments the Total Station is the best alternative choice of survey instrument. Well-established procedures exist to adjust and integrate the readings taken from different Total Station positions (called stations) during a survey and position the survey accurately on existing base mapping. For positioning purpose it is no doubt useful to integrate between GPS and Total Station. The GPS coordinates are geodetic in the positioning system, the goal is to determine the scale actor between GPS and Total Station using common point measurements.

2. LITERATURE REVIEW

2.1Total Stations

Total Stations are an efficient and accurate way of measuring angles and distances. These powerful instruments are capable of making calculations during a survey and of producing X, Y, Z coordinates of points shot during the survey. Total Stations are an extremely efficient way of obtaining accurate locations of artifacts and datum points in an engineering survey. These units are able to correct prism contact distances and to notify the user if the unit becomes unleveled during use or if the prism moves out of range. To obtain accurate results and avoid systematic errors, however, the Total Station must be set up correctly by the user. On a Total Station the angles and distance to surveyed points are recorded digitally and in this way the Total Station locates each point measured relative to itself. As the data are captured digitally, they can readily be passed to a computer with software designed to calculate the x, y and z coordinates of each point and to present the survey as a 2-dimensional (2-D) or 3-dimensional (3-D) drawing [2]. When working with a Total Station, it is useful to understand the basic principles of how it works and the way these affect working practices. Total Stations are considerably more expensive than more traditional measuring tools, such as optical theodolites and plane tables with alidades, but in return they offer considerably more precision and flexibility. Rapid and precise measurement using a Total Station gives a reliable framework for survey work of many kinds. A Total Station enables survey at orders of precision commensurate with both detail (eg 1:20–1:500) and wider area (1:1000 and smaller) scales. Arial photogrammetry, light detection and

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ranging (lidar) and GPS, used singly or in combination, are more cost-effective for such tasks. The Total Station is perfectly capable of delivering highly accurate surveys in almost any terrain but is now used increasingly in combination with survey-grade satellite receivers. Satellite receivers fix positions using information broadcast by constellations of navigation satellites, most commonly those forming the American Global Positioning System (GPS) and Russian Global Orbiting Navigation Satellite System (GLONASS). These and other constellations of navigational satellites are known collectively as global navigation satellite systems (GNSS) although GPS is commonly used as the standard generic term [4].

2.2 The Global Positioning System (GPS)

The introduction of the Global Positioning System (GPS) Satellite navigation system promised to give the instantaneous positioning capability to the navigation community. After all GPS is designed to provide accurate navigation World – Wide, 24 hours a day. But the meaning of accurate to the navigation crowd is quite different to what is considered accurate to land surveyor, but if you are surveying a subdivision that is considered a gross error, at best. The use of GPS receivers is entirely dependent upon the strength and quality of satellite reception and usually also on the maintenance of a radio or mobile phone link to a base receiver. Satellite receivers therefore may not work in some locations, such as steep-sided valleys, among trees or close to buildings [1]. In such environments the Total Station is the best alternative choice of survey instrument. Well-established procedures exist to adjust and integrate the readings taken from different systems [4].

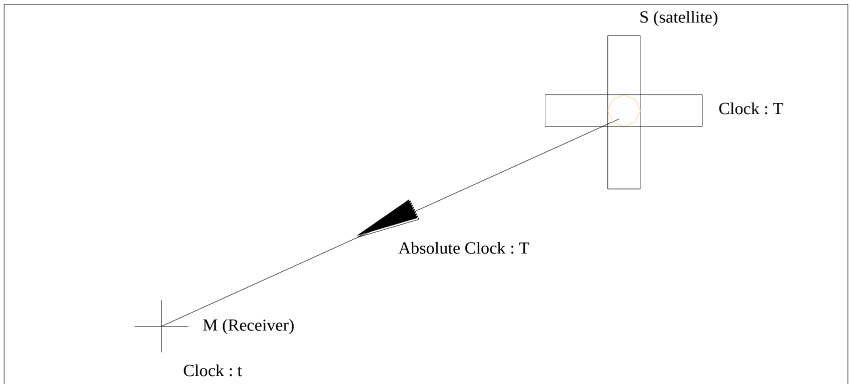

Fig. 2.1: The pseudorange observation.

2.2.1 The GPS Real Time system

Through a great deal of survey measurements research has focused on the use of GPS and, subsequently, many breakthroughs have been made. Centimeter and even millimeter level accuracy became common place. Now, GPS Differential Real Time Kinematic, surveying gives us the capability walk from point to point and see where they are while they are moving. Using both GPS radio-modem technology, GPS Differential Real Time Kinematic produces the exact coordinate of the point while you are occupying it. That means that you can survey points by simply walking to them. But, more than that, if you can get accurate coordinates at any time during the survey, you can use that information to guide you where you need to be. In sense, GPD Differential Real Time Kinematic lets you accurately navigate to traverse points, as well as survey them. Sometimes, than you imagined possible. The specialist survey teams in the Research Departments have used Total Stations as part of their survey toolkit for many years [1].

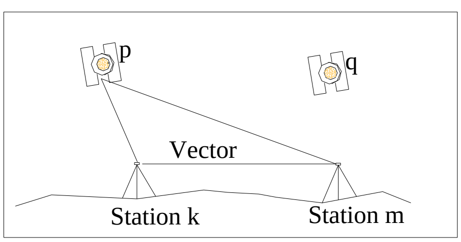

Fig.2.2: The sigle difference, two receivers observe the same satellite at the same epoch.

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3. THE FIELD DATA OBSERVED

The data of this research were collected from the field observation covering the area of Karary academy of technology in Sudan at Khartoum state , located around the station with coordinates (E(32.5273 degrees), N (15.7760 degrees)) with in UTM zone 36, and the area of Kjbar in the Northern Sudan with coordinate (E(30.5572 degrees), N (19.9558 degrees)) with in the same UTM zone (zone 36). Through the field observation the points considered (in each of the two areas) were observed using the Total station and the Differential Global Positioning System (DGPS) Real Time Kinematic (RTK) observation procedure. Then commonly the same points of the two areas were observed by Sokia-Total Station Model 2010 and Topcon-Total Station (Topcon-33N), having common coordinates observed by the two systems (Total Station and DGPS-RTK). Selection of GPS receivers and Total Stations was based on the reasonable and suitable accuracy requested for small area covering an engineering project (scheme) which traversing small area. Figure 3.1 has been showing the GPS traverse distances, where the distances observed by total station represented by the external lines of the traverse (see fig. 3.1). Table 1 and 2 were showing the three dimensional coordinates measured at the area of Karary Academy of Technology with DGPS-RTK receivers and Total Stations respectively, also table 3 was explaining horizontal distances measured by DGPS-RTK receivers and Total Stations respectively at Kjbar .

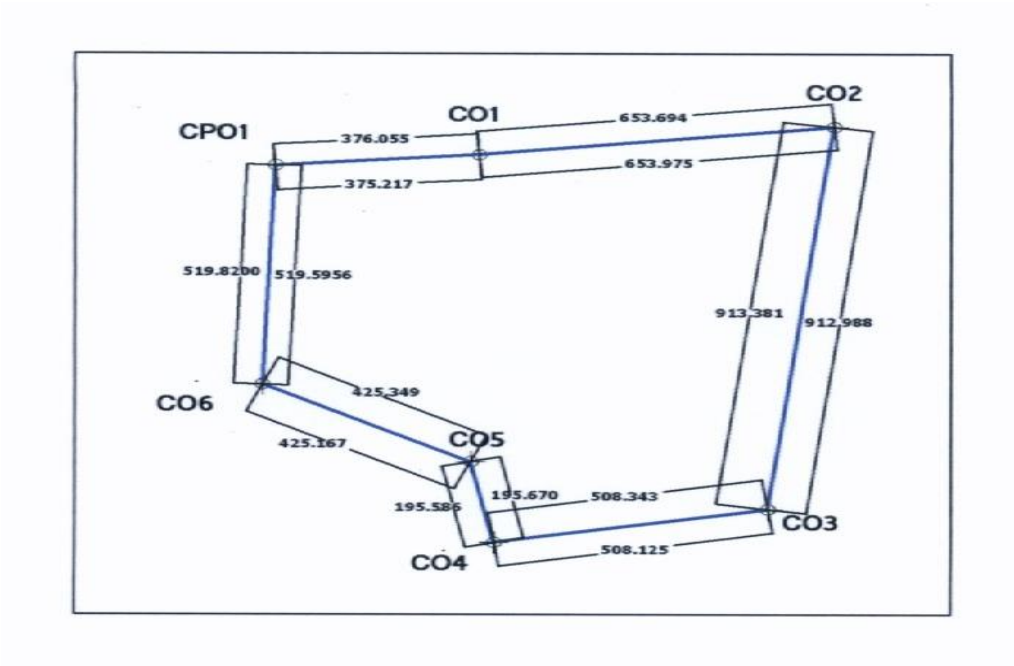

Fig.3. 1: Total Station and GPS common points traverse

Table (1): The observed DGPS-Real Time Three dimensional coordinates at Karary.

Pt. Name	East	North	Elevation
CP1	448968.383	1745112.284	399.369
C1	449342.791	1745136.907	391.630
C2	449993.449	1745202.687	388.990
C3	449872.443	1744297.356	384.739
C4	449370.200	1744218.844	388.334
C5	449327.978	1744409.904	385.609
C6	448944.501	1744593.934	388.886

Table (2): Total Station Three dimensional coordinates at Karary.

Pt. Name	East	North	Elevation
CP1	448968.383	1745112.284	399.369
C1	449342.630	1745136.897	391.461
C2	449993.009	1745202.649	388.823
C3	449872.059	1744297.708	384.573
C4	449370.031	1744219.230	388.167
C5	449327.827	1744410.208	385.443
C6	448944.513	1744594.158	388.719

Table (3): Comparison of the horizontal distances at Kjbar measured by DGPS-RTK and Total Station

From-to	*Total Station distances meters*	GPS distances in meters	Differences in meters
K2 –k3	361.244	361.384	0.140
K2 – K4	236.420	236.502	0.072
K2– K5	267.926	268.025	0.063
K1– K6	135.813	135.839	0.026
K1– K5	233.829	233.941	0.112
K1– K4	429.661	429.823	0.162

3.1 The published equations for the scale factors computation

Equation (1) below is the proposed formula to determine the point scale factor for many surveying applications.

$$\text{Point scale factor} = 0.9996 + 1.23\,(E-500000)^2 x10^{-14}$$

E is eastern coordinates of the point. ………………... (1)

The scale factor of the height in equation (2) below has to be applied on the measured distant after applying the error correction of the instrument and the slope .

$$\text{Height Factor} = 1 - (\text{Mean Height} \times 0.1571 \times 10^{-10})\ldots\ldots\ldots(2)$$

Most of the surveying applications use the combined point scale factor on the distanced measured East – West and the height scale factor (for geoid undulations) as follows (equation 3) .

Combined Scale Factor = Point Scale Factor x Height Factor…(3)

3.2 Data observed and their results at the area of Karay Academy of Technology:

The results of the common observation with the DGPS-RTK andTotal Station at the area of Karay Academy of Technology were shown in table 1 and 2. The horizontal distances which were measured by DGPS were abbreviated by Dg and those which were observed by Total Station were abbreviated by Dt, then the difference between the two measurements is equal to Dg-Dt .The difference in the measurements of the two systems (Total station and DGPS) were clearly shown in table 4. The comparison of the horizontal distances and their computed calibration factor (using DGPS-RTK and Total Station) at Karary academy of technology were explained in table 5.

Table (4): Computed horizontal distant using DGPS and Total Station observed coordinates and their distances difference.

From	to	*Total Station(Dt) Distance(m)*	*DGPS(Dg)* Distance (m)	(Dg – Dt) meters
CP1	C1	375.055	375.217	0.162
C1	C2	653.694	653.975	0.281
C2	C3	912.988	913.381	0.393
C3	C4	508.125	508.343	0.218
C4	C5	195.670	195.754	0.084
C5	C6	425.167	425.349	0.182

Table (5): Comparison of the horizontal distances and their computed calibration factor at Karary measured by DGPS-RTK and Total Station

From-to	*Total Station* / *GPS*	Scale factor
CP1-C1	375.055	0.999568249
	375.217	
C1-C2	653.694	0.999570320
	653.975	
C2-C3	912.988	0.999569730
	913.381	
C3-C4	508.125	0.999571150
	508.343	
C4-C5	195.586	0.999571155
	195.670	
C5-C6	425.167	0.999572116

Table (6): The theoretical and published horizontal scale factor and the practically computed one

From-to	Field observation scale factor	Theoretical and published scale factor	Difference between field and theoretical scale factor
CP1-C1	0.99956849	0.99956941	-0.00000092
C1-C2	0.99957032	0.99957016	0.00000016
C2-C3	0.99956973	0.99956976	-0.00000003
C3-C4	0.99957115	0.99957058	0.00000057
C4-C5	0.99957115	0.99957064	0.00000051
C5-C6	0.99957212	0.99957112	0.00000100

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3.3 Data observed and their results at the area of Kjbar dam:

The area of Kjbar dam was selected as an study area of this research because of the following reasons:

a) There were already common points measured by the considered two systems (DGPS and Total Station) that was during the period of preparing maps for the studying mission and collecting data for modeling designs of the dam, (until this time dam is not executed).

b) The measured difference of the common coordinates between the measurements of the two systems considered as a technical problem between the contractor and the(Sudan) Dam Implementation Unit (DIU) because the calibration factor between the two systems was not known at that time.

c) The location of Kjbar sight relative to the Central Meridian ((C.M.) of zone 36) which in a different location than the area of Karary.

The differences of the measured distances using DGPS and Total Station were shown in table 7. The published and computed scale factors having the Total station over DGPS measurements were explained in table 8.

Table (7): The differences of the measured distances of Total Station and DGPS at Kjbar

From-to	Horizontal distance with *Total station(m)*	Horizontal distance *DGPS(m)*	Difference in meters
K2-K3	361.244	361.384	0.140
K2-K4	236.420	236.502	0.082
K2-K5	267.926	268.025	0.099
K1-K6	135.813	135.839	0.026
K1-K5	233.829	233.941	0.112
K1-K4	429.661	429.823	0.162

Table (8): Published (theoretical) and practically (field measurements) computed DGPS and Total Station scale factor at Kjbar

From-to	Horizontal distance with *Total station(m)*	Horizontal distance *DGPS(m)*	Field measurements *Scale Factor*	Theoretical scale factor	Difference between the two scale factors
K2-K3	361.244	361.384	0.9996348	0.9996337	0.0000011
K2-K4	236.420	236.502	0.9996364	0.9996337	0.0000027
K2-K5	267.926	268.025	0.9996264	0.9996337	-0.0000073
K1-K6	135.813	135.839	0.9996393	0.9996346	0.0000047
K1-K5	233.829	233.941	0.9996348	0.9996346	0.0000002
K1-K4	429.661	429.823	0.9996347	0.9996346	0.0000001

4. RESULTS ANALYSIS

The results of the horizontal distant comparison of the two systems was shown in table 5 and 6 respectively. It was shown that the scale factor of the horizontal distant at Krary area (which is near Central Meridian of the UTM zone 36 is equal to 0.99957 (see table 5 and 6). Table 7 shows the horizontal distance measured in the area of Kjbar by the Total Station (Topcon -33N)also the same table shows the distances measured by DGPS Real Time Kinematic (DGPS-RTK) (by Trimble base 5700 and rover 5800) ,then the differences measured by the two systems (Total Station and DGPS – RTK)were shown in the same table. The calibration scale factor of Total station GPS for Karary and Kjbar areas were determined using equations (1,2and3), the results were shown in table 6 and 8, so that they are the same as the practically computed results determined dividing the difference between the two systems by the actual whole distance.

5. CONCLUSION AND RECOMMONDATION

It is concluded that the practically determined scale factors using the comparison of the distances observed on the points Commonly measured by the two systems (Total Station and DGPS-RTK) and the scale factor computed theoretically using the published equations is very small tending to zero and could be neglected. Then it is no doubt

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useful to recommend each one of the two (the scale factor determined by the equations or the scale factor determined by the practical measurements) scale factors.

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