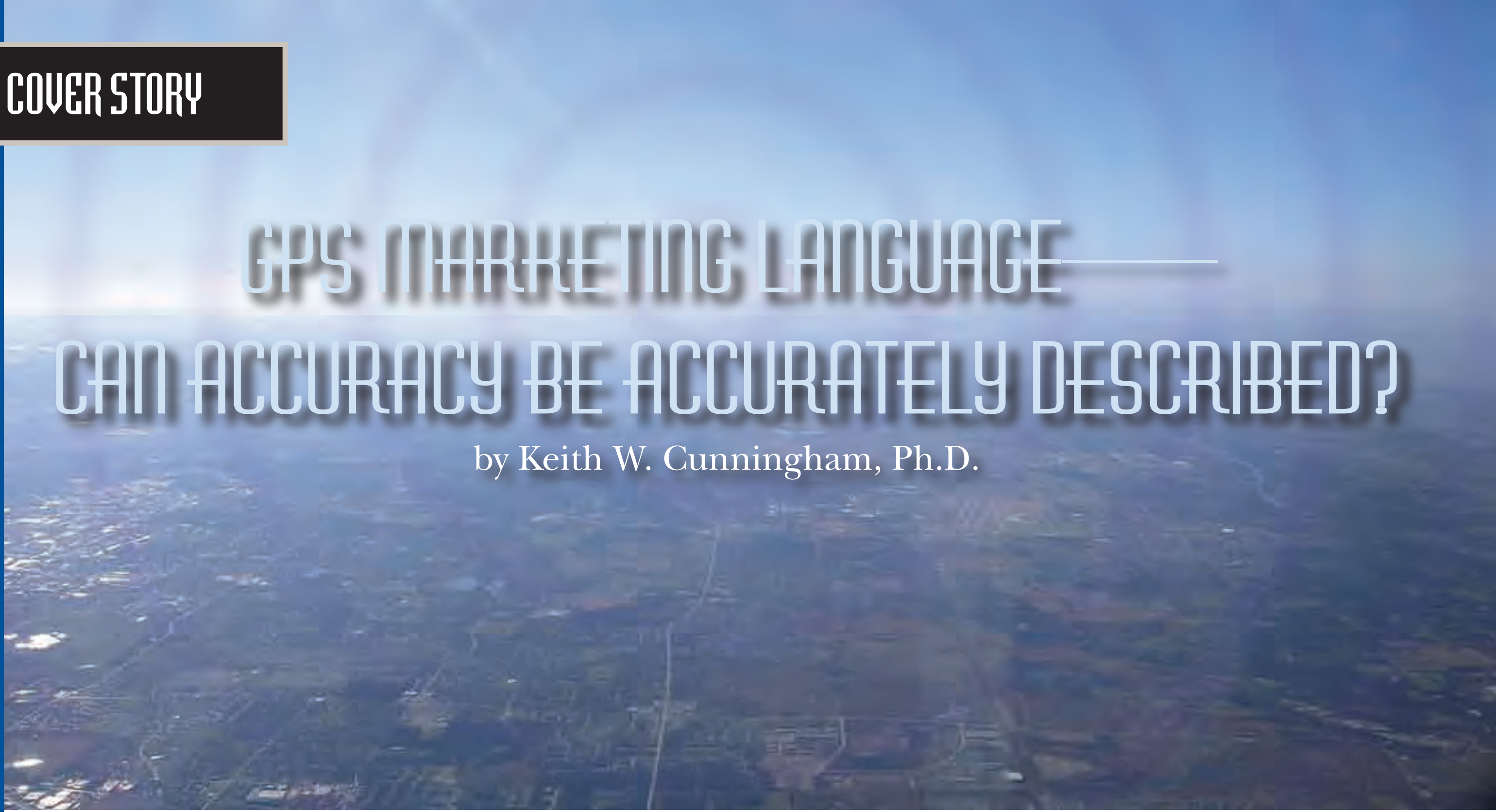

GPS Marketing Language—Can Accuracy Be Accurately Described?

by Keith W. Cunningham, Ph.D.

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As competition among global positioning system (GPS) manufacturers continues to diminish the differences between products, manufacturers have to rely more on marketing to distinguish their products. The manufacturers' goal is to influence a potential buyer to select their product over their competitors' product. To build this credibility with the customer, manufacturers produce a variety of marketing materials, such as product data sheets, advertisements, case studies, and white papers.

Manufacturers can use several approaches to distinguish their product from that of the competition. One method is to vertically segment the market by stating that the product is designed to service a special need. Another approach is to make qualitative claims; for example, the GPS receiver is easier to use, does more, provides peace of mind, is the next generation, or is high performance, rugged, waterproof, and shock-resistant.

Quantitative data are needed to buttress qualitative claims. The obvious information is price and accuracy. In the technical community of GPS users, however, manufacturers build credibility with technical data. Often a product data sheet has a full page of descriptive numbers, figures, and statistics: channels, occupation times, static accuracy, real-time kinematics (RTK) accuracy, horizontal accuracy, vertical accuracy, spatial decorrelation, battery life, time to fix, display, memory, processor speed, etc. These data appeal to an intelligent reader's logic, thus legitimizing manufacturer claims.

Precise numbers, especially with GPS receivers, are probably not a good way to obtain a clear picture of product quality. Considering the complex factors affecting the quality of a GPS position, many manufacturers have difficulty detailing these factors in the limited space of an advertisement or data sheet. Thus many important details may be omitted and only the most favorable features described. Any complexities requiring lengthy explanations may not be described, or they may be relegated to details in the footnotes.

Language

A broad industry marketing language is another problem. Depending on marketing pressures, some manufacturers take advantage of this latitude when stating their product qualities and accuracies, particularly with the use of industry-accepted terms for stating accuracy. Root-mean square (RMS) is a statistical measure of variance from a known; that is, when a GPS calculates positions that are compared to "truth," the variance of the GPS positions is expressed with statistics as standard deviation. In the first standard deviation (RMS), approximately 65% of all measurements would fall within the accuracy stated by the vendor. Thus, if a manufacturer is claiming that its receiver is submeter RMS, the customer could assume that the receiver yields submeter positions about 65% of the time. However, the other third of the time, the positions calculated by the GPS would be less accurate than a meter, some being as much as 5, 10, or possibly even 100 meters removed from the truth.

More conservative manufacturers may use 2dRMS, the second standard deviation from truth, to describe their receivers. The second standard deviation approximates 96% of the positions being calculated with the claimed accuracy and, conversely, the remaining positions worse than their claimed accuracy.

Some manufactures use slack specifications for stating GPS accuracy. When a manufacturer says the accuracy "averages" or is circular-error probable (CEP), this is an industry term for indicating the GPS positions are within the stated accuracy half of the time.

Nuances

Even if the customer compares receivers using one of these specifications, there are additional factors to be considered. First is the difference between horizontal and vertical accuracies. When a manufacturer states an indicator of accuracy, it is usually assumed to be for horizontal measurements only, because vertical measurements with GPS have another set of complexities, complicating how data are presented and how products from different manufacturers can be compared.

Another nuance in describing the accuracy of a GPS receiver is occupation time—the amount of time that a receiver needs to be stationary to collect sufficient information from the satellites to achieve the specified accuracy. Some manufacturers may state receiver accuracies as second-by-second or requiring an occupation time of 10 seconds, 60 seconds, 3 minutes, and so on.

Along with occupation time, the manufacturer may recommend other "settings" to control how the GPS receiver excludes unsatisfactory GPS data. These settings are the elevation mask, the percent dilution of position (PDOP) mask, and the signal strength mask. The term mask describes how any values outside of a specified range are not to be used by the receiver. Elevation masks generally are established to exclude the use of satellites low on the horizon, because the signals from these satellites are theoretically weaker and have more noise. The signal strength mask excludes weak satellite signals, theoretically implying that the data carried by the signal may be degraded. And the PDOP mask is the theoretical estimate of the accuracy achievable because of the arrangement of the orbiting satellites at that moment in the sky. Even though these settings affect the theoretical accuracies of the receiver, the user can still obtain both accurate and inaccurate positions.

Subtleties

There are also subtleties affecting the actual accuracy of a GPS receiver that no manufacturer can adequately describe with marketing. These subtleties are often the result of the unique environment and moment when the GPS receiver is calculating a position. In fact, the same receiver in the same place 10 minutes or 30 minutes later can easily determine that it is at a very different position because of subtle errors.

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A very well understood subtlety that affects all GPS technology is multipath. These reflections of satellite signals cause positioning errors because of the time delay of the reflected signals. Sophisticated antennas have been designed to reduce this problem. Many manufacturers also have designed firmware to "reject" satellites signals with a reversed (opposite) signal polarization. Nevertheless, these approaches have their own subtleties and still allow erroneous positions to be determined. The real world is so dynamic that a passing car or even the movement of the signalling GPS satellites in space can cause "spikes," or positioning errors, of several meters.

A more insidious subtlety that is nearly impossible for a manufacturer to describe is real-time differential corrections. When describing the GPS accuracy with real-time corrections, all the manufacturer can really do is say that these are theoretical accuracies. Theoretical accuracies with a satellite-based augmentation system (SBAS) or beacon corrections can be as accurate as submeter, but SBAS corrections are subject to the same signal propagation problems as the GPS signals. And beacon corrections are broadcast on a low-frequency ground wave that is particularly sensitive to interference from steel. Both systems can suffer signal loss due to electrical or magnetic interference, and the user may never know this is occurring. To compensate, many manufacturers allow the receiver's user to set a real time correction measure (RTCM) latency mask, allowing the receiver to not use any correction data from a source if the correction is past a certain age, usually about 60 seconds. The longer the loss of RTCM data, theoretically, the less accurate the differential corrections become.

In addition, there are external factors that degrade GPS receiver accuracy over a longer period of time and that a user and the GPS receiver may not be aware of. These factors are unusual solar activity, receiver clock bias, receiver heat noise, satellite orbital errors, and, Department of Defense-induced selective ability.

Examples

As an example of how difficult it is to directly compare GPS receiver products, data on four receivers from different vendors are provided below. All manufacturers claim submeter accuracy. All of these numbers were taken from the manufacturers' marketing materials.

It is assumed that these specifications are for an open-sky environment (no physical obstructions between the

Table. Comparison of GPS-receiver product specifications

Receiver	Min # of Sats	Max PDOP	Min SNR	Elevation Mask	Occupation time
Product A	4	6	39dbHz	15	Unavailable
Product B	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable
Product C	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable
Product D	6	3.9	Unavailable	Unavailable	Unavailable

device and satellites). The first two settings, minimum numberof satellites and maximum PDOP, give the user an idea of how useful the receiver would be in non-open-sky environments, such as under trees or next to buildings. Note, however, that none of the manufacturers clearly states whether its receivers are calculating submeter positions with a 1-second occupation or whether the user needs to be stationary for several minutes to let the receiver average its position. If the user is expected to remain stationary for several minutes, data collection productivity could be adversely affected.

Summary

When shopping for a GPS receiver, the customer has many issues to take into consideration. The data needed for a side-by-side product comparison of receivers may not be readily available in the manufacturers' marketing materials. The customer has to rely on manufacturers' qualitative claims, which can be vague if a matrix of understandable quantitative numbers backing them up is not provided. ■

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Abbreviated History of GPS

1920s
Origins of radio navigation
Early WW II
LORAN developed—MIT Radiation Laboratory.
1959
TRANSIT—first operational satellite-based navigation system developed. Transit satellite is launched.
1960
First 3-D (longitude, latitude, altitude) navigation system suggested by Raytheon Corporation—MOSAIC (Mobile System for Accurate ICBM Control).
1963
Aerospace Corporation launches study on space system as the basis for three dimensional navigation, leading directly to the concept of GPS.
1963
Air Force supports Aerospace study, System 621B.
1964
Timation, Navy satellite system, is developed.
1968
DOD establishes NAVSEG (Navigation Satellite Executive Committee) to coordinate Navy's and Army's systems.
1971–1972
User equipment for Air Force system 621B tested. Accuracies of a hundredth of a mile demonstrated.
April 1973
Deputy Secretary of Defense establishes tri-service program—Defense Navigation Satellite System (DNSS).
December 17, 1973
NAVSTAR GPS proceeds, start of concept validation.
June 1974
Rockwell International chosen as satellite contractor for GPS
July 14, 1974
First NAVSTAR satellite is launched.
February 22, 1978
First Block I satellite launched. Eleven Block I satellites were launched between 1978 and 1985.
April 26, 1980
First GPS satellite to carry Nuclear Detonation Detection System sensors is launched.
1982
Budget cuts reduce planned GPS satellite launches from 24 to 18 satellites.
1983
Ronald Reagan announces that GPS system will be made available for civilian uses once completed.
1987
Department of Transportation (DOT) creates office to respond to civil user needs for GPS.
1984
Surveying becomes first commercial GPS market.
March 1988
GPS constellation expanded to 21 satellites.
February 14, 1989
First of 28 Block II satellites launched.
March 25, 1990
DOD activates Selective Ability (SA)—purposeful degradation in GPS navigation accuracy—for the first time.
August 1990
SA is deactivated during Persian Gulf War.
1990–1991
GPS is used for first time under combat conditions during the Persian Gulf War by Allied forces.
August 29, 1991
U.S. government revises export regulations, delineating between military and civil GPS receivers.
July 1, 1991
SA is reactivated after the Persian Gulf War.
September 5, 1991
U.S. offers to make GPS standard positioning service (SPS) available in 1993 on a worldwide basis
September 1992
Secretary of Defense declares Initial Operational Capability of GPS.
January 17, 1994
A complete constellation of 24 satellites was in orbit.
October 11, 1994
DOT Positioning/Navigation Executive Committee is created as forum for making GPS policy.
October 14, 1994
FAA reiterates U.S. offer to make GPS-SPS available for foreseeable future.
March 16, 1995
President Bill Clinton reaffirms U.S. will provide GPS to international civilian community.
April 1995
Full Operational Capability declared by NAVSTAR.
May 2, 2000
"Selective Availability" discontinued as a result of 1996 executive order, allowing users to receive non-degraded signal.
November 2004
QUALCOMM announced successful tests of Assisted-GPS system for mobile phones.
2005
First modern GPS satellite launched with a second civilian signal for enhanced user performance.

(Timeline adapted from http://en.wikipedia.org/wiki/Global_Positioning_System#Timeline, accessed January 2, 2008 and http://www.rand.org/pubs/monograph_reports/MR614/MR614.appb.pdf, accessed January 2, 2008)