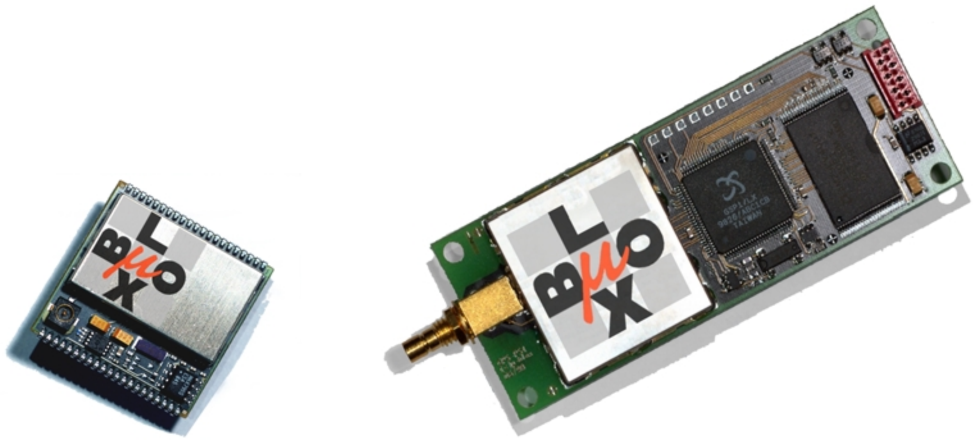
GPS PERFORMANCE
OF GPS-MS1E AND GPS-PS1E

APPLICATION NOTE



Abstract

This application note describes the performance characteristics of µ-blox GPS receivers:
GPS-MS1, GPS-PS1, GPS-MS1E, GPS-PS1E and enhancements –DL-AT-
First, an overview of commonly used GPS performance measures is given, followed by the measurement results.

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The herein presented results are based on measurements that were collected with unobstructed visibility to the sky. All measurements refer to a static position, whereby μ-blox ag cannot guarantee these accuracies or their reproducibility for customer specific applications or under obstructed sky visibility.

GPS receiver accuracy is not only a function of GPS receiver performance. It is also heavily dependent on Time of Day, Satellite Constellation, atmospheric activity and temperature changes.

CONTENTS

1 STANDARD L1 POSITION ACCURACY

1.1 Continuous Operation

The following section describes the position accuracy of a 24 hours measurement period in continuous mode.

Measure		Refers to
rms_v	23.5 m	Altitude
rms_h	5.6 m	LTP
CEP	4.0 m	LTP
R95	13 m	LTP
rms_{3D}	24.2 m	3D
SEP	21 m	3D
Position Accuracy (with S/A off)		

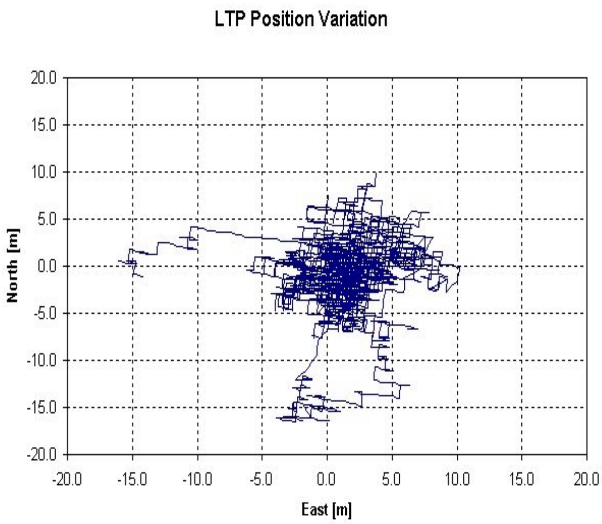

Figure 1-1: 2D Position Variation

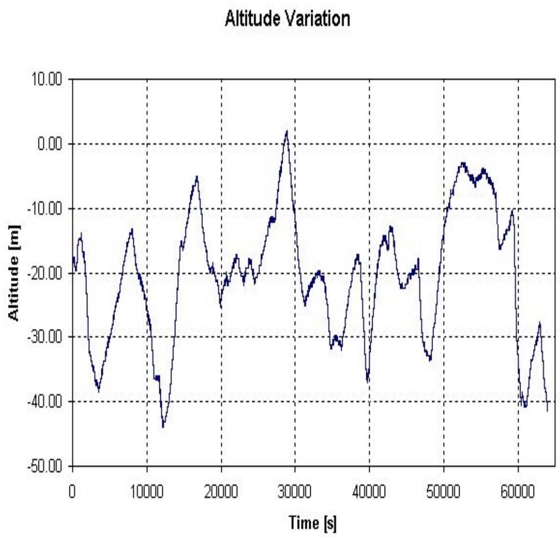

Figure 1-2: Altitude Variation

The figures above describe the position variation over time during continuous operation when S/A was off.

Position accuracy is also a function of atmospheric conditions. The atmosphere affects the signal propagation delay of GPS satellites signals. Atmospheric activity can therefore result in increased position errors. The LTP Position Variation figures above show excursions of the reported position which is an indication for atmospheric turbulences. These turbulences can occur e.g. during sunrise and sunset.

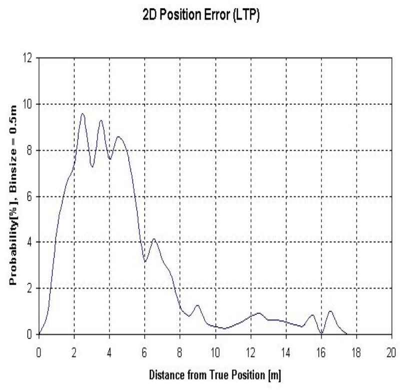

Figure 1-3: LTP Errors

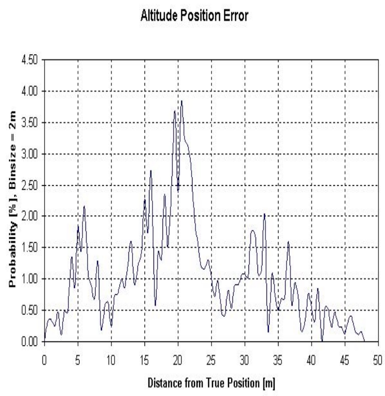

Figure 1-4: Altitude Errors

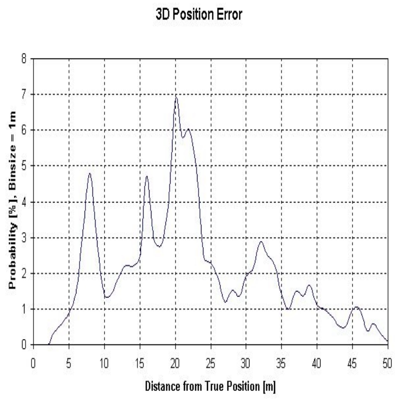

Figure 1-5: 3D Errors

The figures above describe histograms for the position errors in Standard L1 mode.

1.2 Continuous Operation with DGPS

In DGPS mode, a GPS receiver is fed with correction data, usually provided by a third party. Age and accuracy of this datastream has the most significant impact on the position accuracy. Additionally, the distance from the base station where the correction data is being generated, and the GPS receiver consuming this data (commonly referred to as "baseline") does have an impact on the quality that can be achieved.

For these tests, a μ-blox GPS receiver has been fed with an RTCM DGPS correction stream coming from the 'Swiss Landestopografie'. The service quality is called 'Premium Service' and broadcasts RTCM Message Types 1, 2 and 9.

The following table and figures describe the position accuracy of a 24 hours measurement in DGPS continuous mode.

Measure		**Refers to**
rms_v	3.5 m	Altitude
rms_h	2.6 m	LTP
CEP	2.3 m	LTP
R95	4.6 m	LTP
Position Accuracy (with S/A off)		

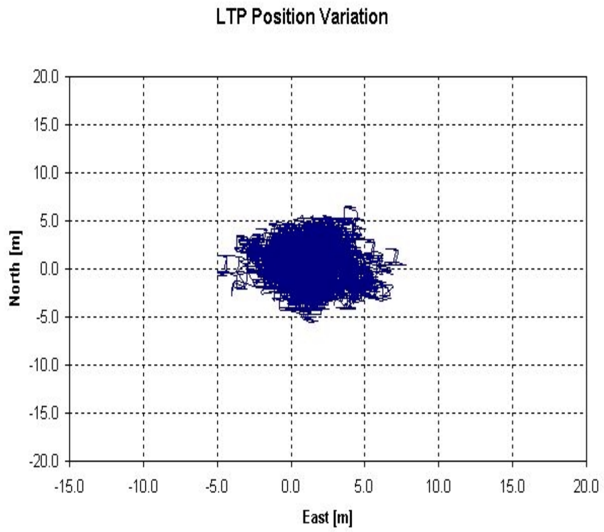

Figure 2-1: 2D Position Variation

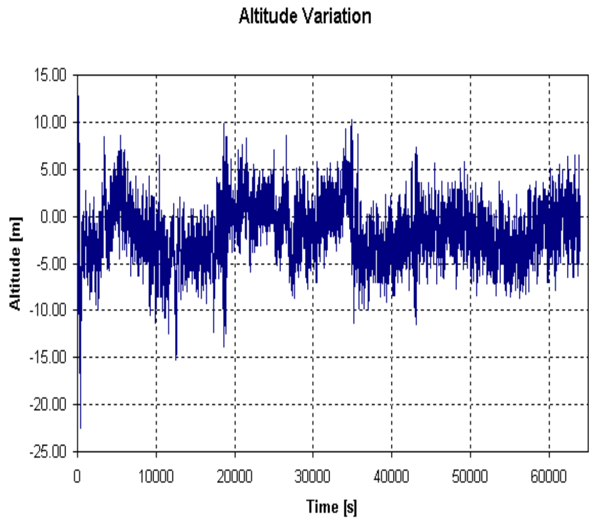

Figure 2-2: Altitude Variation

The figures describe the position variation over time during DGPS continuous operation when S/A was off.

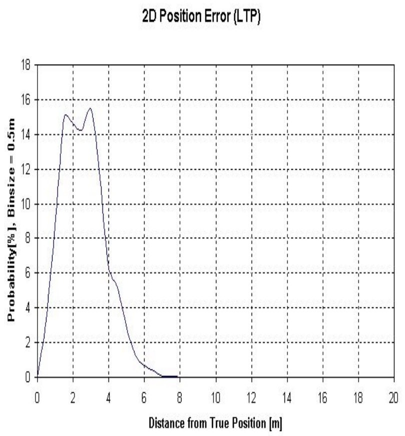

Figure 2-3: LTP Errors

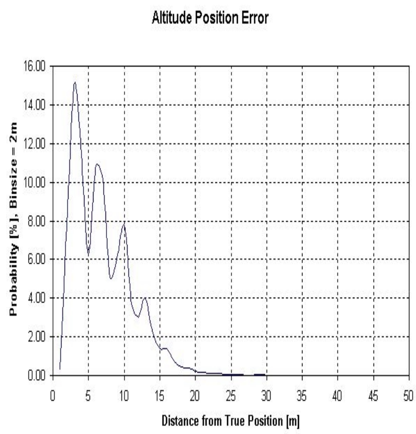

Figure 2-4: Altitude Errors

The figures above describe the histograms for the position errors in Standard L1 mode.

2 START-UP MODES

A GPS receiver has different start-up scenarios, which differs significantly in the Time-to-first-fix (TTFF).

These start-up scenarios depend on the amount of knowledge a GPS receiver has of its last position, current time and the visibility of satellites. Just like GPS accuracy, startup times for GPS receivers are another field where every manufacturer has his own naming scheme, and therefore, comparison between receivers is difficult.

The following sections describe the different start-up modes and give numbers on the time it takes to calculate a first position. Additionally, the quality of the position accuracy after power-up is given. Initial Position accuracy is usually less precise than position accuracy after several minutes of operation, due to internal filters that need to stabilize and ionosphere correction data that is only broadcast with a 12.5 minute period and can usually not be applied to the initial position fixes because it has not been broadcast yet.

The figures presented below show measurement data collected for several days whereby the GPS receiver has been configured to restart repeatedly after having performed a few position fixes.

Please note that these numbers were measured with good visibility (open view to the sky). Obstructed view or motion can result in significantly longer start-up times.

2.1 Cold Start

In Cold Start Scenario, the receiver has no knowledge on last position, approximate time or satellite constellation. The receiver starts to search for signals blindly. This is standard behaviour, if no backup battery is connected.

Cold Start time is the longest startup time for μ -blox GPS receivers.

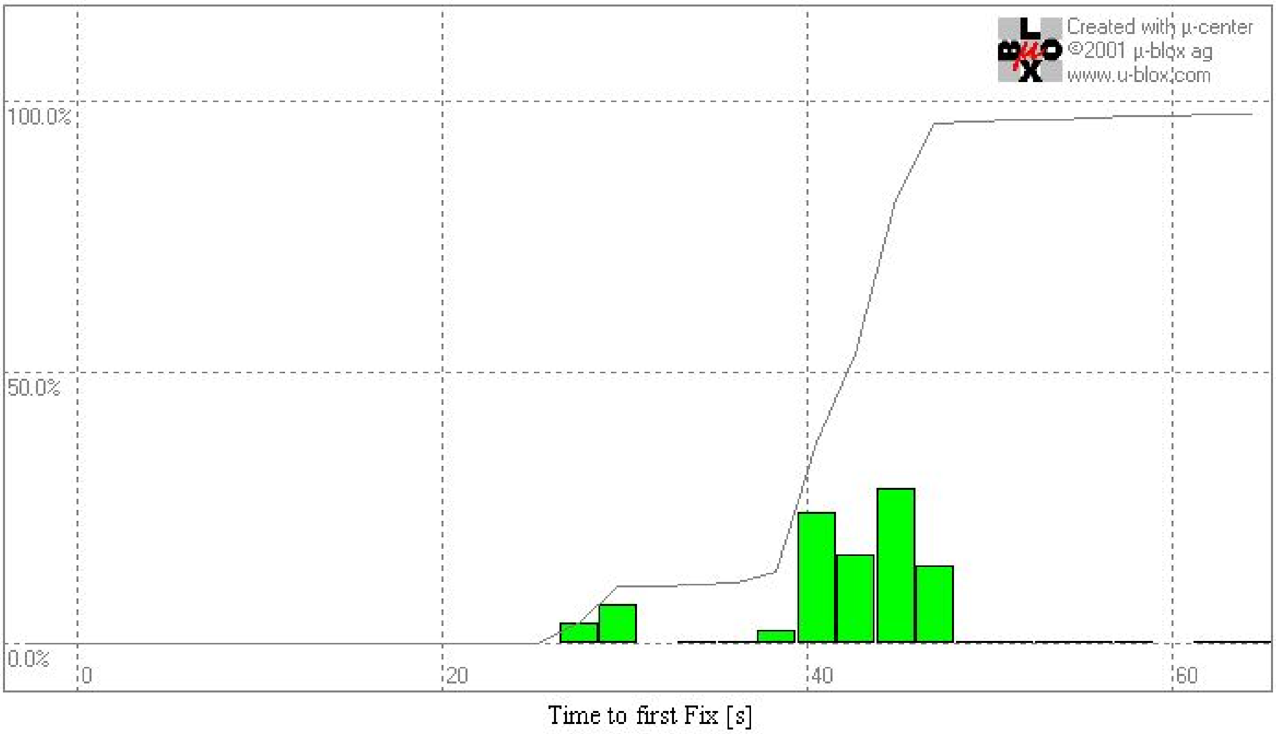

Figure 2-1: Cold start times histogram

The figure above describes the time it takes the receiver from power-up to a first valid position fix. The horizontal axis shows the time since restart and the vertical axis shows the percentages. The green bars in the diagram show the number of fixes that took that long to be calculated. The gray line is the integration over the green bars and gives a statement which tells you how many percent of fixes took a less or equal amount of time to perform a valid position fix.

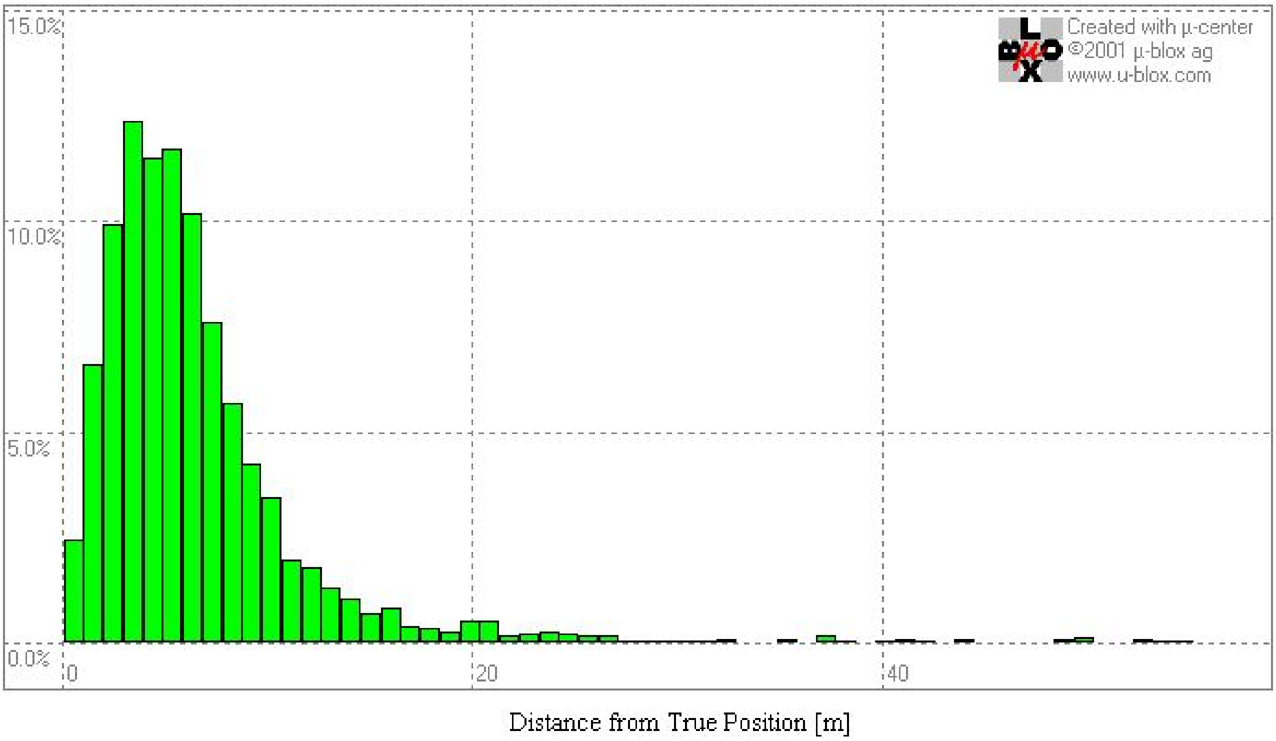

Figure 2-2: Cold Start LTP Position Variation in percent

This figure shows the LTP Position accuracy of the tenth valid position after cold start in percent.

First Fix	Time	LTP accuracy	Altitude accuracy
Average	43 s	8.5 m	12 m
Deviation	9 s	20 m	
R95	47 s	21 m	

2.2 Warm Start

In Warm Start Scenario, the receiver knows - due to a backup battery – his last position, approximate time and almanach. Thanks to this, it can quickly acquire satellites and get a position fix significantly faster than in cold start mode.

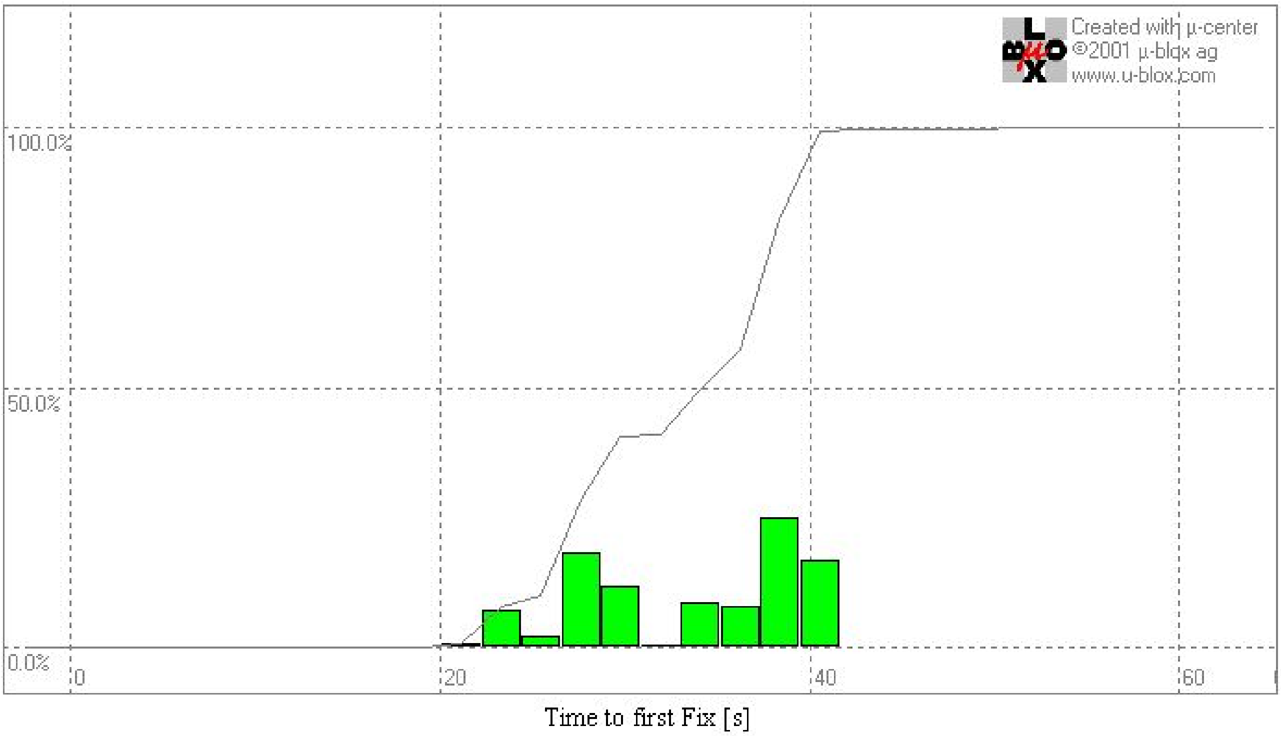

Figure 2-3: Warm start times histogram

The figure above describes the time it takes the receiver from power-up to a first valid position fix. The horizontal axis shows the time since restart and the vertical axis shows the percentages. The green bars in the diagram show the number of fixes that took that long to be calculated. The gray line is the integration over the green bars and gives a statement which tells you how many percent of fixes took a less or equal amount of time to perform a valid position fix.

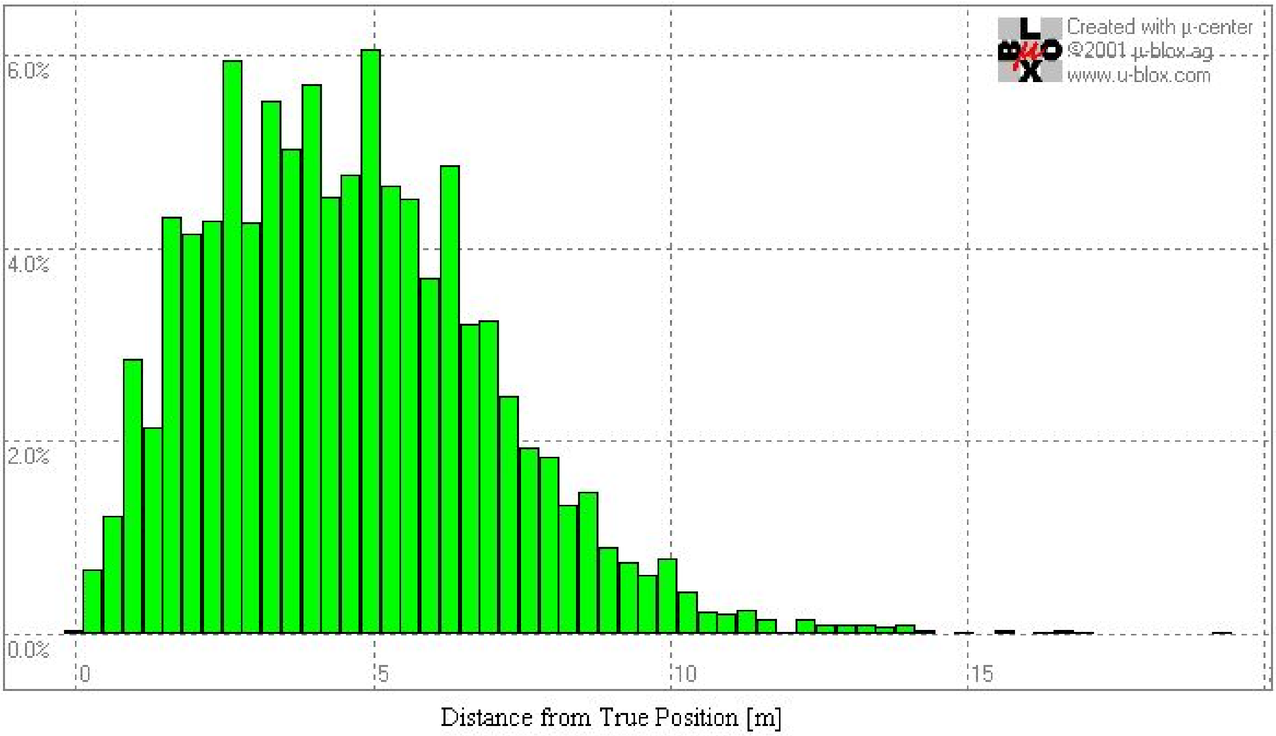

Figure 2-4: LTP Position Variation in percent

This figure shows the LTP Position accuracy of the tenth valid position after warm start in percent.

First Fix	**Time**	**LTP accuracy**	**Altitude accuracy**
Average	34 s	5 m	13 m
Deviation	6 s	3 m	
R95	40 s	9 m	

2.3 Hot Start

In Hot Start Scenario, the receiver was powered down for less than 2 hours. Thanks to a backup battery, it can use its last Ephemeris data to calculate a position fix.

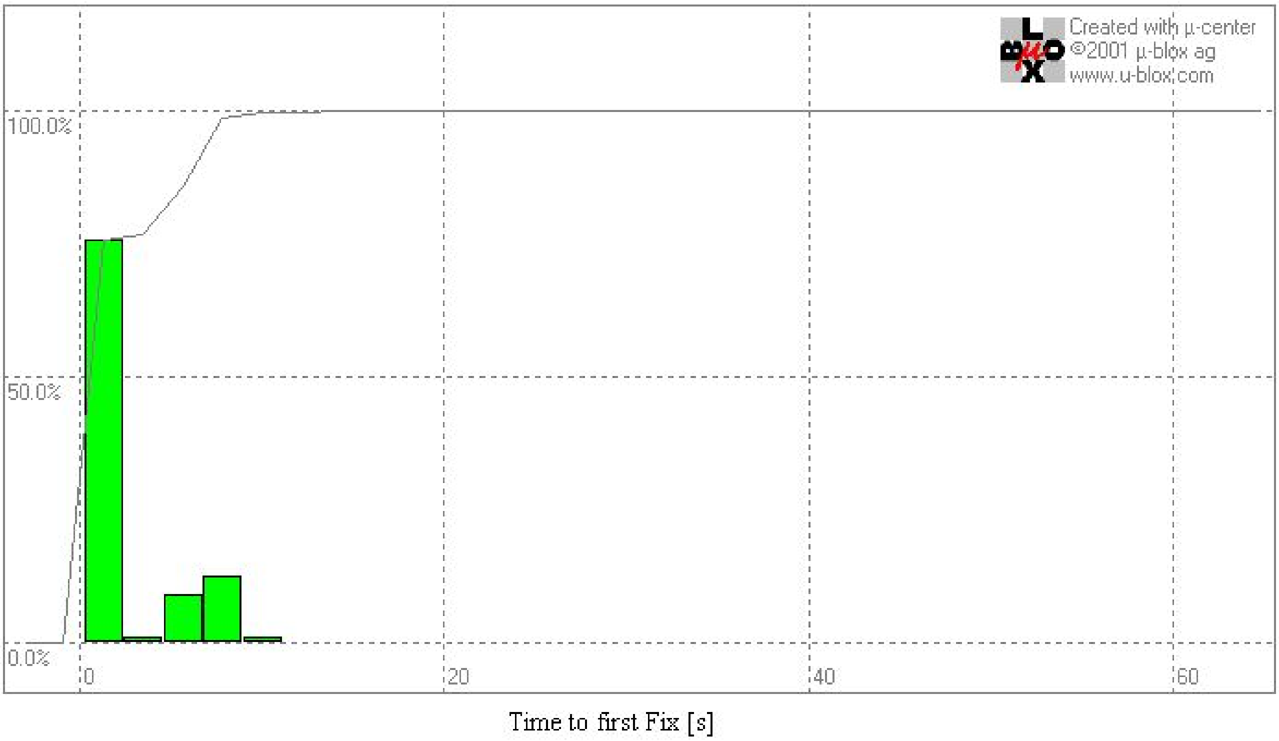

Figure 2-5: Hot start times histogram

The figure above describes the time it takes the receiver from power-up to a first valid position fix. The horizontal axis shows the time since restart and the vertical axis shows the percentages. The green bars in the diagram show the number of fixes that took that long to be calculated. The gray line is the integration over the green bars and gives a statement which tells you how many percent of fixes took a less or equal amount of time to perform a valid position fix.

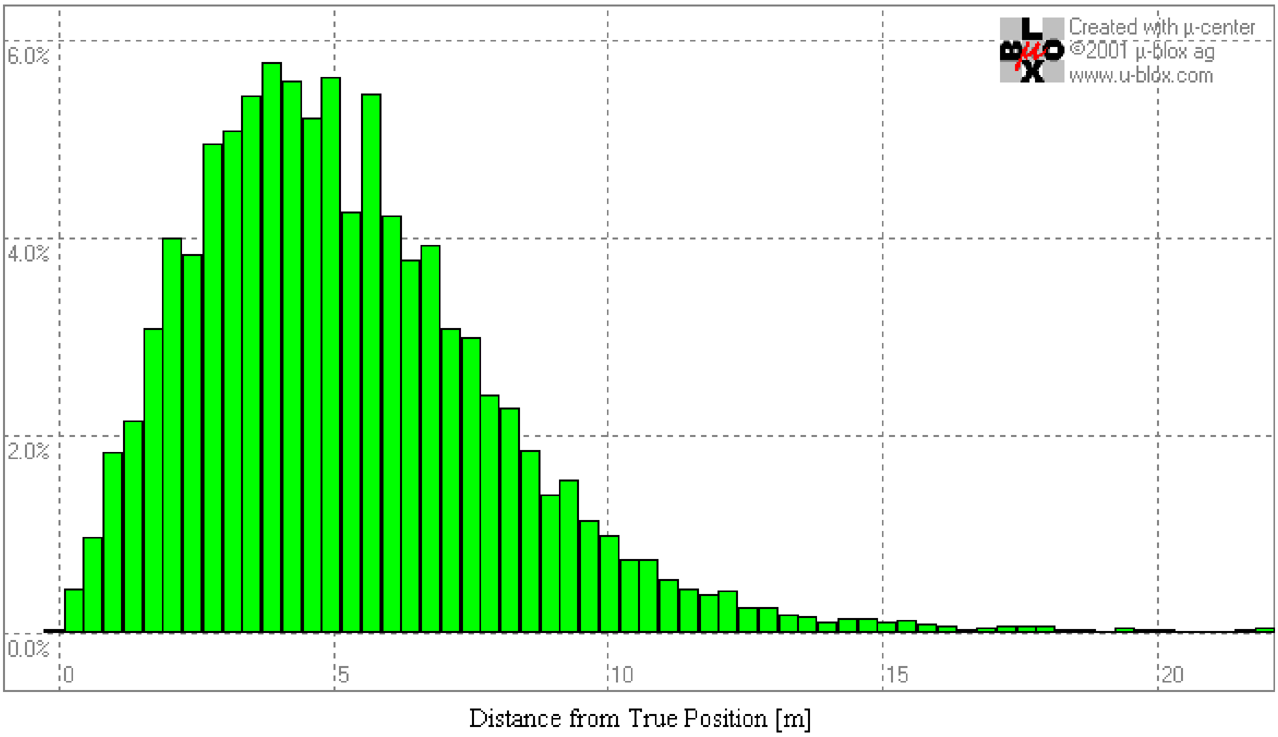

Figure 2-6: LTP Position Variation in percent

This figure shows the LTP Position accuracy of the tenth valid position after hot start in percent.

First Fix	**Time**	**LTP accuracy**	**Altitude accuracy**
Average	2 s	6 m	10 m
Deviation	2.5 s	3 m	
R95	7 s	11.5 m	

A Definition of Accuracy measures

GPS accuracy is not properly defined. Every manufacturer has his own means of defining, measuring and calculating position accuracy. We define commonly used measures and give the values for all them, to simplify comparisons among receivers of different brands.

rms_v	The square root of the average of the squared errors in the vertical dimension. (One dimensional measure)
rms_h	The square root of the average of the squared errors in the local tangential plane. (=LTP)
2drms	Twice the rms_h measure.
CEP	Circular Error Probability. The radius of a circle, centered at antenna's true position, containing 50 % of the fixes. (LTP)
R95	The radius of a circle, centered at the antenna's true position, containing 95 % of the fixes. (LTP)
SEP	Spherical Error Probability. The radius of a sphere, centered at the antenna's true position, containing 50 % of the fixes. (Three Dimensional)
rms_{3D}	The square root of the average of squared errors of the 3D position. (3D)

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