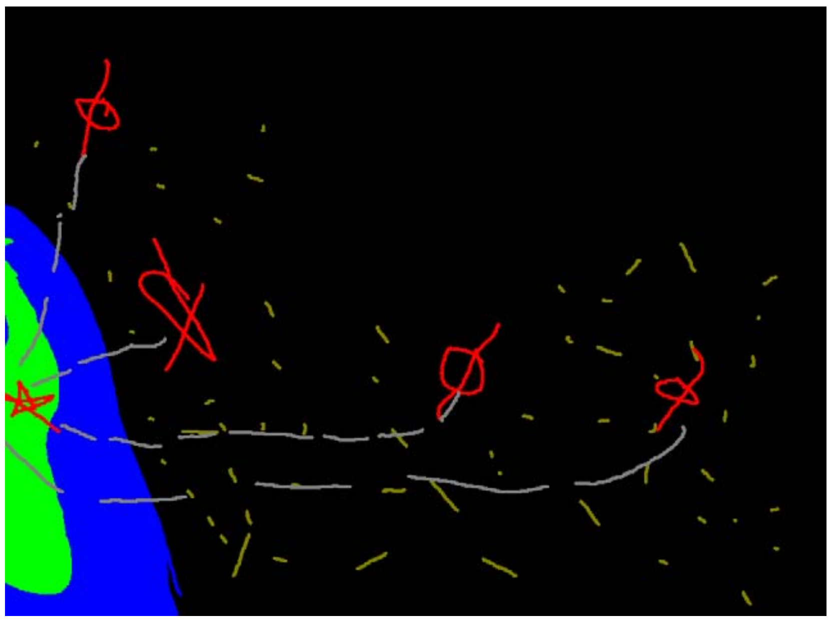
MP Rugged Wireless Modem

Primer on GPS Operations



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Cover illustration by Emma Jantz-Lee (age 11).

An Introduction to GPS

This primer is intended to provide the foundation for understanding the Global Positioning System (GPS) and in particular, the basics of how the GPS module operates in Sierra Wireless products.

This document does not provide a full operating manual or command reference for communication with the GPS module. That information is available in other Sierra Wireless documents.

The Global Positioning System (GPS)

Note: For a detailed explanation of GPS please consult the tutorial provided by Trimble Navigation at www.trimble.com/gps/index.htm.

The Global Positioning System (GPS) provides worldwide navigation information through a network of 24 satellites. These satellites are distributed throughout the sky to provide 24-hour coverage around the globe. The system is operated and maintained by the United States Department of Defense.

GPS receivers use signals from these satellites to triangulate their position on the Earth.

Each satellite transmits a signal containing a unique "Pseudo Random Code" that is repeated at precise times. (The precision is so important that the satellites are equipped with atomic clocks.) When a GPS receiver is activated, it begins searching for signals from the satellites. As soon as a signal is detected, the receiver identifies and reads its code. The receiver then begins "playing" the same code beginning at the exact same times as the satellite.

Because of the time it takes for a signal to travel from the satellite to the receiver, the code received from the satellite will not be in synchronization with the code as played by the receiver. The receiver measures that time delay and uses it to calculate its distance from the satellite.

The receiver simultaneously tracks its distance from multiple satellites. To calculate its current longitude and latitude, the receiver must determine its distance from at least three satellites. A fourth satellite signal is required to determine the receiver's altitude. The receiver can determine longitude, latitude, and altitude with greater accuracy if it is tracking more than four satellites. (The receivers in Sierra Wireless products can track up to eight satellites. Future releases will track up to 12 satellites.)

Position accuracy

The accuracy of the position fix is adversely affected by:

- **Atmospheric Distortion** - Subtle changes in the properties of the upper atmosphere cause shifts in the signals from the satellites as they are transmitted to the surface of the Earth.
- **Clock Errors** - The distance between the GPS receiver and each satellite is calculated based on the time it takes for the signal from the satellite to reach the receiver. An accurate calculation requires that the clock in the satellite and the clock in the receiver be perfectly synchronized.
- **Selective Availability (S/A)** - In order to reduce the usefulness of the GPS system to potential adversaries, the U.S. Department of Defense deliberately degraded the accuracy of the signal, to allow for "selective availability" of accurate position data. (The degraded signal still provided a position fix that was within 100 meters of the actual position.) Selective availability was de-activated in May 2000.

Improving the accuracy of the position fix is an ongoing effort of civilian GPS technicians. By applying computer models of atmospheric behaviour, the effects of this distortion can be partially mitigated. Each satellite sends some clock correction information to be incorporated in the receiver's processing to help reduce that error.

Static and dynamic filtering

Some improvement is made through the use of static and dynamic filtering; processes within the receiver's calculation algorithms. By using a series of previous readings the receiver can determine if it is stationary or in motion. By using this information it can anticipate its next position.

If the receiver was not in motion, then it can deduce that a new fix must be very close to the previous one. If the newly received position jumps by several meters in the brief time between fixes, then it will presume a portion of that jump is a positional error.

If the receiver has an established velocity and direction (heading) then it can calculate a likely position for the next fix (dead reckoning). It will adjust a newly received position that is significantly different from expectation.

Differential GPS (DGPS)

Differential GPS (DGPS) was developed to overcome the full range of errors including the inaccuracies of selective availability. This system involves starting from a very accurately surveyed location on the Earth and doing the position calculations in reverse. These reference ground stations can then determine the errors in the satellite signal and transmit correction data to local receivers.

By adding a signal from a reference station, the receiver can apply correction data to refine the position. Application of differential corrections allows position accuracy to within two to five meters. The level of improvement is dependent on the "freshness" of the data from the differential reference station and your receiver's distance from the reference station's site.

Inverted Differential GPS

The standard mechanism of DGPS involves combining the satellite data with that from the reference station in calculations performed at the mobile receiver. Inverted DGPS shifts the calculations to the reference station.

Consider a sample case in which a GPS user is collecting data from several mobile receivers (such as a fleet of buses) and plotting them on a map. To place a vehicle on a particular street, and know which side of the intersection it is on, requires the accuracy of DGPS. In this application, all of the data from the various vehicles is needed at only one well-known location, the control centre. By making it the reference station, the raw satellite data received by each mobile module can be collected at the control centre and the differential corrections can be applied there to all units.

Standard DGPS requires the modem to receive a correction signal, process it, and then transmit the position fix back to the control centre. This two-way traffic can be reduced to one-way with Inverted DGPS. Only the raw data from the mobile receivers is sent to a base station for processing there. Since it isn't necessary to install the differential receiver in every vehicle, inverted DGPS is generally much cheaper to implement than standard DGPS.

The GPS tutorial on the Trimble web site (www.trimble.com/gps/index.htm) provides a more detailed explanation of inverted differential GPS.

GPS in operation

In order for the GPS to operate and for you to get meaningful information, the module must acquire satellite data. Simply finding and acquiring the signal from the satellites is a complex and potentially time consuming task for the module. Understanding some of the details will help you to understand when and why data from the module is or is not available, and in turn determine how you configure your installation and use the data.

Before discussing how the GPS receiver gets its first position fix, and why it can take longer in some cases than others, it is necessary to know something about the data the satellites are transmitting. This is needed in order to know how the receiver acquires satellites.

The satellite message

The GPS satellites transmit data in 30-second frames. The data each satellite sends includes:

- Unique identification of the satellite
- Its clock correction
- Its own ephemeris (location in orbit)
- A portion of the almanac for the entire GPS network

The GPS almanac contains the data necessary to predict the location of each satellite. The almanac is updated and uploaded to the satellites weekly. The data is valid for months. Each satellite message frame includes 2 pages of the 50-page almanac. The receiver will acquire and retain this data. It takes approximately 12.5 minutes for the receiver to acquire the full almanac.

Ephemeris data is updated and uploaded to each satellite every hour but is valid for up to four hours. The GPS receiver gets this information and uses it to track satellites and perform positional calculations. The ephemeris for a satellite can be acquired in approximately 30 seconds.

Satellite acquisition

For a GPS receiver to locate, identify, and use satellite data, it must set a receiving channel to look for a particular satellite. The receiver can search simultaneously for multiple satellites, up to the number of receive channels available.

Hot start

In situations where the receiver has been powered off for less than four hours, the ephemeris and almanac data should be very reliable. Using this, in conjunction with its last known position and the current time from an internal clock, the receiver can determine which satellites are expected to be in range. The search to acquire satellites will start with this list and acquisition of the minimum of three satellites required to get a position fix should be fairly brief.

Warm start

If the receiver has been switched off for a period of time greater than four hours it will lose accurate ephemeris data. If it still has a current almanac, the current time, and is still within 3000 km of where it last had a fix, then it can still determine a rough list of which satellites are expected to be in range. Such a situation is called a "warm start". This allows the receiver to search first for those particular satellites which are expected to be available.

Cold start

In cases where the receiver does not have the initial information it can only do a random search for satellites. This case is called a "cold start". The receiver will pick eight satellites and allow a limited time to receive a valid signal from them. Any channels that do not receive a valid signal are then assigned to look for another satellite. This process continues until enough satellites are acquired to obtain a position, time, and almanac.

Time to first fix

When a GPS module is powered, it cannot begin reporting its position until it acquires at least four satellites. The time until a first fix is available will vary depending on the situation: cold, warm, or hot start, and the quality of signal reception.

Typical situations require the following times to get a first fix:

- Cold start—up to 3 minutes.
- Warm start—under 45 seconds.
- Hot start—under 18 seconds.

There can be other factors that will slow down this time but in 90% of cases, these times are fairly accurate.

If signal reception is poor due to obstructions, proximity to tall buildings, being in a covered area, and so on, then the time needed to acquire satellites could be longer. In cases where reception is severely impaired, the receiver will not be able to acquire enough satellites to provide a position fix.

GPS data

In a typical GPS implementation, there is an application residing on a centrally-located server that receives and processes the position data from each vehicle's GPS module. There are two formats commonly used by GPS modules to report position data: TAIP and NMEA.

TAIP reporting

TAIP (Trimble ASCII Interface Protocol) is a communications standard designed by Trimble specifically for vehicle-tracking applications. The standard defines the format of messages sent from and to GPS modules. Using TAIP, a remote application can obtain position information from a GPS module by querying the module, or the module can be configured to automatically send position information at specified intervals of time or distance.

NMEA reporting

NMEA (National Marine Electronics Association) is a communications standard designed for marine instruments. The standard defines a format for the reporting of position information. A GPS module configured to use NMEA cannot receive messages from an application; it can only report position data.

Sierra Wireless GPS products support both reporting methods. As shipped, the products are configured to use TAIP.

Sierra Wireless products with GPS

The MP product line consists of rugged wireless modems designed to be installed in vehicles, all of which support GPS. Each MP product operates on a different wireless network:

Table 1-1: GPS products

Product	Description
MP200GPS	This product operates on CDPD networks and provides support for GPS and differential GPS. The **MP200 GPS inverse differential** provides support for inverted differential GPS.
MP GPRS 750	This product operates on GSM/GPRS networks. This product was designed to support inverted differential GPS as of the first product release. (The testing required to provide support for differential GPS had not been completed at the time of this writing.) Support for differential GPS is NOT available in the first release but is planned for a future release.
MP CDMA 555	This is scheduled for release in the Fall of 2003 and will operate on CDMA2000 1X networks. This product is designed to support inverted differential GPS as of the first product release. The first release will NOT support differential GPS, but a later release will.

The AirBooster 350 RF amplifier also supports GPS but as of May 2003, it is no longer being manufactured.

Installation considerations

Note: Detailed installation instructions are provided in the product documentation that comes with each MP product.

A typical MP installation involves:

- Mounting the modem (usually in the trunk)
- Installing the power harness (usually connecting the modem to the vehicle's battery and either the vehicle's ignition or a separate on/off switch)
- Installing an antenna for the appropriate wireless network (CDPD, GSM, or CDMA)

Note: See the product documentation on the Sierra Wireless web site (www.sierrawireless.com) for more specific information about antenna requirements.

Note: See Table 1-1 on page 7 for information about which MP products provide support for differential GPS.

GPS equipment requirements

Where GPS is being implemented, a GPS antenna must be installed. Either separate antennas can be used (one to send and receive signal to the wireless network and one to receive GPS signal) or a combination antenna (for example, a GSM/GPS antenna) can be used. Either a hard-mount antenna (requiring a hole to be drilled in the roof of the vehicle) or magnetic-mount antenna can be used. GPS antennas are best mounted on the roof of the vehicle as a clear view of the sky is required.

Where differential GPS is being implemented, a differential GPS receiver must be installed in the vehicle as well as an I/O cable connecting the differential receiver to the modem. Depending on the implementation, the GPS receiver may or may not require its own antenna, or a combination GPS receiver/antenna might be used.

In inverted differential GPS implementations, the differential receiver is not necessary because the corrections are applied at the central office or dispatch rather than in each vehicle. Note that there is a separate MP200 GPS product to provide support for inverted differential GPS. (This is not the case for the MP GPRS 750 and the MP CDMA 555.)

Power considerations

The GPS module derives power from the modem, and in most cases, the modem derives its power from the vehicle's battery. If the power harness is properly installed, the modem should draw enough power, even when the vehicle and the modem are off, to power the GPS memory used to store the configuration and almanac, as well as the module's real-time clock.

In addition, when the vehicle's battery power is completely removed, the GPS module can continue to stay alive for about two minutes using power from an internal capacitor. The module will not be relaying any messages in these power-off cases but the GPS will be able to perform a warm or hot start when power is restored.

Proper installation of the power harness, modem, and antenna(s) is necessary to ensure continuous reporting from the GPS module. The product documentation for each modem provides all the information necessary to ensure proper installation.