GPS Support Notes

Diaclaimer
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GPS Operating Parameters

When implementing a GPS solution, it is necessary to understand how the final GPS -enabled product is to be used and to optimize the GPS configuration to best meet the expectations of that application. This can be achieved by configuring various parameters that fundamentally effect the operation of the GPS receiver.

The following sections provide information about each of the user-configurable GPS parameters and how each parameter can effect the final GPS operation.

GPS Operation Compromises

For each parameter, there is usually a GPS operation compromise. That is, if a parameter is optimized for a particular operational advantage, then it can be expected that the GPS operation will be disadvantaged in some other manner.

Accuracy verses fix density is the primary compromise and consideration.

•**Accuracy** - If the GPS receiver is optimized for accuracy, then only the highest accuracy positions will be output by the receiver.

•**Fix Density** - If optimized for fix density, then the receiver is configured to provide position fixes whenever possible.

If the GPS receiver is optimized for accuracy then it can be expected that a much lower fix density will result. If the GPS receiver is optimized for fix density then lower-accuracy positions can be expected.

Configurable Operating Parameters

NOTE: These parameters are set and stored in FLASH memory. Please refer to Write to Flash app note.

Table 1 provides a list of each configurable operating parameter along with the valid options and current default value for each parameter

Table 1

Elevation Mask	0 - 90 degrees	5 degrees
Track Smoothing	Enabled | Disabled	Disabled
Altitude Hold	Automatic | Always | Disabled	Automatic with last computed altitude
Degraded Mode	Direction then clock | Clock then direction | Direction only | Clock only | Disabled	Disabled
Dead Reckoning	Enabled | Disabled	Disabled
Power Mask	20 - 50 dB-Hz	12 dB-Hz
DOP Mask	Auto PDOP/HDOP | PDOP | HDOP | GDOP | Do not use	Do not use
Static Navigation	Enabled | Disabled	Disabled
SBAS	Auto scan | User Defined | Disabled	Disabled/Auto scan

Each parameter listed in Table 1 is configurable through SiRFDemo (see the SiRFDemo User Guide) and is discussed in detail in the following sub-sections.

Operating Modes

Operating modes refer to the type of position and operation allowed by the GPS receiver. Available operating modes include:

- 3D positions only (Altitude, degraded, and dead reckoning modes disabled)
- Altitude hold mode
- Degraded mode
- Dead reckoning mode

Each operating mode offers a greater potential fix density and continued navigation but with continually less accuracy. The mode the GPS receiver operates in is dependant on the number of satellites available. A GPS position is made up of four unknowns; 3 dimensions of position (X, Y, Z) and time. Hence, four GPS satellites are required to solve for the four unknown values.

If the number of satellites available is reduced to less than four, then different operating modes can be implemented to continue navigation by using assumptions and holding one or more unknowns fixed to reduce the number of variables and propagate the position.

If all operating modes are allowed, and as the number of satellites available are reduced, the following steps occur:

1. Four satellites or more - all unknown variables are solved for; X, Y, Z, and time. This is a 3D position fix.

2. Three satellites - the altitude (or Z) is held fixed and only X, Y and time are solved for. The receiver is now operating in Altitude hold mode and the resultant position is known as a 2D fix.

3. Two and one satellites - when fewer than 3 satellites are available, additional parameters must be fixed in order to solve the position. The two parameters that are fixed are clock drift (rate of change in clock bias) and heading. The order in which they are fixed depends on the Degraded-Mode setting. If the setting is Direction then Clock, then heading will be fixed when only two satellites are available, and then clock drift when only one is available. If Clock then Direction is selected, the order will be reversed. If Clock only or Direction only is selected, the corresponding parameter for a two-satellite solution will be fixed, and will not create one-satellite solutions. Instead, the receiver will proceed to a dead-reckoning solution.

4. No satellites - as no satellites are being tracked, no information can be used. The position is propagated simply by assuming that the receiver is moving in the same direction and at the same speed as the last calculated position. The receiver is now operating in dead reckoning mode.

The following sub-sections provides additional information about each operating mode.

Altitude Hold

Generally speaking, a GPS solution consists of four unknown values that must be solved for - latitude, longitude, altitude, and time. As there are four unknowns, a minimum of four satellites are required for a complete solution. However, fewer satellites can be used if any unknown is given an assumed or fixed value and not solved for.

If only 3 satellites are available and altitude hold mode is enabled, altitude is held constant and not solved for. While the position solution is still computed in three dimensions plus time, since one parameter has been frozen, the solution is commonly known as a 2D position. This allows positioning to continue even when less than four satellites are available with a 2D position being the result. As positioning can continue with less than four satellites, the advantage of this mode of operation is a higher fix density.

The trade off when using altitude hold is that an error in the assumed or fixed altitude will introduce an error in the horizontal position. As a rule of thumb, the possible error in the horizontal position is approximate 30% of the difference between the actual and the used altitude. In other words, 30 cm error in the horizontal position can be introduced for every 1m error in the altitude As an example, if the altitude used is 100 m but the actual altitude of the receiver is 0m, than an error in the horizontal position of 30 m can be expected.

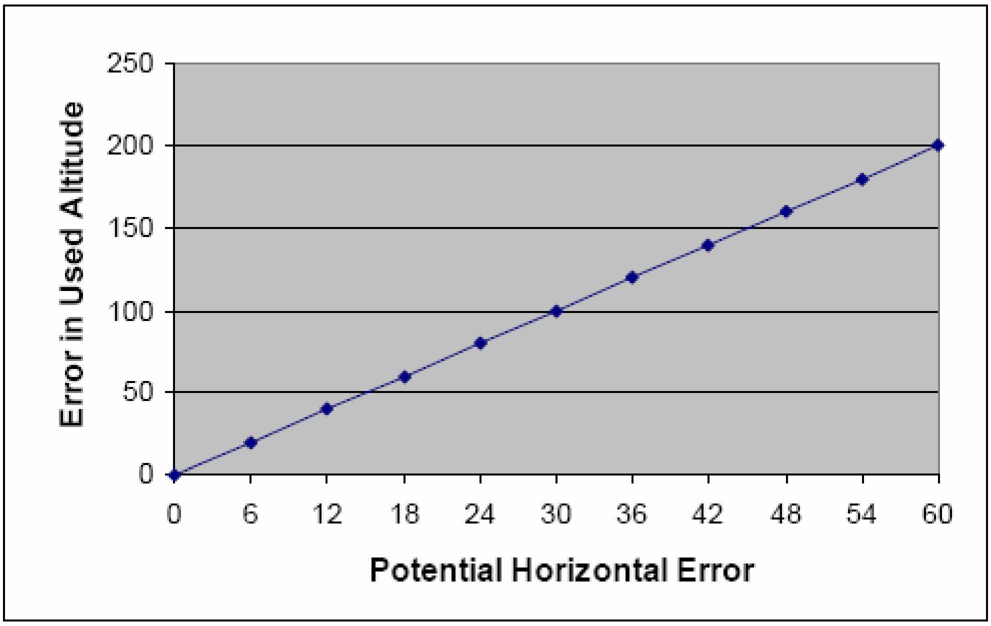

Figure 1 - Potential horizontal error resulting from an error in the used altitude when operating in 2D

Due to the potential error in the horizontal position, the change in altitude that the application may experience should be considered. If significant change in altitude is expected when operating in 2D mode only and horizontal accuracy is important, care must be taken when using altitude hold mode. As an example, the city of San Francisco, California USA has a maximum altitude change of approximately 230 m. If a GPS receiver was set to operate in 2D mode only, then a horizontal error of 70 m is possible simply due to altitude change.

In altitude hold mode exactly what value to use when fixing the altitude must be selected.

Table 2 lists the options.

Option	Description
Last computed altitude	When operating in 2D mode, the receiver will use the last known altitude as the fixed altitude value. This is the preferred altitude hold option as the altitude is updated every time a 3D position can be obtained.
Fixed altitude	When operating in 2D mode, the altitude used is the altitude as defined by the user. This mode of operation is generally suitable only for marine applications or other situations where the user knows that the altitude will change very little.

Degraded Mode

Degraded mode operation begins when the number of available satellites drops below three. As with altitude hold mode, as the number of satellites drops, additional parameters must be held constant. While this can cause the introduction of errors, and increases in noise on the solution, it does provide significantly increased fix density. Degraded mode does have a timeout to limit these effects.

The parameters to be held constant are clock drift and vehicle heading. The order in which these are held is dependent on the Degraded Mode setting. When the Clock then Direction setting is selected, clock drift will be held constant as the number of available satellites drops to two, then vehicle heading will be held constant as the number drops to one. Selecting Direction then Clock reverses this order. Selecting Clock only or Direction only will freeze the selected parameter as the number of satellites drops to two, and will stop using degraded mode when the number drops to one.

Table 3 lists each possible degraded mode option.

Option	Description
Use direction then clock hold	If the number of available satellites is reduced to two, the GPS receiver will hold the elevation fixed, and use the last direction and speed. If the available satellites is then reduced to one, the clock drift is then held constant.
Use clock then direction	This mode is similar to the above Direction then Clock Hold mode. However, the clock drift is held constant, and then the direction.
Direction hold only	This mode restricts degraded mode to two satellites only. When the number of satellites drops below three, vehicle heading will be held constant. If the number of satellites drops to one, the receiver will go to dead-reckoning mode, if enabled.
Clock hold only	This mode restricts degraded mode to two satellites only. When the number of satellites drops below three, clock drift will be held constant. If the number of satellites drops to one, the receiver will go to dead-reckoning mode, if enabled.
Disabled	This mode prevents the system from using degraded modes when the number of available satellites drops below 3. If dead-reckoning mode is enabled, it will be entered whenever the available satellites drop below three.

Degraded mode operation is very useful to continue navigation in environments where satellite visibility may be interrupted. However, as the resulting position is based on assumptions, if these are incorrect, then an error can be introduced. An example of this is if a vehicle makes a turn after the receiver has entered into degraded mode. Also, the longer a GPS receiver operates in degraded mode, the less valid the assumptions become.

Dead Reckoning

Dead reckoning mode is the next step beyond degraded mode and operates when no satellites are available, or fewer satellites than degraded mode allows. The position is propagated by using the last known heading and speed of the GPS unit. Dead reckoning mode operation can potentially be useful in getting past small blockages in satellite visibility such as bridges and overpasses and continue navigation. However, if there is any variation in speed or direction, then position accuracy will degrade significantly. Like degraded mode, the longer the receiver operates in dead reckoning mode, the higher possibility of significant errors.

Navigation Parameters

Other navigation parameters that are not as dramatic as the above operating modes include:

- Track smoothing
- DOP mask
- Elevation mask
- Power mask
- Static navigation
- SBAS

Track Smoothing

Track smoothing applies primarily to dynamic situations. It assists in removing sporadic position jumps or unexpected position variations due to variables such as multipath, poor satellite visibility, or introduced noise. The result of applying track smoothing is a cleaner, more consistent trajectory with all positions appearing relatively correct to each other.

Figure 2 - Track smoothing verses no track smoothing

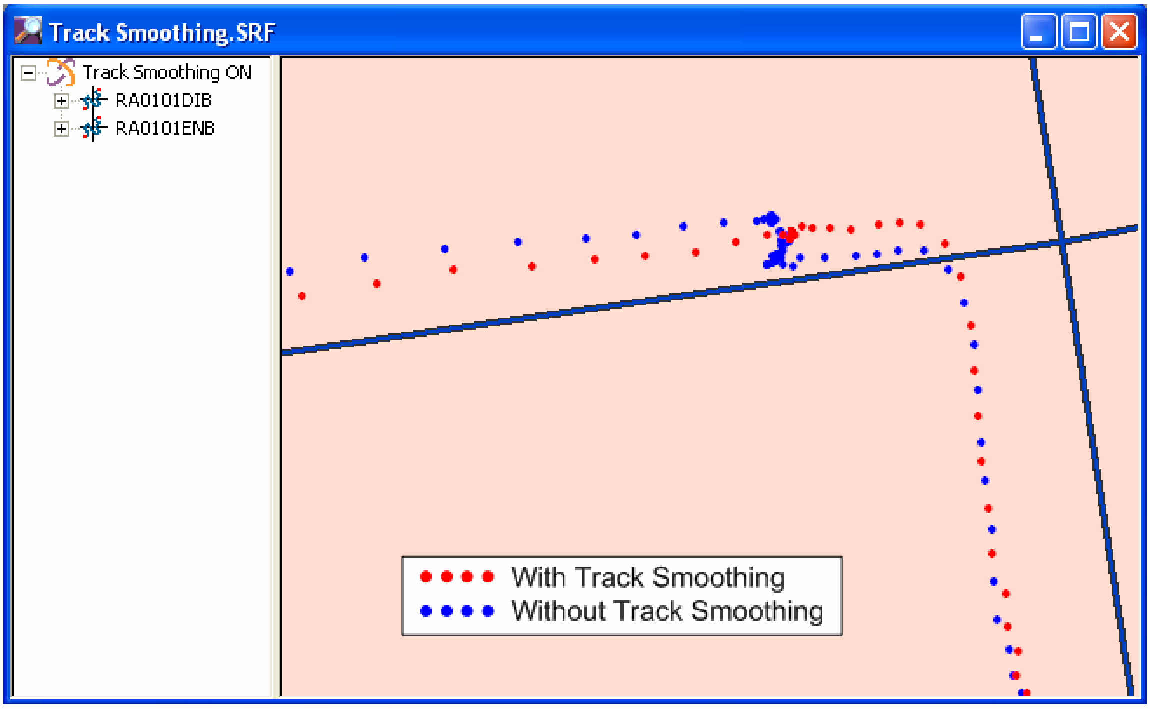

Figure 2 is a plot of the same data set but the data has been processed to represent the results comparing track smoothing verses no track smoothing. The red plot is the one with track smoothing switched on. As can be seen, the data has been smoothed out and better represents what the user would expect when driving along a road. However, the blue path is in fact closer to what the GPS receiver is calculating.

By applying track smoothing the result is a smoother trajectory. However, the resultant GPS operation may be less reactive. This means that in high dynamic or fast applications a perceived lag in the position may be noticed.

DOP Mask

DOP (or Dilution of Precision) is an indicative position accuracy value that is derived from satellite availability and geometry. Typically a high DOP value implies degraded position accuracy while a low DOP value implies good position accuracy.

The DOP mask parameter allows a user to exclude the output of positions that are above a defined DOP value in an effort to ensure that only the higher accuracy positions are output by the GPS receiver. However, by doing so, a decrease in position fix density can be expected.

Various DOP mask options are available. Table 4 provides a list of each of the DOP mask options.

Option	Description
Auto PDOP/HDOP	The PDOP mask will be used if four or more satellites are available. If only three satellites are available, the HDOP mask will be used.
PDOP only	Only the PDOP mask will be used regardless of the number of satellites available.
HDOP only	Only the HDOP mask will be used regardless of the number of satellites available.
GDOP only	Only the GDOP mask will be used regardless of the number of satellites available.
Disabled	No DOP mask is applied.

Elevation Mask

Signals from GPS satellites that are low on the horizon must pass through much more atmosphere, and are subject to more multipath effects than signals from satellites that are directly overhead. Because of this, the signals from lower-elevation satellites are subject to more errors than signals from satellites with higher elevations. Better position accuracy is often achieved if lower elevation satellites are not used in the position solution.

The elevation mask allows a user to exclude the use of lower-elevation satellites from the position solution. While this can improve the quality of the final solution, it effectively reduces the number of satellites available, and can result in situations where the solution has greater noise because of too few satellites, or even too few satellites for a solution to be calculated.

A low elevation mask will result in a potentially less accurate position but with a higher fix density. A high elevation mask will result in a potentially more accurate position, but with a lower fix density due to a decrease in satellite availability. Hence, in applications where accuracy is much more important than fix density, then introducing an elevation mask should be considered.

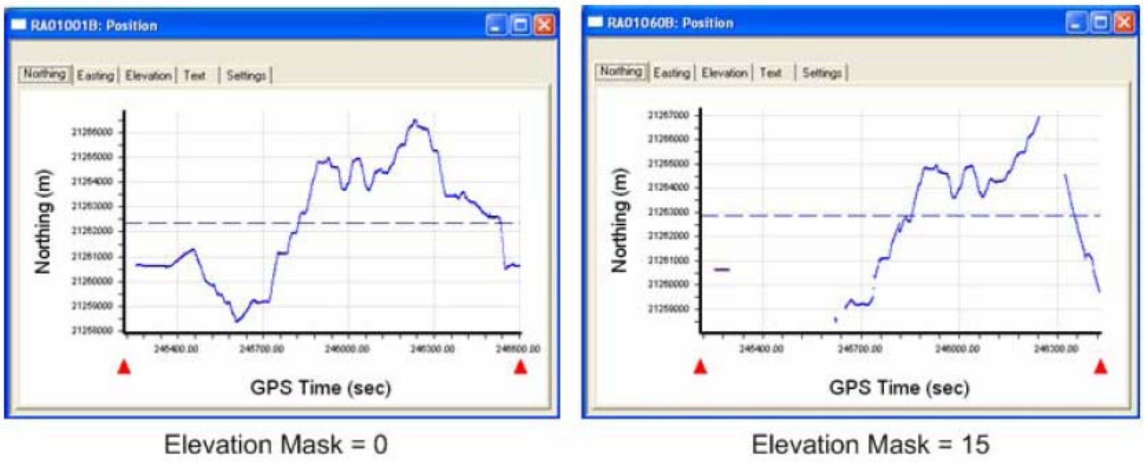

Figure 3 - Results comparing a 0 degree elevation mask and a 15 degree elevation mask

As can be seen in Figure 3, when the elevation mask is increased, then the fix density decreases. In this example, driving through a severe urban canyon environment, increasing the elevation mask to 15 degrees resulted in over 35% of no navigation.

The default value of the elevation mask is typically 5 degrees, meaning satellites that are less than 5 degrees above the horizon are not used in navigation solutions. The mask can be set to any angle from -20.0º to +90.0º, with steps of 0.1º. Typical values chosen by users are 0º for maximum position availability, 5º for users who want high fix densities in vehicles, and 15º by users who require high-quality fixes and are willing to sacrifice fix density.

Power Mask

GPS satellites that have a low signal strength are not easily tracked by a GPS receiver and may result in using signals that are either noisy or have been effected by multipath or other interference source.

The power mask parameter allows a user to prevent the use of satellites with a low signal strength being used in the position solution. This will result in a potentially higher accuracy position. However, as the number of satellites available will be decreased, the fix density will be decreased.

Static Navigation

Even when a GPS receiver is stationary, each calculated position will be different from the last. This gives the appearance of continuous motion of the GPS receiver. In a practical situation such as a car stopped at a traffic light, a user expects to see the position to be stationary. It is the static navigation mode that assists in achieving this.

Static navigation mode determines whether a GPS receiver is in fact stationary based on pre-defined velocity and distance values. When static navigation is enabled, if the vehicle’s velocity drops below a threshold value, then the position and heading are pinned to the last computed value. The position and heading will remain at these values until the receiver detects that the velocity has increased above a slightly higher threshold, or its position is computed to be more than a set distance from that to which it is pinned.

Static navigation is designed specifically for use in motor vehicles where normal speeds are expected to be well above the threshold for pinning. In the hands of a pedestrian, or on a boat drifting with a slow current, the effects of static navigation are likely to be unacceptable since expected velocities are often at or below the threshold for pinning. Even in an automobile or truck, there are likely to be some effects such as delayed starting after a stop, or occasional jumps in position when stopped among high buildings with severe multipath. But the improvement in such displays as maps that place a vehicle’s heading at the top can be dramatic.

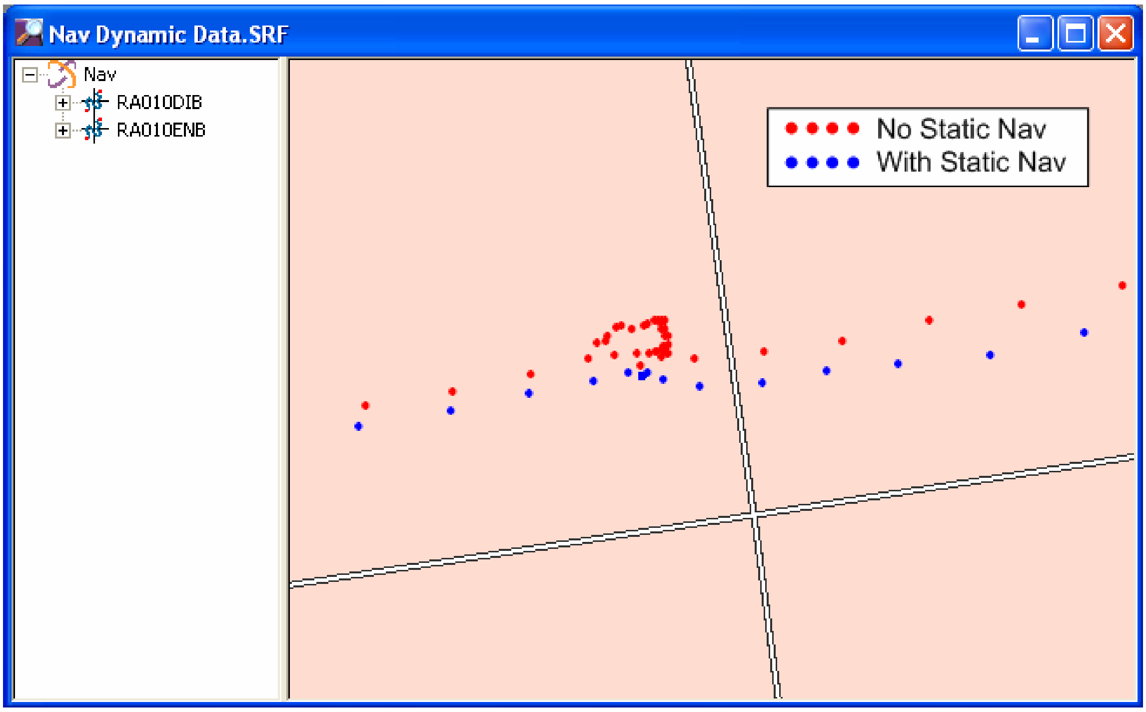

Figure 4 - Plot showing results with static nav being applied verses no static nav

Figure 4 shows the difference in result between using static nav and not. As can be seen, the results with static nav not being used shows a “position wonder” when the vehicle comes to a stop.

SBAS Operation

SBAS (Satellite Based Augmentation System) consists of geostationary satellites that broadcast correction information that can be applied to a calculated position by an SBAS capable GPS receiver. There are three separate SBAS systems that cover almost the entire earth. These are:

•WAAS - positioned over and around North America

•EGNOS - positioned over and around Europe (Not fully useable yet)

•MSAS - positioned over and around Japan and East Asia (Not operational)

The intention of SBAS is to provide a widely available correction service that can potentially increase the accuracy of GPS. However, there are a number of considerations:

•Accuracy - since Selective Availability (S.A.) was switched off, GPS receivers generally provide very accurate solutions when in an open-sky setting. SBAS corrections can only help such receivers a very small amount. And in other settings, the factors which cause increased errors in the position solution are not correctable by SBAS corrections since they are local to the affected receiver and not predictable by the SBAS system. Under the best of conditions, the expected improvement is only one or two meters.

•Availability - SBAS satellite signals are already significantly weaker than GPS signals. The highest strength signal you can expect is only about 32dB-Hz and then the message cannot be decoded when it drops to about 28dB-Hz. This means that any SBAS signal is really only available in a very clear, open environment.

•Continued Tracking - One major problem with the weak SBAS signal is that it is difficult to maintain lock on the signal and continue using the signal, especially when you are in an obstructed dynamic environment.

SBAS signals are designed to provide critical information on the health of specific GPS satellites, and to provide some measure of improvement to navigation solutions. In the rare case of a GPS satellite that has become inaccurate, but has not yet been detected by the GPS controllers, SBAS can improve accuracy significantly. However, under most ground-based applications, and under most normal GPS satellite operations, it does not provide dramatic improvements.