SkyBitz
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The Global Locating System

Background

The GPS System went into full-time service in the early 1990s, replacing the earlier Transit satellite system, as a means of providing continuous, accurate position information to any receiver at any location on the earth. From the civilian GPS user's perspective, GPS satellites transmit signals containing a detailed, known, repeating fine structure overlaid with a low-speed data stream. The fine structure – the spreading "Gold" codes used by the GPS satellites, a different one for each satellite, all operating at 1,023,000 "chips" per second – enable the receiver to resolve very fine differences in the time of arrival of the GPS signal. The low-speed data contains parameters the GPS receiver needs to complete its position calculation. These parameters include time information, clock errors, satellite position information, ionospheric data, and other data necessary for setting up the position solution equations and correcting for system and propagation variations. The user's GPS receiver finds and synchronizes to the codes of the various GPS satellites in view, downloads any data it does not have regarding system and propagation parameters, applies an assumed position as a departure point for the position calculation, and solves the simultaneous GPS equations for accurate position and time. Note that the user's receiver does not transmit anything to the satellite, and correspondingly the GPS satellite receives nothing from the user. Consequently, the position and time information calculated by the GPS receiver is only available locally to the user of that receiver.

The key to accurate position determinations using GPS is accurate knowledge of time, the accurate calculation of satellite position given accurate time and downloaded satellite orbital information, and then using the fine structure of the received signals from each of the satellites to derive an accurate measurement of range from each of the GPS satellites observed. Positions having a given range from a GPS satellite together form a spherical surface centered on the satellite with a radius equal to the range. The known ranges from three satellites form three spheres, one centered on each of the satellites. These spheres intersect in two points, provided their centers are not on one line. Typically only one point will be near the surface of the earth. This is a simple example of the way GPS works.

However, GPS hardware and constellation characteristics complicate the solution environment further. The GPS satellites are in continuous motion relative to the surface of the earth and to each other. They are all in 12-hour inclined orbits, so that the visible satellites and their geometry are always changing. Hence a solution involving ranges from a satellite will only be valid for the actual instant of calculation. Moreover, the user terminal clock is almost always somewhat wrong regarding the precise time. Hence the GPS receiver must solve for the unknown accurate time as well as the unknown position. It does this by taking a measurement from a fourth satellite and by adding a fourth equation to its solution set (a fourth intersecting sphere), thereby permitting it to solve for four unknowns: x, y, z, and time, or equivalently latitude, longitude, altitude, and time. Note that if the user furnishes a known altitude to the GPS receiver, it can solve for the remaining latitude, longitude, and time using only three equations. This is known as a two-dimensional solution, which depends on the accuracy of the provided altitude information.

Two aspects of the GPS design further complicate GPS processing. First, the fine structure (spreading codes) emitted by the GPS satellites (civilian signals) repeat every millisecond. Hence a GPS receiver will see the same structure every 300 kilometers in range from the satellite for a given moment in time. In other words, the repeating structure of the spreading codes causes ambiguities in satellite ranges. Second, the solution algorithm, based on a Taylor series expansion of the range equations, requires a presumed approximate user terminal position in order to begin iteration to a final solution. Typically, GPS receivers resolve the range ambiguity by calculating precise time using the satellite's broadcast time information. GPS receivers also use the most recent past position solution as a start point for the following solution.

Now that the Department of Defense has turned off "Selective Availability", a deliberate error source designed to degrade publically available performance slightly (for security reasons); typical commercial GPS receivers deliver positions with less than 30 meters of error. Upcoming enhancements, such as the Wide Area Augmentation System (WAAS) will permit reducing position errors to less than 5 meters.

The Remote Tracking Opportunity and its Challenges.

Since GPS service began, users have recognized the advantages that could accrue from a system that made GPS positions available for remote monitoring. The simplest approach to doing this has been to couple a GPS receiver to a communications radio, so that the calculated position results could be relayed to a remote facility for storage and dissemination. Most remote tracking devices today use this approach, using either a cellular or satellite link to provide the communications path.

However, this approach suffers from two significant weaknesses, which have limited the usefulness of these remote tracking devices. First, GPS receivers operating continuously consume enough power that small (AA-sized) battery packs are depleted in less than a day. If the GPS receiver is not operated continuously, then its must search and reacquire satellite codes and, depending on the time since it last operated, reacquire parameters from the GPS data downlink. This can lead to 1-2 minutes or more of on-time before developing a position fix. This can extend to even longer times if the terminal has not taken an observation for many days.

Second, most communications channels available today are not optimized for the short, bursty messages a remote position-reporting terminal requires. Classic communications approaches require setting up a circuit over which the position data can be sent, and involve a large amount of overhead in time and energy in order to open and maintain this circuit. More efficient packet-based communications media, such as Cellular Digital Packet Data (CDPD) and Short Message Service (SMS), are only just emerging in the cellular marketplace, however their coverage is limited to a subset of terrestrial cellular/PCS coverage, and even where available is plagued by the well known cellular coverage holes, even in otherwise well-served areas. Little exists in the way of suitable packet-based satellite services, although satellite service offers much better coverage over an operating region.

Consequently, typical remote positioning systems coupling GPS with cellular or satellite communications suffer from excessive power consumption, and a consequent inability to operate for multi-year periods using small (AA-sized) battery packs. This complicates logistics support for such terminals, making them operationally less attractive.

Moreover, such terminals also themselves include a substantial degree of electronic complexity, including as they do the complete GPS reception and processing capabilities, plus the additional electronics and processing capabilities necessary to support the radio functions. The cost of assembling such a solution has proven to cause difficulties in achieving significant market penetration. Less than attractive coverage has only worsened the appeal of many such services when they are cellular-based.

GLS

The GLS radios and processing scheme were designed from the outset to offer wide area coverage while minimize complexity, power consumption, and hence investment and operations costs. The SkyBitz GLS achieves this through several unique features. First, it uses a satellite reporting link, thereby offering an unbroken wide area of coverage. Second, SkyBitz determined that it is essential to move as much complexity as possible out of the Mobile Terminal (MT) to the Gateway as possible. That meant above all simplifying the SkyBitz Mobile Terminal. To that end, the SkyBitz Mobile Terminal does not calculate position. Nor does it need precise time or GPS parameters to do so. Hence, unlike the GPS receivers described above, regardless of the duration of time the MT has been asleep or how far it has moved in the meantime, after it awakes and receives a confirming command to send position data, it need only gather on the order of 10 milliseconds of the GPS signal environment rather than minutes worth.

Once it has gathered its signal samples, the SkyBitz MT powers down its receiver and processes the signal samples to detect and extract the fine structure timing ("code phases") for each of a number of GPS satellites. It then transmits this information to the Gateway over an L-band satellite link using a GLS-burst-message-optimized proprietary protocol, having a 1.5 second packet (total report) length, before going back to sleep. The MT does no position calculation internally. That is left to the Gateway station and its computer suite.

However, this approach introduces some complications, which GLS resolves in a unique fashion. As discussed earlier, GPS satellite codes repeat every millisecond, creating valid range solutions spaced every 300 kilometers from every satellite. Hence the code phase measurements reported by the MT may apply to a large number of possible points in three-dimensional space. The Gateway (not the MT!) must resolve these ambiguities to find the correct solution. To do so, the GLS processing system at the Gateway uses the carefully measured round-trip communications time over the communications satellite to determine a range figure from the communications satellite to the SkyBitz MT. Knowing the round trip range to reference terminals whose positions are known (enabling a calculation of the communication satellite's precise position, which is not normally available), knowing thereby the propagation time to the satellite from the Gateway, and knowing the signal delays through the satellite and in the mobile terminal, the Gateway is able to derive the propagation delay from the communications satellite to the MT, and hence the range from the satellite to the MT. Points having this range describe a sphere centered on the Communications satellite, on which the MT must be located. This