

THE USE OF GPS FOR DETERMINING A TRUE NORTH BEARING FOR MEASUREMENT OF MAGNETIC DECLINATION

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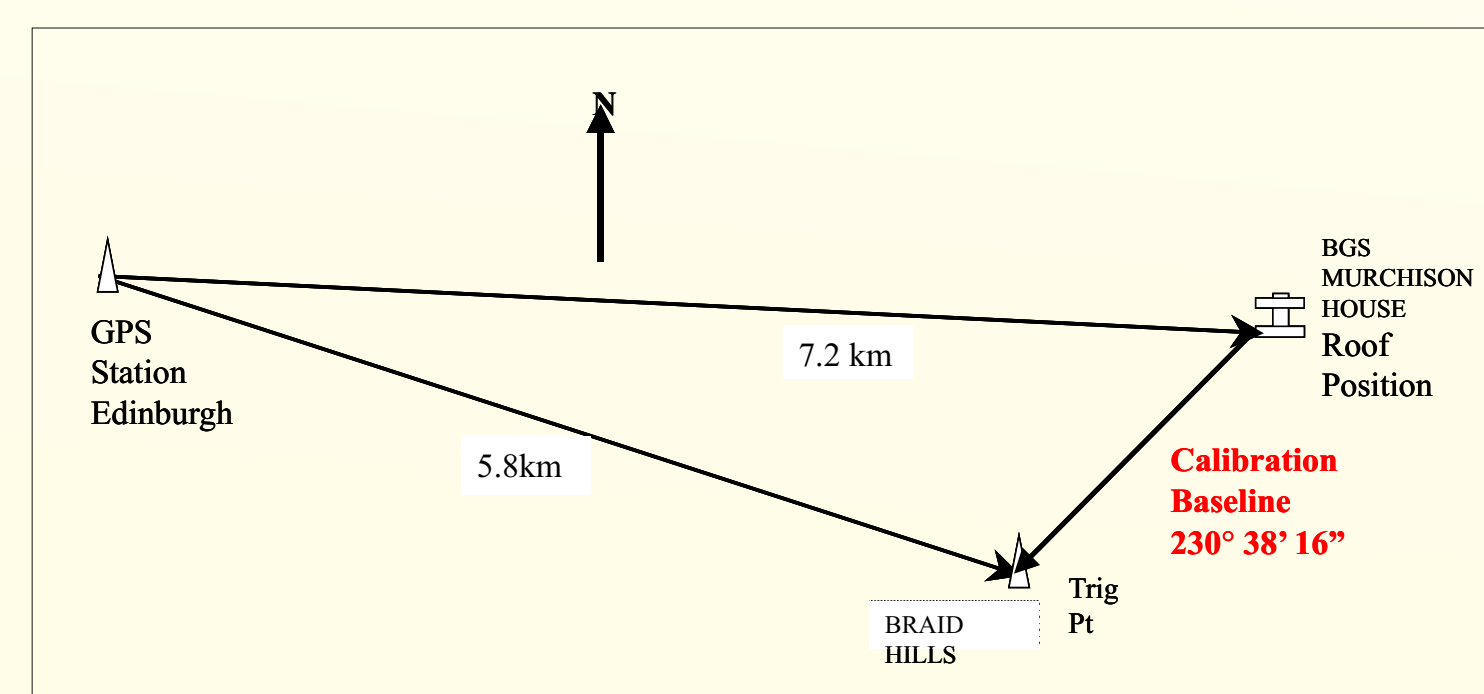


When two GPS receivers are placed some distance apart and positional data are logged simultaneously using the same satellite combinations errors common to both receivers are eliminated and it is thus possible to obtain very accurate relative positional accuracy. This technique of differential GPS processing allows computation of an accurate true bearing between the two receivers. If the bearing of one receiver position from the other is then used as an azimuth reference then a true bearing for magnetic declination (D) measurements is obtained. This technique is examined using different types of GPS receivers, ranging in sophistication, practicality and price, from survey grade receivers to basic handheld units. The use of GPS networks is also examined which enable measurement of true bearing using only one receiver.

GPS Overview

A GPS receiver obtains its position by measuring the transit times of signals transmitted from at least 4 satellites whose orbital paths are precisely known. Each satellite has a very accurate atomic clock on board which is used to generate the satellite signals at a fundamental frequency of 10.23 Mhz. The satellites broadcast two carrier waves: the L1 carrier at 1575.42 MHz (10.23×154); and the L2 carrier at 1227.60 MHz (10.23×120). Modulated on these two carrier frequencies (the carrier phase) are much lower frequency codes referred to as code phase which is a pseudo-random code used for matching satellite and receiver signals for measurement of range. This code also contains information about the satellite, including an accurate position. A wide range in the sophistication of GPS receivers is available depending on how they utilise the GPS signals. Basic GPS receivers such as handheld receivers which are often used for recreational purposes use the code phase of the signal. However, as this has a relatively large period the results can be in error by several metres. More sophisticated survey grade receivers achieve much greater positional accuracy ($< 10 \text{ cm}$) by using the carrier phase which has a frequency 1000 times greater than code phase and a wavelength of just a few cms. Also survey grade receivers can be dual frequency, receiving both carrier frequencies, thus making estimates about the refraction effects of the atmosphere. A technique called Differential GPS involves twin receivers tracking the same satellites with one receiver installed at an accurately known position and the apparent location error used to obtain an accurate position for the other receiver, thus accounting for any error which is common to both receivers. This can be done in real time with corrections being transmitted from the base to the remote receiver or it can be done by post-processing data.

The Edinburgh Calibration Baseline

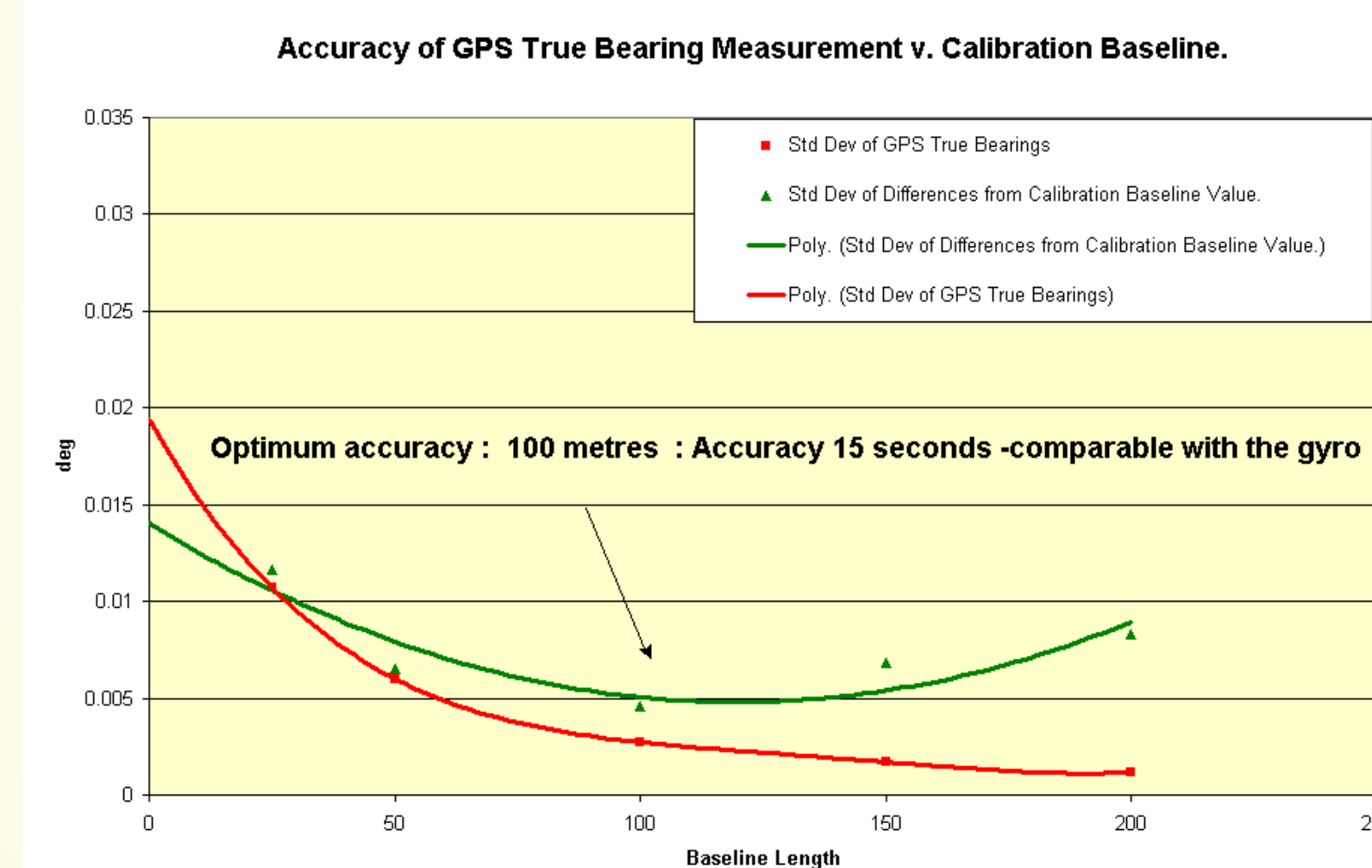
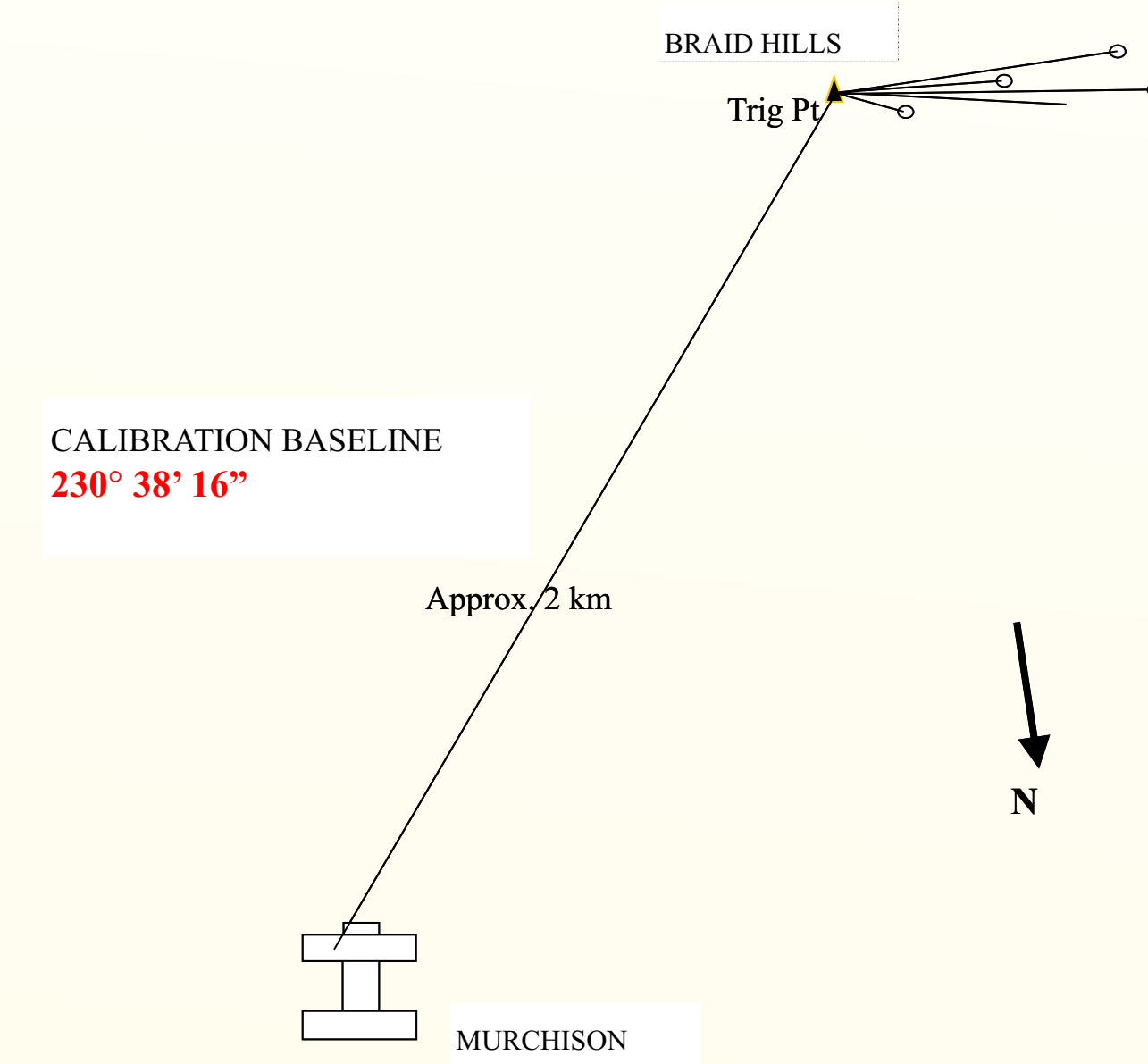


In addition to an existing calibration baseline at Eskdalemuir Observatory, a second baseline was established at British Geological Survey offices in Edinburgh. The baseline azimuth was obtained by two independent measuring systems. Firstly, twin Leica 500 GPS receivers were used at each end of the baseline which is approximately 2 km in length to obtain a true azimuth. The relative positional accuracy over this distance provides an azimuth accurate to within 1 arc second. A permanent GPS reference station operated by the national mapping station in Edinburgh was used to provide accurate absolute positional values and as a means of checking the azimuth. The baseline azimuth was also measured using a Wild GAK-1 gyro-theodolite. This baseline is then used as a reference for testing all GPS equipment and for checking gyro-theodolites.



The Leica GPS 530 System

This system represents the top of the range in survey grade GPS and consists of a pair of dual frequency, carrier phase receivers which has a specified positional accuracy of 5-50 mm. One of the receivers is set up on the calibration baseline; the other receiver is set up about 25 metres away. The receivers are operated in differential mode with data being logged simultaneously for ten minutes on each receiver. The lack of obstructions in the area ensures that each receiver can track at least the same four satellites. The data are then post-processed using Leica's Ski-Pro software. Ten minutes of data seems to be sufficient for the software to resolve ambiguities in the number of carrier phase wavelengths from each satellite. Data processing results in high relative positional accuracy and a true azimuth from the base to the remote receiver is calculated. The base receiver is then removed and replaced with the Carl Zeiss theodolite. Great care was taken to ensure that the theodolite was placed in exactly the same position as the GPS receiver. The results from the GPS are then compared with the known baseline value. The test was repeated several times on a 25-metre baseline length. These tests were then duplicated but baseline lengths were increased to 50m, then 100m, 150m, and 200m. During the tests each receiver was monitored to check that the number of satellites and the satellite positional geometry was sufficient to give reliable results.



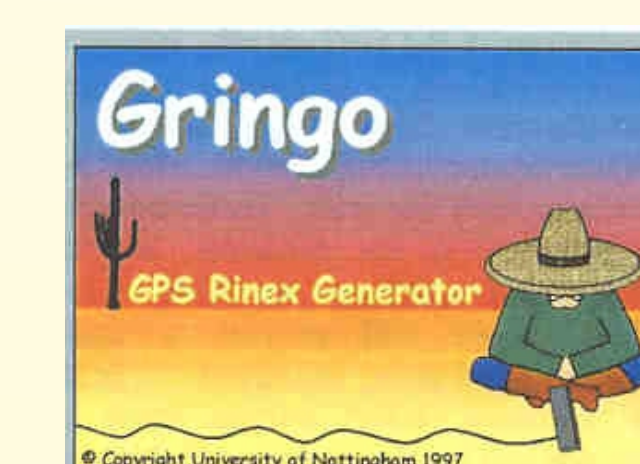
The results show that, as would be expected, as the distance between receivers increases, the standard deviation in values is reduced. The rate of improvement is small at separations greater than 50 metres. When the results are compared to the known calibration baseline value, the accuracy improves up to an optimum at just over 100 metres. Accuracy seems to degrade at lengths greater than this which may be due to difficulty sighting on the remote antenna over larger distances. From the results it can be seen that over a baseline of 100 metres a true bearing azimuth can be obtained to an accuracy of less than 20 arc seconds. This is close to the accuracy of the north seeking gyro method and sun observations. The cost of the Leica GPS 530 system may be in the order of € 50000 for twin receivers. However dual frequency receivers are not essential for this application since the baseline lengths required are very short. It is sufficient to use single frequency receivers which are available at approximately a fifth of the cost of dual frequency receivers. Tests made with a single frequency system verified that accuracy is not reduced over such short baseline lengths although longer observation periods may be required.

The Garmin GPS II

This is a relatively basic handheld receiver which is most often used for recreational purposes. In normal use this has a positional accuracy of only about 10 metres. However through the use of special data acquisition software the accuracy can be improved to 100 mm. The GARMIN GPS II was tested on the Edinburgh calibration baseline with data logged to a laptop PC using special software developed by the University of Nottingham's Institute of Engineering Surveying and Space Geodesy (IESSG). This software is called the GPS RINEX generator (GRINGO) which stores data from the GARMIN GPS II in the standard RINEX format.



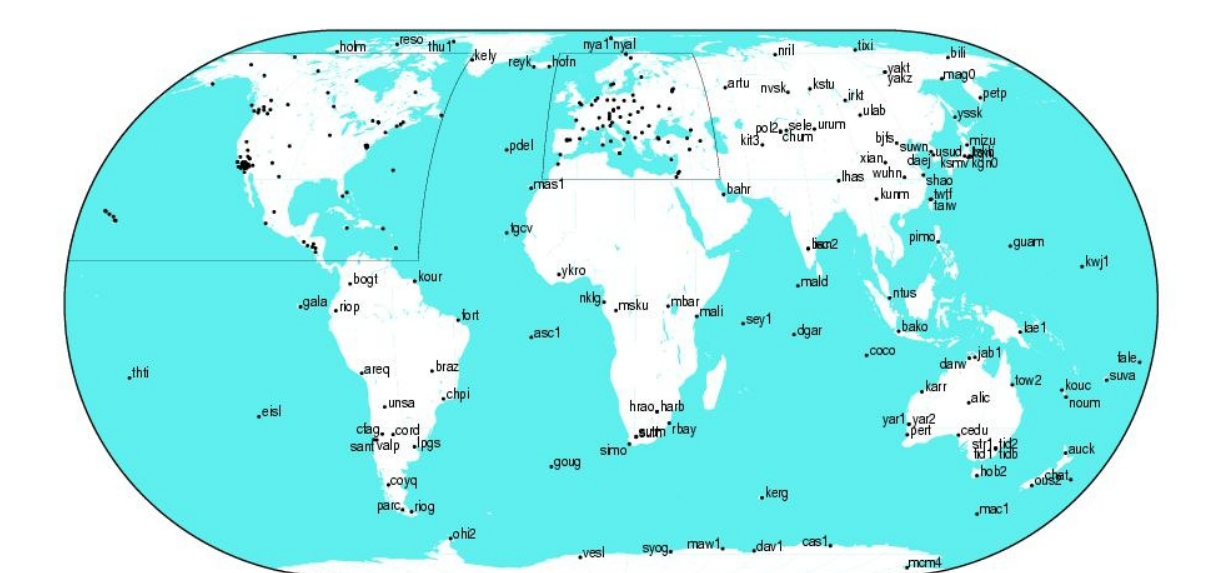
In normal operation the GARMIN GPS II receiver uses the code phase of satellite signals to establish the ranges to satellites which results in a positional accuracy of approximately ten metres. The IESSG have deciphered undocumented GARMIN protocols which consist of the raw code phase and carrier phase measurements. The raw carrier phase data is used to reduce the error in the code phase pseudoranges. When this data is post-processed differentially with RINEX data from the permanent GPS station, a positional accuracy of 0.1 m or better is obtained. The accuracy of this system was checked by setting up the Garmin precisely over the positions on either end of the Edinburgh calibration baseline. Data were logged for one hour and then post-processed with the Edinburgh GPS station data using Leica's Ski-Pro software. The optimum statistical solution provided by this software is able to resolve carrier phase ambiguities if the data are of sufficient quality. If the ambiguities are unresolved the software resorts to other solutions so a position is always obtained. The results of these tests confirm the positional accuracy of about 0.1m quoted by the IESSG. This would require a baseline length of 486 metres or longer to obtain a true bearing accurate to 1 arc minute.



Institute of Engineering Surveying and Space Geodesy, University of Nottingham.
GRINGO GPS RINEX Generator
Web Site:-
<http://www.nottingham.ac.uk/iessg>

GPS Networks

The Edinburgh GPS station is part of a nationwide GPS network operated by the national mapping agency, the Ordnance Survey. Similar networks are available nationally and internationally throughout the globe. Data is often available free of charge and in Receiver Independent Exchange Format (RINEX) allowing for differential processing from a range of different receivers. It should be noted that when using GPS, as observation time and accuracy are mainly a function of baseline length, then baseline lengths and observation times should be maximised whenever possible.



IGS (Global network):- <http://igsb.jpl.nasa.gov/index.html>
EUREF (European network):- <http://epncb.oma.be/>
CORS (US territories):- <http://www.ngs.noaa.gov/CORS/>

Conclusion

The use of GPS provides accurate and practical methods for obtaining a true bearing to the required accuracies. The disadvantage over other methods is that a good clear view of the sky in all directions is required. Out of eleven repeat station visits made by the Geomagnetism section of BGS in 2001, it was not possible to use GPS for this purpose at three of these sites due to adjacent trees. GPS is a continually developing technology which has great potential for the future. Ever improving accuracy of receivers, falling costs, and further GPS constellations make consideration of this technology for geomagnetic surveying applications essential.