REV 1.3

iSuite^{TM} 3 Application Note

SBAS Support

This document describes how SBAS support can be enabled in iTrax03 receiver. The document will also describe how SBAS systems enhance receiver performance by briefly explaining what kind of information and corrections SBAS systems provide. Finally, this document explains how iTrax03 uses the corrections provided by SBAS systems. Examples of SBAS systems are WAAS, EGNOS and MSAS.

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Change log

Rev.	Notes	Date
1.0	Initial revision	24-01-2006
1.1	Updated figures, vocabulary and known issues & shortcomings	03-03-2006
1.2	Updated known issues	2007-02-15
1.3	Document review. Updated WAAS/EGNOS status	2007-02-23

CONTENTS

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1. COMPLEMENTARY READING

The following reference documents are complementary reading for this document:

Ref. #	File name	Document name
1	PRO_nmea.html	NMEA protocol specification

2. VOCABULARY

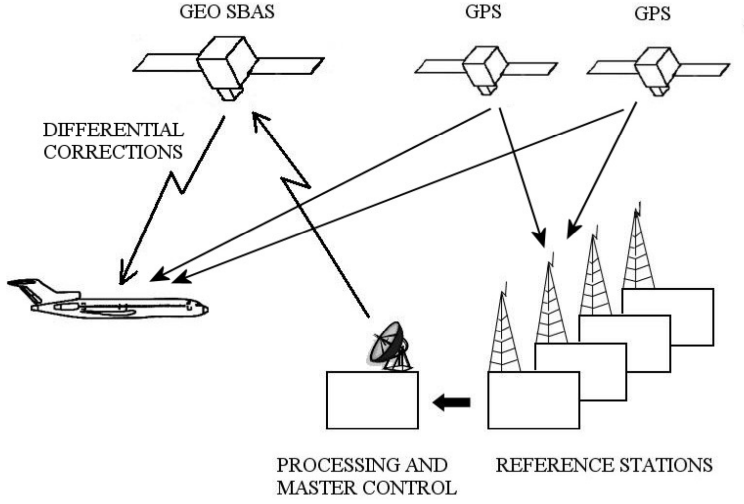
Term	Explanation
EGNOS	European Geostationary Navigation Overlay Service
MSAS	Multi-function transportation Satellite-based Augmentation System
Ionospheric Pierce Point	A point at the height of the ionosphere, where the line of sight vector from GPS satellite to the user pierces the ionosphere.
PRN	Pseudo Range Number used to identify a GPS or SBAS satellite
SBAS	Satellite Based Augmentation System
TTFF	Time To First Fix
WAAS	Wide Area Augmentation System

3. INTRODUCTION

Satellite based augmentation systems (SBAS) provide additional accuracy and reliability for the GPS system by providing differential corrections and integrity information for the GPS user. All information is provided via geostationary satellites that broadcast a similar signal to GPS. Thus, user needs no additional hardware.

In principle all SBAS systems work in similar manner. They consist of a network of ground reference monitoring stations, processing and control facilities, uplink stations and a few geostationary satellites. The ground reference monitoring stations are decentralized data collection sites that constantly monitor and measure all signals from visible GPS and SBAS satellites. From reference stations all measurements are relayed to the central processing sites for processing. Because the exact position of the reference monitoring stations is known, the central processing sites are able to compute the differential corrections and integrity messages by comparing the known measurements and known data.

Finally the central processing sites generate the navigation message to be transmitted to the SBAS satellites using uplink stations. SBAS satellites then broadcast the differential corrections and integrity information for the users.



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4. SUPPORTED FEATURES

4.1 SUPPORTED CORRECTION TYPES

FEATURE	YES	NO
Fast corrections	X	
Slow corrections	X	
Ionospheric corrections	X	
Integrity info	X	
SBAS ranging		X

4.2 SUPPORTED MESSAGE TYPES

MESSAGE Type	YES	NO
PRN mask (1)	X	
Fast correction (2-5)	X	
Integrity info (6)	X	
Fast correction degradation factor (7)	X	
GEO navigation message* (9)		X
Degradation parameters* (10)		X
WAAS Network time / UTC offset parameters* (12)		X
Geo satellite almanacs* (17)		X
Ionospheric grid point mask (18)	X	

* iSuite 3 supports message decoding, but data is not used.

Mixed fast correction / Long term SV corrections (24)	X	
Long term SV corrections (25)	X	
Ionospheric delay corrections (26)	X	
WAAS Service Msg (27)		X
Clock-Ephemeris Covariance Message (28)		X

4.3 KNOWN ISSUES & SHORTCOMINGS*

- Ionospheric correction bands 9 and 10 for northern and southern latitudes are not supported

- Ionospheric corrections are not available for GPS satellites, whose ionospheric pierce point is above 75 degree of north or below 75 degree of south.

- To support the EGNOS MT0/2 message transmission SBAS data is used even if MSG type 0 is transmitted. In this mode the contents of fast correction MSG type 2 are transmitted in MSG type 0. User can select by parameter WAAS_MSG_0_ENA if the MSG type 0 is accepted or not.

* These apply to software version 3.41 unless otherwise mentioned

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5. SBAS STATUS

5.1 WAAS STATUS

There are total of 19 PRN numbers reserved for SBAS systems. The status of the each PRN is shown in the table below.

Note that at present the WAAS constellation is being improved. The satellite, which has been broadcasting the PRN 122 has been moved towards west to a new location at 142° W to improve the overlay in western part of U.S.

Two new WAAS satellites has been taken into use to ensure a comprehensive service level in eastern part of U.S. The are the PRNs 135 and 138.

5.2 EGNOS STATUS

At present* the PRNs 120 and 126 are used for EGNOS initial operations. The PRN 124 is used for system testing

PRN	SBAS SYSTEM
120	EGNOS
121	-
122	WAAS
123	-
124	EGNOS
125	-
126	EGNOS
127	-
128	-
129	MSAS
130	-
131	EGNOS
132	-
133	-
134	WAAS

* February 23, 2007

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135	WAAS
136	-
137	MSAS
138	WAAS

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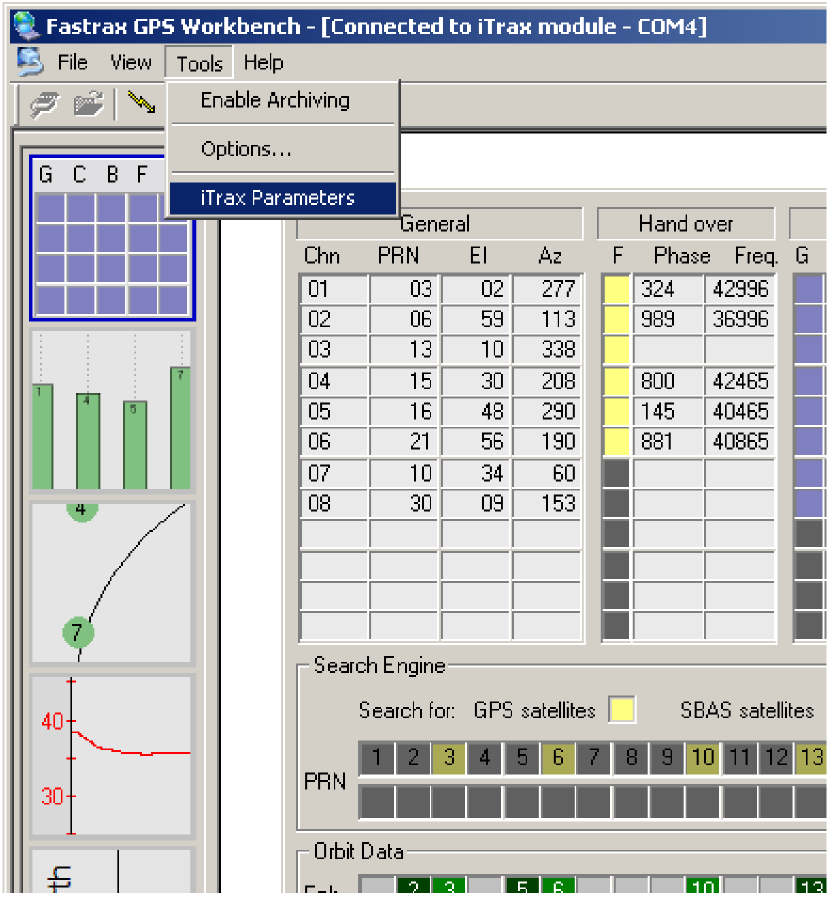
6. HOW TO ENABLE SBAS SUPPORT IN ITRAX 3

6.1 USING FASTRAX GPS WORKBENCH

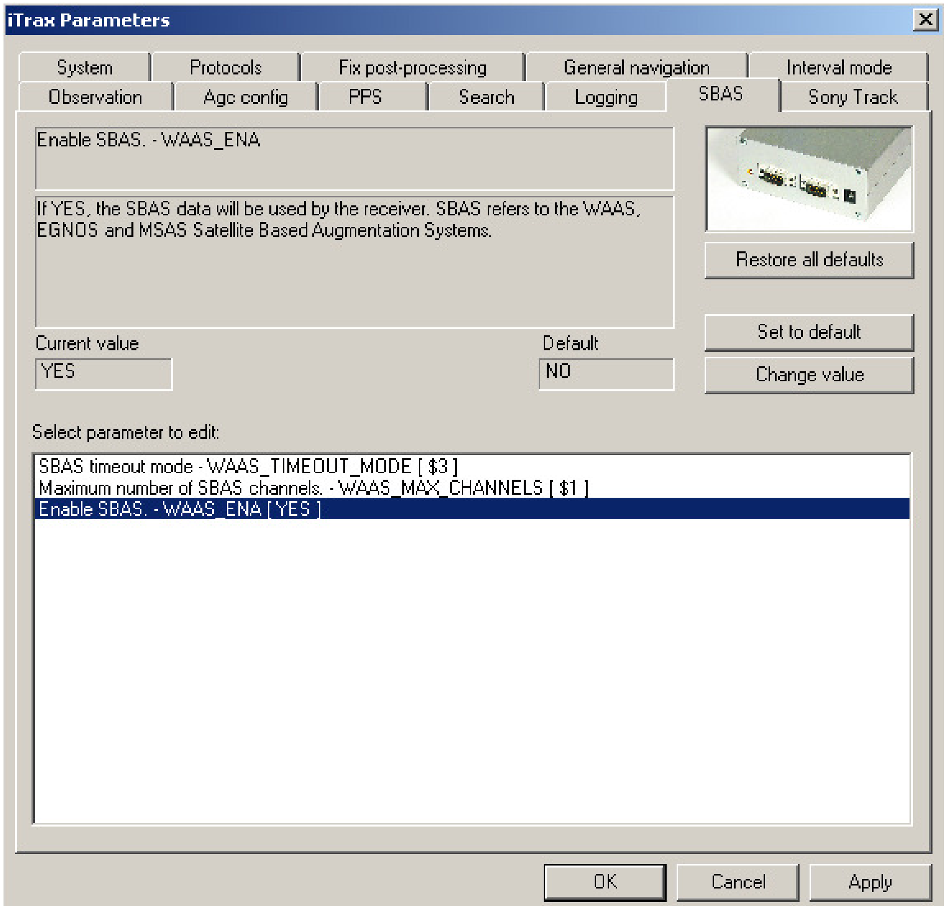
The SBAS support is default off in iTrax 3 receiver. The support can be enabled by turning on the appropriate parameter and defining a search mask for SBAS satellites.

This can be done using Fastrax GPS Workbench. Open GPSWB and connect it to the iTrax receiver. Then click on "Tools" and choose "iTrax parameters" as described below.



Now the iTrax parameter configuration window should open. From the configuration window choose "SBAS" tab and click on the "Enable

SBAS". By pressing "Change value" and "Apply" buttons the parameter will be turned on and SBAS navigation enabled. See picture below.



The next step is to configure the search mask for SBAS satellites. This defines what satellites the search engine will look for.

From parameter configuration window choose "Search" tab and click on "Search mask for SBAS signals"

The search mask in parameter configuration window is a bit mask that enables or disables the SBAS satellite corresponding to the bit in mask. The satellites are defined in order from 120 to 138 starting from the least significant bit.

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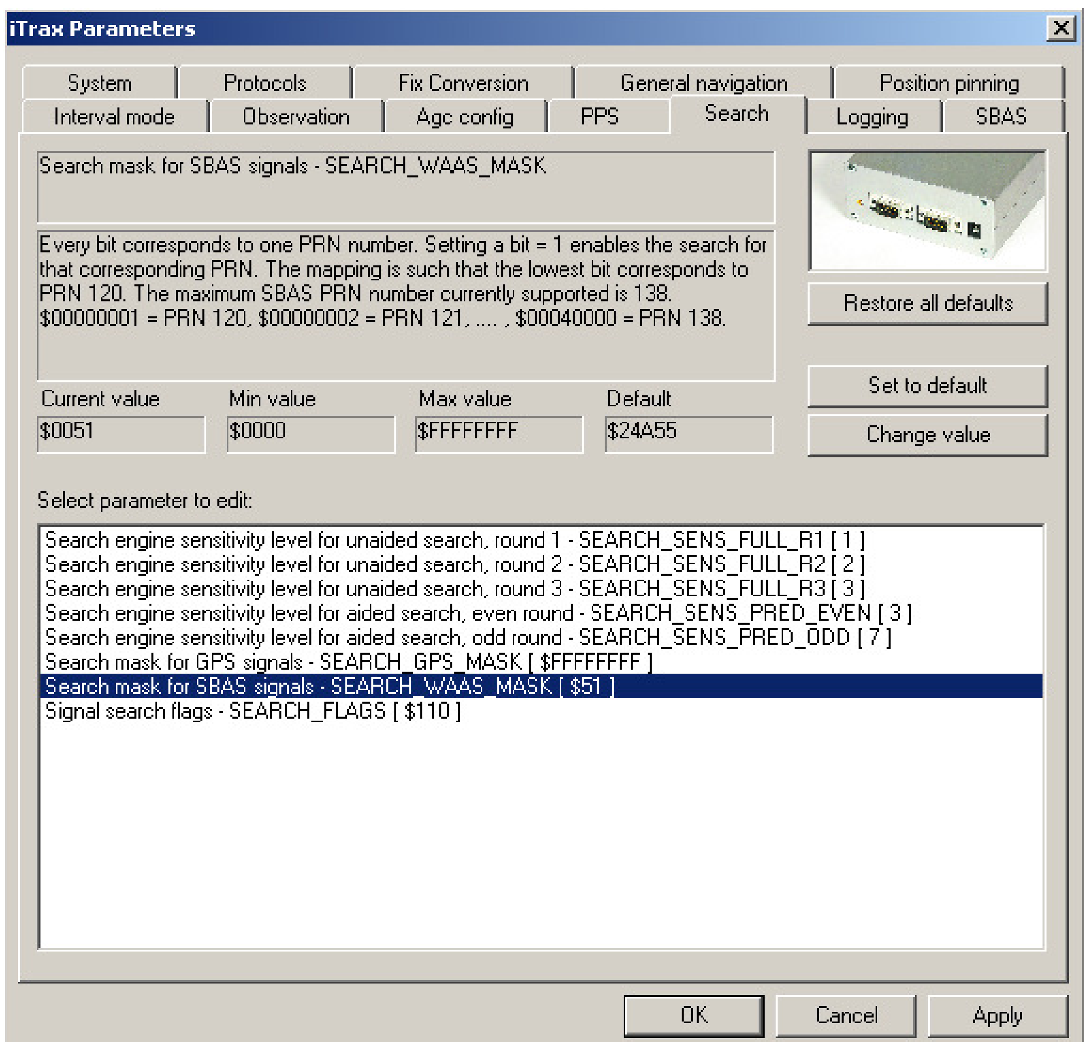
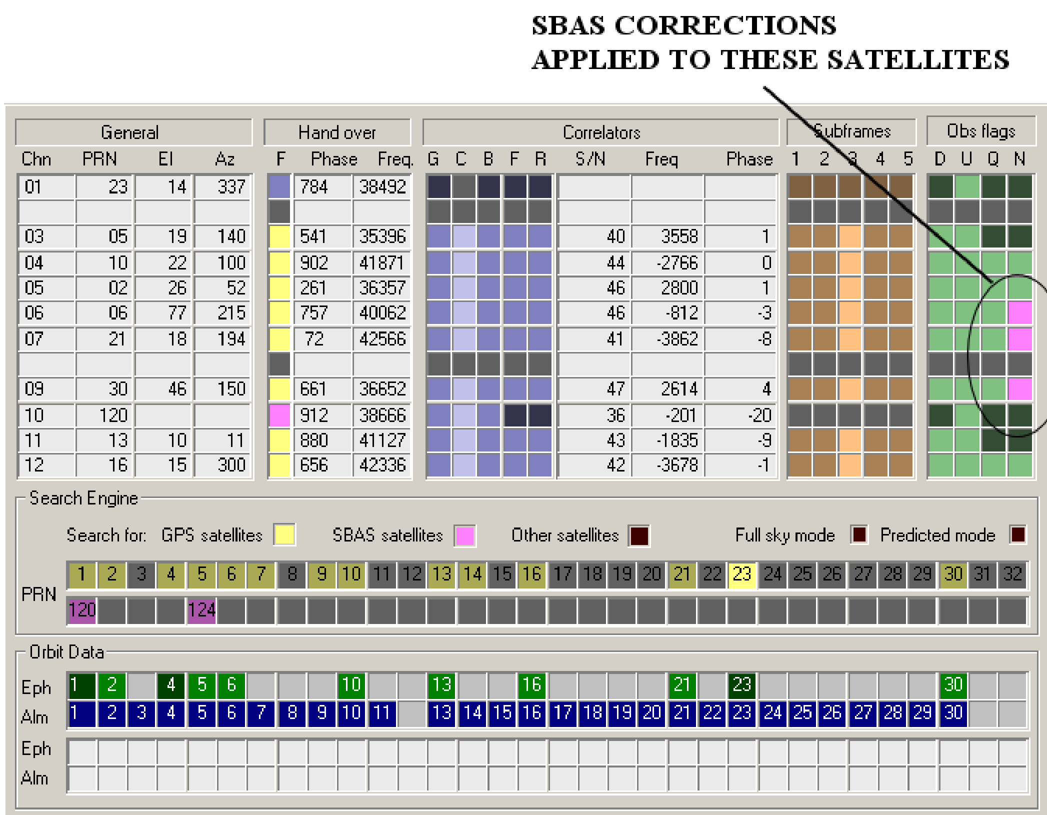
The default search mask for SBAS satellites is hexadecimal value 24A55. This means that all SBAS satellites mentioned in the table above are selected.

Example: How to define the EGNOS satellites 120, 124 and 126.

- Click on “Search mask for SBAS signals”. Press “Change value”
- Set search mask value to hexadecimal 0x0051 and press “Apply”



The SBAS corrected GPS satellites will be shown in light red color in Fastrax GPS workbench as can be seen from the figure below. Note that time from the moment the SBAS satellite was found and tracking started to the moment the corrections appear can be several minutes, because receiver needs to download a fair amount of data, before corrections can be applied.



6.2 USING NMEA COMMANDS

In iTrax 3 parameters can be configured using the appropriate NMEA commands. Thus, it is possible to enable the SBAS support and set the appropriate search mask.

The parameters can be configured using the NMEA command "$PFST,CONF". (See ref #1.)

When configuring parameters using NMEA, the parameters are identified by unique key. The key consists of a parameter ID and group ID as described in ref #1.

Enable SBAS support using NMEA command

- "$PFST,CONF,0BC0,1"

Disable SBAS support using NMEA command

- "$PFST,CONF,0BC0,0"

Set the SBAS satellite mask using the command

- "$PFST,CONF,070D,XXXX", where XXXX is replaced with appropriate bit mask value.

Note! Now the bit mask value has to be defined using decimal number (unlike in Fastrax GPS workbench, where it is set using a hexadecimal value).

Example: Set EGNOS PRNs 120, 124, 126:

The bit mask for these PRNs is 0x0051 and decimal value 81. The NMEA command is "$PFST,CONF,070D,81".

7. SBAS CORRECTIONS

7.1 EXISTING SBAS SYSTEMS

- Wide Area Augmentation System (WAAS) is a satellite based augmentation system that covers the continental U.S.
- European Geostationary Navigation Overlay Service (EGNOS) is similar system to WAAS covering the European area.
- Multi-function transportation Satellite-based Augmentation System (MSAS) is a similar system to WAAS and EGNOS being implemented in Japan.

7.2 ERRORS IN GPS SIGNALS

During the transmission, there are several stages, where degradation of the GPS signal can take place. As an example some of these are mentioned below.

Space segment

- Errors in broadcasting satellite clock
- Errors in modeling the satellite motion (ephemeris errors)
- Satellite geometry

Propagation

- Both ionosphere and troposphere refract GPS signals. This causes the GPS signal to have a different speed compared to the GPS signal speed at space.

Local errors

- Multipath
- Receiver noise

There are limited ways for a standalone GPS system to resist these errors. E.g. the health messages in GPS system are transmitted up to 2 hours late.

The purpose of the SBAS system is to try to correct the errors in space segment and propagation stage. There is no way for the SBAS system to correct the local errors such as multipath conditions or receiver errors.

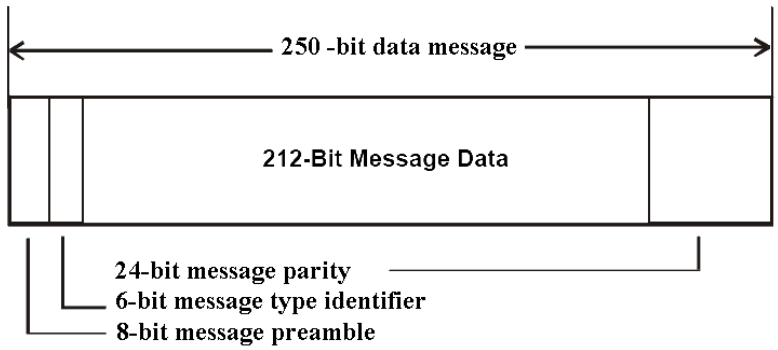
Integrity is provided via real-time monitoring. The SBAS system monitors constantly the quality of the GPS satellites and is able to warn the users of faulty satellites. These satellites can then be rejected from the position solution.

Accuracy is provided by differential corrections. The SBAS system uses three types of correction methods, fast corrections, slow corrections and ionospheric corrections.

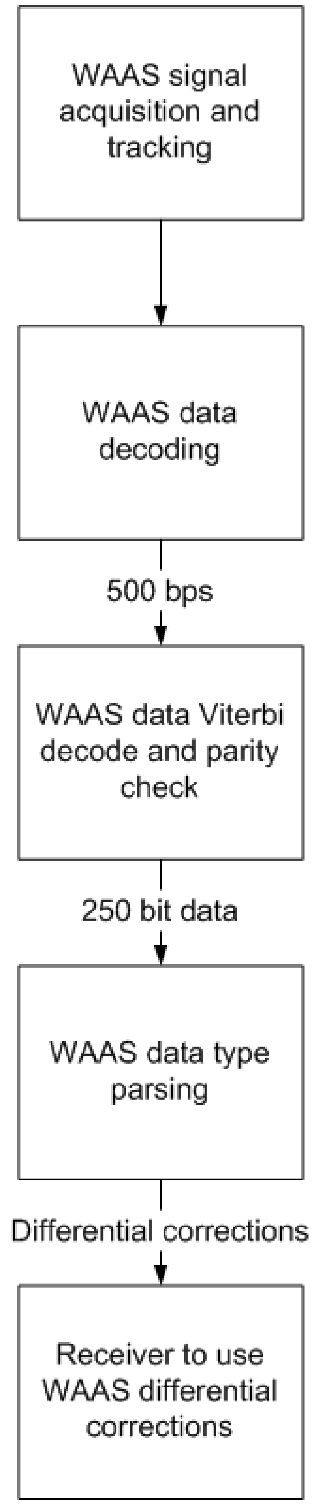
7.3 SBAS DATA PROCESSING IN ISUITE 3

The SBAS satellites broadcast the information and corrections in raw navigation data message that has a baseline data rate of 250 bits per second. This navigation message is protected by ½-rate convolutional forward error correction code, which duplicates the actual bit rate to 500 bits per second. The purpose of this coding is to provide means for the receiver to correct bit errors that take place in reception of the SBAS data.

All messages have identical format as described below



Before the received data can actually be used, the convolutional encoding has to be decoded by using Viterbi algorithm. iSuite 3 includes a powerful Viterbi decoder, which is able to perform this process. After the Viterbi decoder the SBAS messages are extracted from the raw data and handled accordingly. The complete flow chart of the data processing of SBAS data is presented below.


WAAS signal acquisition and tracking
WAAS data decoding
500 bps
WAAS data Viterbi decode and parity check
250 bit data
WAAS data type parsing
Differential corrections
Receiver to use WAAS differential corrections

7.4 FAST CORRECTIONS

As name suggests the fast corrections are used to correct fast changing errors caused mostly by the fluctuations in satellite clock.

The correction is provided as a common correction for all users to be applied to the user computed pseudorange. The actual pseudorange correction is computed by differencing the consecutive fast corrections and summing the difference term (range rate correction) to the plain fast correction term.

Although there is also a dedicated message for the integrity information, the fast correction message includes a field to provide integrity info for specific set of satellites. This integrity is used to flag unhealthy satellites.

iSuite 3 software supports fast correction computation and integrity information computation. As SBAS specification states, it is able to detect faulty satellites within 6 seconds from the event and leave them out from the navigation solution.

Note! After careful evaluation and testing, the computation of the range rate term was left out from the iSuite3 software. This was done, because

a. Range rate term had a very small effect to the total correction.

b. As a compromise to save RAM memory for other features

7.5 SLOW CORRECTIONS

The slowly varying errors are modeled and corrected by the slow corrections (or long term corrections). This kind of slowly varying errors are for example the satellite position and velocity errors caused by errors in the ephemeris transmission and the degradation of the satellite position in time.

The slow corrections also correct the errors in satellite clock although there already is clock correction in GPS navigation data message. Also the satellite clock drift can be modeled.

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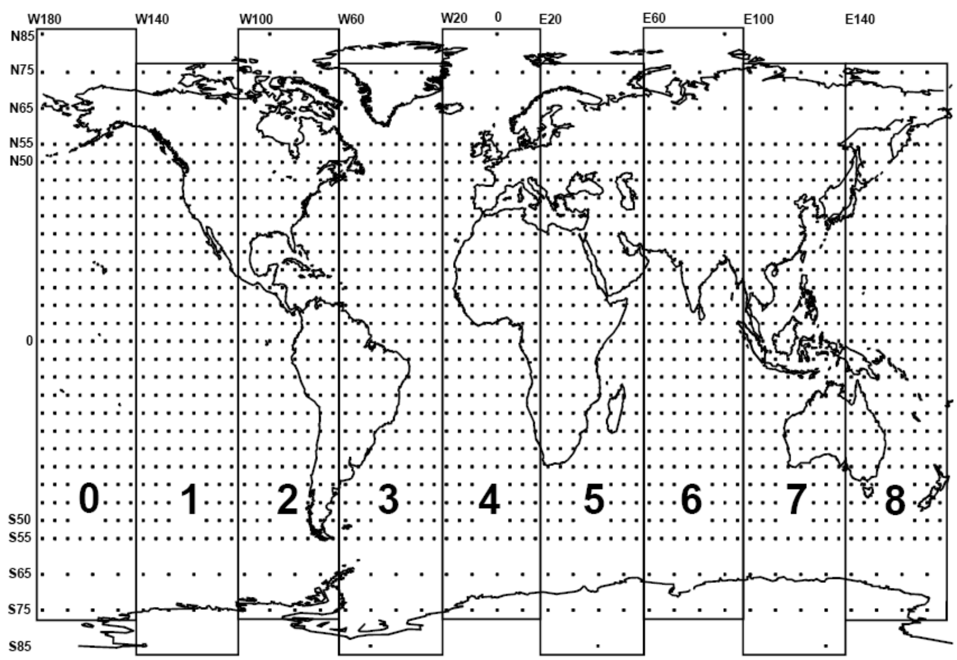
7.6 IONOSPHERIC CORRECTIONS

The SBAS systems model the ionosphere using an interpolated grid that is 350 km above the earth at the height of the ionosphere. The ionospheric grid has predefined grid points at known locations as defined in the global map below.

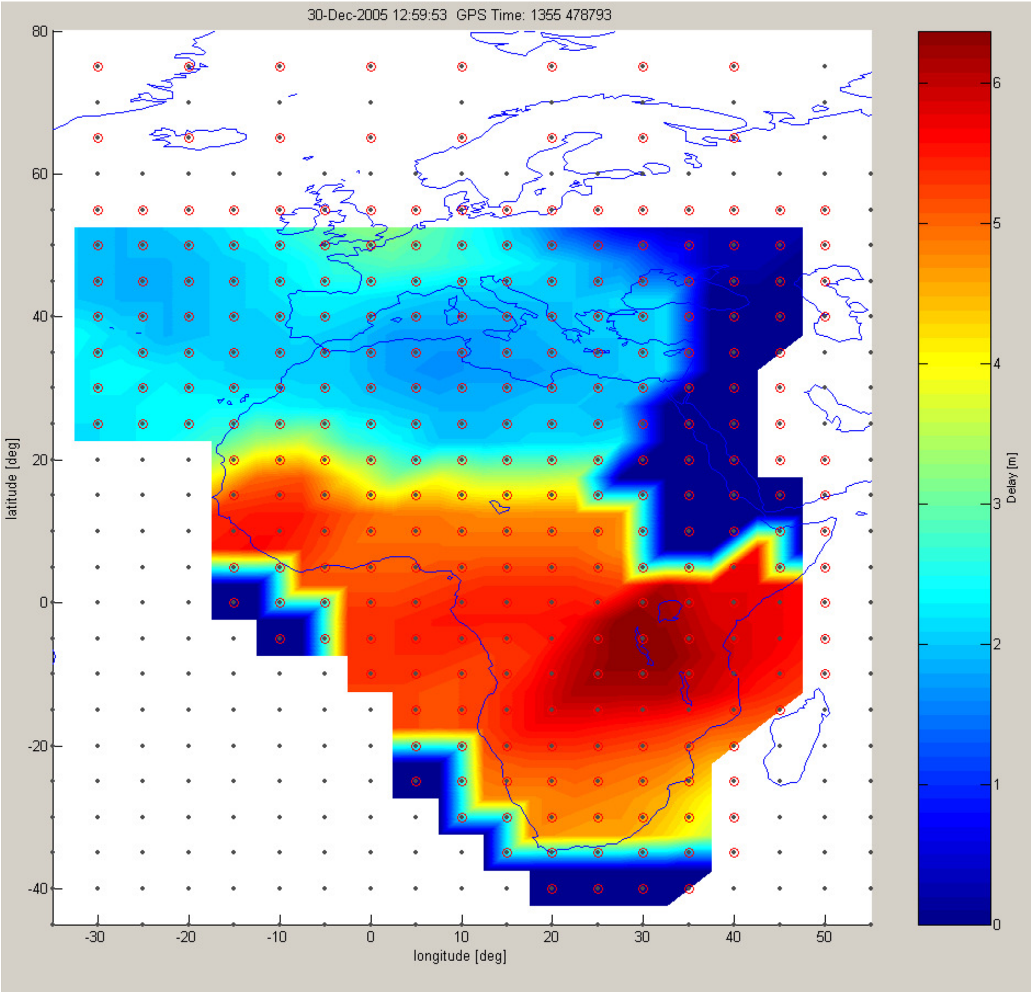


The SBAS systems have two dedicated messages for broadcasting the ionospheric corrections.

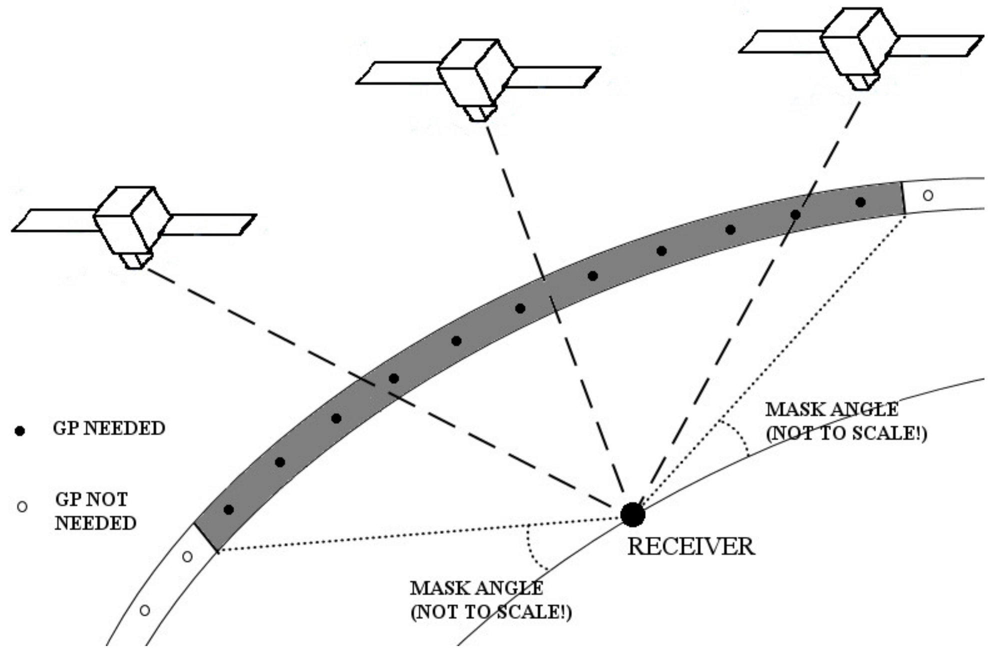
The ionospheric grid point mask message is sent for a certain band from 0 to 8 at a time. It defines, which grid points in the band are active and which are inactive. A certain SBAS satellite can provide information only about the grid points that are visible from its location on the ground and at the controlling systems service area.

The ionospheric correction message provides correction values as a vertical delay values for active grid points. It is also sent to a given band at a time.

As an example, below is a picture showing the active grid points and ionospheric delay values broadcast by the EGNOS PRN 120. The active grid points are marked using a small red circle around the grid point. The delay values range from 0 m (blue) to 6 m (red).



iSuite 3 software uses a sophisticated method to compute ionospheric corrections. The process starts by reception and decoding of the ionospheric grid point mask message. When this type of message is received, the grid point data is saved and ionospheric correction data decoding enabled. Now iSuite 3 software can start to wait for ionospheric delay data.



As shown in the picture above, we do not need to save all ionospheric corrections. Only those corrections that are sent to grid points in the visible part of the interpolation mask from the user's current location need to be saved. Others can be discarded. iSuite 3 keeps in storage a smaller sub-grid of the interpolation grid, which covers this visible area. This sub-grid storage contains information of the grid points and ionospheric delay values for these grid points.

The actual delay corrections are done for a single satellite at a time by first computing the pierce point (the point, where line-of-sight vector pierces the ionosphere) and choosing three or four available grid points that are closest to this point. The final delay correction is interpolated from these points delay values.

8. SBAS ADVANTAGES AND DISADVANTAGES

8.1 INTRODUCTION

How much does the iTrax 3 user benefit from the SBAS support?

There is no straightforward answer and the user has to carefully evaluate the performance issues before enabling the SBAS support. The improvements to the navigation accuracy depend completely on the situation where SBAS is used and also the user location.

8.2 VISIBILITY ISSUES

One thing to remember is that the receiver needs an open visibility to work well. The SBAS satellites broadcast from geostationary orbital slots that are located over equator. Looking from northern latitudes the SBAS satellites are in low elevation and their signal levels are often low. If SBAS support is enabled in urban environment, it is likely that high buildings will block the signal. Also other errors caused for example by the multipath signals will most likely override the benefit gained from SBAS support. On the other hand, if the SBAS satellite is located high above it might well provide corrections in urban environment too.

8.3 INTEGRITY AND IONOSPHERIC CORRECTIONS

The two most important reasons to turn on the SBAS support are the integrity information and ionospheric corrections. If the receiver is in the service area of the SBAS satellite and the SBAS signal power is high enough for Viterbi decoding and data extraction, the user will always gain the integrity information. This means that the system is able to very rapidly warn the user about the unhealthy GPS satellites. Something that standalone GPS system is not able to do.

When looking at the ionospheric corrections, the important thing to remember is again the user location. As shown in the ionospheric map below, the delay values are much smaller in the northern latitudes, where the error caused by the ionosphere is small. Thus the

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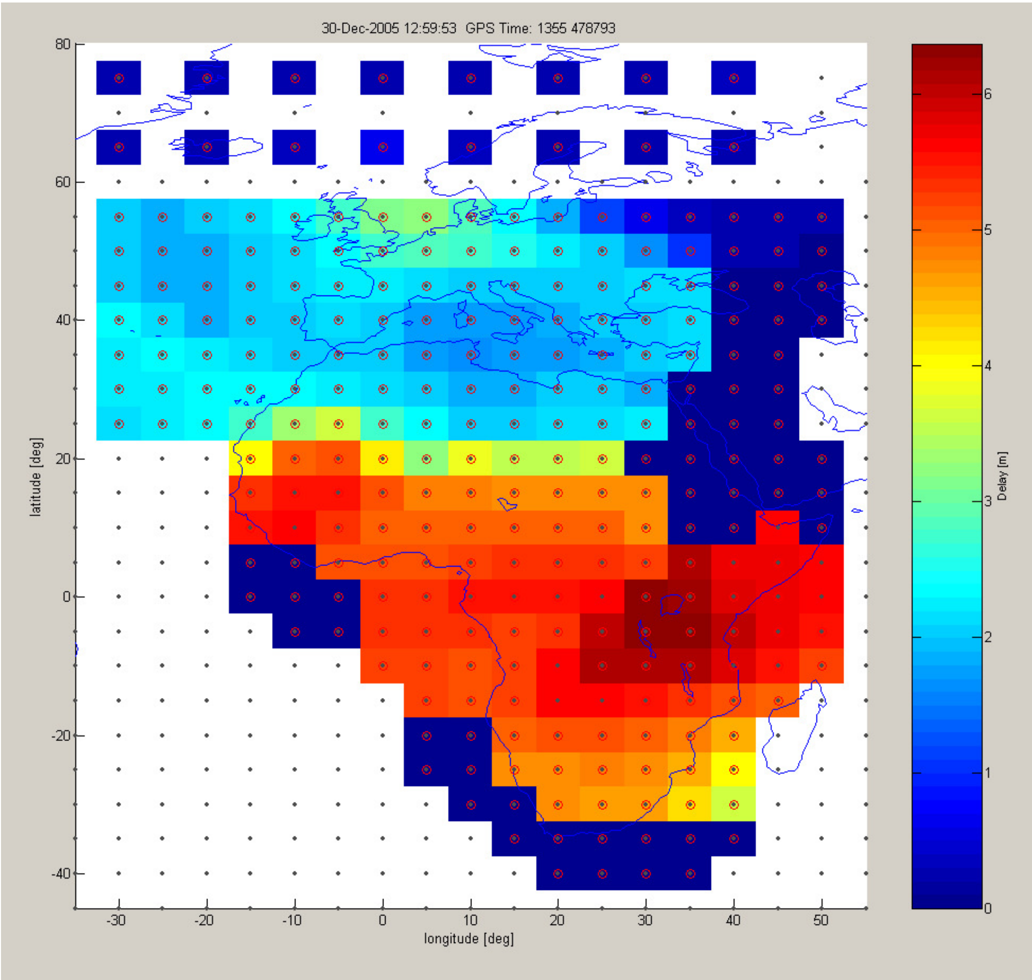
benefit gained from the SBAS ionosphere corrections is small in these areas. However, in rare cases, (e.g. during the ionospheric storms) the ionospheric corrections provided by the SBAS satellite provide much more accurate corrections compared to normal ionospheric models.



8.4 POWER CONSUMPTION ISSUES

The final thing to remember is that when SBAS support is enabled, the iTrax 3 receiver needs to search for additional satellites, which causes the search engine to consume more power. Also the main central processing needs to run extra code source code (e.g. Viterbi decoding, data handling, etc.), which increases the CPU load and thus power consumption.

Below are shown test results of a short test, where a cold start was performed using iTrax 3 receiver module with and without SBAS support. The power consumption was sampled for 5 minutes from the start.

	WAAS OFF	**WAAS ON**
Average power consumption	108,85 mW	113,93 mW
Average current drain (base band only)	15,30 mA	17,16 mA
Average current drain (RF-unit only)	23,58 mA	23,52 mA

9. EXAMPLE USE CASES

9.1 ASSET TRACKING

SBAS support is not recommended for use in asset tracking.

The search for SBAS satellites in iSuite 3 software doesn't start before the receiver has started navigation. The SBAS corrections are not used to improve the first fix accuracy, because the time to download the needed information is very long and this would ruin the TTFF times.

In order to use integrity information, slow and fast corrections the receiver needs to download PRN mask message and correction data. The procedure for this takes several minutes. Similarly, in order to use ionospheric corrections, the receiver needs to download the ionospheric interpolation map and corrections for the active grid points for visible area. The procedure for this may take even longer.

The power consumption is also a one thing that must be taken into consideration. Remember that the SBAS support increases power consumption slightly.

Thus for user, who only needs to the receiver location on regular basis, it is better not to enable SBAS support.

9.2 CAR NAVIGATION IN URBAN ENVIRONMENT

SBAS support is recommended for use in car navigation.

In car, when the receiver is turned on, the device usually stays on for rather long time. During this time, the receiver is able to download all needed data from SBAS satellite and correct the signals. The increased accuracy can for example mean that you know what lane you are driving in highway.

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Also the slightly increased power consumption may not be a big issue in car.

Remember that high buildings may cause an issue if the SBAS satellites are in low elevation. In urban environment the effects caused by multipath typically cause more serious degradation than the ionospheric and satellite effects and SBAS might not help in most serious cases. In these cases the SBAS is only to provide reliability through integrity info.