AEROFLEX

GPSG-1000
GPS/Galileo
Positional Simulator

Operation Manual

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GPSG-1000

GPS/Galileo Positional Simulator

Operation Manual

PUBLISHED BY
Aeroflex

Original Issue Jun 2011
Issue 2 Sep 2011

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ELECTROMAGNETIC COMPATIBILITY

Double shielded and properly terminated external interface cables must be used with this equipment when interfacing with the RS-232 and Ethernet.

For continued EMC compliance, all external cables must be shielded and 3 meters or less in length.

NOMENCLATURE STATEMENT

In this manual, GPSG-1000, Test Set or Unit refers to the GPSG-1000 GPS/Galileo Positional Simulator.

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Declaration of Conformity

The Declaration of Conformity Certificate included with the Unit should remain with the Unit.

Aeroflex recommends the operator reproduce a copy of the Declaration of Conformity Certificate to be stored with the Operation Manual for future reference.

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Precautions

SAFETY FIRST - TO ALL OPERATIONS PERSONNEL

GENERAL CONDITIONS OF USE

This product is designed and tested to comply with the requirements of IEC/EN61010-1 ‘Safety requirements for electrical equipment for measurement, control and laboratory use’ for Class I portable equipment and is for use in a pollution degree 2 environment. The equipment is designed to operate from installation supply Category II.

Equipment should be protected from liquids such as spills, leaks, etc. and precipitation such as rain, snow, etc. When moving the equipment from a cold to hot environment, allow the temperature of the equipment to stabilize before the equipment is connected to the supply to avoid condensation forming.

The equipment must only be operated within the environmental conditions specified in the performance data.

CASE, COVER OR PANEL REMOVAL

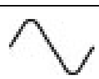
Opening the Case Assembly exposes the operator to electrical hazards that may result in electrical shock or equipment damage. Do not operate this Test Set with the Case Assembly open.

SAFETY IDENTIFICATION IN TECHNICAL MANUAL

This manual uses the following terms to draw attention to possible safety hazards that may exist when operating or servicing this equipment:

CAUTION	IDENTIFIES CONDITIONS OR ACTIVITIES THAT, IF IGNORED, CAN RESULT IN EQUIPMENT OR PROPERTY DAMAGE, E.G., FIRE.
WARNING	**IDENTIFIES CONDITIONS OR ACTIVITIES THAT, IF IGNORED, CAN RESULT IN PERSONAL INJURY OR DEATH.**

SAFETY SYMBOLS IN MANUALS AND ON UNITS

	**CAUTION**: Refer to accompanying documents. (This symbol refers to specific CAUTIONS represented on the unit and clarified in the text.)
	Indicates a Toxic hazard.
	Indicates item is static sensitive.
	**AC TERMINAL:** Terminal that may supply or be supplied with AC or alternating voltage.

SAFETY FIRST - TO ALL OPERATIONS PERSONNEL (cont)

EQUIPMENT GROUNDING PROTECTION

Improper grounding of equipment can result in electrical shock.

USE OF PROBES

Refer to Performance Specifications for the maximum voltage, current and power ratings of any connector on the Test Set before connecting a probe from a terminal device. Be sure the terminal device performs within these specifications before using the probe for measurement, to prevent electrical shock or damage to the equipment.

POWER CORDS

Power cords must not be frayed or broken, nor expose bare wiring when operating this equipment.

USE RECOMMENDED FUSES ONLY

Use only fuses specifically recommended for the equipment at the specified current and voltage ratings. Refer to Performance Specifications for fuse requirements and specifications.

INTERNAL BATTERY

This unit contains a Lithium Ion Battery, serviceable only by a qualified technician.

EMI (ELECTROMAGNETIC INTERFERENCE)

CAUTION	SIGNAL GENERATORS CAN BE A SOURCE OF ELECTROMAGNETIC INTERFERENCE (EMI) TO COMMUNICATION RECEIVERS. SOME TRANSMITTED SIGNALS CAN CAUSE DISRUPTION AND INTERFERENCE TO COMMUNICATION SERVICE OUT TO A DISTANCE OF SEVERAL MILES. USER OF THIS EQUIPMENT SHOULD SCRUTINIZE ANY OPERATION THAT RESULTS IN RADIATION OF A SIGNAL (DIRECTLY OR INDIRECTLY) AND SHOULD TAKE NECESSARY PRECAUTIONS TO AVOID POTENTIAL COMMUNICATION INTERFERENCE PROBLEMS.

SAFETY FIRST - TO ALL OPERATIONS PERSONNEL (cont)

TOXIC HAZARDS

WARNING	SOME OF THE COMPONENTS USED IN THIS EQUIPMENT MAY INCLUDE RESINS AND OTHER MATERIALS WHICH GIVE OFF TOXIC FUMES IF INCINERATED. TAKE APPROPRIATE PRECAUTIONS IN THE DISPOSAL OF THESE ITEMS.

	BERYLLIA
WARNING	BERYLLIA (BERYLLIUM OXIDE) IS USED IN THE CONSTRUCTION OF SOME OF THE COMPONENTS IN THIS EQUIPMENT. THIS MATERIAL, WHEN IN THE FORM OF FINE DUST OR VAPOR AND INHALED INTO THE LUNGS, CAN CAUSE A RESPIRATORY DISEASE. IN ITS SOLID FORM, AS USED HERE, IT CAN BE HANDLED SAFELY, HOWEVER, AVOID HANDLING CONDITIONS WHICH PROMOTE DUST FORMATION BY SURFACE ABRASION. USE CARE WHEN REMOVING AND DISPOSING OF THESE COMPONENTS. DO NOT PUT THEM IN THE GENERAL INDUSTRIAL OR DOMESTIC WASTE OR DISPATCH THEM BY POST. THEY SHOULD BE SEPARATELY AND SECURELY PACKED AND CLEARLY IDENTIFIED TO SHOW THE NATURE OF THE HAZARD AND THEN DISPOSED OF IN A SAFE MANNER BY AN AUTHORIZED TOXIC WASTE CONTRACTOR.

	BERYLLIUM COPPER
WARNING	SOME MECHANICAL COMPONENTS WITHIN THIS INSTRUMENT ARE MANUFACTURED FROM BERYLLIUM COPPER. THIS IS AN ALLOY WITH A BERYLLIUM CONTENT OF APPROXIMATELY 5%. IT REPRESENTS NO RISK IN NORMAL USE. THE MATERIAL SHOULD NOT BE MACHINED, WELDED OR SUBJECTED TO ANY PROCESS WHERE HEAT IS INVOLVED. IT MUST BE DISPOSED OF AS “SPECIAL WASTE.” IT MUST NOT BE DISPOSED OF BY INCINERATION.

	LITHIUM
WARNING	A LITHIUM BATTERY IS USED IN THIS EQUIPMENT. LITHIUM IS A TOXIC SUBSTANCE SO THE BATTERY SHOULD IN NO CIRCUMSTANCES BE CRUSHED, INCINERATED OR DISPOSED OF IN NORMAL WASTE. DO NOT SHORT CIRCUIT OR FORCE DISCHARGE SINCE THIS MIGHT CAUSE THE BATTERY TO VENT, OVERHEAT OR EXPLODE.

SAFETY FIRST - TO ALL OPERATIONS PERSONNEL (cont)

FIRE HAZARD

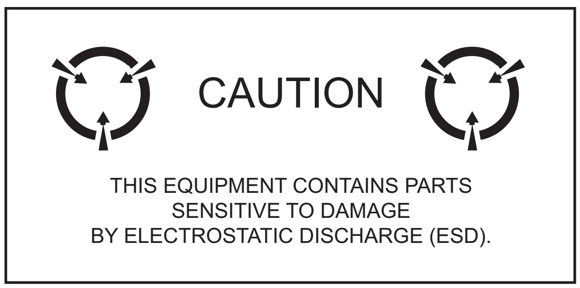
WARNING	**MAKE SURE THAT ONLY FUSES OF THE CORRECT RATING AND TYPE ARE USED FOR REPLACEMENT. IF AN INTEGRALLY FUSED PLUG IS USED ON THE SUPPLY LEAD, ENSURE THAT THE FUSE RATING IS COMMENSURATE WITH THE CURRENT REQUIREMENTS OF THIS EQUIPMENT.**

INPUT OVERLOAD

CAUTION	TX PORT MAXIMUM REVERSE POWER 100 mW

CAUTION	RX LEVEL MUST NOT EXCEED -20 dBm

STATIC SENSITIVE COMPONENTS



	This equipment contains components sensitive to damage by Electrostatic Discharge (ESD). All personnel performing maintenance or calibration procedures should have knowledge of accepted ESD practices and/or be ESD certified.

Preface

SCOPE

This Manual contains instructions for operating the GPSG-1000. It is strongly recommended that the Operator become thoroughly familiar with this manual before attempting to operate the equipment.

ORGANIZATION

This manual is composed of the following chapters:

CHAPTER 1 - INTRODUCTION

Provides an introduction and a brief overview of Test Set functions and features.

CHAPTER 2 - TEST SET OPERATION

Identifies Test Set Controls, Connectors and Indicators.

Provides Power On and Power Off procedures.

Provides functional description of Graphic User Interface (GUI) components.

Provides instructions for defining Test Set parameters.

CHAPTER 3 - TEST SET FUNCTIONS

Provides functional description of Test Set functions.

CHAPTER 4 - TESTING

Provides GPS and Galileo Receiver test guidelines.

CHAPTER 5 - MAINTENANCE

Identifies Maintenance and Software Update procedures.

CHAPTER 6 - PRINCIPLES OF OPERATION

Provides information regarding Test Set principles of operation.

CHAPTER 7 - SPECIFICATIONS

Identifies Test Set specifications.

APPENDIX A - PIN-OUT TABLES

Identifies connector pin locations.

APPENDIX B - ABBREVIATIONS

Lists terms and abbreviations used in this manual.

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Service Upon Receipt of Material

UNPACKING TEST SET

Special design packing material inside this shipping container provide maximum protection for the Test Set. Avoid damaging the shipping container and packaging material when unpacking equipment; if necessary the shipping container and packaging material can be reused to ship the Test Set.

Use the following steps to unpack the Test Set:

STEP	PROCEDURE
1.	Cut and remove sealing tape on top of the shipping container. Open shipping container and remove top packing mold.
2.	Grasp the Test Set firmly while restraining the shipping container. Lift the equipment and packing material vertically out of the shipping container.
3.	Place Test Set and end cap packing on a flat, clean and dry surface.
4.	Remove protective plastic bag from the Test Set.
5.	Place protective plastic bag and end cap packing materials inside shipping container.
6.	Store shipping container for possible future use.

CHECKING UNPACKED EQUIPMENT

Inspect equipment for possible damage incurred during shipment. If Test Set has been damaged, report the damage to Aeroflex Customer Service.

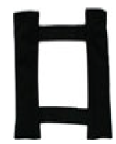
Review packing slip to verify shipment is complete. Packing slip identifies the standard items as well as purchased options. Report all discrepancies to Aeroflex.

Contact:

Aeroflex	
	Customer Service Department
	10200 West York Street
	Wichita, Kansas 67215
Telephone:	800-835-2350
FAX:	316-524-2623
email:	service@aeroflex.com

Standard Items

ITEM		PART NUMBER	QTY
GPS/Galileo Positional Simulator		87339	1
Transit Case		88493	1
Coax Cable (50ft)		90114	1
Power Supply		67374	1
Power Cord (U.S.)		62302	1
Power Cord (European)		64020	1
GPSG Antenna Coupler		87636	1

ITEM		PART NUMBER	QTY
Shot Bag		**88753**	**1**
RX Antenna		**90113**	**1**
Operation Manual (CD)		**88037**	**1**
Getting Started Manual (paper)		**88038**	**1**

Optional Items

ITEM		PART NUMBER	QTY
Battery Pack		**86196**	**1**
External Battery Charger		**87040**	**1**
Antenna Coupler Placement Pole Kit (Pole and D Ring)		**90106**	**1**

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Chapter 1 - Description

1.1 INTRODUCTION

Fig. 1-1 The Aeroflex GPSG-1000

1.1.1 Scope

Type of Manual: Operation Manual

Equipment Name and Model Number: GPSG-1000 GPS/Galileo Positional Simulator

Equipment Uses: Satellite constellation simulator for testing GPS and Galileo receivers.

1.1.2 Nomenclature Cross-Reference List

Common Name Official Nomenclature

GPSG-1000, Test Set or Unit GPSG-1000 GPS/Galileo Positional Simulator

1.2 EQUIPMENT CAPABILITIES AND FEATURES

The GPSG-1000 is a single carrier simulator, designed to be used for portable or bench testing in the GPS/Galileo Receiver testing environment. The GPSG-1000 is available in a six or twelve channel configuration, which is software upgradable. The simulator provides GPS legacy and modernization signals as well as Galileo signals. Simultaneous GPS and Galileo operation is provided. The GPSG-1000 simulates static or dynamic 3D positions. The GPSG-1000 and supplied accessories are stored in a hard plastic transit case.

1.2.1 Capabilities

The GPSG-1000 provides users with the following standard capabilities:

- Selectable single carrier
- Six or twelve channel configuration
- GPS Signals Simulated - L1, L1C, L2C, L5
- Galileo Signals Simulated – E1, E5 (E5a, E5b), E6
- Simultaneous GPS/Galileo simulation
- SBAS Satellites Simulated – WAAS/EGNOS L1, L5 - MSAS and GAGAN (future release)
- RF Port DC isolation for direct connect to any receiver
- Antenna coupler
- Large 12” touch screen with simple user interface
- Remote control interface USB/LAN
- Auto Almanac/Ephemeris Load via built in GPS Receiver

1.2.2 Features

- System Screen
- SV Selection Table displays SV Geometry for RAIM testing
- Programmable SV Parametrics and Health
- Static or Multi-leg Dynamic Positional Simulation via Waypoint Entry System
- Receiver NMEA Bus Interface
- Receiver ARINC 429 Interface

1.2.3 Utilites

- Software Upgrade
- Waypoint Data Base
- Operational Status
- Setup

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Chapter 2 - Test Set Operation

2.1 INTRODUCTION

This chapter refers to local operation of a GPSG-1000 configured with factory default settings unless specified otherwise. New Test Sets are configured to start in the factory default setting. Review Installation and Power Requirements before using the Test Set.

2.2 POWER REQUIREMENTS

2.2.1 Power

The GPSG-1000 is powered by an internal Lithium Ion Battery. The battery charging circuit enables the operator to recharge the battery anytime the unit is connected to the DC power supply. The GPSG-1000 can operate continuously utilizing the DC power supply.

The internal battery is equipped to power the GPSG-1000 for four hours of continuous use. The charge indicator illuminates yellow when the battery needs charging. The GPSG-1000 conserves battery power with the battery saver function. The battery saver function shuts off the GPSG-1000 after 30 minutes without touch screen power when operating on battery power. The battery could remain in trickle mode for several hours if the battery is dead.

2.2.2 AC Power Requirements

The DC Power Supply supplied with the GPSG1000 operates over a voltage range of 100 to 250 VAC at 47 to 63 Hz. The battery charger operates whenever DC Power (11 to 32 Vdc) is applied to the Test Set with the supplied DC Power Supply or a suitable DC power source.

NOTE: If the supply voltage is <11V, the unit will switch to internal battery. If the voltage is >32V, a 7 AMP resettable fuse on the DC input port will open, protecting the Test Set.

When charging, the battery reaches a 100% charge in approximately four hours. The Battery Charge temperature range is >-10° to <60° C, controlled by an internal battery charger.

2.2.3 Battery Recharging Using GPSG-1000

STEP	PROCEDURE
1.	Connect AC Line Cable to AC PWR Connector on the AC Adaptor and an appropriate AC power source.
2.	Connect the AC Adaptor DC output to the DC POWER Connector on the GPSG-1000.
3.	Verify the BATTERY indicator displays blinking green.
4.	Allow four hours for battery charge or until the BATTERY Indicator displays a steady green.

BATTERY LED INDICATORS

Battery Voltage Low (red)

The unit turns off within one minute w/o charger.

Battery Pre-Charging (flashing yellow)

Trickle charge during extremely low voltage on the battery.

Battery Charging (flashing green)

Charge in progress.

Battery Fully Charged (green)

Battery Temperature Extreme (solid blue)

Temperature <0° C or >45° C can't charge battery.

Battery Error (red)

The unit has a problem with the battery or charging system.

Battery Missing (off)

AC applied w/o battery in place.

Battery Suspended Charge (blinking red)

AC applied with battery charging suspended.

2.2.4 Battery Recharging Using Battery Cradle

STEP	PROCEDURE
1.	Connect AC Line Cable to AC PWR Connector on the AC Adaptor and an appropriate AC power source.
2.	Connect the AC Adaptor DC output to the DC POWER Connector on the Battery Cradle.
3.	Allow four hours for battery to charge.

2.3 INSTALLATION

2.3.1 Ventilation Requirements

The GPSG-1000 is convection cooled via the enclosure case. Avoid standing the instrument on or close to other equipment that is hot.

2.3.2 Bench Top Installation

The Test Set can be positioned in flat or tilted position by utilizing the built in screen cover/stand when used in a bench top environment (Fig. 2-1).

CAUTION	TO AVOID DAMAGE TO TOUCH SCREEN, DO NOT STACK OTHER EQUIPMENT ON TOP OF THE TEST SET.

Fig. 2-1 GPSG-1000 Screen Cover/Stand

2.4 CONTROLS AND CONNECTORS

2.4.1 Front Panel Controls

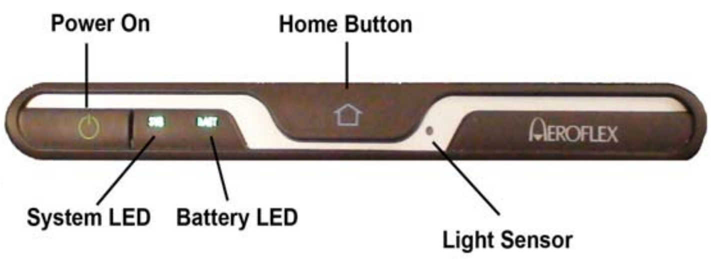


Fig. 2-2 Front Panel Controls

Control	Description
Power ON/OFF	The Power On/Off Button is used to power the Test Set on and off.
System LED	**Powered On** (green) Indicates the unit is in an operational status.
	Failure (red) Some form of failure has occurred which precludes using the display to indicate the problem (e.g. main processor failure, power supply fault, etc.).
	Boot (blinking blue) Unit is booting and is not yet able to indicate status on the display (during initial OS and application load).
	Off/Standby (orange) Unit is off, but power is supplied to the power supply from the AC power supply.
	Off w/o External Supply (off) Unit is off, no external power supplied.
Home Button	Pressing and holding the Home Button for 5 sec sets the backlight to maximum brightness.
Light Sensor	Monitors the ambient light and adjusts the display brightness. The light sensor is not operational at this time. Currently the display brightness must be set manually.
Magnetic Sensor	Detects if the display cover is open or closed and used to turn off the display as part of power management.

Control	Description
Battery LED	**Battery Voltage Low** (red) The unit turns off within one minute without charger **Battery Pre-Charge** (flashing yellow) Trickle charge during extremely low voltage on the battery. **Battery Charging** (flashing green) Charge in progress **Battery Fully Charged** (green) **Battery Temperature Extreme** (blue) Temperature <0° C or >45° C can't charge battery **Battery Error** (red) Problem with the battery or charging system. **Battery Missing** (Off) AC applied without battery in place. **Battery Suspended Charge** (flashing Red) AC applied w/ battery charging suspended

2.4.2 Rear Panel Controls and Connectors

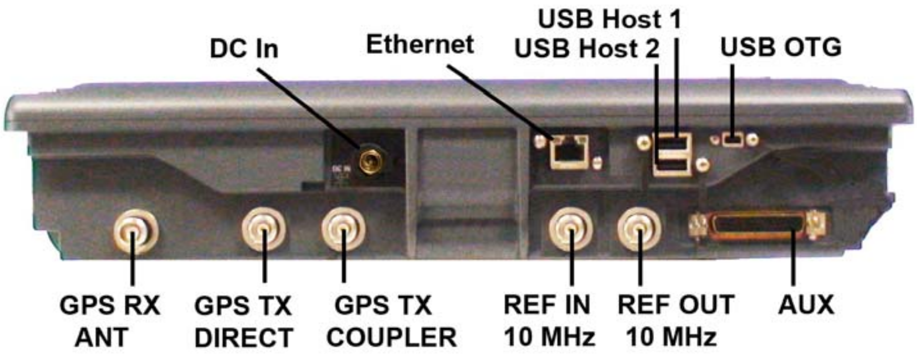


Fig. 2-3 Test Set Rear Panel Controls and Connectors

Connector	Description
USB Host 1	USB standard connection that allows connection of USB devices (e.g. a USB memory stick or Network connectors). Recommended USB memory device is Aeroflex PN 67325.
USB Host 2	USB standard connection that allows connection of USB devices (e.g. a USB memory stick or Network connectors). Recommended USB memory device is Aeroflex PN 67325.
USB OTG	Connects multiple test sets.
GPS Rx Ant	External Antenna connection for Test Set internal GPS receiver.
GPS Tx Direct	RF output for direct connection to receiver under test. AC coupled, Maximum DC 50 V.
GPS Tx Coupler	RF output for connection to Antenna Coupler.
REF In 10MHz	The 10MHz In (5V p-p Max) Connector, is a BNC connection, used to connect the Test Set to an external frequency standard, providing a TTL signal.
REF Out 10MHz	The10MHz Out (1.5V p-p Nom) Connector, is a BNC connection, providing an output of the internal 10MHz reference Oscillator.
Ethernet	Standard Base T RJ45 connection. This connection can be used for software upgrades and for remote operation.
Aux	26 pin D type, providing ARINC 429 I/O, RS-232 I/O and a 1PPS TTL L1 C/A code frame sync output.

2.5 OPERATING PROCEDURES

2.5.1 Power ON Test Set

After completing Initial Installation, perform the following steps to Turn On the Test Set:

STEP	PROCEDURE
1.	Press On/Off Button on Front Panel to power on Test Set.
2.	The Power Up window is displayed when the unit is first powered on or after Factory Defaults have been restored. If the unit has previously been used, the last used window is displayed.

.

Fig. 2-4 Power Up Window

IP Address Displayed During Boot

If the GPSG-1000 is connected to an Ethernet port during system boot and IP is available, the IP address will be displayed in the upper right-hand corner of the splash screen. This will allow the unit to be debugged in case of system lockup or boot failure. In the following example the IP Address is 10.170.170.38.

.

Fig. 2-5 IP Address displayed during system boot

STEP	PROCEDURE

Debug Files:

If the GPSG-1000 encounters a problem during the boot process and is unable to boot up properly, a debug file may be obtained from the GPSG-1000 and sent to Aeroflex to assist in determining the cause of the boot issue.

To obtain a copy of the debug files, install a USB memory device into one of the USB ports on the GPSG-1000. Press the power button to turn on the GPSG-1000. During the boot process two text files will be created on the USB Memory Device (Fig. 2-6). One file is called “gps1000rs232.txt”; and the other file is called “gps1000last_rs232.txt”; these files contain the latest debug files.

Each time the GPSG-1000 is booted with the USB Memory Device installed in one of the USB ports, the debug files are overwritten with the latest boot information. The information contained in the debug file is not intended for use by the user. Both files should be sent to Aeroflex if support is being requested for a boot issue.

Name	Size	Type
Aeroflex		File Folder
gps1000last_rs232.txt	30 KB	Text Document
gps1000rs232.txt	19 KB	Text Document

Fig. 2-6 Text files displayed on USB Memory Device

2.5.2 Power OFF Test Set

Perform the following steps to power off the Test Set:

STEP	PROCEDURE
1.	Press On/Off Button on Front Panel to power down the Test Set, then press OK to confirm.

2.6 USER INTERFACE COMPONENTS

The Test Set User Interface (UI) is a touch screen control panel that provides a flexible working environment for all users. The UI uses maximized Function Windows i.e. one function window occupies the entire screen area. The Test Set User Interface (UI) is navigated locally using the Front Panel Touch Screen

2.6.1 Launch Bar

The Launch Bar is a vertical scrolling menu located at the left side of the User Interface. The Launch Bar provides access to the Function Icons as shown in Fig. 2-5. The menu must be opened to access the Function Icons. The Launch Bar is opened and closed by touching or clicking on the light gray bar at the Left side the menu.

Fig. 2-7 Launch Bar - Open/Close Tab

When the Launch Bar is opened, it appears in front of any Simulation Function Windows currently occupying that area of the display. The Launch Bar can be closed to view the complete Simulation Function Window.

Fig. 2-8 Launch Bar and Simulation Function Window

2.6.2 Launch Bar Navigation

The arrows on the top and bottom of the Launch Bar are used to move the Launch Bar Up and down.

2.6.3 Function Keys

The Launch Bar consists of keys that identify functions installed on the Test Set.

Fig. 2-9 Function Keys

2.6.4 Function Windows

Function Windows provide visual access to the Test Set's control parameters and displayed data.

Function	How to
Opening/Closing Function Windows	Function Windows are opened by selecting the Function Icon from the Launch Bar. Function Windows are closed by selecting the blue circle icon at the bottom of the window or by selecting the Function Icon on the Launch Bar.

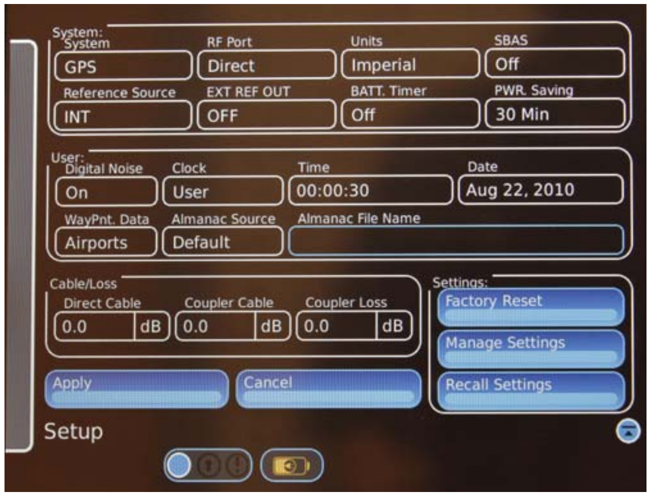
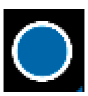
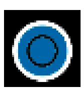


Fig. 2-10 Function Window

2.6.5 Function Window Icons

Function Windows use the following icons to indicate various functions or states:.

ICON	DESCRIPTION
	Closes the Function Window while leaving the function in the Active State.
	Maximizes Function Window and opens Status Bars.
	Maximizes Function Window and closes Status Bars.
	Displays Running and a green circle when the simulation is running.
	Displays Stopped and a gray circle when the simulation is stopped.
	Displays remaining battery capacity in %.

2.7 DEFINING PARAMETERS

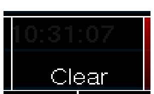
2.7.1 Entering Numeric Values

Numeric values are used to define a variety of test parameters such as frequency and level. When a numeric data field is selected for editing, a group of data entry pop-up windows is launched which provides the following methods for defining the value:

2.7.2 Numeric Keypad and Slider Bar

The Numeric Keypad allows the user to enter a specific numeric value. A value is entered by pressing the numbers on the keypad. The value is enabled pressing the unit of measurement on the Numeric Keypad (Fig 2-9).

Fig. 2-11 Numeric Keypad

Icon	Description
	Pressing Cancel voids any un-entered changes and closes the group of data entry pop-up windows. Pressing Cancel does not “undo” a changed value that was set using the Rotary Knob or Slide Bar.
	Pressing Clear resets a numeric value to 0.
	Pressing Backspace deletes the last digit in the numeric value.
	Pressing Next Value Selection replaces the Numeric Keypad with the Slew Data Bar. Press again and the Numeric Keypad appears.

2.7.3 Data Slew Bar

The Data Slew Bar incrementally selects specific data values by spinning the wheel. Selecting x10 increases the step increment by a factor of 10. Selecting /10 decreases the step increment by a factor of 10.

Select UP arrow to increase data value. Select DOWN arrow to decrease data value. Select CANCEL to void data entry.

Selecting Enter closes the Data Slew Bar.

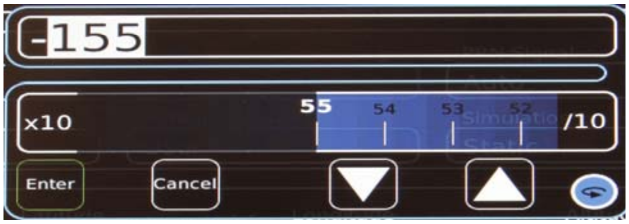


Fig. 2-12 Data Slew Bar

2.7.4 Drop-down Menus

Drop-down Menus are used to list pre-defined variables. Selecting a Drop-down Menu opens the list of variables available for that field. The variable currently selected is displayed on the menu as bold white label on a green background. Drop-down Menus can be dragged up and down on the display in order to view long lists.

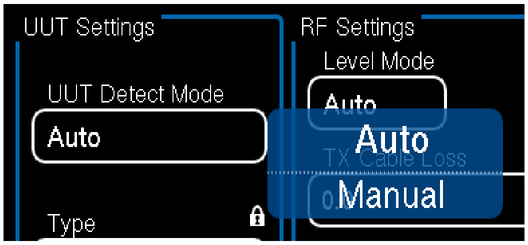


Fig. 2-13 Drop-down Menu

2.7.5 Selectable Units

Some fields may have selectable units. For those fields identified, select the units field and a drop-down menu will be displayed (Fig 2-12).

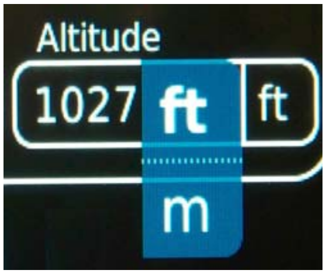


Fig. 2-14 Selectable Units

2.7.6 Locked Fields

A small padlock symbol may be displayed against certain fields indicating that the field is locked and may not be edited or accessed (Fig. 2-13). Altitude field is locked and can only be modified when a manual simulation is running, then paused.

Fig. 2-15 Locked Field

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Chapter 3 - Test Set Functions

3.1 INTRODUCTION

This chapter provides an operational description of standard simulator functions.

3.2 TEST SET FUNCTIONS

3.2.1 Simulation Function Window

The Simulation Function Window is used to control the GPS/Galileo carrier, signal selection, specific functions applied to all SV's, SBAS, RF Level and entry and display of static position or current waypoint. The Simulation Function Window also displays selected SV PRN's, On Board Clock, Date and Time.

Fig. 3-1 Simulation Function Window (Static)

Control Component	Description
Carrier	Drop down menu provides selection of carrier, dependent on System selection in Setup. **NOTE:** The GPS Services and Galileo Services are displayed in Advisory field. **System: GPS** Carrier: L1 GPS Services: C/A, Pseudo P(Y), C Carrier : L2 GPS Services: L2C, Pseudo P(Y), Carrier: L5 GPS Services: SoL System: Galileo Carrier: E1 Galileo Services: I/NAV, Pseudo-G/NAV Carrier: E5 Galileo Services: I/NAV, F/NAV System: GPS/Galileo Carrier: L1/E1 GPS Services: C/A, Pseudo P(Y) Galileo Services: I/NAV, Pseudo-G/NAV Carrier : L2 GPS Services: L2C, Pseudo P(Y), Carrier: L5/E5 GPS Services: SoL Galileo Services: I/NAV, F/NAV
PRN Signal	Variable - Ensures the relative SV signal levels are set proportional to the respective pseudo ranges. Fixed - All SV Levels are set to the amplitude selected in the RF Level control Component.
Advisory	Displays GNSS service generated.
Fading	Drop down menu. SV signal amplitudes have amplitude fading applied STATIC, PEDESTRIAN, LAND VEHICLE, AIRCRAFT. PEDESTRIAN, LAND VEHICLE, AIRCRAFT available in Dynamic mode only. NONE - SV signal amplitudes do not have fading applied.
Simulation	Drop down menu. STATIC - single waypoint entry fixed position simulation. DYNAMIC - position simulation is dynamically changing according to parameter entries in waypoint tables.
Position Source	Drop down menu. USER - User entered position. GPS - On board GPS receiver derived position.
RF Level	Numeric Pad. RF Level: -68 dBm to -130 dBm in Coupler mode or -93 dBm to -155 dBm in Direct mode,
Latitude	Numeric Pad. Latitude entered in decimal format Example: 37°39.0000N (37 degrees, 39.0000 minutes North) Sign: N or S **NOTE:** This field is displayed when SIMULATION = STATIC.
Longitude	Numeric Pad. Longitude entered in decimal format Example: 97°26.0000E (97 degrees, 26.0000 minutes East) Sign: E or W **NOTE:** This field is displayed when SIMULATION = STATIC.
Altitude	Numeric Pad. Altitude: 0 to 60,000 ft in 1 ft steps or 0 to 18,288 M in 1 M steps

Display Component	Description
GPS SV PRN	Displays selected GPS SV PRN's. Range: 1 to 32
GAL SV PRN	Displays selected Galileo SV PRN's Range: 1 to 30
CLOCK	Displays clock type. Setup Function Window CLK field selection UTC - simulation uses GPS UTC time & date in conjunction with loaded almanac and ephemeris data. USER- simulation uses User entered time & Date which sets SV parameters against loaded almanac and ephemeris.
Sim. Date	Displays Date in DD/MM/YYYY format.
Sim. Time	Displays Time in 24 Hr format HH/MM/SS.
SBAS	Displays SBAS status, System and SV PRN. Example: AUTO EGNOS SV PRN 138

3.2.2 SV PRN Selection Function Window

The SV PRN Selection Function Window allows the user to select specific GPS/Galileo SV's. The available SV's, according to the currently loaded almanac and UTC, are displayed in two tables. One table for GPS SV's and one table for Galileo SV's. The tables display the SV PRN number, satellite geometry, relative RF signal levels and health. The satellites selected determine the accuracy of the positional simulation.

Fig. 3-2 SV PRN Selection Function Window

Display Component	Description
SELECT	Displays SV status On or Off
SV	Displays SV number. Range GPS: 1 to 32, GAL: 1 to 30
Elevation	Displays SV Elevation in degrees. Range: 0 to 90 deg
Azimuth	Displays SV Azimuth in degrees. Range 0 to 359 deg
Status	Displays SV Health GOOD or BAD
RF Level	Displays SV actual RF levels

3.2.3 SV PRN Edit Window

The SV PRN Edit Window opens when an SV line is selected in either the GPS or GAL tables, displayed in the SV PRN Selection Function Window. The SV PRN Edit Window allows the user to set parameters specific to the SV such as Doppler Step, Pseudo Range Step Error, Carrier Coherence, Satellite Health and Amplitude offset.

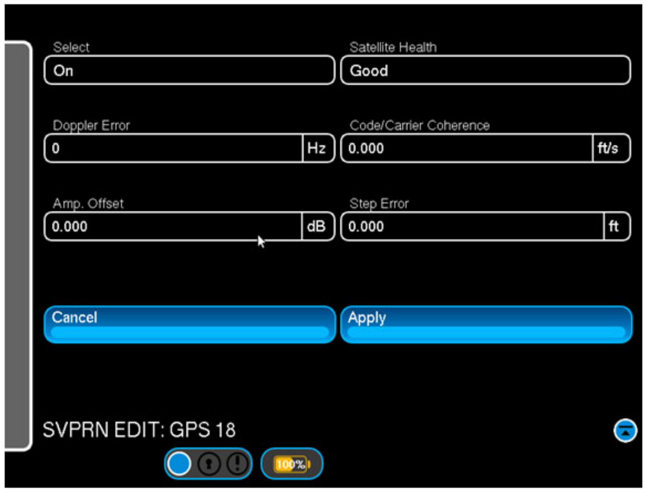


Fig. 3-3 SV PRN Edit Window

Control Component	Description
Select	Drop down selections: On - Turns SV on Off - Turns SV off Replace - Opens SV select window
Doppler Error	Numeric Pad: Sets SV doppler shift +/- 5KHz in 1Hz increments. **NOTE:** Doppler shift for each SV is applied dynamically throughout the simulation run time. This parameter introduces a step change in Doppler (used for RAIM testing).
Amp Offset	Numeric Pad: Sets SV carrier amplitude offset from nominal +15dB to -15dB in .1dB increments. **NOTE:** If PRN Signal is set to Variable - SV amplitudes are set according to SV geometry and RF Level setting. If set to Fixed - equal SV amplitudes are set.
Step Error	Numeric Pad: Sets SV pseudo range error +/- 10km in .1 m increments or +/- 32808.4 Ft in .1 Ft increments.
Code/Carrier Coherence	Numeric Pad: Sets frequency variation between SV code carriers 2m/S range 1mm/S increments or 6.562 ft/S range in .001 ft/S increments.
Satellite Health	Drop down: Allows selection of GOOD or BAD. (Carried in GPS Nav Data) **NOTE:** Not displayed for Galileo SV's
GAL Integrity	Allows selection of CONNECTED or DISCONNECTED (Carried in Galileo Nav Data). Only displayed in Galileo SV's. **NOTE:** Not displayed for GPS SV's

Control Component	Description
Cancel	Cancel parameter change, reverts to previous setting
Apply	Applies parameter change

3.2.4 Waypoint Function Window

The Waypoint Function Window is used to configure the waypoints that comprise a 3D Navigation simulation.

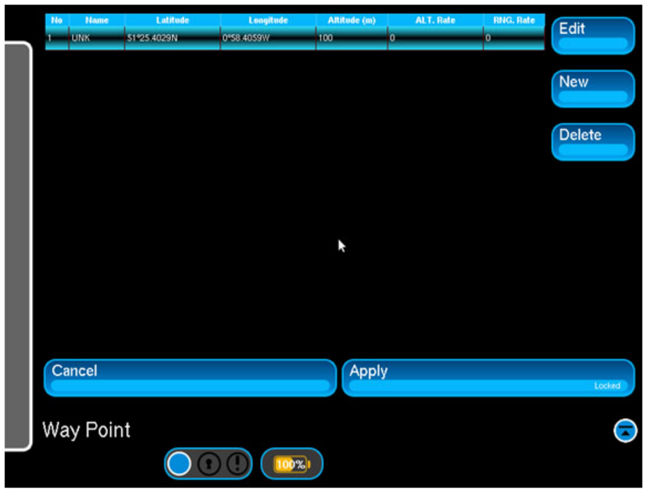


Fig. 3-4 Waypoint Function Window

Control Component	Description
Edit	Opens Waypoint Edit Window for selected waypoint line
New	Creates new waypoint entry in the next free line and opens Waypoint Edit Window
Delete	Deletes selected waypoint line
Cancel	Cancels Airport Code selection
Apply	Applies Airport Code Selection

Display Component	Description
Name	Displays Waypoint Name
Latitude	Displays Waypoint Latitude in decimal format. Example: 37^{o}39.0000N (37 degrees, 39.0000 minutes North) Sign: N or S
Longitude	Displays Waypoint Longitude in decimal format. Example: 97^{o}26.0000E (97 degrees, 26.0000 minutes East) Sign: E or W
Altitude	Displays Altitude 0 to 60,000 ft in 1 ft steps
Altitude Rate	Displays Altitude Rate 0 to 5000 ft/min or 18,288 m in 1 m steps. Mutually exclusive with Range Rate
Range Rate	Displays Range Rate 0 to 1000 kts. Mutually exclusive with Altitude Rate
Waypoint #	Displays waypoints in sequential numeric order. Up to 99 waypoint legs may be defined in a Nav Track

3.2.5 Waypoint Edit Window

The Waypoint Edit Window is used to set specific waypoint parameters. New waypoints can be created and saved or waypoints can be selected from an Airport Code table.

Fig. 3-5 Waypoint Edit Window

Control Component	Description
Name	Alpha Numeric Pad: Enter waypoint name. Up to 20 characters may be entered. **NOTE:** Airport Code look up automatically populates this field with the three letter airport code.
Latitude	Alpha Numeric Pad: Enter Waypoint Latitude in decimal format. Example: 37°39.0000N (37 degrees, 39.0000 minutes North) Sign: N or S
Longitude	Alpha Numeric Pad: Enter Waypoint Longitude in decimal format. Example: 97°26.0000E (97 degrees, 26.0000 minutes East) Sign: E or W
Airport Code	Opens Airport Code table for code selection. Selection of three letter Airport Code in table, creates waypoint and sets Latitude and Longitude for the airport into the waypoint when APPLY is touched
Altitude	Alpha Numeric Pad: Enter Altitude 0 to 60,000 ft in 1 ft steps or 18,288 m in .1 m steps.
OK	Confirms Waypoint parameter edits
Cancel	Cancels Waypoint parameter edits, reverts to previous setting
"US Airport Data: Sorted By"	Can be sorted by CODE, NAME, CITY, STATE, LATITUDE, LONGITUDE or ALTITUDE.

3.3 SETUP

3.3.1 Setup Functional Window

The Setup Functional Window is used to configure the test set operational parameters.

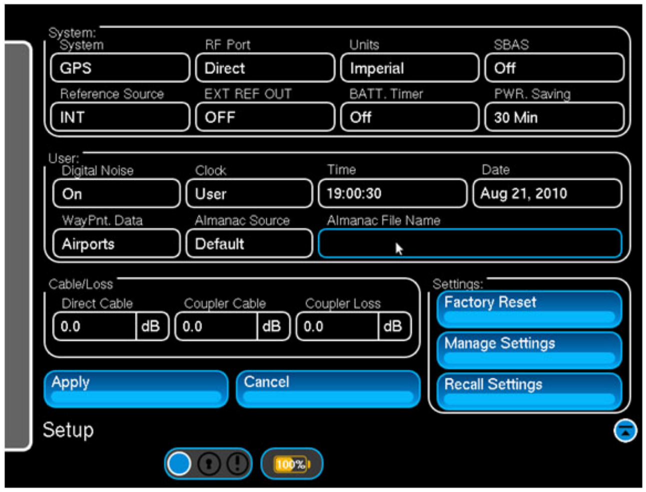


Fig. 3-6 Setup Functional Window

Control Component	Description
User Time	Numeric Pad: User entered Time. Displayed if Clock selected is USER.
User Date	Numeric Pad: User entered Date. Displayed if Clock selected is USER.
Direct Cable	Numeric Pad: Direct RF coax cable loss in dB. Range: 0 to 12 dB
Coupler Cable	Numeric Pad: Antenna Coupler RF coax cable loss in dB. Range: 0 to 12 dB
Coupler Loss	Numeric Pad: Antenna Coupler insertion loss in dB. Range: 0 to 40 dB
Units	Drop Down Selections: SI - parameters displayed/entered in SI units. IMPERIAL - parameters displayed/entered in Imperial units.
Reference Source	Drop Down Selections: INT - Internal 10 MHz TCXO. EXT - External 10 MHz input.
External Reference Out	Drop Down Selections: ON - reference output on. OFF - reference output off.
Almanac Source	Drop Down Selections: Default - Simulation uses the default almanac files. GPS Receiver - Simulation uses almanac file downloaded directly from the internal GPS receiver. File - Simulation uses a previously saved almanac file which is selected by the user from a list of saved almanac files.

Control Component	Description
System	Drop down selections: GPS - GPS satellites only simulated. GAL- Galileo satellites only simulated. GPS/GAL - both GPS and Galileo satellites simulated.
RF Port	Drop down selections: COUPLER - generator uses coupler RF port DIRECT- generator uses direct RF port.
SBAS	AUTO- Automatic optimized selection of SBAS satellite (WAAS/EGNOS/ *MSAS/*GAGAN) according to simulated position. **NOTE:** with AUTO selected only 5 or 11 positional SV's are available. OFF- SBAS satellites are turned OFF, this allows a full 6 or 12 positional SV's to be available.
Waypoint Data	Drop down selections: AIRPORT- Airport Data Base used for waypoint LAT/LONG entry in Waypoint Page. CITY- City Data Base used for waypoint LAT/LONG entry in Waypoint Page.
Clock	Drop down selections: UTC - simulation uses GPS UTC time and date in conjunction with loaded almanac and ephemeris data. USER- simulation uses User entered Time and Date which sets SV parameters against loaded almanac and ephemeris.
BATT Timer	ON/OFF selection
PWR Saving	Drop down selections: 15 minutes 30 minutes 45 minutes 1 hour 2 hours OFF
Manage Settings	Displays Store Settings Function Window
Recall Settings	Displays Load Settings Function Window
Factory Reset	Resets all settings to factory default. Changes all user entered data in memory to zero.

Display Component	Description
Almanac File Name	Displays file name of current almanac

3.3.2 Configuration Controls

The configuration controls provide named storage and recall for all test set settings. Only one configuration may be loaded in memory use. Up to 20 configurations may be stored. Selecting the Manage Settings key displays the Store Settings Function Window, then select file name to display the alpha numeric pad.

Settings files are stored in entry sequence.

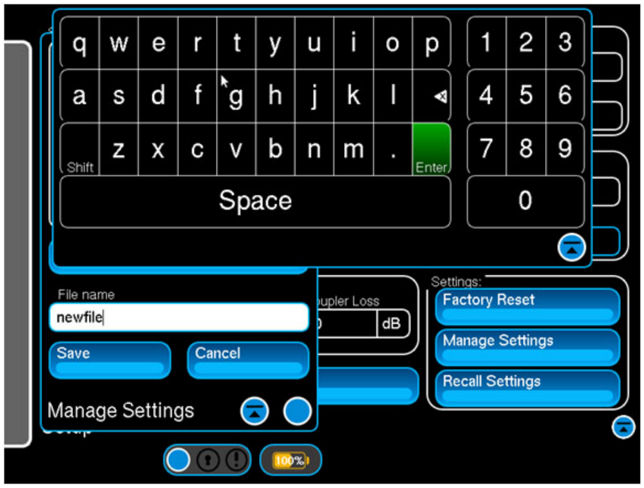


Fig. 3-7 Store Settings Window

Manage Settings Window

A 27 character file name may be entered. Selecting Save key stores the named settings which will then appear in the Manage Settings Name list.

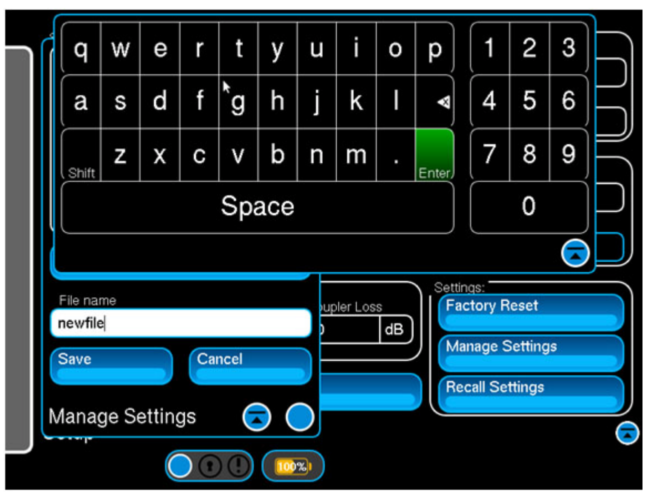


Fig. 3-8 Manage Settings Window

Control Component	Description
Delete	Deletes selected store
Save	Stores named Settings
Cancel	Cancel storage operation and closes window

Display Component	Description
File Name	Displays selected Settings name
File List Box	Displays list of stored Settings files

Recall Settings Window

Selecting the Recall Settings key displays the Recall Settings window which is used to select and load stored settings files into test set memory for execution.

Fig. 3-9 Recall Settings Window

Control Component	Description
Open	Loads selected Settings file into memory for execution
Cancel	Deletes selected Settings file

Display Component	Description
File List Box	Displays Settings file name

3.4 MAINTENANCE FUNCTION WINDOW

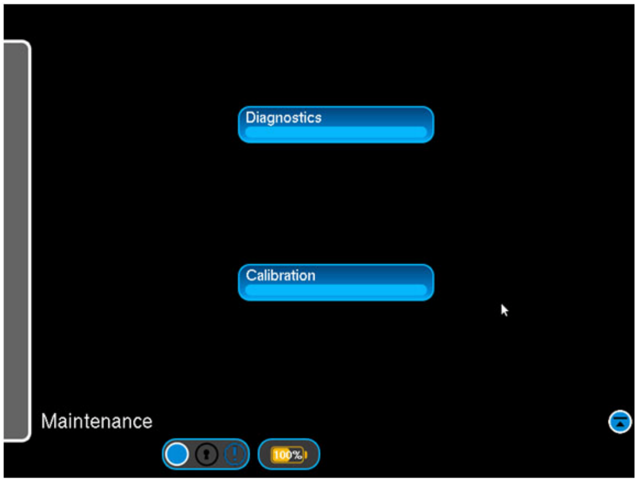


Fig. 3-10 Maintenance Window

Fig. 3-11 Diagnostics Window

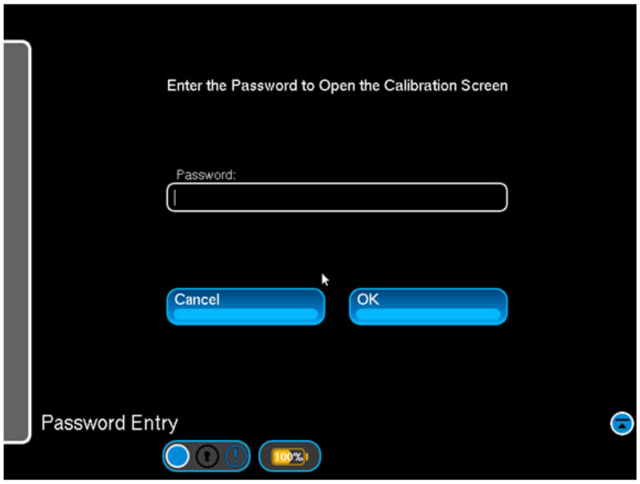


Fig. 3-12 Calibration Window

Control Component	Description
Cancel	Close calibration operation
Password	Selecting Password will display and alpha numeric pad for entering the password to un-lock the calibration table
OK	Start calibration of GPSG-1000

3.5 GPS RECEIVER FUNCTION WINDOW

The Internal GPS Receiver may be used to obtain a current Almanac and UTC for use in simulations. This removes the requirement for a periodic manual yuma text format almanac (*.alm), download from the U.S. Coast Guard website and subsequent upload to the GPSG-1000 memory.

When testing a GPS receiver, if the simulated position is too far from the last acquired position the receiver will initiate a warm start which, dependant on receiver type, will take longer than a hot start to acquire a position fix. As the last location would likely be the current position, the latitude and longitude from the internal GPS receiver may be used by the simulation, which would then allow the receiver under test to hot start.

Fig. 3-13 GPS Receiver Window

Control Component	Description
GPS Receiver	Selects GPS (Internal GPS Receiver) or UUT/ External GPS Receiver (via NMEA interface)
Almanac Status	Indicates Almanac Loaded or Almanac Not Loaded

Display Component	Description
Latitude	Waypoint Latitude in decimal format. Ex: 37°39,0000N (37 degrees, 39,0000 minutes North) Sign: N or S
Longitude	Waypoint Longitude in decimal format. Ex: 97°26,0000E (97 degrees, 26,0000 minutes East) Sign: E or W
MSL Attitude	Displays GPS Altitude 0 to 60,000 ft, resolution 1 ft
Postion Fix	Indicates No Positon Fix, 2D Solution or 3D Solution
Active Satellite	Displays SV's in view
SNR	GPS Receiver SNR figure
Load Almanac from GPS Rx	Loads almanac from GPS Rx
Current Data/Time	Displays the current date and UTC time received by the GPS Rx

Chapter 4 - Testing GPS/ Galileo Receivers

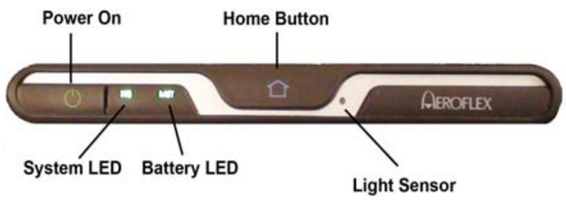
4.1 INTRODUCTION

This chapter provides details of standard tests for GPS receivers.

4.1.1 Identifying Installed Software Version

Perform the following steps to identify the software version installed in the GPSG-1000.

STEP	PROCEDURE
1.	Press the On/Off button to turn the test set on.



2.	Allow the test set to complete the boot process, approxiamately 3 to 5 mins.
3.	Open the Launch Bar by touching the light gray bar located on the left side of the user interface and scroll down to the System function key.

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4.	Touch the System function key to open the System pull down menu and select System Update.

STEP	PROCEDURE
5.	In the Version window the unit model number, unit serial number and currently installed software version number is displayed. In the following example, “GPSG-1000” is the unit model number, “1000372866” is the unit serial number, and “1.0.0,201109081459” is the currently installed software version number.

4.1.2 Antenna Coupler Installation

Perform the following steps to Install the Antenna Coupler

STEP	PROCEDURE
1.	Ensure the GPSG-1000 is within 50 ft of the aircraft under test GPS antenna (top fuselage).
2.	Place the Shot Bag weight over the center section of the GPS Antenna Coupler.
3.	Connect the 50 ft RF Coax Cable to the GPSG-1000 Coupler TX TNC connector.
4.	Perform Setup procedure 4.1.2
5.	Place the Antenna Coupler over the GPS antenna on the top side of the aircraft frame.

NOTE: In a dual or triple GPS system installations, additional Antenna Couplers may be used via a power splitter.

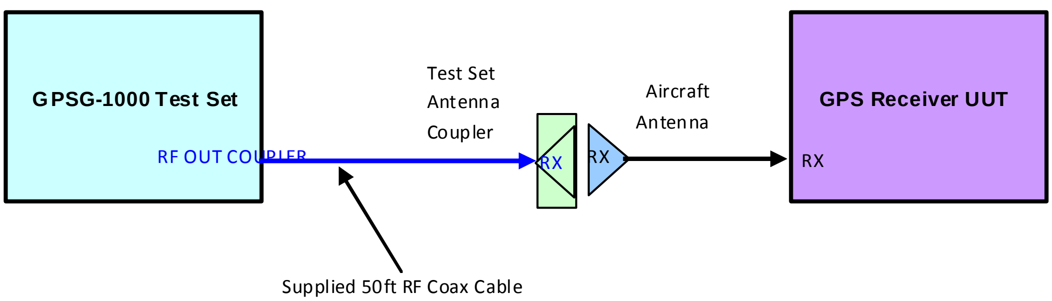

Fig. 4-1 GPSG-1000 RF Connection

4.1.3 Setup/Simulation

Perform the following steps for Setup.

STEP	PROCEDURE
1.	Press **Power On/Off** Key for a minimum of one second to power up test set.
2.	Select **Launch Bar** tab to display launch bar.
3.	Select **Setup** function key to display Setup Window.
4.	Confirm the following settings and change as necessary.

Cable Loss:

Coupler Loss = Figure in dB marked on Antenna Coupler.

Direct Cable = Figure in dB marked on RF Coax Cable.

Coupler Cable = Figure in dB marked on RF Coax Cable.

System:

System = GPS

RF Port = COUPLER (if using antenna coupler) or DIRECT (direct connect to GPS UUT).

Units = Imperial

SBAS = Off

Reference Source - INT

EXT REF OUT = OFF

BATT Timer = Off

PWR Saving = 30 Min

User:

Digital Noise = OFF – when coupling to the receiver antenna. ON – when connecting directly to the receiver, bypassing the antenna/LNA.

NOTE: Use of digital noise via receiver antenna, will result in degraded SV Signal to Noise ratio and may cause receiver to loose track or not obtain a stable fix.

Digital Noise = ON

Clock = User

Time = For optional entry of time

Date = For optional entry of date

WayPnt. Data = Airports

Almanac Source = Default, GPS Receiver or select file from list.

NOTE: The procedure for loading Almanacs may be found in section 5-2-3.

STEP	PROCEDURE
5.	Select **Apply** Key which will automatically activate the **Simulation** menu.
6.	Perform the following steps to complete Simulation: **Name/Positions:** RF Level = For setting the output level of GPS generated signal Latitude = For Optional entry of test Latitude Longitude = For Optional entry of test Longitude Altitude = For Optional entry of test Altitude
7.	Select **RUN** key to start simulation.
8.	Select STOP key to discontinue simulation.

NOTE: Most GPS receivers expect ACTIVE antennas, this means they supply a DC voltage to the antenna connector. The GPSG-1000 has built in DC voltage blocking on the GPSG TX Port.

CAUTION	GPS TX PORT: APPLIED DC SHOULD NOT EXCEED +50 V

NOTE: Some receivers "sense" current draw on the DC supply to their active antenna. If there is no current drawn, they may assume that no antenna is connected. In such cases, the current draw must be simulated by some resistive load and perhaps a series inductor between the signal line and the ground. Such a device may need to be custom built, depending on the receiver requirements.

NOTE: It is recommended that the receiver under test is "cold started" and a fresh almanac obtained from the GPSG-1000 simulation. This process may take several minutes, dependent on specific receiver.

NOTE: Some receivers will not obtain a stable fix when using a simulation time earlier than the selected almanac. Generally it is best to utilize an almanac that is dated at least one day before the simulation date.

4.1.4 GPS Receiver Communication

Some receivers may have maintenance pages the user can access to view SV parameters and positional information. Access may either be directly via a display/control or by the use of proprietary software.

For a standardized means of accessing all receiver data most receivers support the NMEA-183 protocol. NMEA -183 compliant receivers send data continuously through either a serial or USB interface, in the form of text sentences, which may be monitored by PC using a suitable application. The NMEA-183 protocol supports six basic sentences, and each provides a different data type. Refer to table 4-1. The first word in each sentence is the three letter data type.

Data Type	Description
GGA	Fix information
GLL	Latitude and longitude information
GSA	Overall satellite data
GSV	Detailed data for satellites in view
RMC	Recommended minimum data for GPS
VTG	Vector track and speed over ground

Table 4-1 Basic NMEA-183 Sentences

The information from the GSA sentence can be used to verify if the receiver has achieved a position fix and may be used in TTFF measurements. The GSV sentence provides the C/N_0 (carrier-to-noise) ratios for each satellite that the receiver is tracking, which may be used for sensitivity tests.

4.1.5 Sensitivity

GPS receivers usually have two sensitivity figures specified: Acquisition Sensitivity and Signal Tracking Sensitivity. Acquisition Sensitivity specifies the lowest power level at which the receiver is able to achieve a position fix. Signal Tracking Sensitivity is the lowest power level at which a receiver is able to track an individual satellite.

4.1.5.A Signal Tracking Sensitivity

Perform the following steps for signal tracking sensitivity test.

STEP	PROCEDURE
1	If connecting GPSG-1000 via Antenna Coupler, perform Antenna Coupler Installation procedure Section 4.1.1. If directly connecting GPSG-1000 to GPS receiver under test, proceed to step 2.
2.	Perform Setup procedure Section 4.1.2.
3.	Select **Launch Bar** tab to display launch bar. Select **SV PRN** function key to display the SV PRN Function Window. The GPS SV's in view will be displayed in a table.
4.	Turn ON a single high elevation SV by selecting ON/OFF field to ON in the SV line and then select **Apply.** Select the **close icon** to close the Function Window.

Fig. 4-2 SV PRN Single SV Selection

STEP	PROCEDURE
5.	Select **PRN Signal** drop down menu. Select **MANUAL,** this ensures the SV signal level does not change during the simulation.
6.	Select **RF Level** and set to -136 dBm. **NOTE**: This is 6 dB above the typical GPS receiver positional tracking sensitivity of -142 dBm. If the active antenna is not in circuit, the gain of the antenna should be subtracted from these figures.
7.	Reduce the **RF level** in 0.1 dB increments until the specified C/N_0 is displayed on the receiver test page or read from the receiver using the NMEA-183 protocol.

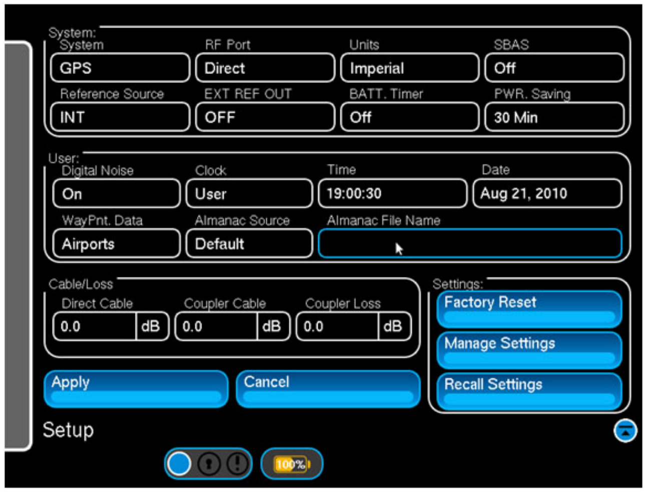

Fig. 4-3 Simulation Function Window

4.1.5.B Acquisition Sensitivity

Perform the following steps for acquisition sensitivity test.

STEP	PROCEDURE
1	If connecting GPSG-1000 via Antenna Coupler, perform Antenna Coupler Installation procedure Section 4.1.1. If directly connecting GPSG-1000 to GPS receiver under test, proceed to step 2.
2.	Perform Setup procedure Section 4.1.2.
3.	Select **Launch Bar** tab to display launch bar. Select **SV PRN** function key to display the SV PRN Function Window. The GPS SV's in view will be displayed in a table.
4.	Turn ON all SV's by selecting ON/OFF field to ON in each SV line, then select **Apply**. Select the close icon to close the Function Window. Select **PRN Signal** drop down menu. Select **VARIABLE** to ensure the relative SV signal levels are set proportional to the respective pseudo ranges
5.	Select **RF Level** and set to -136 dBm. **NOTE**: This is 6 dB above the typical GPS receiver positional tracking sensitivity of -142 dBm. If the active antenna is not in circuit, the gain of the antenna should be subtracted from these figures.
6.	Increase the RF Level in steps of 0.5 dB, until positional fix is displayed on the receiver or read from the receiver using the NMEA-183 protocol. Allow several minutes at each power level.
7.	Increase the **RF Level** in steps of 0.5 dB until the positional fix is displayed on the receiver or read from the receiver using the NMEA-183 protocol. Allow several minutes at each power level. **NOTE**: This is 6 dB above the typical GPS receiver positional tracking sensitivity of -142 dBm. If the active antenna is not in circuit, the gain of the antenna should be subtracted from these figures.

4.1.5.C C/N_0 Measurement Options

In scenarios where measurement speed is important, such as a production environment, you can use a higher C/N_0 value and extrapolate the sensitivity information from the result.

There is a linear relationship between RF power and C/N_0 ratio, refer to table 4-2. As an alternative to measuring the receiver's C/N_0 ratio at the given sensitivity level, it is possible to derive sensitivity based on the C/N_0 at a different power level. Typical receiver C/N_0 ratio is 28 to 32 dB-Hz to achieve a position fix. If the receiver reports a C/N_0 value of 28 dB-Hz at -145 dBm, it also reports a C/N_0 value of 43 dB-Hz at -130 dBm.

NOTE: It is important that a given receiver is first characterized by measuring the acquisition sensitivity to ensure that receiver self-interference (e.g. spurs) or digitisation noise, does not adversely effect the C/No figure before applying this technique.

While the exact RF level used to measure sensitivity varies from one receiver to the next, the ratio of the receiver of C/N_0 to RF power level is perfectly linear.

RF Level	Receiver C/N_0
-110.0 dBm	56 dB –Hz
-115.0 dBm	56 dB –Hz
-120.0 dBm	53 dB –Hz
-125.0 dBm	48 dB –Hz
-130.0 dB	43 dB –Hz
-135.0 dB	38 dB –Hz
-140.0 dB	33 dB –Hz
-145.0 dB	28 dB –Hz

Table 4-2 Receiver C/N_0 as a function of RF level

NOTE: When a high input level is used to stimulate the C/N_0 ratio, the receiver reports the maximum possible C/N_0 value allowed by the chipset. Typically this figure is between 54 to 66 dB -Hz, (56 dB - Hz in Table 6-2 example).

4.1.6 Measuring Time to First Fix (TTFF) and Position Accuracy

TTFF and position accuracy measurements are important parameters in GPS receiver testing. In many GPS applications, the time it takes for the receiver to return its actual location can significantly affect the receiver's usability. In addition, the accuracy with which a receiver returns its reported location is important.

For a receiver to obtain a position fix, it must download the almanac and ephemeris information from the satellite through a navigation message. Because it takes 30 seconds for a receiver to download an entire GPS frame, a “cold start” TTFF condition can take anywhere from 30 to 60 seconds.

Signal strength also is a factor in correlation lock time and hence TTFF (Fig 4-4).

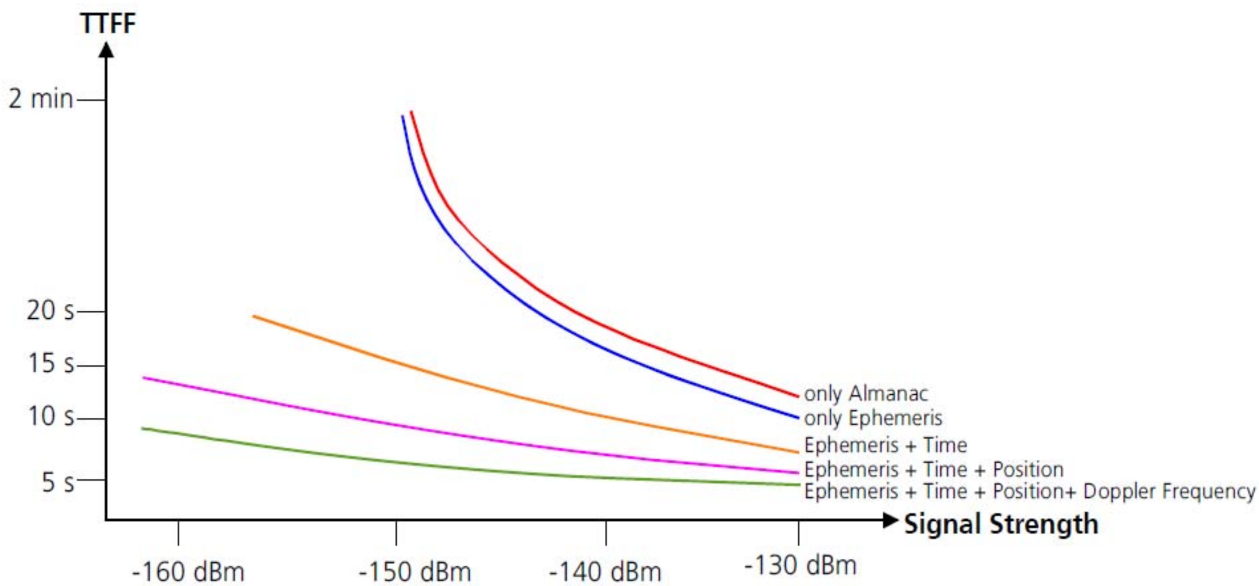

Fig. 4-4 TTFF vs. Signal Strength

Many receivers specify several TTFF conditions, including Acquisiton (cold and warm start), Reacquistion (hot start) and Positional Accuracy.

4.1.6.A Acquisition (cold start)

Under this condition the receiver does not have any current Almanac or Ephemeris data and has no memory of previous location. Firstly, at least one GPS frame must be downloaded from each of the SV’s in view however, as the receiver does not even know it approximate location and hence what SV’s may be in view, this requires all SV PRN codes to be searched, over 5000 Hz doppler frequency shift. Most modern receivers achieve a position fix from a cold start condition in 30 to 60 seconds. In older receivers this process may take several minutes.

Perform the following steps for Acquisition (cold start) TTF measurement.

STEP	PROCEDURE
1.	If connecting GPSG-1000 via Antenna Coupler, perform Antenna Coupler Installation procedure Section 4.1.1. If directly connecting GPSG-1000 to GPS receiver under test, proceed to step 2.
2.	Perform Setup procedure Section 4.1.2.
3.	Ensure GPS receiver is in cold start mode i.e. no almanac or ephemeris in memory.
4.	Select **Launch Bar** tab to display launch bar. Select **SV PRN** function key to display the SV PRN Function Window. The GPS SV's in view will be displayed in a table (Fig 4-4).
5.	Turn ON all SV's by selecting ON/OFF field to ON in each SV line and then select **Apply.** Select the **close icon** to close the Function Window.
6.	Select **PRN Signal** drop down menu. Select **VARIABLE,** this ensures the relative SV signal levels are set proportional to the respective pseudo ranges.
7.	Select **RF Level** and set to the receiver manufacturers TTFF RF level.
8.	Select **Run** key to restart simulation and measure the Time to Fix (TTF).

4.1.6.B Acquisition (warm start)

The receiver has some almanac information that is less than one week old but does not have any ephemeris information.

NOTE: Ephemeris information is only valid for 4 hrs. Typically, the receiver knows the time to within 20 seconds and the position to within 100 km. Most modern GPS receivers achieve a position fix from a warm condition in less than 60 seconds but can sometimes achieve a position fix in much less time.

Perform the following steps for Acquisition (warm start) TTF measurement.

STEP	PROCEDURE
1,	If connecting GPSG-1000 via Antenna Coupler, perform Antenna Coupler Installation procedure Section 4.1.1. If directly connecting GPSG-1000 to GPS receiver under test, proceed to step 2.
2.	Perform Setup procedure Section 4.1.2.
3.	Ensure GPS receiver is in warm start mode i.e. no ephemeris in memory or receiver has not seen an ephemeris for over 4 Hrs.
4.	Select **Launch Bar** tab to display launch bar. Select **SV PRN** function key to display the SV PRN Function Window. The GPS SV's in view will be displayed in a table.
5.	Turn ON all SV's by selecting ON/OFF field to ON in each SV line and select **Apply.** Select the **close icon** to close the Function Window.
6.	Select **PRN Signal** drop down menu. Select **VARIABLE,** this ensures the relative SV signal levels are set proportional to the respective pseudo ranges.
7.	Select **RF Level** and set to the receiver manufacturers TTFF RF level.
8.	Select **Run** key to restart simulation and measure the Time to Fix (TTF).

4.1.6.C Reacquisition (hot start)

The receiver has up-to-date almanac and ephemeris information, has not been turned off for more than two hours and has not moved location more than 100m. In this scenario, the receiver needs to obtain only timing information from each SV to return its position fix location. Most modern GPS receivers return a position fix from a hot start condition within 0.5 to 20 seconds.

Perform the following steps for Reacquisition (hot start) TTF measurement.

STEP	PROCEDURE
1.	If connecting GPSG-1000 via Antenna Coupler, perform Antenna Coupler Installation procedure Section 4.1.1. If directly connecting GPSG-1000 to GPS receiver under test, proceed to step 2.
2.	Perform Setup procedure Section 4.1.2.
3.	Select **Launch Bar** tab to display launch bar. Select **SV PRN** function key to display the SV PRN Function Window. The GPS SV's in view will be displayed in a table.
4.	Turn ON all SV's by selecting ON/OFF field to ON in each SV line and select **Apply.** Select the **close icon** to close the Function Window.
5.	Select **PRN Signal** drop down menu. Select **VARIABLE,** this ensures the relative SV signal levels are set proportional to the respective pseudo ranges.
6.	Select **RF Level** and set to the receiver manufacturers TTFF RF level.
7.	Select the **Run key** to start the simulation. Wait until a position fix is achieved and select the **Stop** Key.
8.	Wait 60 seconds and then select **Run** key to restart simulation and measure the Time to Fix (TTF).

4.1.6.D TTFF Accuracy

As GPS satellites circle the earth every 12 hours, the range of available satellites varies substantially throughout the course of one day. TTFF and position accuracy are usually specified at a specific power level and to ensure that your receiver returns the appropriate result under a broad range of conditions it is useful to verify the accuracy of both of these specifications under a variety of circumstances.

The GPSG-1000 allows the user to enter a specific UTC time, which correlate's with the almanac loaded in the test set. This feature allows a 3D position to be entered, which is then simulated utilizing either optimal geometry satellites automatically determined, or user selected satellites, available in that location, at that time, thereby providing a means to verify receiver positional accuracy under variable conditions.

NOTE: As GPS and Galileo time are different, the GPSG-1000 allows a common frame of reference by utilizing UTC time for testing.

When measuring TTFF, first start the GPSG-1000. After five seconds, manually place the receiver into "cold" start mode. Once the receiver obtains a position fix, it reports the TTFF information. Example results for Cold and Hot TTFF are shown in Table 4-3.

All table simulations utilize the same 3D position.

Initial UTC	Cold TTFF (S)	Hot TTFF (S)	Maximum SV C/No	SV's
10:14:02m	38.21	1.30	46	6,9,12,14,2
14:06:18	32.01	0.52	49	16,21
16:12:01m	33.09	0.60	47	11,4,8
18:32:22	36.45	1.21	46	24,9,7,15
Average	34.94	0.90	47	
Standard DEV	2.88	0.40	1.41	

Table 4-3 TTFF Values for Four Simulations at different UTC

4.1.6.E Positional Accuracy

3D position accuracy and repeatability can be determined by creating simulations at various UTC's. It is important to test accuracy at various UTC's, because the available satellites and their geometries, change substantially even over the course of several hours. An example of latitude, longitude and altitude information, taken at four different UTC's, is shown in Table 4-4.

Initial UTC	Latitude	Longitude	Alt (MSL)	Horizontal Error (m)
10:14:02m	37.658331	-97.438891	603.000000	0.268341
14:06:18	37.658325	-97.438888	597.000000	0.900046
16:12:01m	37.658320	-97.438887	598.000000	1.457469
18:32:22	37.658310	-97.438891	601.000000	2.559818
Average	34.94	97.438889	599.750000	1.296419
Standard DEV	2.88	0.00000156	2.75378527	.0972312
SIM Position DEC	2.88	-97.438889	-	
SIM Position	2.88	97:96:20 E	600.000000	

Table 4-4 Horizontal Accuracy for Various UTC Simulations

Table 4-4 shows that you can calculate horizontal error in meters absolutely based on the simulated position. The horizontal error is determined from the equation:

$$Error(m) = \sqrt{\left(\left(LatitudeError(m) \times 111325m\right)^2 + \left(LongitudeError(m) \times 111325m\right)^2\right)}$$

The accuracy that a receiver can attain, is highly dependent on the available satellites that it has to lock to. Whilst a receiver's accuracy will vary over the course of several hours (when satellites change), the positional repeatability for a given UTC will usually result in only a small deviation. With the GPSG-1000, you can perform multiple trials of a particular simulated 3D position. This also can confirm that the GPSG-1000 does not add uncertainty to the simulated GPS signal.

4.1.7 RAIM Testing and SV Geometry

The orbital characteristics of SV's within a GPS constellation are contained in the transmitted almanac and ephemeris data. The GPSG-1000 does not permit the user to directly change individual SV orbital parameters, therefore individual SV Elevation and Azimuth, at any UTC within the simulation, are determined by almanac and the ephemeris generated from the almanac.

RAIM requires at least 5 SV's to be in view and monitors specific accuracy boundaries which if crossed, will initiate specific alerts. Positional accuracy is dependent on SV geometry, examples of poor geometry are groups of SV's with azimuth angles close together and/or groups of SV's with low elevation angles. Positions with low elevation SV 's will also exhibit low relative RF Levels, due to the longer pseudo ranges. Due to the SV orbital plane inclination of 55 deg, positions in temperate latitudes, the equator and polar regions.

Temperate latitudes exhibit SV azimuths that range in an arc either side of 90 and 270 degs.

Equator exhibits SV azimuths through a full 360 degs and elevations up to 90 deg.

Polar regions at 0 and 180 deg. Polar regions are devoid of satellites. Polar positions exhibit SV elevations that are low on the horizon (Fig 4-5).

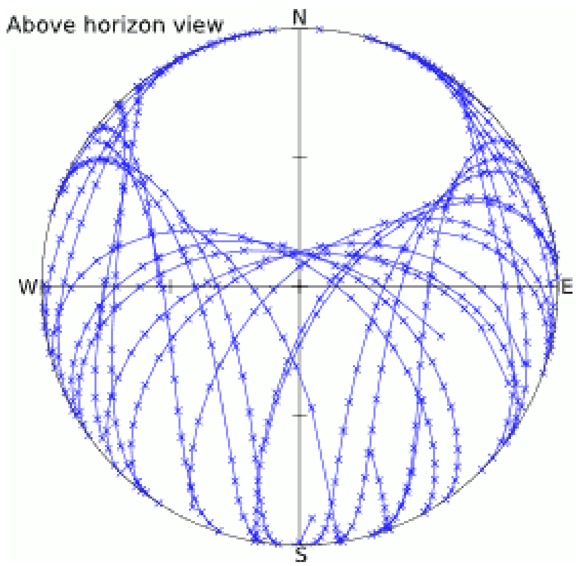

Fig. 4-5 Global SV Tracks

The simulated position and Almanac/Ephemeris UTC, will determine the individual SV's elevation, azimuth and RF level. The SV PRN Elevation and Azimuth indications are used to select combinations of SV's that exhibit poor geometry for RAIM testing.

A bad geometry scenario may be setup in the SV PRN table by selecting only low elevation SV's, only SV's with closely spaced azimuths or only high elevation SV's.

Alternatively polar positions may be simulated, which inherently have low elevation SV's. SV health may be set to BAD to ensure the receiver does not use that SV.

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Chapter 5 - Maintenance

5.1 INTRODUCTION

5.1.1 Visual Inspections

Visual inspections should be performed periodically depending on operating environment, maintenance and use.

5.1.2 External Cleaning

STEP	PROCEDURESTEP PROCEDURE
1.	Clean front panel buttons and display face with soft lint-free cloth. If dirt is difficult to remove, dampen cloth with water and a mild liquid detergent.
2.	Remove grease, fungus and ground-in dirt from surfaces with soft lint-free cloth dampened (not soaked) with isopropyl alcohol.
3.	Remove dust and dirt from connectors with soft-bristled brush.
4.	Cover connectors, not in use, with suitable dust cover to prevent tarnishing of connector contacts.
5.	Clean cables with soft lint-free cloth.
6.	Paint exposed metal surface to avoid corrosion.

5.2 MAINTENANCE PROCEDURES

5.2.1 Battery Replacement

Perform the following steps to replace battery:

STEP	PROCEDURESTEP PROCEDURE
1.	Verify the GPSG-1000 is OFF and not connected to AC power via the AC Adaptor.
2.	Place the GPSG-1000 on a flat surface, lower side up.
3.	Lift the battery cover Pull Tab to a vertical position to release the Battery Cover and lift away from the Case Assembly. **NOTE:** Some batteries may be fitted with a sliding catch. Depress catch to release battery.
4.	Remove the battery from the battery housing (Fig 5-1).
5.	Install new battery in the battery housing.
6.	Replace the battery cover on the case assembly by locating the lipped end of the cover in the case assembly. Lift the pull tab and push the battery cover down, ensuring the catch engages. Release the pull tab and ensure battery lays flat inside the recess. **NOTE:** Some batteries may be fitted with a sliding catch. Depress catch to release battery.

WARNING	DISPOSE OF OLD BATTERY ACCORDING TO LOCAL STANDARD SAFETY PROCEDURES.

Fig. 5-1 Battery Replacement

5.2.2 GPSG-1000 Software Update

Perform the following steps to Update GPSG-1000 Software via the USB port using a USB memory device*****:

STEP	PROCEDURE
1.	Using your PC, obtain the latest software update zip file from Aeroflex.
2.	Insert a USB memory device* into the PC and copy the zip file to the root directory of the USB memory device.
3.	Remove any AEROFLEX directories that may reside on the root directory of the USD memory device.
4.	Unzip the file onto the root directory of the USB memory device.
5.	Upon completion you will have an Aeroflex/Common/ directory that will contain all the .rpm files for the update.
6.	Safely remove the USB memory device from the PC.
7.	Power up the GPSG-1000.
8.	Once booted, select **System** then select **System Update** from the drop down menu.

STEP	PROCEDURE
9.	Insert the USB memory device in USB Host 1 or Host 2 Port.

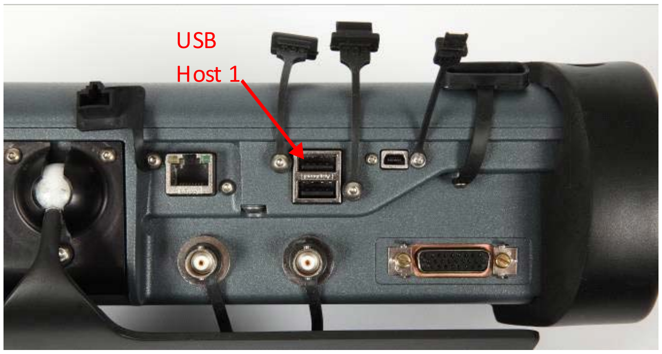

Fig. 5-2 USB Ports

10. Wait 5 to 10 seconds for the device to be recognized and select **Copy from USB**.****** The status screen should indicate 'Copying RPMS from USB'.

    NOTE: This step may take several minutes

    NOTE: RPMs with older version numbers will not be displayed.

    NOTE: Once all of the files have been copied from the USB Memory Device to the GPSG-1000 internal memory, the files to be updated will be displayed in the RPM LIST window and the message COPYING FROM USB DONE will be displayed in the STATUS window.

11. Select **Install Software**. The update will start and the progress screen appears.
12. When both progress bars reach 100%, press the close icon to return to the **System Update** screen. The status message will read 'Done'.
13. Remove the USB memory device and Reboot.

***** Recommended USB memory Device: Aeroflex PN 67325.

****** If you experience a USB Error when trying to copy from USB, the USB memory device being used may not be compatible with the GPSG-1000.

5.2.3 GPSG-1000 Almanac Update

Perform the following steps to Update GPSG-1000 Almanac using a USB memory device*****:

STEP	PROCEDURE
1.	Obtain the current GPS almanac for the week from the United States Coast Guard Navigation Center at http://www.navcen.uscg.gov/?pageName=gpsAlmanacs and save the file as "**current.alm**" or as "**weekXYZ.alm**" with XYZ being the current almanac week (week617.alm).
2.	Copy the almanac file, named "**current.alm**" to the USB memory device (Aeroflex P/N 67325) under the directory name of **Aeroflex/almanacs/** plus almanac file name (/Aeroflex/almanacs/week617.alm).
3.	Power up the GPSG-1000.
4.	Select **System**, then select **System Update** from the drop down menu on the GPSG-1000
5.	Insert the USB memory device into USB Host 1 Port.
6.	Wait 5 to 10 seconds for the device to be recognized and then select **Copy from USB**.
7.	Select **Install Software** and the update will start. The Update Progress screen will briefly flash stating updating files.
8.	The status message should read 'Upgrade Done'.
9.	Remove the USB memory device.
10.	Proceed to **Setup** window, then press **Almanac Source**. Press **File**, then select the newly loaded almanac file to load.

5.2.4 System Configuration Function Window

The System Configuration Function window is accessible via the Launch Bar System function key, as a sub selection. System Configuration displays five selectable tabs across the top of the screen. Status, Hardware, UI Options, Network and Date/Time.

5.2.4.A Status

The Status tab displays test memory status, operating time, hardware module temperatures and provide internal SD card formatting control.

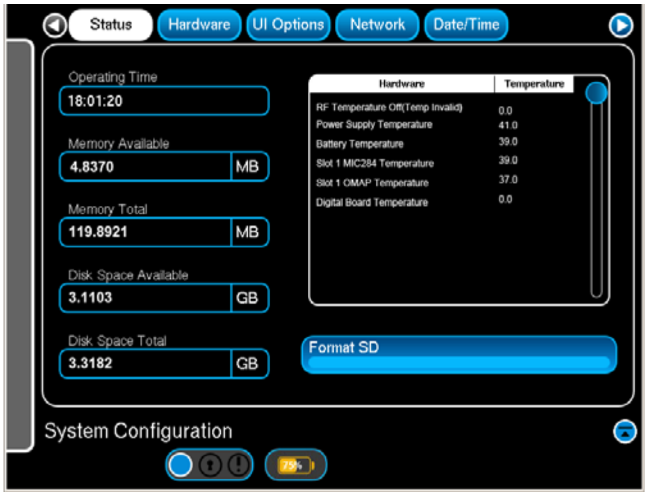

Fig. 5-3 System Configuration - Status

Display Component	Description
Operating Time	Displays the total operating time in hrs: mins:secs since power up
Memory Available	Displays memory available to software resources in GB, MB or KB
Memory Total	Displays total test set memory in GB, MB or KB
Disk Space Available	Displays remaining disk space available in GB, MB or KB for settings and profile storage.
Disk Space Total	Displays total test set disk space in GB, MB or KB
RF Temperature	Displays the current RF card temperature in degrees Celsius
Power Supply Temperature	Displays the current power supply module temperature in degrees Celsius
Battery Temperature	Displays the current battery pack temperature in degrees Celsius

Display Component	Description
Slot 1 MIC284 Temperature	Displays the current PXI slot 1 controller MIC284 temperature in degrees Celsius
Slot 1 OMAP Temperature	Displays the current PXI slot 1 controller OMAP processor temperature in degrees Celsius
Digital Board Temperature	Displays the current PXI digital board temperature in degrees Celsius

Control Component	Description
Format SD	Formats the internal SD memory card overwriting all stored settings and profile data. **NOTE:** The user will be prompted YES or NO prior to execution of formatting. **Caution:** Formatting will result in complete irretrievable loss of settings and profile data.

5.2.4.B Hardware

The Hardware tab displays hardware module/board identification, version and software revision numbers for configuration control purposes.

Fig. 5-4 System Configuration - Hardware

Display Component	Description
Digital Board Card ID	Displays five digit digital board card ID number
Digital Board Card Version	Displays digital board card version number
Digital Board Firmware Version	Displays seven digit digital board firmware version number
Digital Board Application Firmware Version	Displays seven digit digital board application firmware version number
Upconverter Card ID	Displays five digit upconverter card ID number
Upconverter Card Revision	Displays upconverter card revision number
Upconverter Firmware Version	Displays seven digit upconverter firmware version number
RF Combiner Card ID	Displays five digit RF combiner card ID number
RF Combiner Card Revision	Displays RF combiner card revision number
RF Combiner Firmware Version	Displays seven digit RF combiner card firmware version number
Slot 1 PCI Net Version	Displays PCI net version number
Slot 1 CPLD Version	Displays five digit Slot 1 CPLD version number
Power Supply Version	Displays five digit power supply version number

5.2.4.C UI Options

The UI Options tab controls the screen back light level and touch screen calibration utility.

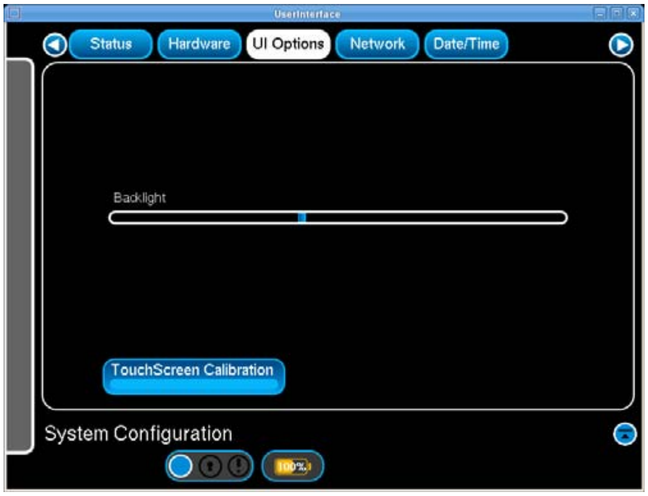

Fig. 5-5 System Configuration – UI Options

Control Component	Description
Backlight	Move the slider to the right to increase backlight level. Move the slider to the left to reduce backlight level.

5.2.4.D Network

The Network tab controls the test set Ethernet adaptor local area connection settings. The Ethernet bus is used for remote control of the test set.

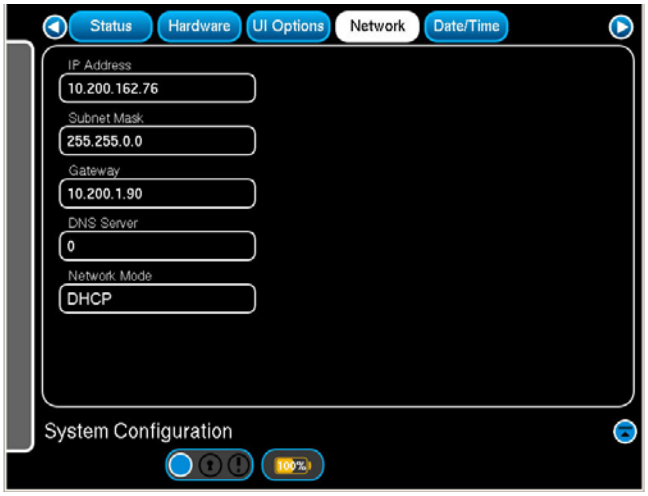

Fig. 5-6 System Configuration – Network

Control Component	Description
IP Address	Numeric pad: IP address, entry in the format 10.200.120.148 (example)
Subnet Mask	Numeric pad: Subnet mask, entry in the format 255.255.255.0 (example)
Gateway	Numeric pad: Gateway, entry in the format 10.101.0.1 (example) **NOTE**: This field is only selectable with Network Mode = DHCP
DNS Server	Connection specific Domain Name Server suffix. **NOTE**: Reserved for future use.
Network Mode	Drop down menu: Selections Network Off – Disables Ethernet adapter. Static IP - Uses entered static IP address. DHCP – Uses dynamically allocated address from DHCP server **NOTE**: Sever will populate IP Address, Subnet Mask and Gateway fields automatically. **NOTE**: The unit must be connected to a LAN before any change to this field is allowed.

5.2.4.E Date/Time

The Date/Time tab controls the test set date /time clock parameters.

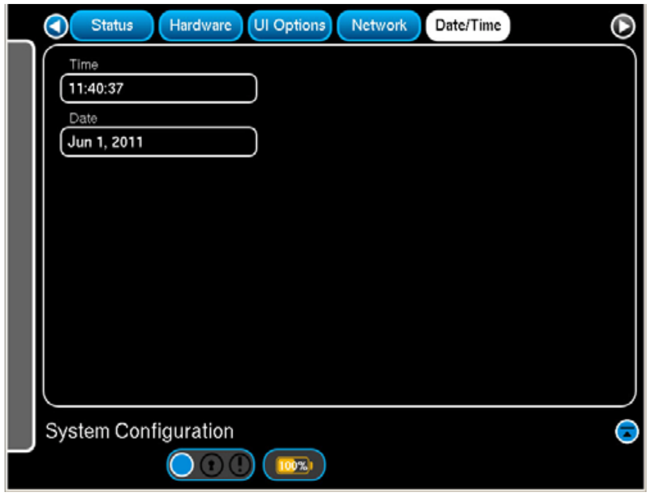

Fig. 5-7 System Configuration – Date/Time

Control Component	Description
Time	Numeric pad: Time entry in the 24 Hour format HH:MM:SS
Date	Numeric pad: Date entry in the format MM:DD:YYYY

5.2.4.F Diagnostics Function Window

The Diagnostics Function window is accessible via the Launch Bar Maintenance function key, as a sub selection. Diagnostics provides control for generating test signals, with specific power and frequency parameters.

Fig. 5-8 Diagnostics

Control Component	Description
Mode	Drop down menu: Selections OFF, CW or MODULATED
Amplitude	Numeric pad: Power in dBm. Range -93 dBm to +155 dBm DIRECT or -68 dBm to -130 dBm COUPLER
Frequency	Drop down menu: Selections 1176.45 MHz, 1207.14 MHz, 1227.60 MHz, 1278.75 MHz or 1575.42 MHz.
Doppler Error	Numeric Pad: +/- 5000Hz in 1Hz increments.
EXT REF OUT	Drop down menu. ON or OFF.
Reference Sources	Drop down menu. INT or EXT.
LOG AMP	Displays the output from the internal up convertor module. Displayed in dB.
Read	Displays the output from the internal up convertor module. Displayed in dB.
PLL Lock Status	Indicates the state of the LO, 800 Mhz, EXT REF and EXT REF DET. ON (Green) indicates locked condition, OFF indicates unlocked condition.

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Chapter 6 - Principles of Operation

6.1 PRINCIPLES OF OPERATION

6.1.1 GPSG-1000

Control Panel Assembly

The Control Panel Assembly, provides On/Off, Home Buttons and Status LED’s.

Power Supply Assembly

The Power Supply Assembly is responsible for supplying power for module operation and providing +5 Volt bias for applied power status.

Converter Assembly

The Converter Assembly provides the Test Set’s AF, RF and Modulated Output signals.

RF Combiner Assembly

The RF Combiner Assembly provides Signal Attenuation and 10MHz system reference.

PXI Backplane Assembly

The PXI Backplane Assembly routes electrical signals between the various system assemblies.

Rear Panel Assembly

The Rear Panel Assembly provides access to Tests Set’s Input/Output connectors and AC charger.

6.1.2 Interconnect Block Diagrams

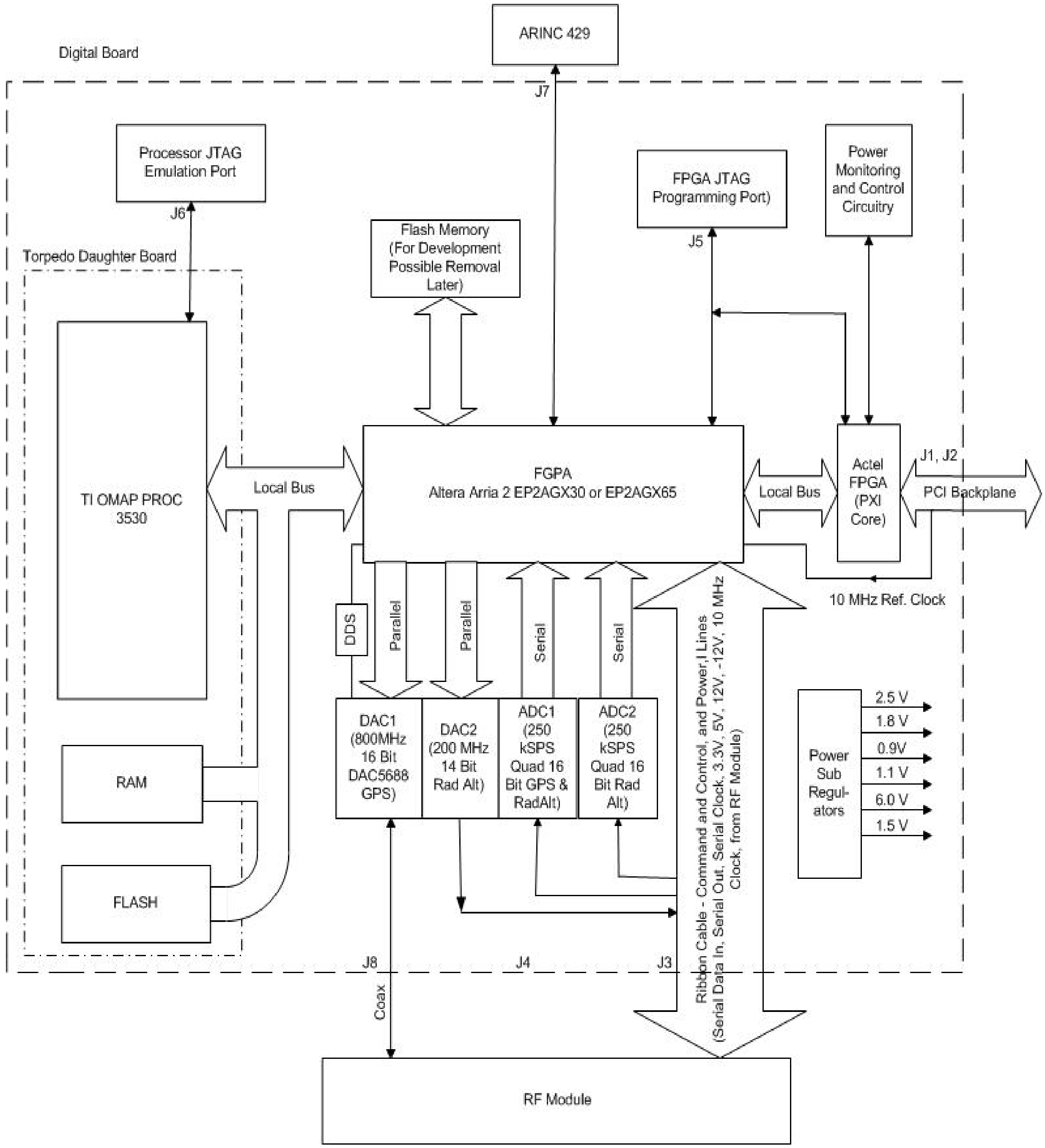

Fig. 6-1 Assembly Interconnect Block Diagram)

6.1.3 GPS System

The **NAVSTAR,** (**N**avigation **S**atellite **T**iming **A**nd **R**anging), GPS, (**G**lobal **P**ositioning **S**ystem) is a satellite based navigation system offering precision navigation capability. The system was originally designed for military use, funded and controlled by the U.S. Department of Defense. Civilian access has been permitted to specific parts of the GPS.

GPS offers a number of features making it attractive for use in aircraft navigation. Civilian users can expect a position accuracy of 100 m or better in three dimensions. The GPS signal is available 24 hours per day throughout the world and in all weather conditions. GPS offers resistance to intentional (jamming) and unintentional interference. The equipment necessary to receive and process GPS signals is affordable and reliable and does not require atomic clocks or antenna arrays. For the GPS user, the system is passive and requires a receiver only, without the requirement to transmit.

GPS determines the position of the user by triangulation. By knowing the position of the satellite and the distance from the satellite, combinations of satellites can be used to determine the exact position of the receiver. The fundamental means for GPS to determine distance is the use of time. Distance is computed by using accurate time standards and by measuring changes in time.

The GPS System is comprised of three segments:

- Space Segment
- Control Segment
- User Segment

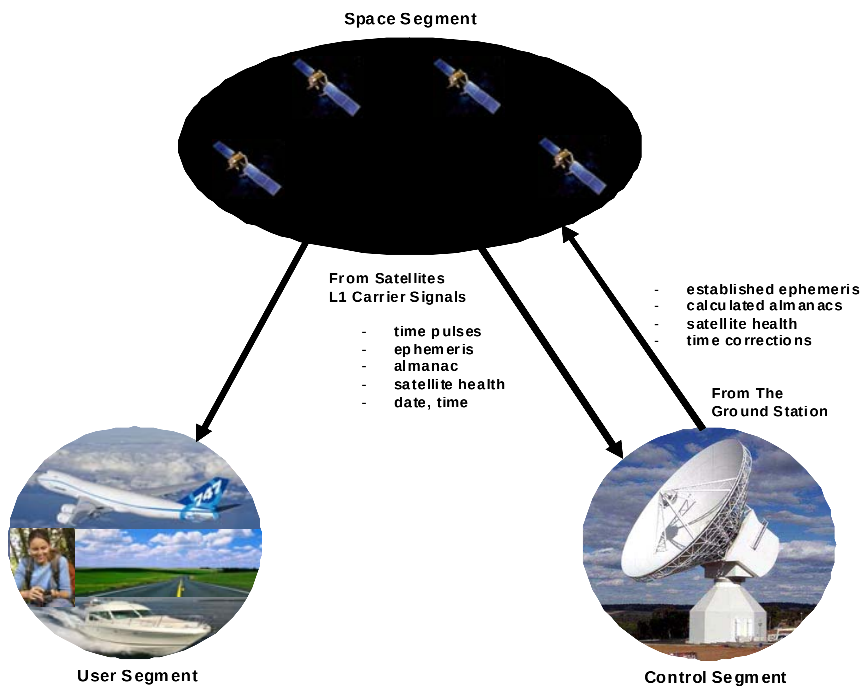

Fig. 6-2 GPS System Segments

6.1.3.A Space Segment

The Space segment consists of the GPS space vehicles (SV's) or Satellites, nominally 24 SV's plus spares. The terms SV and satellite shall be interchangeable in this document. Each vehicle has a 12 hour orbit at 20,200 km above the earth and repeats same ground track daily. 5 to 12 SV's are visible from anywhere on earth.

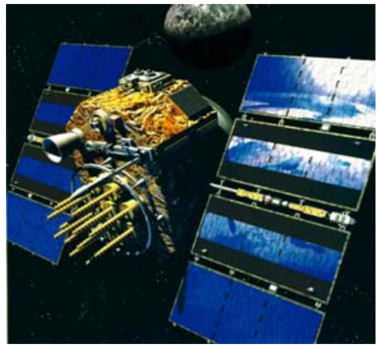

Fig. 6-3 GPS Satellite

Six orbital planes are used, each spaced equally around the earth, separated by 60 degrees (360 degrees/6 planes=60 degrees) and inclined 55 degrees from equatorial plane. The planes are named A to F. Each orbital plane hosts four satellites. These satellites are not spaced evenly on each plane. Spacing between adjacent satellites varies from 31.13 degrees to 119.98 degrees. Each plane exhibits a different angular spacing for the satellites resident to it.

A computer model determines the satellite spacing to accommodate a single satellite failure and still maintain optimal satellite geometry.

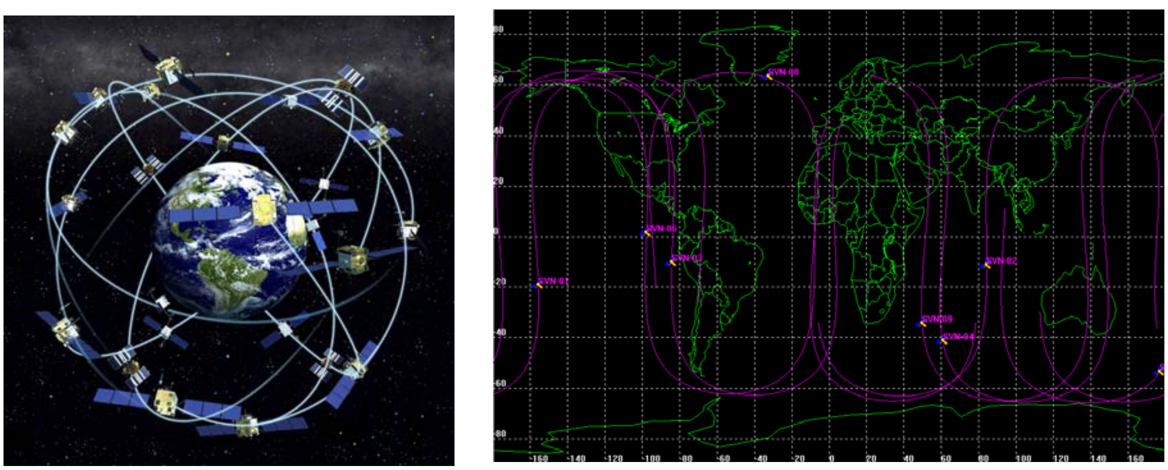

Fig. 6-4 GPS Satellite Orbital Planes

Fig 6-4 shows the motion of nine satellites. The ground tracks show the movement of these satellites over a twelve hour period and the position of the satellites at one moment in time.

The ground tracks show a number of features. Each satellite follows a unique path over the ground. Also, every satellite operates between 55 degrees North and 55 degrees south.

The primary mission of GPS satellites is the transmission of precisely timed GPS signals and the data stream required to decode the signals to produce a position. The timing signals are referenced to atomic clocks, either cesium or rubidium.

With the GPS satellites in constant motion, the number of satellites in view and their relative location is dynamic. A 24 satellite configuration provides adequate satellite coverage to perform three-dimensional position fixing. Failures of satellites and/or the requirement for more than four satellites may result in inadequate satellite coverage.

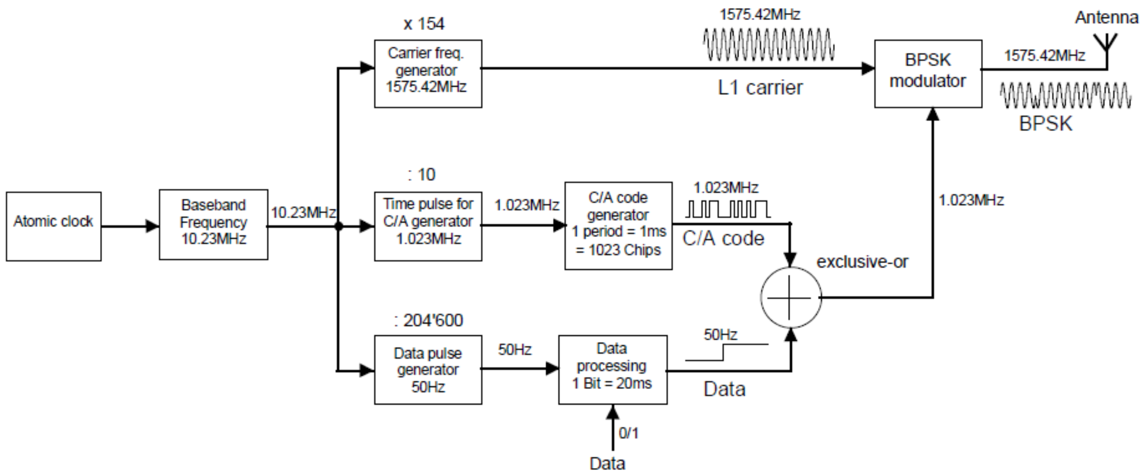

Fig. 6-5 GPS SV Block Schematic

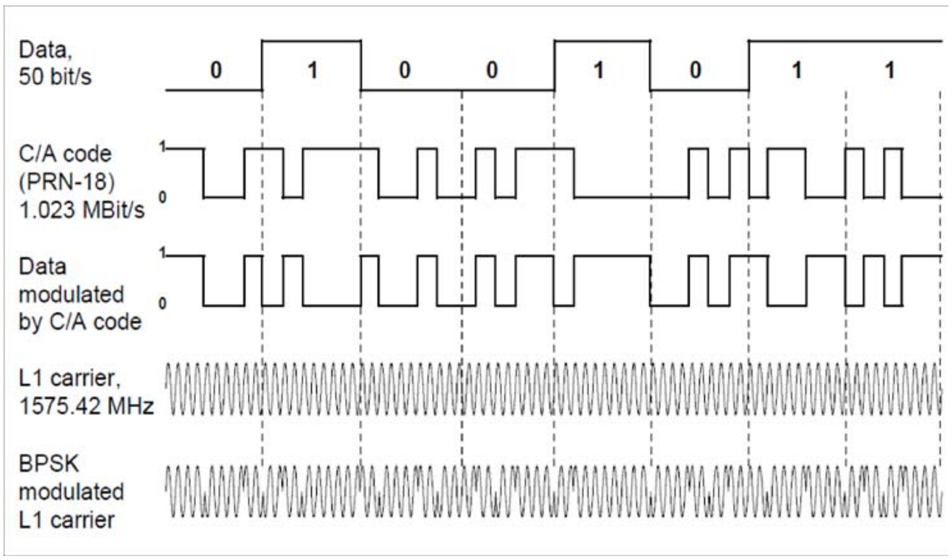

Fig. 6-6 GPS SV Signal Data Structure

Refer to Figures 6-5 and 6-6. Each GPS satellite transmits a unique signature assigned to it on the same carrier frequency. This signature consists of a Pseudo Random Noise (PRN) Code of 1023 zeros and ones, broadcast with a duration of 1 ms and continually repeated. The PRN code is exclusively OR'd (modulo 2 added on), with 50 bit/s Navigation Data (Nav Data). The combined code is then used to BPSK modulate a 1575.42 MHz carrier frequency. The resultant signal is spread spectrum.

6.1.3.B Control Segment

Six unmanned monitoring stations are located throughout the world. Each Station constantly monitors and receives information from the GPS satellites and sends the orbital and clock information to the master control station. Five of these stations (except Hawaii) have the ability to upload information to the GPS satellites

Colorado Springs is designated a Master Control Station (MCS). The MCS constantly receives GPS satellite, orbital and clock information from the monitor stations. The MCS makes precise corrections to the data as necessary and sends the information, known as ephemeris data, to the GPS satellites using ground based antennas.

Fig. 6-7 GPS Monitor Stations

The objective of the GPS control segment is:

- Maintain each of the satellites in its proper orbit through infrequent, small commanded maneuvers.
- Make corrections and adjustments to the satellite clocks and payload as needed.
- Track the GPS satellites and generate and upload navigation data to each of the GPS satellites.
- Command major relocations in the event of satellite failure to minimize the impact.

6.1.3.C User Segment

The signals broadcast from the GPS satellites form the means for a GPS receiver to perform the timing and distance calculations. GPS receivers are passive devices, meaning that signals are received only with no requirement or means to transmit.

GPS ranging signals are broadcast on two frequencies: L1 (1575.42 MHz) and L2 (1227.6 MHz).The L1 frequency is available for civilian use. The L2 frequency was designed primarily for Military use.

6.1.4 SPS Standard Positioning Service

The Clear Acquisition Code, or C/A, is the principal civilian ranging signal and is always broadcast in a clear or unencrypted form. The use of this signal is sometimes called the Standard Positioning Service or SPS. This signal may be degraded intentionally but is always available. The signal creates a short Pseudo Random Noise (PRN) code broadcast a rate of 1.023 MHz. The satellite signal repeats itself every millisecond. The C/A code is also used to acquire the P Code.

6.1.4.A PPS Precise Positioning Service

Protected Code or P Code: this is also known as the Precise Positioning Service. The P Code is never transmitted in the clear and is encrypted with a W code. When encrypted the signal is know as P(Y) code and is not available to civilian users. The C/A PRN's are unique for each satellite however, the P-code PRN is actually a small segment of a master P-code approximately 2.35 × 1014 bits in length (235,000,000,000,000 bits) and each satellite repeatedly transmits its assigned segment of the master code.

6.1.5 Position Calculation

Position calculations consists of the following elements:

- Deciding which satellites to acquire and track
- Code and frequency correlation
- Measure distance to satellites
- Obtain satellite positions
- Adjust local clock bias
- Perform triangulation calculations (Trilateration)
- Adjust for time delay errors

6.1.5.A SV's to Acquire and Track

The L1 and L2 frequencies broadcast a GPS Navigation Message (Nav Data) as part of their signal. This low frequency (50 bits per second) data stream provides the receiver with a number of critical items required in determining a position. A data bit frame consists of 1500 bits divided into five, six second 300-bit subframes. A data frame is transmitted every thirty seconds. An entire set of twenty-five frames (125 subframes) makes up the complete Navigation Message that is sent over a 12.5 minute period.

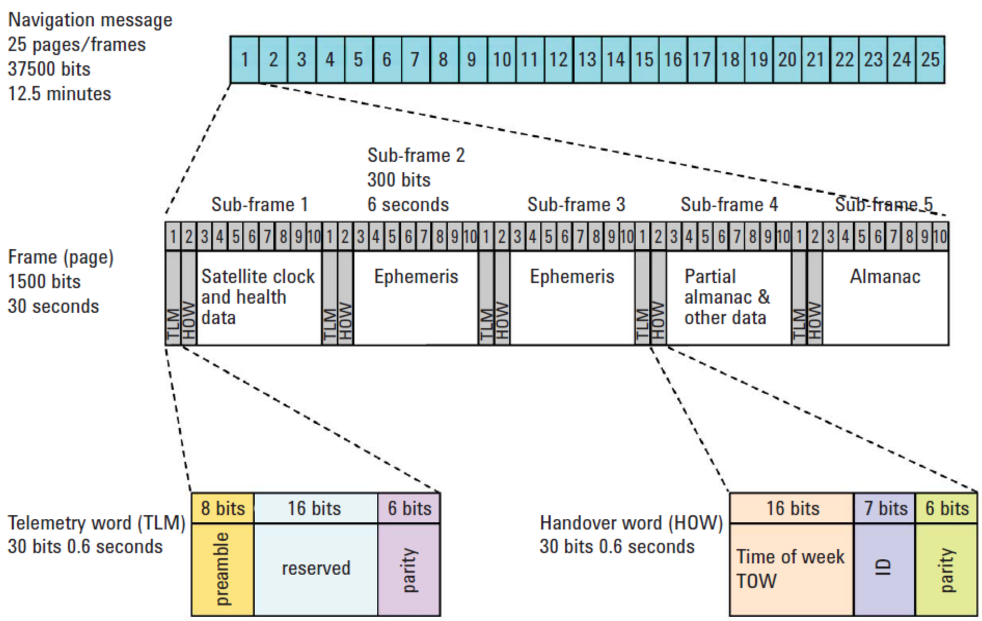

Fig. 6-8 GPS Navigation Data

Subframes

Subframes 1 to 5 each provide a synchronization, hand-over word and a C/A code time ambiguity removal. The remainder of the data is formatted as follows:

Subframe 1:

Contains the time values of the transmitting satellite, including the parameters for correcting signal transit delay and onboard clock time, as well as information on satellite health and an estimate of the positional accuracy of the satellite.

Subframe 2 and 3:

Ephemeris.

Subframe 4:

Ionospheric model, UTC data, flags for each satellite indicating whether anti-spoofing is on, almanac (approximate satellite ephemeris allowing the receiver to select the best set of satellites or to determine which satellites are in view) and health information for satellite number 25 and greater.

Subframe 5:

Almanac and health information for satellite number 1 to 24.

The reception and decoding of the data stream is performed automatically by a receiver without any intervention by the operator. The information within this data is critical to GPS operation. If a GPS receiver has never seen the GPS constellation before and does not know its approximate location, the first action of the receiver is to acquire any SV in view. Once a satellite has been acquired, the almanac is downloaded.

Refer to Fig 6-9. Subframes 4 and 5 contain almanac information. Once the almanac is acquired, the information it contains is used to determine which satellites are in view and select the set of satellites with the best geometry. The almanac structure for one SV PRN is shown in Fig 6-9. Almanac data is typically updated every 24 hours. Data for a few weeks is also provided in case of a delay in update. Once a receiver has an almanac loaded in its memory, it can be used for a faster acquisition of satellites on the next occasion of use. Once a satellite has been acquired, it's ephemeris information can be obtained.

```
******** Week 572 almanac for PRN-03 ********
ID:                          03
Health:                      000
Eccentricity:                0.1350402832E-001
Time of Applicability(s):   405504.0000
Orbital Inclination(rad):    0.9279594421
Rate of Right Ascen(r/s):   -0.8203642210E-008
SQRT(A)  (m 1/2):            5153.669922
Right Ascen at Week(rad):    0.3102266431E+001
Argument of Perigee(rad):    1.020882249
Mean Anom(rad):             -0.7818025351E+000
Af0(s):                      0.5941390991E-003
Af1(s/s):                    0.3637978807E-011
week:                         572
```

Fig. 6-9 GPS Almanac

The almanac provides a basic description of each satellite orbit. Refer to Fig. 6-10. Two parameters are commonly displayed on GPS receivers which describe the basic position of a satellite relative to a GPS receiver at a specific location.

Elevation describes the angle of a satellite relative to the horizontal plane. If a satellite is directly above the point of observation on the ground, then the elevation is 90°. If the satellite is at the horizon, then the elevation is 0°.

Azimuth is the angle between a reference plane and a point. In the case of satellites the reference plane is the plane of the horizon based on true North. The Azimuth is the angle between the satellite and true North (North = 0°, East = 90°, South = 180°, West = 270°).

Of course many other parameters are used to define satellite orbit. Each satellite will downlink a more precise description of its orbit, which is contained in sub-frames 2 and 3, and is known as ephemeris. With this information the receiver can determine the satellite's position at any time and combine this with the receiver distance from the satellite, yielding a GPS position.

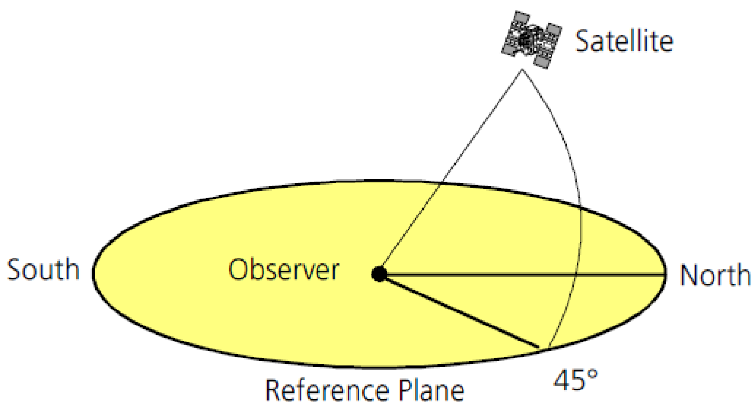

Fig. 6-10 Satellite Relative Position

The health information transmitted in subframe 5, is critical to prevent a receiver from using the ranging information from a satellite that has been declared unfit for navigation purposes.

The remainder of the information found in the data stream (clock corrections, ionospheric model, UTC data) are used to resolve potential sources of GPS position errors.

6.1.5.B Code and Frequency Correlation

The power of the received GPS signal in open sky is at least -160 dBW (-130 dBm). The maximum of the spectral power density of the received signal is -190 dBm/Hz. The spectral power density of the thermal background noise is approximately -174 dBm/Hz (at a temperature of 290 K). Refer to Fig, 6-11. The maximum received signal power is approximately 16 dB below the thermal background noise level.

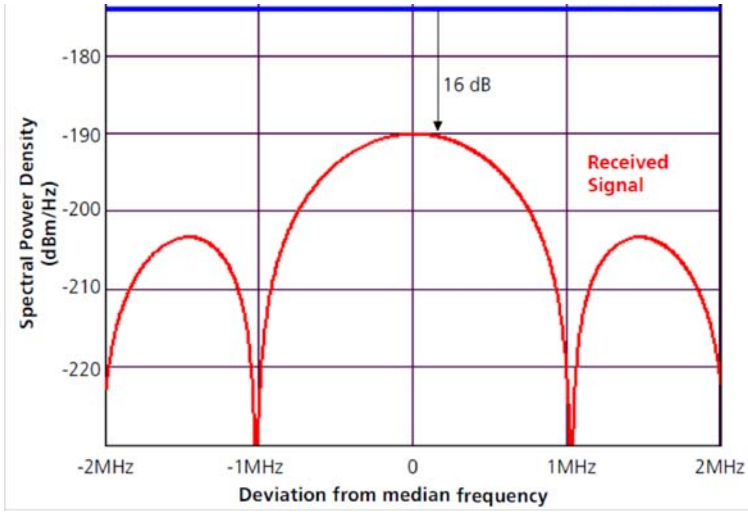

Fig. 6-11 GPS Received Signal

To recover the data from spread spectrum signal at the receiver, the energy spread over a wide bandwidth must be correlated or de-spread into a narrow bandwidth by frequency and code shifting. Fig. 6-12 shows the criticality of correlation in terms of recovering the signal.

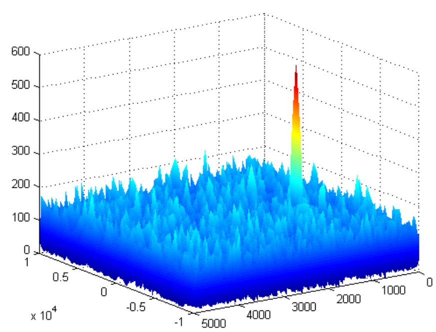

Fig. 6-12 GPS Received Signal

Each GPS satellite transmits unique PRN code. The receiver first demodulates received BPSK signal to extract the satellite PRN code overlaid with Nav Data. The receiver then generates a local copy of the PRN code and then shifts the timing of the local code by 1 bit, relative to a receiver time mark, until all 1,023 bits of the local code are in phase (correlated), with the PRN code received from the satellite. Refer to Fig 6-13 and Fig 6-14. A modulo 2 addition process is used to recover the Nav Data.

If all 1,023 bit shifts have been tried without achieving correlation, the receiver local oscillator frequency is offset to the next value and the process is repeated. The reason for this frequency offset, is because satellites and receivers are in relative motion to one another and hence Doppler shift in the transmitted carrier frequency occurs. The transmitted signals can be shifted by up to +/- 5000 Hz at the point of reception.

The determination of the signal travel time and data recovery therefore requires not only correlation with all possible codes at all possible phase shifts, but also identification of the correct phase carrier frequency.

In the case of a receiver cold start, where the receiver does not have a current almanac loaded, every PRN would be tried until an SV is found in view, after which the almanac can be downloaded and used to determine which SV's to acquire next. Because the search for the first SV may take some time, GPS receiver cold starts take appreciably longer than warm starts, where the GPS receiver has a current almanac stored in memory.

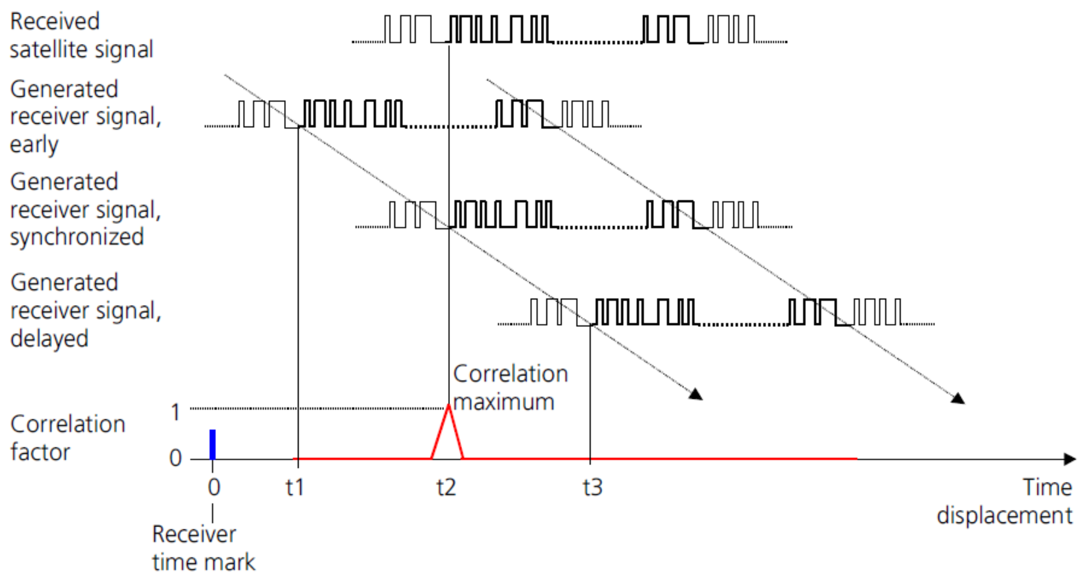

Fig. 6-13 GPS Code Correlation Process

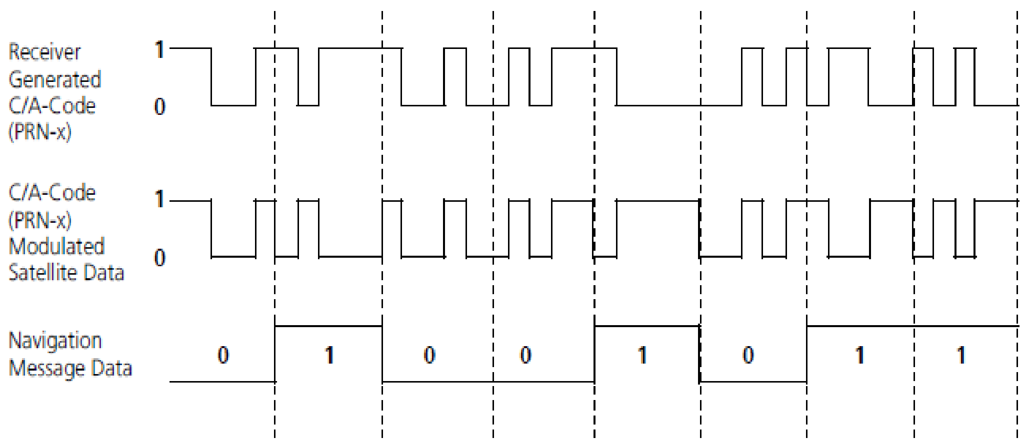

Fig. 6-14 GPS Nav Data Recover by Moduo 2 Addition

Refer to Fig. 6-15. The spectral power density of the received GPS signal lays at approximately 16 dB below the spectral power density of the thermal or background noise. The demodulation and de-spreading of the received GPS signal causes a system gain G of:

After despreading, the power density of the usable signal is greater than that of the ther mal or background signal noise.

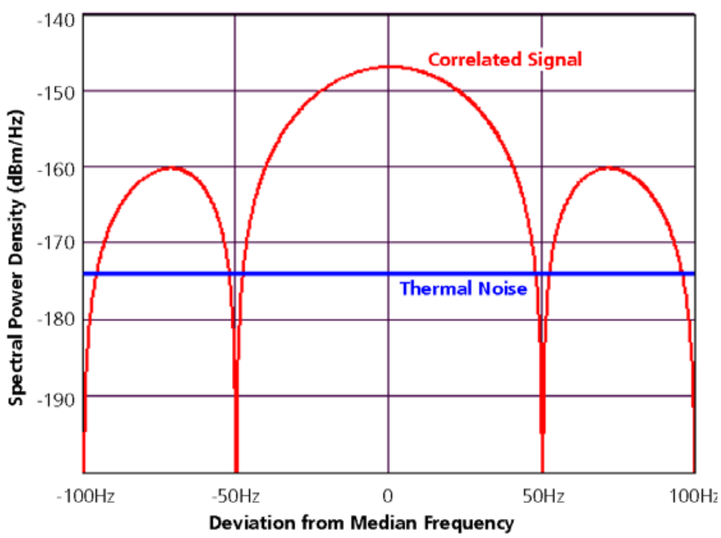

Fig. 6-15 GPS Signal After De-spreading

6.1.5.C Measuring Distance (Pseudo Range)

GPS satellites orbit 200km above the earth and are distributed in such a way that from any point on the ground there is line-of-sight contact to at least four satellites.

Each one of these satellites is equipped with onboard atomic clocks. In order to make them even more accurate, they are regularly adjusted or synchronized from various control points on Earth. GPS satellites transmit their exact position and onboard clock time to Earth.

These signals are transmitted at the speed of light (300,000 km/s) and therefore require approximately 67.3 ms to reach a position on the Earth's surface directly below the satellite. The signals require a further 3.33 µs for each additional kilometer of travel. To establish position, all that is required is a receiver and an accurate clock.

By comparing the arrival time of the satellite signal with the onboard clock time the moment the signal was transmitted, it is possible to determine the signal travel time.

Distance = Velocity * Time: Velocity is 300,000 km/s and Time is the travel time of the signal.

To measure the travel time:

- Receiver generates the same codes as the Satellite (PRN codes)
- Measure delay between incoming codes and self generated codes
- D = Speed of light * measured delay (Pseudo Range)

The first word of every single frame, the Telemetry word (TLM), contains a preamble sequence 8 bits in length (10001011) used for synchronization purposes, followed by 16 bits reserved for authorized users. As with all words, the final 6 bits of the telemetry word are parity bits.

The handover-word (HOW) immediately follows the telemetry word in each subframe. The handover-word is 17 bits in length (a range of values from 0 to 131071 can be represented using 17 bits) and contains within its structure the start time for the next subframe, which is transmitted as time of the week (TOW).

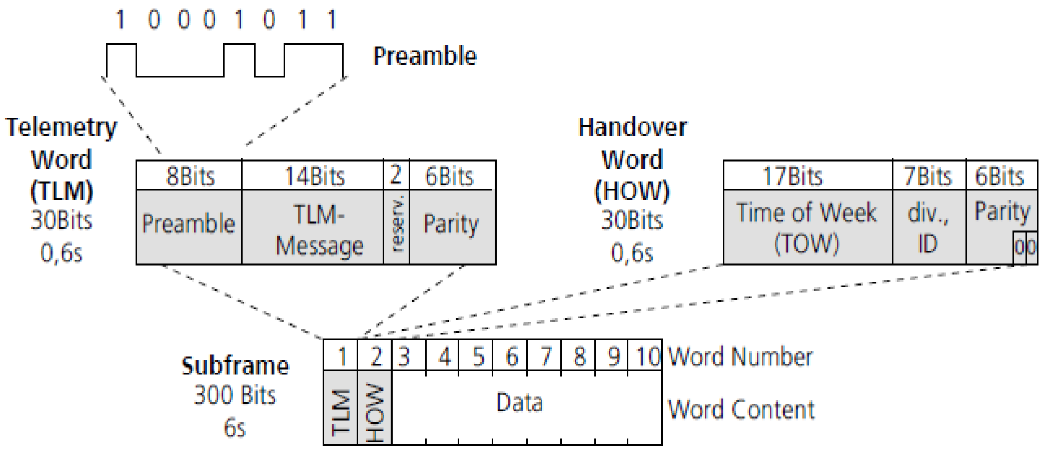

Fig. 6-16 GPS Subframe Hand-Over Word

The transmission time in the first bits of the preamble are provided in the Navigation Message in the TOW Message of the previous frame. This time is given in Satellite Time. Information in the Navigation Message allows translation into Receiver Time. If the preamble is validated, the arrival time of the first bits in the preamble is measured. This time is given in Receiver Time.

Refer to Fig 6-17. Due to the atomic clocks onboard the satellites, the time at which the satellite signal is transmitted is known very precisely. All satellite clocks are adjusted to be synchronized with each other and UTC (universal time coordinated). In contrast, the receiver clock is not synchronized to UTC and is therefore slow or fast by $\Delta t0$ (clock bias). The sign $\Delta t0$ is positive when the user clock is fast. The resultant time error $\Delta t0$, causes inaccuracies in the measurement of signal travel time and the distance R. As a result, an incorrect distance is measured that is known as a pseudorange.

$$G_G = \frac{\text{Modulation rate of C/A - Code}}{\text{Data rate of information signal}} = \frac{1023\text{bps}}{50\text{bps}} = 20{,}500 = 43\text{dB}$$

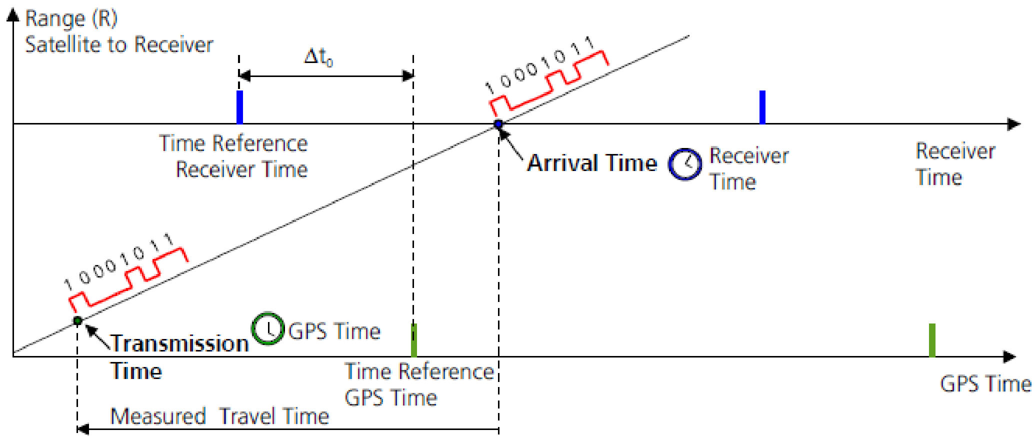

Fig. 6-17 GPS Pseudo Range

6.1.5.D Obtain Satellite Positions

GPS receivers download an almanac into memory which defines where in the sky each satellite is, moment by moment. GPS satellites are constantly monitored by the U.S. Department of Defense. Slight orbital errors are caused by gravitational pulls from the moon and sun and by the pressure of solar radiation on the satellites. Radar is used to check each satellite's exact altitude, position and speed. This information (ephemeris data), is then relayed back up to the respective satellite, which in turn transmits the ephemeris data in Nav Data subframes 2 and 3. Ephemeris data is updated every two hours and is valid for four hours.

6.1.5.E Clock Bias

To solve the problem of clock bias, consider a receiver is placed on a straight line beneath two satellites. As the position of all GPS satellites is known via information contained in the almanac and ephemeris, the distance between any two satellites (S), is known. By measuring the travel times from each satellite, it is possible to exactly establish the distance (D) despite having an imprecise receiver clock, using the following formula:

$$D = \frac{(\Delta t1 - \Delta t2) \times c + S}{2}$$

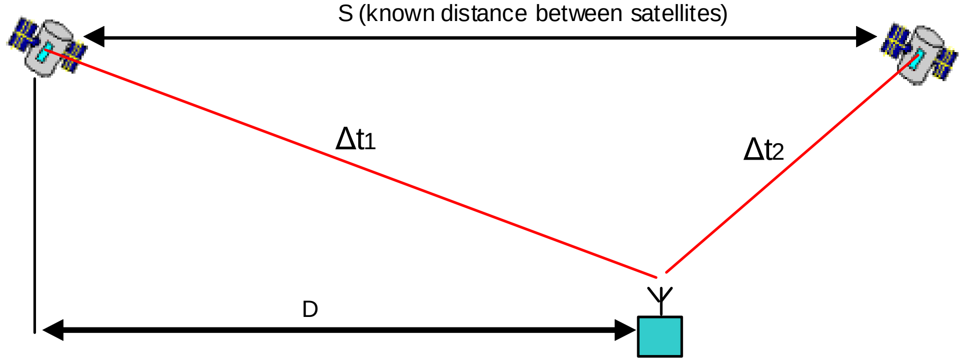

Fig. 6-18 GPS Pseudo Range

In this example two pseudo ranges were employed to determine a position in one dimensional space. To calculate a position in two dimensional space, three pseudo ranges are required, Latitude, Longitude and Δt.

To calculate a position in three dimensional space, four pseudo ranges are required; Latitude, Longitude, Altitude and Δt. The number of pseudo ranges (GPS satellites), must exceed the number of unknown dimensions by a value of one.

6.1.5.F Triangulation Calculations (Trilateration)

Consider triangulation in 2D space. Refer to Fig 6-19. If location of point A is known, and the distance to point A is known, desired position lies somewhere on a circle.

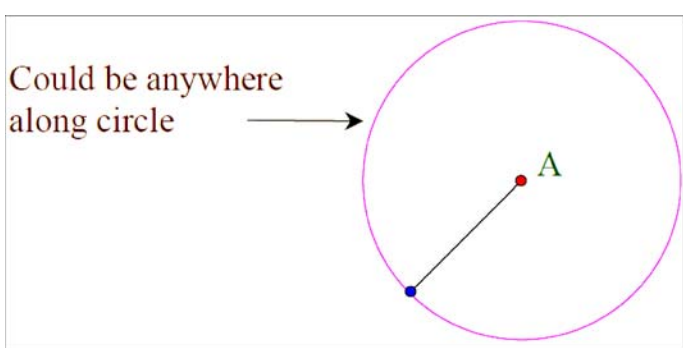

Fig. 6-19 Triangulation using one known point

Refer to Fig 6-20. Distance to two points is known, desired position is in one of two locations

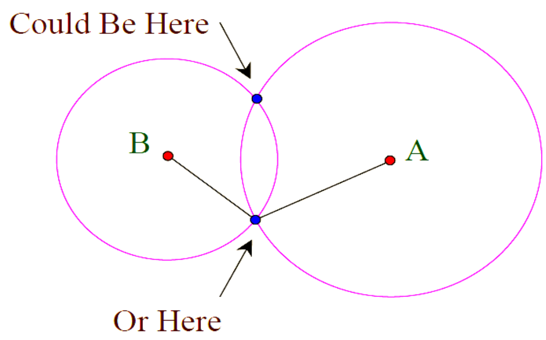

Fig. 6-20 Triangulation using two known point

Refer to Fig 6-21. Distance to three points is known, position is known.

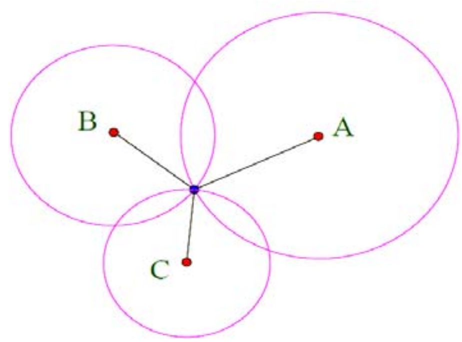

Fig. 6-21 Triangulation using three known point

Refer to Fig 6-22. Consider triangulation in 3D Space. Distance to two points is known.

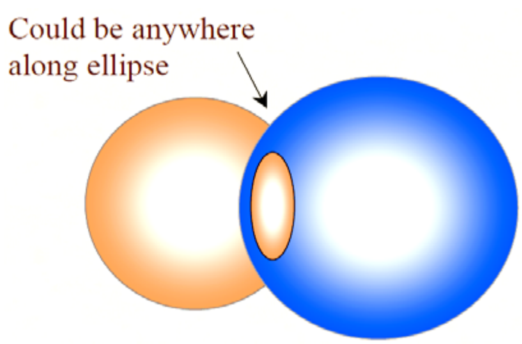

Fig. 6-22 Triangulation using two known points in 3D space

Refer to Fig 6-23. Distance to three points is known, position is known in 3D space.

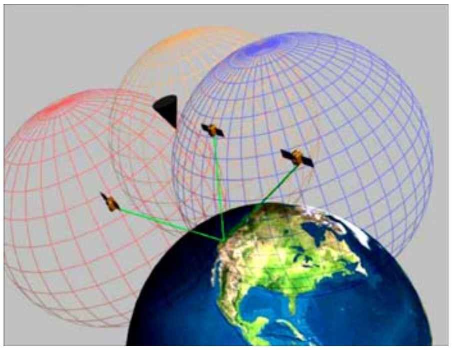

Fig. 6-23 Triangulation using three known points in 3D space

6.1.5.G Time Delay Errors

Sources of Time Delay Error are:

Ephemeris data:

The data concerning ephemeris errors may not exactly model the true satellite motion. The disparity in ephemeris data can introduce 1 to 5 meters of positional error. Ephemeris data is valid for a period of about 4 hours

Satellite clocks:

The data concerning the satellite's four atomic clocks may not reflect the exact rate of clock drift. Distortion of the signal by measurement noise can further increase positional error. Clock drift disparity can introduce 0 to 2.5 meters of positional error and measurement noise can introduce 0 to 10 meters of positional error.

Receiver Clock Inaccuracies and Rounding Errors:

Despite the synchronization of the receiver clock with the satellite time during the position determination (compensation for clock bias), the remaining inaccuracy of the time still leads to an error of about 2 m in the position determination. Rounding and calculation errors of the receiver sum up approximately to 1 m.

Multipath:

Refer to Fig 6-24. GPS signals can also be affected by multi-path issues where the radio signals reflect off of surrounding terrain such as buildings, canyon walls, and hard ground. These delayed signals can result in periodic signal cancellation but typically they change dynamically with location and may just cause short term inaccuracy.

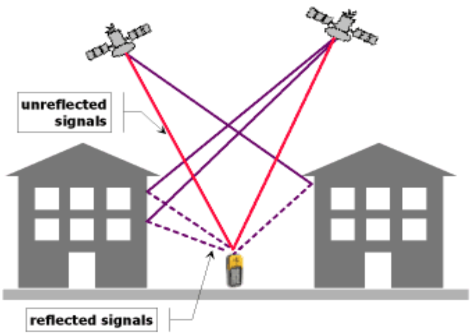

Fig. 6-24 Multipath Delays

6.1.5.H Atmospheric Delays

Ionosphere:

The ionosphere is an atmospheric layer situated between 90 to 1000 km above the Earth's surface. The gas molecules in the ionosphere are heavily ionized. The ionization is caused mainly by solar radiation, hence the thickness of this layer varies during the course of the day. Signals from the satellites travel through a vacuum at the speed of light. However, in the ionosphere the velocity of these signals slows down due to the ionized gas, an effect called dispersion, which is frequency dependent.

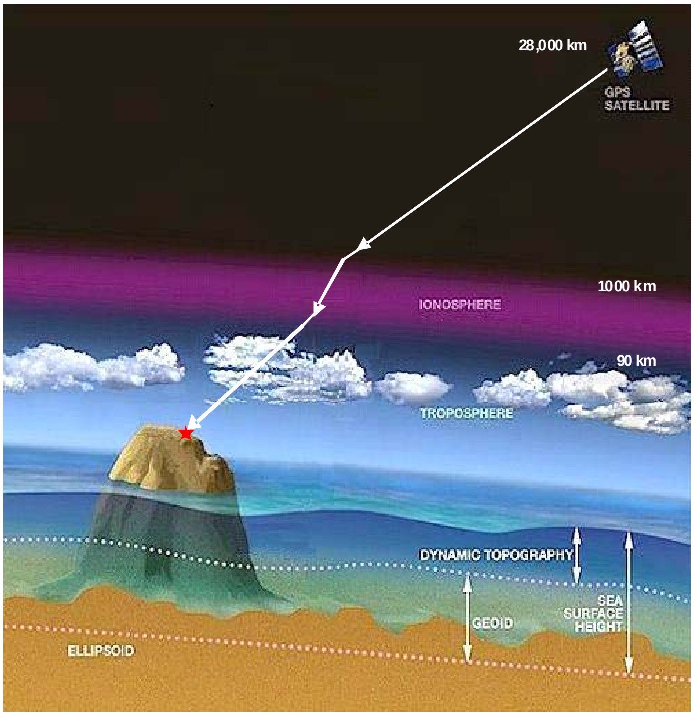

Fig. 6-25 Atmospheric Delays

Ionospheric dispersion is one of the most significant error sources. These effects are smallest when the satellite is directly overhead and become greater for satellites nearer the horizon as the signal passes through the ionosphere at a shallow angle, hence a thicker band has to be traversed. Two methods can be used to correct for Ionospheric delays.

- Once the receiver's approximate location is known, a mathematical model can be used to estimate and compensate for these errors.
- Because ionospheric delay affects the speed of microwave signals differently based on frequency, a second carrier frequency, L2 can be used to measure atmosphere dispersion and apply a more precise correction to help compensate for this error. This is the method employed in military GPS receivers using L1 and L2.

  This can also be realized in more expensive civilian GPS receivers without decrypting the P(Y) signal carried on L2 by tracking the carrier wave instead of the modulated code. To do this on lower cost receivers, a new civilian code signal on L2 called L2C was added to the satellites. This new signal allows a direct comparison of the L1 and L2 signals using the coded signal instead of the carrier wave.

Troposphere:

The troposphere is the lower part of the earth's atmosphere (0 -15km), that encompasses our weather. It's full of water vapor and varies in temperature and pressure and causes a variable but predictable delay. This delay is corrected using a simple model based on pressure, temperature and altitude.

The errors of the GPS system are summarized in table 1-1. The individual values are no constant values, but are subject to variances, all numbers are approximate values. Altogether this sums up to an error of between ± 12 to ± 15 meters.

Type of Time Delay Error	Positional Error
Ephemeris Errors	± 2.5 m
Satellite Clock Errors	± 2 m
Multipath Delays	± 1 m
Receiver Clock Inaccuracies and Rounding Errors:	± 1 m
Ionospheric Delays	± 5 m
Tropospheric Delays	± 0.5 m

Table 6-1 PS Positional Error Sources

6.1.6 GPS Timekeeping

Most clocks are synchronized to Coordinated Universal Time (UTC) however, the atomic clocks on the satellites are set to GPS time. GPS time is not corrected to match the rotation of the Earth, so it does not contain leap seconds or other corrections that are periodically added to UTC. GPS time was set to match Coordinated Universal Time (UTC) in 1980, but has since diverged. The lack of corrections means that GPS time remains at a constant offset with International Atomic Time (TAI) (TAI - GPS = 19 seconds). Periodic corrections are performed on the on-board clocks to correct relativistic effects and keep them synchronized with ground clocks.

The GPS navigation message includes the difference between GPS time and UTC, which as of 2010 is 15 seconds due to the leap second added to UTC December 31, 2008. Receivers subtract this offset from GPS time to calculate UTC and specific time zone values. New GPS units may not show the correct UTC time until after receiving the UTC offset message.

The GPS-UTC offset field can accommodate 255 leap seconds (eight bits) which, given the current rate of change of the Earth's rotation (with one leap second introduced approximately every 18 months), should be sufficient to last until approximately the year 2300. As opposed to the year, month, and day format of the Gregorian calendar, the GPS date is expressed as a week number and a seconds-into-week number.

GPS	2010-10-12 13:31:38	week 1605	221498 s	cycle 1 week 0581 day 2
UTC	2010-10-12 13:31:23	Tuesday	day 285	MJD 55481.56346

Fig. 6-26 GPS v. UTC Time Format

The week number is transmitted as a ten-bit field in the C/A and P(Y) navigation messages, and so it becomes zero again every 1,024 weeks (19.6 years). GPS week zero started at 00:00:00 UTC (00:00:19 TAI) on January 6, 1980, and the week number became zero again for the first time at 23:59:47 TC on August 21, 1999 (00:00:19 TAI on August 22, 1999).

To determine the current Gregorian date, a GPS receiver must be provided with the approximate date (to within 3,584 days) to correctly translate the GPS date signal. To address this concern the modernized GPS navigation message uses a 13-bit field, which only repeats every 8,192 weeks (157 years), thus lasting until the year 2137 (157 years after GPS week zero).

6.1.7 GNSS Accuracy

A GNSS receiver determines its Position (horizontal and vertical), its Velocity and the Time from the signals of at least four satellites by means of triangulation. The precision of the computations by triangulation depends on the constellation of all satellites of which the signals are taken into account (four or more). As the number and position of satellites will seldom be ideal, the maximum obtainable precision will be diluted in practice. Here we present the different terms of dilution of precision.

Dilution of precision (DOP) is a measure of the quality of the GPS data being received from the satellites. DOP is a mathematical representation for the quality of the GPS position solution. The main factors affecting DOP are the number of satellites being tracked and where these satellites are positioned in the sky. The effect of DOP can be resolved into HDOP, VDOP, PDOP and TDOP.

HDOP (Horizontal Dilution Of Precision) is a measure of how well the positions of the satellites, used to generate the Latitude and Longitude solutions, are arranged. PDOP less than 4 gives the best accuracy, between 4 and 8 gives acceptable accuracy and greater than 8 gives unacceptable poor accuracy. Higher HDOP values can be caused if the satellites are at high elevations.

VDOP (Vertical Dilution Of Precision) is a measure of how well the positions of the satellites, used to generate the vertical component of a solution, are arranged. Higher VDOP values mean less certainty in the solutions and can be caused if the satellites are at low elevations.

TDOP (Time Dilution Of Precision) is a measure of how the satellite geometry is affecting the ability of the GPS receiver to determine time.

PDOP (Positional Dilution OF Precision) is a measure of overall uncertainty in a GPS position solution with TDOP not included in the estimated uncertainty. The best PDOP (lowest value) would occur with one satellite directly overhead a
nd three others evenly spaced about the horizon. PDOP = SQRT(HDOP^2 + VDOP^2).

GDOP (Geometric Dilution Of Precision) is a measure of the overall uncertainty in a GPS position solution. GDOP = SQRT(TDOP^2 + HDOP^2 + VDOP^2) or in another form
GDOP = SQRT(PDOP^2 + TDOP^2). GDOP value should be less than 5.

The Position Accuracy = Dilution Of Precision (DOP) times Measurement Precision. So, if the Measurement Precision = 1m and the DOP = 5, then the best position accuracy will be 5m.

6.1.8 GNSS Augmentation

Augmentation of GNSS, is a method of improving the navigation system accuracy, reliability and availability through the integration of external information into the calculation process. SBAS (Satellite Based Augmentation System) and RAIM (Receiver Autonomous Integrity Monitoring System) are GNSS augmentation systems.

Satellite Based Augmentation System (SBAS)

SBAS is a system that supports wide-area or regional augmentation through use of additional satellite broadcast messages that contain correctional data obtained from multiple ground stations at surveyed locations.

The effects of the ionosphere generally change slowly and can be averaged over time. The effects for any particular geographical area can be easily calculated by comparing the GPS-measured position to a known surveyed location. This correction is also valid for other receivers in the same general location.

The data is transmitted via satellites in the SBAS system and is transmitted on the GPS L1 frequency using a special pseudo-random number, allocated for SBAS use. This allows the civilian L1 C/A code receivers that support SBAS, to use the correctional data. All SBAS satellites support the same protocols and therefore can support seamless augmentation from one region to another.

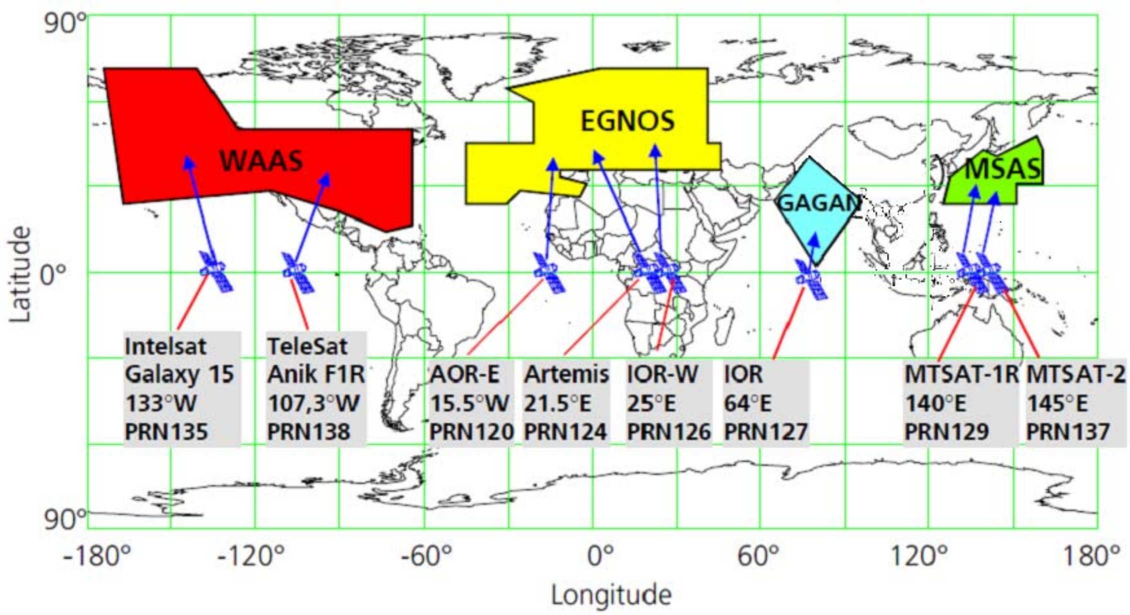

Fig. 6-27 SBAS Coverage

6.1.8.A SBAS Systems

WAAS (Wide **A**rea **A**ugmentation **S**ystem)

Developed and managed by the FAA, to augment GPS, with the goal of improving its accuracy, integrity, and availability. WAAS is intended to enable aircraft to rely on GPS for all phases of flight, including precision approaches to any airport within its coverage area. The system communicates with several ground stations and provides atmospheric corrections & early warning of GPS failures. The data rate is higher that L1 C/A code at 250 Hz and two geostationary satellites provide area coverage.

EGNOS (**E**uropean **G**eostationary **N**avigation **O**verlay **S**ystem)

Managed by the European tripartite group. Corrections for GPS and GLONASS

Similarly to WAAS, EGNOS is mostly designed for aviation users which enjoy unperturbed reception of direct signals from three geostationary satellites up to very high latitudes. The use of EGNOS on the ground, especially in urban areas is limited due to relatively low elevation of geostationary satellites: about 30° above horizon in central Europe and much less in the North of Europe. To address this problem, ESA released in 2002 SISNeT, an Internet service designed for continuous delivery of EGNOS signals to ground users. SV PRN 126 is used for test purposes at this time (2010).

MSAS (**M**ulti-Functional **S**atellite **A**ugmentation **S**ystem

Managed by the Japanese Civil Aviation Bureau (JCAB), a satellite navigation system which supports differential GPS, designed to supplement the GPS system by reporting (then improving) on the reliability and accuracy of those signals. MSAS for aviation use was commissioned on September 27, 2007. Two geostationary satellites provide area coverage. **GAGAN** (**G**PS **A**ided **G**eo **A**ugmented **N**avigation)

The GAGAN system is a planned implementation of a regional Satellite Based Augmentation System (SBAS) by the Indian government. It is a system to improve the accuracy of a GNSS receiver by providing reference signals. Two geostationary satellites will eventually provide area coverage. One SV is currently deployed, PRN 127.

6.1.8.B RAIM (Receiver Autonomous Integrity Monitoring System)

A unique aviation requirement of GPS avionics is RAIM. While GPS provides the user with unparalleled levels of accuracy, one significant deficiency of GPS is integrity, or the ability of the system to provide a timely warning if the navigation solution is inaccurate or erroneous. Navigation systems prior to GPS, particularly aviation applications, provided a means to warn the aircraft that the signal was outside certain limits. For example, a Category I ILS provides this warning within six seconds.

The only means available for the GPS system itself to provide the user with a warning of system unreliability is through the data message forming part of the GPS signal. The “health” flag found in subframe 4 and 5 will alert the receiver to a failure of a GPS satellite.

The time lag from the beginning of the failure to when it is incorporated in the health flag (up to eight hours) represents an unacceptably long period of time for aviation.

To overcome this, RAIM was developed and is a mandatory feature of all aviation-grade receivers. RAIM uses combinations of satellites to determine the receiver position. Should a large discrepancy between position solutions occur, a RAIM alert is created rendering the GPS navigator unreliable. Refer to Table 1-2. Different phases of flight use different values of “integrity alarm limits” prior to issuing a RAIM alert.

The ability of a receiver to perform RAIM computations is dependent upon the number of satellites in view, their geometry and the mask angle which is dependent upon the ability of the antenna to track satellites near the horizon and any local terrain. Whereas GPS needs a minimum of four satellites to produce a three-dimensional position, a minimum of five satellites are required for RAIM. For this reason, RAIM may not be available in circumstances of poor satellite coverage or poor satellite geometry.

Phase of Flight	Alarm Limit	Time to Alarm
Enroute (oceanic, domestic, random and JV routes)	2.0 nm	30 sec
Terminal	1.0 nm	10 sec
RNAV Approach Non Precision	0.3 nm	10 sec

Table 6-2 RAIM Alarms

6.1.9 GPS Modernization Signals

A process of GPS system modernization is now underway, which involves the introduction of new signals to provide improvements in accuracy and integrity.

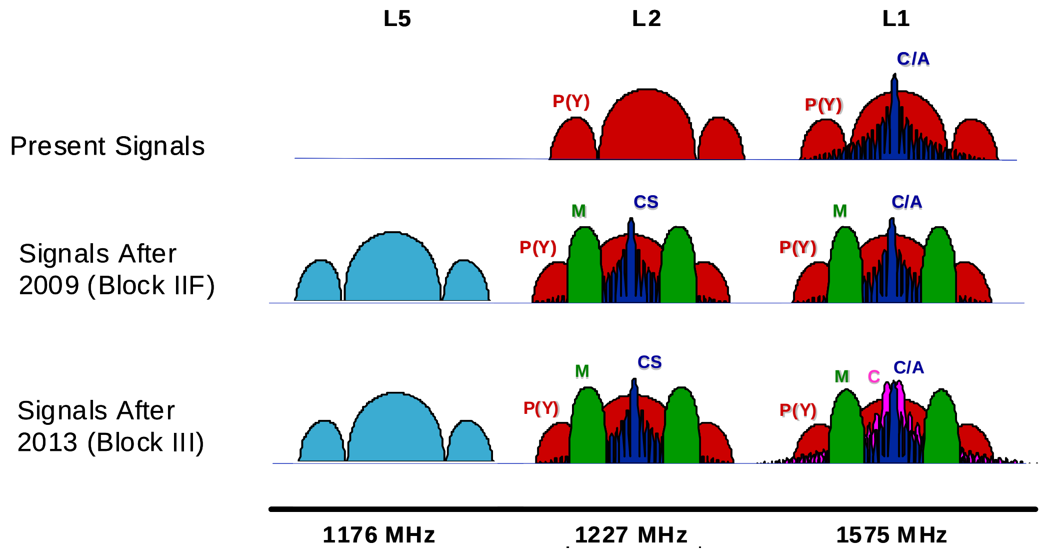

Fig. 6-28 GPS Modernization Signals

6.1.9.A L2CS

The L2CS system provides a civilian-use signal transmitted on a frequency other than the L1 frequency used for the Coarse Acquisition (C/A) signal, and broadcast on the L2 frequency. Because it requires new hardware onboard the satellite, it is only transmitted by the so-called Block IIR-M and later design satellites. The L2CS signal is tasked with improving accuracy of navigation, providing an easy to track signal, and acting as a redundant signal in case of localized interference.

Unlike the C/A code, L2CS contains two distinct PRN code sequences to provide ranging information; the *Civilian Moderate* length code (called CM), and the *Civilian Long* length code (called CL). The CM code is 10,230 bits long, repeating every 20 ms. The CL code is 767,250 bits long, repeating every 1500 ms. Each signal is transmitted at 511,500 bits per second (bit/s); however, they are multiplexed together to form a 1,023,000 bit/s signal.

CM is modulated with the CNAV Navigation Message (see below), whereas CL does not contain any modulated data and is called a *data-less sequence*. The long, data-less sequence provides for approximately 24 dB greater correlation (~250 times stronger) than L1 C/A-code.

When compared to the C/A signal, L2CS has 2.7 dB greater data recovery and 0.7 dB greater carrier-tracking, although its transmission power is 2.3 dB weaker.

6.1.9.B CNAV Navigation Message

The CNAV data is an upgraded version of the original NAV navigation message. It contains higher precision representation and nominally more accurate data than the NAV data. The same type of information (Time, Status, Ephemeris, and Almanac) is still transmitted using the new CNAV format; however, instead of using a frame / subframe architecture, it features a new pseudo-packetized format made up of 12-second 300-bit message packets.

In CNAV, two out of every four packets are ephemeris data and at least one of every four packets will include clock data, but the design allows for a wide variety of packets to be transmitted.

With a 32-satellite constellation, and the current requirements of what needs to be sent, less than 75% of the bandwidth is used. Only a small fraction of the available packet types have been defined; this enables the system to grow and incorporate advances.

Important changes in the new CNAV message

CNAV message uses Forward Error Correction (FEC) in a rate 1/2 convolution code, so while the navigation message is 25 bit/s, a 50 bit/s signal is transmitted.

The GPS week number is now represented as 13 bits, or 8192 weeks, and only repeats every 157.0 years, meaning the next return to zero won't occur until the year 2137. This is longer compared to the L1 NAV message's use of a 10-bit week number, which returns to zero every 19.6 years.

There is a packet that contains a GPS-to-GNSS time offset. This allows for interoperability with other global time-transfer systems, such as Galileo and GLONASS, both of which are supported.

The extra bandwidth enables the inclusion of a packet for differential correction, to be used in a similar manner to SBAS and which can be used to correct the L1 NAV clock data.

Every packet contains an alert flag, to be set if the satellite data can not be trusted. This means users will know within 6 seconds if a satellite is no longer usable. Such rapid notification is important for safety-of-life applications, such as aviation.

Finally, the system is designed to support 63 satellites, compared with 32 in the L1 NAV message.

L2CS Frequency information

An immediate effect of having two civilian frequencies being transmitted is the civilian receivers can now directly measure the ionospheric error in the same way as dual frequency P(Y)-code receivers. However, if a user is utilizing the L2C signal alone, they can expect 65% more position uncertainty than with the L1 signal.

6.1.9.C L5

Civilian, safety of life signal planned to be available with first GPS IIF launch (2009). Two PRN ranging codes are transmitted on L5: the in-phase code (denoted as the I5-code); and the quadrature-phase code (denoted as the Q5-code). Both codes are 10,230 bits long and transmitted at 10.23 MHz (1ms repetition). In addition, the I5 stream is modulated with a 10-bit Neuman-Hofman code that is clocked at 1 kHz and the Q5-code is modulated with a 20-bit Neuman-Hofman code that is also clocked at 1 kHz.

- Improves signal structure for enhanced performance
- Higher transmitted power than L1/L2 signal (-3 db, or twice as powerful)
- Wider bandwidth provides a 10× processing gain
- Longer spreading codes (10× longer than C/A)
- Uses the Aeronautical Radio-Navigation Services band
- The recently launched GPS IIR-M7 satellite transmits a demonstration of this signal.

L5 Navigation message

The L5 CNAV data includes SV ephemerides, system time, SV clock behavior data, status messages and time information, etc. The 50 bit/s data is coded in a rate 1/2 convolution coder. The resulting 100 symbols per second (sps) symbol stream is modulo-2 added to the I5-code only; the resultant bit-train is used to modulate the L5 in-phase (I5) carrier. This combined signal will be called the L5 Data signal. The L5 quadrature-phase (Q5) carrier has no data and will be called the L5 Pilot signal.

L5 Frequency information

Broadcast on the L5 frequency (1176.45 MHz, 10.23 MHz × 115), which is an aeronautical navigation band. The frequency was chosen so that the aviation community can manage interference to L5 more effectively than L2.

6.1.9.D L1C

Civilian use signal, broadcast on the L1 frequency (1575.42 MHz), which currently contains the C/A signal used by all current GPS users. The L1C will be available with first Block III launch, currently scheduled for 2013. The PRN codes are 10,230 bits long and transmitted at 1.023 Mbps. It uses both Pilot and Data carriers like L2C.

The modulation technique used is BOC(1,1) for the data signal and TMBOC for the pilot. The Time Multiplexed Binary Offset Carrier (TMBOC) is BOC(1,1) for all except 4 of 33 cycles, when it switches to BOC(6,1). Of the total L1C signal power, 25% is allocated to the data and 75% to the pilot. Implementation provides C/A code to ensure backward compatibility

Assured of 1.5 dB increase in minimum C/A code power to mitigate any noise floor increase

Data-less signal component pilot carrier improves tracking

Enables greater civil interoperability with Galileo L1

CNAV-2 Navigation message

The L1C navigation message, called CNAV-2, is 1800 bits (including FEC) and is transmitted at 100 bit/s. It contains 9-bit time information, 600-bit ephemeris, and 274-bit packetized data payload

6.1.9.E M Code (Military)

A major component of the modernization process, a new military signal called M-code was designed to further improve the anti-jamming and secure access of the military GPS signals. The M-code is transmitted in the same L1 and L2 frequencies already in use by the previous military code, the P(Y) code. The new signal is shaped to place most of its energy at the edges (away from the existing P(Y) and C/A carriers).

Unlike the P(Y) code, the M-code is designed to be autonomous, meaning that users can calculate their positions using only the M-code signal. P(Y) code receivers must typically first lock onto the C/A code and then transfer to lock onto the P(y)-code.

The M-code is intended to be broadcast from a high-gain directional antenna, in addition to a wide angle (full Earth) antenna. The directional antenna's signal, termed a *spot beam*, is intended to be aimed at a specific region (i.e. several hundred kilometers in diameter) and increase the local signal strength by 20 dB (10X voltage field strength, 100X power). A side effect of having two antennas is that the GPS satellite will appear to be two GPS satellites occupying the same position to those inside the spot beam.

While the full-Earth M-code signal is available on the Block IIR-M satellites, the spot beam antennas will not be available until the Block III satellites are deployed.

Other M-code characteristics are:

- Satellites will transmit two distinct signals from two antennas: one for whole Earth coverage, one in a spot beam.
- Modulation is Binary Offset Carrier (BOC) and occupies 24 MHz of bandwidth
- Uses a new MNAV navigational message, which is packetized instead of framed, allowing for flexible data payloads
- There are four effective data channels; different data can be sent on each frequency and on each antenna.
- Can include FEC and error detection
- The spot beam is ~20 dB more powerful than the whole Earth coverage beam M-code signal at Earth's surface: -158 dBW for whole Earth antenna, -138 dBW for spot beam antennas.

6.1.10 The Galileo System

Galileo is the European global navigation satellite system which provides a highly accurate, guaranteed global positioning service under civilian control. It is inter-operable with GPS and GLONASS, the two other global satellite navigation systems.

Fig. 6-29 Galileo Satellite (GIOVE Test SV)

A user can take a position with the same receiver from any of the satellites in any combination. By offering dual frequencies as standard, Galileo delivers real-time positioning accuracy down to the metre range. Galileo guarantees availability of the service under all but the most extreme circumstances and informs users within seconds of a failure of any satellite. This makes it suitable for applications where safety is crucial, such as running trains, guiding cars and landing aircraft.

The first experimental satellite, part of the so-called Galileo System Test Bed (GSTB-V1), was launched in 2003. The objective of this satellite was to characterize the critical technologies, developed under ESA contracts. Two initial test satellites were launched GIOVE-A, in 2005, and GIOVE-B, in 2008, to validate the basic Galileo space segment. Four In Orbit Validation (IOV) satellites are scheduled to be launched in the 2010 to 2011 time frame, to complete the validation of the space segment in conjunction with the ground segment. A further 16 satellites are currently funded, which will provide a minimum operational capability. The balance of 14 satellites required to reach Full Operational Capability (FOC), as of 2010, are not currently funded.

The fully deployed Galileo system will consist of 30 satellites (27 operational + 3 active spares), positioned in three circular Medium Earth Orbit (MEO) planes at 23 222 km altitude above the Earth, and at an inclination of the orbital planes of 56 degrees with reference to the equatorial plane. The Galileo navigation signals provide good coverage even at latitudes up to 75 degrees north, which corresponds to the North Cape, and beyond.

The large number of satellites together with the optimization of the constellation, and the availability of the three active spare satellites, ensures that the loss of one satellite has no discernible effect on the user. The use of BOC (Binary Offset Carrier) Modulation minimizes interference with GPS BPSK.

6.1.10.A Ground Element

Two Galileo Control Centers:

- Located in Europe
- Combine range of facilities: orbit control, integrity, mission control, satellite control, services products, Precise Time Facilities (PTF)

15 Galileo Up-Link Stations:

- Located around the globe
- 5 Telemetry, Telecommand and Tracking Stations
- 9 Mission Up-Link Stations

30 Galileo Sensor Stations:

- Located around the globe
- Monitor quality of the satellite navigation signal (Signal In Space, SIS) Services

6.1.10.B Services

The Galileo system consists of five main services:

OS (Open Service):

'Free to air' and for use by the mass market; Simple timing and positioning down to 1 meter.

CS (Commercial Service) (Encrypted):

Higher data rate, improved accuracy to the centimeter. Guaranteed service for which service providers charge fees.

SoL (Safety Of Life):

Open service; For applications where guaranteed accuracy is essential; Integrity messages will warn of errors.

PRS (Public Regulated Service): (Encrypted):

Continuous availability even in time of crisis; Government agencies will be main users.

SAR (Search And Rescue):

System picks up distress beacon locations; Feasible to send feedback, confirming help is on its way. Based on Cospas-Sarsat system re-broadcasts distress messages.

Signal	E5 (E5a + E5b)				E6			E1		
Centre Frequency	1191.795 (E5)				1278.75			1575.42		
	1176.45 (E5a)			1207.14 (E5b)						
Nominal Bandwidth	51.15 (E5)				40.92			24.552		
	20.46 (E5a)			20.46 (E5b)						
Modulation	ALTBOC				INTERPLEX			INTERPLEX/CBOC		
Sub-carrier	a-I	a-Q	b-I	b-Q	A	B	C	A	B	C
Sub-modulation	None	None	None	None	BOC(10,5)	None	None	BOC(15,2.5)	CBOC(6,1,1)	CBOC(6,1,1)
Services	F/NAV (OS)	Pilot	I/NAV (OS/CS/SoL)	Pilot	G/NAV (PRS)	C/NAV (CS)	Pilot	G/NAV (PRS)	I/NAV (OS/CS/SoL)	Pilot
Code Rate (Mc/s)	10.23	10.23	10.23	10.23	5.115	5.115	5.115	2.5575	1.023	1.023
Encrypted	No	No	No	No	Yes	Yes	Yes	Yes	No	No
Sequence Length (primary x secondary)	10230 x 20	10230 x 100	10230 x 4	10230 x 100	TBC	TBC	TBC	TBC	4092 x 1	4092 x 25
Symbol rate (sps)	50	N/A	250	N/A	TBC	1000	N/A	TBC	250	N/A

Table 6-3 Galileo Signals

6.1.10.C GPS Receivers

Signal

The strength of the received GPS signal relies on the following parameters:

- Signal strength of satellite
- Attenuation in transmitter hardware
- Gain of transmission antenna (in direction to the receiver)
- Free space loss due to distance of satellite and receiver
- Attenuation by the atmosphere (negligible)
- Deflection and superposition of the direct signal by reflected indirect signals (multipath)
- Gain of receiver antenna
- Attenuation in receiver hardware
- Signal tracking technique

Noise

The level of noise seen by a GPS receiver consists mainly of thermal noise but also background and inter-modulation noise. Most of the single influences are constant or can be assumed to be constant in the order of measurement accuracy.

SNC

Many GPS receivers indicate signal strengths in manufacturer specific units, which are determined from measurements made on the signals by the signal processing hardware. The values are the result of integrating the output of a signal correlator, that is fed the noisy input signal and a clean local replica of the expected PRN code. The integrated result is a linear indication of the signal-to-noise-ratio, over the bandwidth of the correlated signals.

In any particular receiver, this result can vary due to differences in receiver bandwidth and integration time. Often the result is scaled to be consistent across a product range. The resultant values are often referred to as SNC (Signal-to-Noise-Counts) and are scaled to match a measurement made over a 1KHz bandwidth. The 1KHz comes from the fact that many of the early receivers integrated for 1 millisecond, resulting in an effective 1KHz bandwidth.

Converting SNC to SNR

Normally SNR (Signal to Noise Ratio) is expressed as a power ratio on a logarithmic scale instead of an amplitude ratio on a linear scale.

To convert:

- SNC in a 1KHz bandwidth = (sA/nA).
- Where sA = Signal Amplitude and nA is the Noise Amplitude.
- SNR in a 1KHz bandwidth [in dB] = 20*Log10(SNC) - 3db

Converting to C/N_0

A more technically precise and common measurement of GNSS signal strength is known as C/N_0 (carrier-to-noise density) and is the ratio of received carrier (i.e., signal) power to noise density.

Many receivers have the ability to display or output values in these units however, these values are not measured directly, but are calculated from the directly measured SNC count values, refer to table 1-4.

NOTE:

C/N_0 is *not* the same as SNR (signal-to-noise ratio), although the terms are sometimes used interchangeably. Effectively, C/N_0 assumes that the noise has infinite bandwidth (and thus power) and therefore characterizes it using a density, that is, as the amount of noise power per unit of bandwidth.

C/N_0 = the SNR (usually in dB) in a 1Hz bandwidth. That bandwidth is typically 1000 times less than the actual receiver bandwidth, which implies a 30db change in dB-power units:

- C/N_0 = SNR[dB]@1KHz + 30db
- Therefore. C/N_0 = 30 + 10*Log10(SNC^2/2)
- = 30 + 10*Log10(SNC^2) – 3
- = 27 + 20*Log10(SNC)

SNC	SNR (dB - 1KHz)	C/N_0 (dB - 1Hz)
3	6.5	36.5 (very weak signal)
5	11	41
10	7	47
20	23	53
30	26.5	56.5
40	29	59 (very strong signal)

Table 6-4 SNC, SNR and C/N_0

C/N_0 provides a metric that is more useful for comparing one GPS receiver to another than SNR because the bandwidth of the receivers is eliminated in the comparison. Higher C/N_0 results in reduced data bit error rate (when extracting the navigation data from the GPS signals) and reduced carrier and code tracking loop jitter. Reduced carrier and code tracking loop jitter, in turn, results in less noisy range measurements and thus more precise positioning.

Determining Noise Figure

Generally, the GPS decoding chipset on a receiver determines the minimum C/N_0 ratio, required to achieve a position fix. However, it is the noise figure of the entire receiver that determines the C/N_0 ratio that you can achieve at a given power level. When measuring sensitivity it is important to know the minimum C/N_0 ratio required to achieve a position fix.

Referring to table 1-5, assuming a constant satellite power, you can observe that the C/N_0 ratio reported by the receiver is a function of the noise figure of the receiver.

Noise Figure	RF Power Level	C/N_0
1 dB	-143 dBm	31 dB -Hz
2 dB	-143 dBm	30 dB -Hz
3 dB	-143 dBm	29 dB -Hz
4 dB	-143 dBm	28 dB -Hz
5 dB	-143 dBm	27 dB -Hz
6 dB	-143 dBm	26 dB -Hz

Table 6-5 C/N_0 as a Function of Noise Figure

Table 1-5 shows that the noise figure of a receiver is directly proportional to the RF power level and C/N_0 ratio. Based on this relationship, you can measure the receivers noise figure by applying the following formula. *N figure = -174dBm/Hz + SVpower* + C/N_0

For example: -174.0 dBm + -136.1 dBm + 30.0 dB-Hz = 7.9 dB.

Rounding C/N_0

Receivers that support the NMEA-183 protocol, report satellite C/N_0 to the nearest decimal digit, therefore estimating noise figure beyond one digit of precision requires you to investigate the C/N_0 rounding of the receiver.

Table 1-6 example results show that RF power levels between -136.6 and -135.7 dBm all produce the same C/N_0 ratio of 30 dB-Hz. Based on the rounding principles involved when reporting NMEA-183 data, it is safe to assume that a power level of -136.1 dBm produces a C/N_0 ratio of 30.0 dB-Hz.

RF Power Level	Receiver C/N_0
-135.6 dBm	31 dB -Hz
-135.7 dBm	31 dB -Hz
-135.8 dBm	30 dB -Hz
-135.9 dBm	30 dB -Hz
-136.0 dBm	30 dB -Hz
-136.1 dBm	30 dB -Hz
-136.2 dBm	30 dB -Hz
-136.3 dBm	30 dB -Hz
-136.4 dBm	30 dB -Hz
-136.5 dBm	30 dB -Hz
-136.6 dBm	30 dB -Hz
-136.7 dBm	30 dB -Hz
-136.8 dBm	29 dB -Hz
-136.9 dBm	29 dB -Hz
-137.0 dBm	29 dB -Hz
-137.1 dBm	29 dB -Hz

Table 6-6 Correlation of RF Power Level and Receiver C/N_0

Chapter 7 - Product Specifications

7.1 GENERATOR

RF Output Level Direct:-	-93 to -155 dBm in 1 dB steps. ± 2 dB accuracy into 50Ω
DC Isolation:	50V DC
RF Output Level Ant Coupler:-	-68 dBm to -130 dBm in 1 dB steps, ± 2 dB accuracy into 50Ω
Signal Quality:	Spurious: <-35 dBc over the bandwidth (40 MHz) Harmonics: -<-45dBc
External Modulation Input:	TTL
Carriers:	Single (GPS and Galileo channels may be mixed)
GPS Carriers:	L1: 1575.420 MHz (C/A, pseudo P(Y), SBAS) L1C: 1575.420 MHz L5: 1176.450 MHz (New Civil SOL)
Galileo Carriers:	E1/L1: 1575.420 MHz (PRS, OS, CS, SOL) (pseudo-G/NAVL) E5a: 1191.795 MHz (OS, CS, SOL) E6: 1278.750 MHz (PRS, CS) Galileo E1 (pseudo-G/NAV)
Glonass:	1602 MHz (center) **NOTE:** Future feature
Accuracy:	Same as Master Oscillator
Inter Channel Bias:	Zero (Digital Design)
Channels:	1-6, 1-12 SV simulation, selectable GPS: PRN=1 to 32. Galileo: PRN=1 to 30. SBAS: PRN=120 to138.
User Defined Doppler Error:	Selectable frequency offset ± 5.0 kHz 1Hz increment
Amplitude Offset:	Sets SV carrier amplitude offset from nominal +/-15dB in .1dB increments.
Step Error:	Sets SV psuedo range error +/- 10km in .1m increments or 32,808.4 ft in .1ft increments (used for RAIM testing)
Satellite Health:	Allows selection of GOOD or BAD. (Carried in GPS Nav Data)
Gal Integrity:	Allows selection of CONNECTED or DISCONNECTED. (Carried in Galileo Nav Data) **NOTE:** Future feature not currently specified.

GENERATOR (cont)

Code Carrier Coherence: Sets frequency variation between code carriers
Range 2m/S or 6.562 ft/S
Increment 1mm/S or .001 ft/S

L1 C/A code:
Code Rate: 1.023 Mc/s
Primary Code Length: 1023 bits
Modulation: BPSK
Symbol Rate: 50 sps

SBAS Codes:
WAAS/EGNOS L1/L5
MSAS (available 2011), GAGAN (available 2011)

L1C Code:
Code Rate: 1.023 Mc/s
Primary Code length: 10,230 bits
Modulation: BPSK

L1 P(Y) pseudo code:
Code Rate: 10.230 Mc/s
Primary Code Length: 15,345,000 bits
Modulation: BPSK
NOTE: Long random codes simulated

L2C Code:
CM Code Rate: 511.500 b/s
Primary Code length: 10,230 bits
CL Code Rate: 511.500 b/s
NOTE: Long random codes simulated
Primary Code length: 767,250 bits
Modulation: QPSK

L5 Code:
Code Rate: 10.230 Mc/s
Primary Code length: 10,230 bits
Modulation: QPSK

Galileo Codes
From Open Service SIS ICD, Draft 1, European Space Agency/
European GNSS Supervisory Authority

Signal	E5 (E5a + E5b)				E6			E1		
Centre Frequency	1191.795 (E5)				1278.75			1575.42		
	1176.45 (E5a)		1207.14 (E5b)							
Nominal Bandwidth	51.15 (E5)				40.92			24.552		
	20.46 (E5a)		20.46 (E5b)							
Modulation	ALTBOC				INTERPLEX			INTERPLEX/CBOC		
Sub-carrier	*a-I*	*a-Q*	*b-I*	*b-Q*	*A*	*B*	*C*	*A*	*B*	*C*
Sub-modulation	None	None	None	None	BOC(10,5)	None	None	BOC(15,2.5)	CBOC(6,1,1)	CBOC(6,1,1)
Services	F/NAV (OS)	Pilot	I/NAV (OS/CS/SoL)	Pilot	G/NAV (PRS)	C/NAV (CS)	Pilot	G/NAV (PRS)	I/NAV (OS/CS/SoL)	Pilot
Code Rate (Mc/s)	10.23	10.23	10.23	10.23	5.115	5.115	5.115	2.5575	1.023	1.023
Encrypted	No	No	No	No	Yes	Yes	Yes	Yes	No	No
Sequence Length (primary x secondary)	10230 x 20	10230 x 100	10230 x 4	10230 x 100	TBC	TBC	TBC	TBC	4092 x 1	4092 x 25
Symbol rate (sps)	50	N/A	250	N/A	TBC	1000	N/A	TBC	250	N/A

GENERATOR (cont)

NAV Data: Navigation Data is computed in real-time to match the simulation

Positional Simulation: Maximum Relative Velocity (Range Rate) ± 1000 kts
Maximum Relative Jerk ± 500 m/s3
Maximum Altitude 60,000 ft

Positional Simulation Accuracy: Pseudorange <2mm (RMS)
Pseudorange Rate <1mm/s (RMS) with respect to master oscillator
Pseudorange Jerk ±0.02 m/s3 (RMS over >1s)
Delta Pseudorange <2mm (RMS)
Interchannel Code Phase Alignment ± 0.02 m (RSS)
Interchannel Carrier Phase Alignment ± 0.265mm (RSS)

7.2 MASTER OSCILLATOR

Frequency: 10 MHz nominal (* see note)

Temperature Stability:± ±0.05 ppm

Aging Rate: ±0.3 ppm/yr, ± 2.5 ppm/ 10 yr

Uncertainty: ±1 ppm

External Reference Input

Input Level: 0.25 to 6.0 Vp-p

Input Impedance:50 ohm nominal

Input Frequency:10.0 MHz ±10 Hz

External Reference Output

Output Level: 1.5 Vp-p nominal into 50Ω

Output Frequency:10.0 MHz nominal

Reliability

MTBF: >10000 hrs

MTTR: 1hr

7.3 COUPLER

Type: Patch in RF Absorbent Foam

Coupling: -21.5 dB typical at 1575.420 MHz.

Isolation: > 25 dB at 1575.42 MHz
> 30 dB typical at 1575.42 MHz

7.4 BATTERY

Type:	Lithium Ion, Removable Pack
Voltage:	14.4 VDC
Capacity:	6.94 AH
Duration:	4 Hrs
Note:	Battery charging temperature range: >-20°C and <60°C.

7.5 PHYSICAL CHARACTERISTICS

Height:	10.63 inches (27.0 cm)
Width:	13.97 inches (35.5 cm)
Depth:	3.425 inches (8.7 cm)
Weight (Test set only):	<10 lbs. (4.5 kg)

7.6 ENVIRONMENTAL

Test Set Certifications

Operational Temperature:	-20° to 55° C
Storage Temperature:-	-51° to 71° C when no battery is installed
Operational Humidity:	MIL-PRF-28800F Class 2
Storage Humidity:	MIL-PRF-28800F Class 2
Altitude:	4600 meters Class 1
Vibration Limits:	MIL-PRF-28800F Class 2
Shock, Function:	MIL-PRF-28800F Class 2
Transit Drop:	MIL-PRF-28800F Class 2
Drip Proof:	MIL-PRF-28800F Class 2
Dust:	MIL-PRF-28800F Class 1
Salt Fog:	MIL-PRF-28800F Class 1
Explosive Atmosphere:	MIL-PRF-28800F Class 1
EMI/EMC:	MIL-PRF-28800F and EN-61010-1
Safety Compliance:	UL-61010-1 and EN-61010-1

ENVIRONMENTAL (cont)

EMC

Emissions:	MIL-PRF28800F Class 2 EN 61326:1998 Class A EN 61000-3-2 EN 61000-3-3
Immunity:	MIL-PRF28800F Class 2 EN 61326:1998Class A

External AC-DC Converter Certifications

Safety Compliance:	UL 1950 DS CSA 22.2 No. 234 VDE EN 60 950
EMI/RFI Compliance:	FCC Docket 20780 Curve "B"
EMC:	EN 61326

External AC to DC Converter

Use:	Indoors
Altitude:	$\leq$ 10,000 m
Operating Temperature:	0° to 40° C
Storage Temperature:	-20° to 71° C

Transit Case Certifications

Drop Test:	FED-STD-101C Method 5007.1 Paragraph 6.3, Procedure A, Level A
Falling Dart Impact:	ATA 300 Category I
Vibration, Loose Cargo:	FED-STD-101C Method 5019
Vibration, Sweep:	ATA 300 Category I
Simulated Rainfall:	MIL-STD-810F Method 506.4 Procedure II of 4.1.2
FED-STD-101C:	Method 5009.1 Sec 6.7.1
Immersion:	MIL-STD-810F Method 512.4

7.7 ACCESSORIES

RF Coax Cable x 1: Low Loss Coax 50 ft loss calibrated

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Appendix A - Pin-Out Tables

ETHERNET CONNECTOR

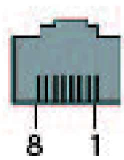

Fig. A-1 Ethernet Pin-Out Diagram

Pin Number	Signal Type	Signal Type	Function
1	Data	Transmit +	Ethernet TX +
2	Data	Transmit -	Ethernet TX -
3	Data	Receive +	Ethernet RX +
4	NC	NC	
5	NC	NC	
6	Data	Receive -	Ethernet RX -
7	NC	NC	
8	NC	NC	

USB HOST 1 CONNECTOR

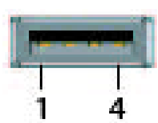

Fig. A-2 USB Host 1 Pin-Out Diagram

Pin Number	Signal Type	Signal Type	Function
1	Power	VCC	USB Power
2	Data	Data -	USB Data -
3	Data	Data +	USB Data +
4	GND	GND	Ground

USB HOST 2 CONNECTOR

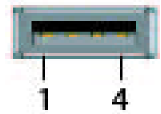

Fig. A-3 USB Host 2 Pin-Out Diagram

Pin Number	Signal Type	Signal Type	Function
1	Power	VCC	USB Power
2	Data	Data -	USB Data -
3	Data	Data +	USB Data +
4	GND	GND	Ground

USB OTG CONNECTOR

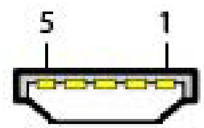

Fig. A-4 USB OTG Pin-Out Diagram

Pin Number	Signal Type	Signal Type	Function
1	Power	VCC	USB Power
2	Data	Data -	USB Data -
3	Data	Data +	USB Data +
4	Control	ID	Identify
5	GND	GND	Ground

DC POWER CONNECTOR

Fig. A-5 DC Power Connector Pin-Out Diagram

Pin Number	Signal Type	Signal Type	Function
Inner	Power	VCC	HHCP Power
Outer	GND	GND	Ground

AUX CONNECTOR

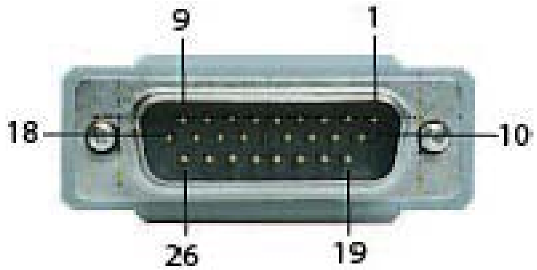

Fig. A-6 AUX Connector Pin-Out Diagram

Pin Number	Signal Type	Signal Type	Function
1	DATA	ARINC 429 in A	ARINC 429 Channel 1 RX A
2	DATA	ARINC 429 in B	ARINC 429 Channel 1 RX B
3	NC	NC	
4	DATA	ARINC 429 Out A	ARINC 429 Channel 1 TX A
5	DATA	ARINC 429 Out B	ARINC 429 Channel 1 TX B
6	NC	NC	
7	Control	RS232 CTS	RS 232 Clear to Send
8	DATA	RS232 TX	RS 232 Transmit
9	Control	RS232 RTS	RS 232 Ready to Send
10	DATA	RS232 RX	RS 232 Receive
11	NC	NC	
12	NC	NC	
13	NC	NC	
14	NC	NC	
15	NC	NC	
16	NC	NC	
17	NC	NC	
18	NC	NC	
19	NC	NC	
20	NC	NC	
21	NC	NC	
22	NC	NC	
23	NC	NC	
24	NC	NC	
25	DATA	1 PPS Sync	One Pulse Per Second
26	GND	GND	Ground

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Appendix B - Terminology

Term	Description
Anti-Spoofing (AS)	Is a policy of the U.S. Department of Defense by which the P-Code is encrypted (by the additional modulation of a so-called W-Code to generate a new "Y-Code"), to protect the militarily important P-Code signals from being "spoofed" through the transmission of false GPS signals by an adversary during times of war. Hence civilian GPS receivers are unable to make direct P-Code pseudo-range measurements and must use proprietary (indirect) signal tracking techniques to make measurements on the L2 carrier wave (for both pseudo-range and carrier phase). All dual-frequency instrumentation must therefore overcome AS using these special signal tracking and measurement techniques.
Availability	The number of hours per day that a particular location has sufficient satellites (above the specified elevation angle, and perhaps less than some specified PDOP value) to make a GPS position determination possible.
BIAS	All GPS measurements are affected by biases and errors. Their combined magnitudes will affect the accuracy of the positioning results (they will bias the position or baseline solution). Biases may be defined as being those systematic errors that cause the true measurements to be different from observed measurements by a "constant, predictable or systematic amount", such as, for example, all distances being measured too short, or too long. Biases must somehow be accounted for in the measurement model used for data processing if high accuracy is sought. There are several sources of biases with varying characteristics, such as magnitude, periodicity, satellite or receiver dependency, etc. Biases may have physical bases, such as the atmosphere effects on signal propagation or ambiguities in the carrier phase measurements, but may also enter at the data processing stage through imperfect knowledge of constants, for example any "fixed" parameters such as the satellite ephemeris information, station coordinates, velocity of light, antenna height errors, etc. Random errors will not bias a solution. However, outlier measurements, or measurements significantly affected by multipath disturbance (which may be considered a transient, unmodelled bias), will bias a solution if the proportion of affected measurements is relatively high compared to the number of unaffected measurements. For this reason, long period static GPS Surveying is more accurate (less likely to be biased) than "rapid static surveying" or kinematic (single-epoch) positioning.
Binary Shift-Key (BSK) Modulation	BSK is a modulation technique by which a binary message, such the Navigation Message or the PRN codes (consisting of 0's and 1's), is imprinted on the carrier wave. Unlike Amplitude Modulation (AM) and Frequency Modulation (FM), BSK Modulation does not alter the signal level (the "amplitude") or the carrier wavelength (the "frequency"). At a change in value of the message from 0 or 1, or from 1 to 0, the carrier wave is reversed (the phase is "flipped" by 180°). All reversals take place at the zero-crossings of the carrier (sine) wave (i.e., where the phase is zero).

Term	Description
C/A Code	The standard (Clear/Acquisition) GPS PRN code, also known as the Civilian Code or S-Code. A spread spectrum direct sequence code only modulated on the L1 carrier,used by the GPS receiver to acquire and decode the L1 satellite signal, and from which the L1 pseudo-range measurement is made.
Carrier	A radio wave having at least one characteristic (e.g., frequency, amplitude, phase) that can be varied from a known reference value by modulation. In the case of GPS there are two transmitted carrier waves: (a) L1 at 1575.42MHz, (b) L2 at 1227.60MHz, modulated by the Navigation Message (both L1 and L2), the P-Code (both L1 and L2) and the C/A-Code (L1).
Carrier Phase	GPS measurements made on the L1 or L2 carrier signal. May refer to the fractional part of the L1 or L2 carrier wavelength (approximately 19cm for L1, 24cm for L2), expressed in units of metres, cycles, fraction of a wavelength or angle. (One cycle of L1 is equivalent to one wavelength, and similarly for L2.) In carrier phase-based positioning, such as employed in GPS Surveying techniques, carrier phase may also refer to the accumulated or integrated measurement which consists of the fractional part plus the whole number of wavelengths (or cycles) since signal lock-on.
Carrier Aided Tracking	A signal processing strategy that uses the GPS carrier signal to achieve an exact lock-on the PRN code. More efficient and accurate than the standard approach.
Clock Bias	The difference between the receiver or satellite clock's indicated time and a well-defined time scale reference such as UTC (Coordinated Universal Time), TAI (International Atomic Time) or GPST (GPS Time).
Code Phase	GPS measurements based on the C/A-Code. The term is sometimes restricted to the C/A- or P-Code pseudo-range measurement when expressed in units of cycles.
Constellation	Refers to either the specific set of satellites used in calculating a position, or all the satellites visible to a GPS receiver at one time, or the entire ensemble of GPS satellites comprising the Space Segment.
Control Segment	A world-wide network of GPS monitoring and upload telemetry stations operated by, or on behalf of, the US Department of Defense. The tracking data is used by the Master Control Station at Colorado Springs to calculate the satellites' positions (or "broadcast ephemerides") and their clock biases. These are formatted into the Navigation Message which is uploaded on a daily (perhaps more frequently) basis by the Control Segment stations.
Correlator	The GPS receiver "software" or electronic means, implemented in some fashion (either analogue or digital) within a Tracking Channel, used to shift or compare the incoming signal with an internally generated signal. This operation is performed on the PRN codes, but may be used for more "exotic" mixed signals in the case of L2 measurements, where under the policy of Anti-Spoofing (AS) the L2 PRN code is not known. Correlator design may be influenced such that it is optimised for accuracy, mitigation of multipath, acquisition of signal under foliage, etc.

Term	Description
Cut Off Angle	The minimum acceptable satellite elevation angle (above the horizon) to avoid blockage of line-of-sight, multipath errors or too high Tropospheric or Ionospheric Delay values. May be preset in the receiver, or applied during data post-processing. For navigation receivers may be set as low as 5°, while for GPS Surveying typically a cutoff angle of 15° is used.
Data Message	Also known as the Navigation Message. A 1500 bit message modulated on the L1 and L2 GPS signal, which contains the satellite's location (or ephemeris), clock (bias) correction parameters, constellation almanac information and satellite health.
Differential GPS (DGPS)	A technique to improve GPS accuracy that uses pseudo-range errors measured at a known Base Station location to improve the measurements made by other GPS receivers within the same general geographic area. It may be implemented in real-time through the provision of a communication link between the GPS receivers, transmitting the correction information in the industry-standard RTCM format, or various proprietary formats. May be implemented in single Base Station mode, in the so-called Local Area DGPS (LADGPS), or using a network of Base Stations, as in the Wide Area DGPS (WADGPS) implementation.
Dilution of Precision (DOP)	An indicator of satellite geometry for a unique constellation of satellites used to determine a position. Positions tagged with a higher DOP value generally constitute poorer measurement results than those tagged with lower DOP. There are a variety of DOP indicators, such as GDOP (Geometric DOP), PDOP (Position DOP), HDOP (Horizontal DOP), VDOP (Vertical DOP), etc.
Dithering	The introduction of digital noise into the system. "Clock dithering" is the process by which the U.S. Department of Defense (DoD) degrades the accuracy of the Standard Positioning Service (i.e. absolute positioning of a C/A-Code capable receiver). "Clock dithering" is the additional satellite clock "bias" induced by the DoD's "Selective Availability" policy that cannot be corrected for by the broadcast Navigation Message clock correction parameters.
Doppler Shift	The apparent change in the frequency of a signal caused by the relative motion of the transmitter and receiver.
Dual Frequency	Refers to the instrumentation that can make measurements on both L-Band frequencies, or to the measurements themselves (e.g., L1 and L2 pseudo-range or carrier phase measurements). Dual-frequency measurements are useful for high precision (pseudo-range-based) navigation because the Ionospheric Delay bias can be determined, and the data corrected for it. In the case of Double-Differenced carrier phase, dual-frequency observations can account for the residual ionospheric bias (for case of long baselines), or aid Ambiguity Resolution for "rapid static" or "kinematic" baseline determination. All "top-of-the-line" GPS receivers are of the dual-frequency variety, and are comparatively expensive because of the special signal processing techniques that must be implemented to make measurements on the L2 carrier under the policy of Anti-Spoofing.

Term	Description
Ephemeris (plural: Ephemerides)	The file of values from which a satellite's position and velocity (the so-called "satellite state vector") at any instant in time can be obtained. The "Broadcast Ephemeris (or Ephemerides)" for a satellite are the predictions of the current satellite position and velocity determined by the Master Control Station, uploaded by the Control Segment to the GPS satellites, and transmitted to the user receiver in the Data Message. "Precise Ephemeris (or Ephemerides)" are post-processed values derived by, for example, the International GPS Service (IGS), and available to users post-mission via the Internet.
Fix	A single position with latitude, longitude (or grid position), altitude (or height), time, and date.
Geometric Dilution of Precision (GDOP)	An indicator of the geometrical strength of a GPS constellation used for a position/ time solution.
Global Navigation Satellite System (GNSS)	This is an umbrella term used to describe a generic satellite-based navigation/ positioning system. It was coined by international agencies such as the International Civil Aviation Organisation (ICAO) to refer to both GPS and GLONASS, as well as any augmentations to these systems, and to any future civilian developed satellite system. For example, the Europeans refer to GNSS-1 as being the combination of GPS and GLONASS, but GNSS-2 is the blueprint for an entirely new system
Global Orbiting Navigation Satellite System (GLONASS)	This is the Russian counterpart to GPS. It consists of a constellation of 24 satellites (though the number may vary due to difficulties in funding for the system) transmitting on a variety of frequencies in the ranges from 1597-1617MHz and 1240-1260MHz (each satellite transmits on two different L1 and L2 frequencies). GLONASS provides worldwide coverage, however, its accuracy performance is optimised for northern latitudes, where it is better than GPS's SPS (there being no "Selective Availability" on GLONASS satellites). GLONASS positions are referred to a different Datum to those of GPS, i.e. PZ90 rather than WGS84.
Global Positioning System (GPS)	A system for providing precise location which is based on data transmitted from a constellation of 24 satellites. It comprises three segments: (a) the Control Segment, (b) the Space Segment, and (c) the User Segment.
GPS Time (GPST)	GPST is a form of Atomic Time, as is, for example, Coordinated Universal Time (UTC). GPST is "steered" over the long run to keep within one microsecond of UTC. The major difference is that while "leap seconds" are inserted into the UTC time scale every 18 months or so to keep UTC approximately synchronised with the earth's rotational period (with respect to the sun), GPST has no leap seconds. At the integer second level, GPST matched UTC in 1980, but because of the leap seconds inserted since then, GPST is now (end 1998) ahead of UTC by 12 seconds (plus a fraction of a microsecond that varies from day to day). The relationship between GPST and UTC is transmitted within the Navigation Message.
Height (Orthometric)	The Orthometric Height is the height of a station on the earth's surface, measured along the local plumbline direction through that station, above the Geoid surface. It is approximated by the "Height Above Mean Sea Level", where the MSL Datum is assumed to be defined by the mean tide gauge observations over several years. The relationship between Orthometric Height (H) and Ellipsoidal Height (h) is : $h = H + N$, where N is the Geoid Height or Geoid Undulation with respect to the Reference Ellipsoid. Orthometric Height is traditionally derived from geodetic levelling (using such techniques as optical levelling, trigonometrical levelling, barometric levelling).

Term	Description
Ionosphere, Ionospheric Delay	The Ionosphere is that band of atmosphere extending from about 50 to 1000 kilometres above the earth's surface in which the sun's ultraviolet radiation ionises gas molecules which then lose an electron. These free electrons influence the propagation of microwave signals (speed, direction and polarisation) as they pass through the layer. The Ionospheric Delay on GPS signals is frequency-dependent and hence impacts on the L1 and L2 signals by a different amount (unlike that within the Troposphere). A linear combination of pseudo-range or carrier phase observations on the L1 and L2 carrier waves can be created to almost entirely eliminate the Ionospheric Delay. The resulting observable is known as the Ionosphere-Free carrier phase (or pseudo-range). For single-frequency receivers it is not possible to account for this signal bias in this way. A broadcast model is contained within the transmitted Navigation Message, however, it is a relatively poor model (unlikely to account for more than 50% of the effect) as the Delay is very difficult to predict. The magnitude of the Ionospheric Delay is a function of the latitude of the receiver, the season, the time of day, and the level of solar activity. The Delay in the Zenith direction can be several tens of metres, increasing as the elevation angle of the satellite signal reduces (being 3-5 times greater than in the Zenith direction). The Delay is largely eliminated in Relative or Differential Positioning, however, the residual Ionospheric Delay increases as the baseline length increases and may be a significant source of error (especially in the height component) for very high precision GPS Geodesy. Even when using dual-frequency instrumentation, the Ionospheric Delay can still cause problems during the process of rapid Ambiguity Resolution when phase and range combinations other than the Ionosphere-Free one are used.
L1 Frequency **1575.42MHz**	GPS carrier frequency which contains the C/A-Code, the encrypted P-Code (or Y-Code) and the Navigation Message. Commercial GPS navigation receivers can track only the L1 carrier to make pseudo-range (and sometime carrier phase and Doppler frequency) measurements.

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