Re: NEW GPS with the best sensitivity of antenna!!!

Source: http://sci.tech−archive.net/Archive/sci.geo.satellite−nav/2005−02/0378.html

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From: Sam Wormley (*swormley1_at_mchsi.com*)
Date: 02/05/05

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Date: Sat, 05 Feb 2005 23:34:11 GMT
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Kravets Igor wrote:
> *I have head that under tree cover after rain GPS doesn't work. Which GPS has*
> *the best sensitivity? :(*
>
> *After reading several reviews I came to conclusion that the best sensetivity*
> *of its antenna has Lowrance, than Magellan Sportrak Pro (C), than Garmin*
> *60C, than Garmin 76C and finally Garmin eTrex....*
>
> *IS IT GOOD? Please help me... Which GPS has the best sensitivity?*
>
> *THANKS*
>
>

More sensitivity might not be the answer because of wet tree cover
increased multipath...

See: GPS Evaluation: West Coast Test Site
http://www.fs.fed.us/database/gps/mtdc/96712341/index.htm

http://www.trimble.com:80/products/pd_gi.htm

My purpose in this posting is to raise the awareness of canopy and
it's resulting attenuation, multipath and obstruction on the performance
of GPS positioning, especially as it applies to trail mapping.

Most authors, including the ones cited below, categorize GPS ranging
errors into two broad categories, the signal source and propagation
path, and the receiver. But inherent in any accuracy estimation is also
the geometry of the satellites being used with respect to receiver
position, and any interference in the reception of those signals such
as attenuation, blockage, and RFI.

Moisture in canopy effects both attenuation and multipath. Because there
is not a convenient way to measure the effects of multipath, most folks
just ignor it, but it is probably the dominant error source under canopy.

Ref: http://www.oc.nps.navy.mil/~jclynch/gpsbtoc.html

"Global Positioning System: Theory and Applications", Volume I

B. Parkinson, J. Spilker Editors.
American Institute of Aeronautics and Astronautics, Washington, DC
1996, ISBN 1−56347−106−X

Chapter
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> 14. Multipath Effects 547 − 568 M. Braasch 9 Figs. 3 Refs.
> 15. Foliage Attenuation for Land Mobile Users 569 − 583
J. Spilker 11 Figs. 14 Refs.

First paragraph of Chapter 15 of the reference above, "Foliage Attenuation for Land Mobile Users", by J.J. Spilker Jr.:

"Land mobile users are expected to be one of the largest categories of GPS users, and it is important to examine specific GPS propagation issues for this environment. It has already been shown that the optimum geometric dilution of precision (GDOP) is provided when several of the GPS satellites are at low elevation angle near the horizon. However, the land mobile user environment differs from that of aircraft in flight or ships at sea in that the users driving along a road or freeway [or hiking in the woods] is often subject to shadowing, diffraction, ans scattering of the satellite signal by trees, utility poles, buildings, or hills. These effects are accentuated by the need for operation a low elevation angles for at least some of the GPS satellites. In addition, the requirement for receiver simplicity, and the need to track several satellites widely spaced in angle simultaneously, generally dictates the use of an omni− directional or hemispherical antenna. Thus, while receiving the direct line−of−sight ray from the satellite, the user has little means to discriminate against multipath signals scattered from ground reflections, tree limbs and foliage, or other scattering elements. In addition, the direct ray may itself be attenuated by tree foliage".

No matter what quality of L1 C/A receiver, an HDOP (B) that is twice as great as HDOP (A) will result in increasing a probability error circle (ellipse) by about a factor of two. If a certain specified level of accuracy is required for a particular purpose, careful attention must be paid to the potential obstacles to achieving that level of accuracy.

The following is adapted from Chapter 11, "GPS Error Analysis", pages 478−483, Global Positioning System: Theory and Applications by Bradford W. Parkinson, James J. Spilker Jr. Eds.

A. Six Classes of Errors

Ranging errors are grouped into the six following classes:
1) Ephemeris data−−Errors in the transmitted location of the
satellite
2) Satellite clock−−Errors in the transmitted clock, including SA
3) Ionosphere−−Errors in the corrections of pseudorange caused by
ionospheric effects
4) Troposphere−−Errors in the corrections of pseudorange caused by
tropospheric effects
5) Multipath−−Errors caused by reflected signals entering the receiver
antenna
6) Receiver−−Errors in the receiver's measurement of range caused by
thermal noise, software accuracy, and interchannel biases

Each class is briefly discussed in the following sections. Representative values for these errors are used to construct an error table in a later section of this chapter. A more complete discussion of individual error sources can be found in succeeding chapters.

B. Ephemeris Errors

Ephemeris errors result when the GPS message does not transmit the correct satellite location. It is typical that the radial component of this error is the smallest: the tangential and cross−track errors may be larger by an order of magnitude. Fortunately, the larger components do not affect ranging accuracy to the same degree. This can be seen in the fundamental error Eq. (12). The AW represents each satellite position error, but when dot−multiplied by the unit satellite direction vector (in the A matrix), only the projection of satellite positioning error along the line of sight creates a ranging error.

Because satellite errors reflect a position prediction, they tend to grow with time from the last control station upload. It is possible that a portion of the deliberate SA error is added to the ephemeris as well. However, the predictions are long smooth arcs, so all errors in the ephemeris tend to be slowly changing with time. Therefore, their utility in SA is quite limited.

As reported during phase one, (Bowen, 1986) in 1984,[5] for predictions of up to 24 hours, the rms ranging error attributable to ephemeris was 2.1 m. These errors were closely correlated with the satellite clock, as we would expect. Note that these errors are the same for both the P− and C/A−codes (see Chapter 16 of this volume for a more detailed discussion of ephemeris and clock errors).

C. Satellite Clock Errors

Fundamental to GPS is the one−way ranging that ultimately depends on satellite clock predictability. These satellite clock errors affect both the C/A− and P−code users in the same way. The error effect can be seen in the fundamental error Eq. (11) as delta−B. This effect is also independent of satellite direction, which is important when the technique of differential corrections is used. All differential stations and users measure an identical satellite clock error.

A major source of apparent clock error is SA, which is varied so as to be unpredictable over periods longer than about 10 minutes. The rms value of SA is typically about 20 m in ranging, but this can change after providing appropriate notice, depending on need. The U.S. Air Force has guaranteed that the twodimensional rms (2 DRMS) positioning error (approximately 90th percentile) will be kept to less than 100 m. This is now a matter of U.S. federal policy and can only be changed by order of the President of the United States. [Note that SA was removed May 2, 2000 @4:05 UTC.]

More interesting is the underlying accuracy of the system with SA off. The ability to predict clock behavior is a measure of clock quality. GPS uses atomic clocks (cesium and rubidium oscillators),' which have stabilities of about I part in 10E13 over a day. If a clock can be predicted to this accuracy, its error in a day (~10E5 s) will be about 10E−8 s or about 3.5 m. The experience reported in 1984 was 4.1 m for 24−hour predictions. Because the standard deviations of these errors were reported to grow quadratically with time, an average error of 1−2 m for 12−hour updates is the normal expectation.

D. Ionosphere Errors

Because of free electrons in the ionosphere, GPS signals do not travel at the vacuum speed of light as they transit this region. The modulation on the signal is delayed in proportion to the number of free electrons encountered and is also (to first order) proportional to the inverse of the carrier frequency squared (1/f squared). The phase of the radio frequency carrier is advanced by the same amount because of these effects. Carrier−smoothed receivers should take this into account in the design of their filters. The ionosphere is usually reasonably well−behaved and stable in the temperate zones; near the equator or magnetic poles it can fluctuate considerably. An in−depth discussion of this can be found in Chapter 12, this volume.

All users will correct the raw pseudoranges for the ionospheric delay. The simplest correction will use an internal diurnal model of these delays. The parameters can be updated using information in the GPS communications message (although the accuracy of these updates is not yet clearly established). The effective accuracy of this modeling is about 2−5 m in ranging for users in the temperate Zones.

A second technique for dual−frequency P−code receivers is to measure the signal at both frequencies and directly solve for the delay. The difference between L1 and L2 arrival times allows a direct algebraic solution. This dual−frequency technique should provide 1−2 m of ranging accuracy, due to the ionosphere, for a well−calibrated receiver.

A third technique is to rely on a near real−time update. An example would be the proposed Wide Area Differential GPS system (WADGPS). This should also produce corrections with accuracies of 1−2 m or better in the temperate zones of the world.

E. Troposphere Errors

Another deviation from the vacuum speed of light is caused by the troposphere. Variations in temperature, pressure, and humidity all contribute to variations in the speed of light of radio waves. Both the code and carrier will have the same delays. This is described further in the chapter devoted to these effects, Chapter 13 of this volume. For most users and circumstances, a simple model should be effectively accurate to about 1 m or better.

F. Multipath Errors

Multipath is the error caused by reflected signals entering the front end of the receiver and masking the real correlation peak. These effects tend to be more pronounced in a static receiver near large reflecting surfaces, where 15 m in or more in ranging error can be found in extreme cases. Monitor or reference stations require special care in siting to avoid unacceptable errors. The first line of defense is to use the combination of antenna cut−off angle and antenna location that minimizes this problem. A second approach is to use so−called "narrow correlator, receivers which tend to minimize the impact of multipath on range tracking accuracies. With proper siting and antenna selection, the net impact to a moving user should be less than 1 m under most circumstances. See Chapter 14 of this volume for further discussion of multipath errors.

G. Receiver Errors

Initially most GPS commercial receivers were sequential in that one or two tracking channels shared the burden of locking on to four or more satellites. With modem chip technology, it is common to place three or more tracking channels on a single inexpensive chip. As the size and cost have shrunk, techniques have improved and five− or six−channel receivers are common. Most modem receivers use reconstructed carrier to aid the code tracking loops. This produces a precision of better than 0.3 m. Interchannel bias is minimized with digital sampling and all−digital designs.

The limited precision of the receiver software also contributed to errors in earlier designs, which relied on 8−bit microprocessors. With ranges to the satellites of over 20 million meters, a precision of 1:10E10 or better was required. Modem microprocessors now provide such precision along with the co−requisite calculation speeds. The net result is that the receiver should contribute less than 0.5 ms error in bias and less than 0.2 m in noise. Further information on receiver errors is available in Chapters 3, 7, 8, and 9 of this volume.

V. Standard Error Tables

These overview discussions on error sources and magnitudes, as well as the effects of satellite geometry, can be summarized with the following error tables. Each error is described as a bias (persistence of minutes or more) and a random effect that is, in effect "white" noise and exhibits little correlation between samples of range. The total error in each category is found as the root sum square (rss) of these two components.

Each component of error is assumed to be statistically uncorrelated with all others, so they are combined as an rss as well. The receiver is assumed to filter the measurements so that about 16 samples are effectively averaged reducing the random content by the square root of 16. Of course, averaging cannot improve the bias−type errors.

Finally, each satellite error is assumed to be uncorrelated and of zero mean, so the application of HDOP and VDOP are justified as the last step. Despite these limiting assumptions, the resulting error model has proved to be surprisingly valid. Of course, the assumptions on uncorrelated errors is almost always violated to some degree. For example, if the estimate of zenith ionosphere delay is in error, a proportional error is induced in all measurements through the obliquity calculation. Clearly, such an error would be correlated. These and other correlations have not caused serious problems in the use of this model.

A. Error Table without SA: Normal Operation for C/A Code

Table 2 assumes that SA is not operating. Consequently, the residual satellite clock error, at 2.1 m, is not the dominant error; in fact, the largest error is expected to be the mismodeling of the ionosphere, at 4.0 m. Thus, the worldwide civilian positioning error for GPS is potentially about 10 m (horizontal), as shown in Table 2.

B. Error Table with SA

A second example shows the impact of SA on these errors. Because the deliberately mismodeled clock so dominates the ranging error, all other effects could be safely ignored in the error budget. The results of Table 3 have been repeatedly corroborated by actual measurements. Note that SA is listed as a bias because it cannot be averaged to zero with a 1 s (or less) filter. Selective availability is expected to be zero mean, but only when averaged over many hours or perhaps days. Of course, such averaging is not practical for a dynamic user who only sees the satellite for a portion of the orbit. If differential corrections are used, they will eliminate the SA error entirely (if corrections are passed at a sufficiently high data rate) as discussed in Chapter 21, this volume.

The 41−m horizontal error is a one−sigma result; under the existing agreement between the U.S. Department of Transportation (DOT) and the

U.S. Department of Defense (DOD), the 2 DRMS horizontal error is to be less than 100 m. The impact on the vertical error is probably greater, because the VDOP value usually exceeds the HDOP value.

Table 2 Standard error model − L1 C/A (no SA)

	One−sigma error, m			
Error source	Bias	Random	Total	DGPS
Ephemeris data	2.1	0.0	2.1	0.0
Satellite clock	2.0	0.7	2.1	0.0
Ionosphere	4.0	0.5	4.0	0.4
Troposphere	0.5	0.5	0.7	0.2
Multipath	1.0	1.0	1.4	1.4
Receiver measurement	0.5	0.2	0.5	0.5
User equivalent range error (UERE), rms*	5.1	1.4	5.3	1.6
Filtered UERE, rms	5.1	0.4	5.1	1.5

Vertical one−sigma errors−−VDOP= 2.5 12.8 3.9
Horizontal one−sigma errors−−HDOP= 2.0 10.2 3.1

*This is the statistical ranging error (one−sigma) that represents the total of all contributing sources. The dominant error is usually the ionosphere. A horizontal error of 10 m (one−sigma) is the expected performance for the temperate latitudes using civilian (C/A−code) receivers.

Table 3 Standard error model − L1 C/A (with SA)

	One−sigma error, m			
Error source	Bias	Random	Total	DGPS
Ephemeris data	2.1	0.0	2.1	0.0
Satellite clock (dither)	20.0	0.7	20.0	0.0
Ionosphere	4.0	0.5	4.0	0.4
Troposphere	0.5	0.5	0.7	0.2
Multipath	1.0	1.0	1.4	1.4
Receiver measurement	0.5	0.2	0.5	0.5
User equivalent range error (UERE), rms*	20.5	1.4	20.6	1.6
Filtered UERE, rms	20.5	0.4	20.5	1.5

Vertical one−sigma errors−−VDOP= 2.5 51.4 3.9
Horizontal one−sigma errors−−HDOP= 2.0 41.1 3.1

C. Error Table for Precise Positioning Service (PPS Dual−Frequency P/Y Code)

The errors for dual−frequency PN code are similar to those above except that SA errors are eliminated because the authorized user can decode the magnitude as part of a classified message. An expected horizontal error is less than 10 m. The ionosphere error is reduced to 1−m bias and about 0.7 m of noise by the dual−frequency measurement. The dominant sources are the satellite ephemeris and clocks. This is illustrated in Table 4.

Table 4 Precise error model, dual−frequency, P(Y) code

	One−sigma error, m			
Error source	Bias	Random	Total	DGPS
Ephemeris data	2.1	0.0	2.1	0.0
Satellite clock	2.0	0.7	2.1	0.0
Ionosphere	1.0	0.5	1.2	0.1
Troposphere	0.5	0.5	0.7	0.1
Multipath	1.0	1.0	1.4	1.4
Receiver measurement	0.5	0.2	0.5	0.5
User equivalent range error (UERE), rms*	3.3	1.5	3.6	1.5
Filtered UERE, rms	3.3	0.4	3.3	1.4

Vertical one−sigma errors−−VDOP= 2.5 8.3 3.7
Horizontal one−sigma errors−−HDOP= 2.0 6.6 3.0

VI. Summary

Excluding the deliberate degradation of SA, the dominant error source for satellite ranging with single frequency receivers is usually the ionosphere. It is on the order of four meters, depending on the quality of the single−frequency model. For dual−frequency (P/Y−code) receivers (which eliminate SA) the Standard Error Model of Table I has one principal change (in addition to the elimination of the SA error). The ionospheric error is reduced from four meters to about one meter.

Greater variations in the errors are due to geometry, which are quantified as dilutions of precision or DOPs. While geometric dilutions of 2.5 are about the worldwide average, this factor can range up to 10 or more with poor satellite geometry. Reduced satellite availability (and consequent increases in DOP) could be caused by satellite outages, local teff ain masking, or user antenna tilting (for example due to aircraft banking). Typical normal accuracy (one−sigma) for welldesigned civil equipment under nominal operating conditions with SA off should be about 10 m horizontal and 13 m vertical.

References

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