ACUTIME
6-CHANNEL GPS SMART ANTENNA

SPECIFICATION
AND
USER'S MANUAL

Part Number 21250-00
Revision A

Trimble Navigation Limited
585 North Mary Avenue
Sunnyvale, CA 94086

Printed in USA

Table of Contents

1.0 INTRODUCTION

This document covers the specification and installation of the GPS Acutime self contained 6 channel GPS position & timing sensor for incorporation into a variety of system designs including tracking and data communications. The GPS Acutime sensor is available with options to match system integrators' needs. These options cover interfacing protocols, external battery backup, timing outputs and mechanical mounting.

There are several stages in the successful integration of a GPS sensor into a system design starting with the main functional specification and proceeding to the equivalent specification for the GPS element of the system. The specification should delineate the GPS measurement parameters together with the electrical, interface, environmental and mechanical requirements. The information in this manual is tailored to help the specification process and bring the system design and execution to a successful conclusion.

Some of the terms and theory of operation of GPS may also be new to the system integrator. To this end a set of references for further reading are given in Section 2; additionally a glossary of terms used in GPS is appended.

We are certain that we have not covered all aspects of the subject in this manual; if there are any errors and omissions they are the fault of the authors; however, please let us know how we can improve this document. Our objective in assembling this corpus of information is to make the job easier for you, the engineer, software specialist and system integrator.

1.1 Checklist

The minimum specification for an Acutime GPS sensor should cover the following:

Maximum distance of cable run
Maximum environmental conditions
Mechanical Installation including RFI protection
Provision for mechanical strain relief of connecting cable
Power Supply
Interface protocol
Provision for Differential corrections

1.2 Getting Started

Not everyone wants to read through a large manual before putting the new sensor into operation! The Acutime unit is self-contained and requires little work to get initial results. Place the unit in an area open to the sky, making sure it is firmly fixed in a vertical position. Connect the 15 meter cable (19360-50) using the 7 pin Conxall connector. Referring to Drawing 18637-XX in this manual, connect a source of DC power (e.g. a 12V battery) capable of delivering at least 300mA. to conductors 6 and 7 of the cable. Connect a PC serial port using the drawing as a guide, whether RS232 or RS422. Determine whether the unit is TSIP type (part number usually ends in -00) or ASCII (other endings). If a TSIP unit then ensure that the following utilities are available on the PC from the GPS Toolkit diskette (19317-01):

SPDRIVE	Conditions the computer serial port. If the COM2 port is used then enter SPDRIVE/2
PKTMON	General purpose utility. Most TSIP commands can be entered using this utility. Outputs are shown automatically on the computer screen.

If the sensor has an ASCII interface then use a readily available communications utility such as PROCOMM (in ASCII mode) to send and receive data to the Acutime sensor. The serial interface should be set up to 9600,8,n,1. The NMEA protocol units will show the NMEA sentences on the screen automatically. TAIP units need to have queries sent to them, e.g. a >QVR< query will respond with the firmware version.

The Acutime sensor and the GPS satellites together make up a very reliable system. If difficulties are experienced in getting initial reactions from the sensor/computer combination, the problems are almost certainly to do with the interface wiring or the correct use of the utilities. In particular check for RX and TX being the right way round, baud rate and parity, if necessary using a serial breakout box to aid in identifying the right connections for the data stream. Some computers have problems with voltage levels with their RS232 interfaces being temporarily connected to an RS422 Acutime. In this case use the 16637-00 or 12480 RS422/RS232 converters. We have found also that the self powered 16637-00 converter occasionally does not do a complete conversion with slow data rates (15 seconds); the cure is to speed up the data rate or change the type of converter used.

If GPS is unfamiliar, spend some time reviewing the outputs and inputs so that the reaction of the sensor to the varying availability of satellites can be checked. A good test is also to mount the Acutime sensor on the roof of a car or truck, perhaps using the magnetic mount (12920-00) and adapter (17030), recording data using either the GPSREC utility (TSIP versions) or PROCOMM. When the run has been completed the results can be displayed using a spreadsheet with good graphical facilities such as Quattro Pro or Excel. The files recorded with GPSREC will first need to be converted into an ASCII version using GPSLSTLL. The ASCII files are imported into the spreadsheet and are then split up into time, latitude, longitude and altitude using the string parsing commands in the spreadsheet, e.g. @LEFT, @MID, etc.

From these initial results the integration of the Acutime sensor into the intended system can be planned. The detailed operation of the sensor is covered in the rest of this manual.

2.0 GENERAL DESCRIPTION

GPS Acutime Antenna/Receiver assembly

The GPS Acutime 6 channel self contained antenna-receiver is designed as a zero maintenance unit readily able to interface with a wide variety of equipment. The maintenance objective has been achieved by mounting the antenna and receiver board sub-assembly in a sealed white polycarbonate housing. Trimble's long experience in marine GPS has shown that the antenna seal joint is the weakest link, being subject to extreme shear forces when the housing is struck by green water or ice chunks breaking loose from masts or rigging. We have thus eliminated this source of potential problems in the GPS Acutime design. The GPS Acutime unit has a digital interface; the unit requires only a DC voltage source to operate, providing position, velocity and a 1PPS output every second together with a hex output of UTC time.

3.0 SYSTEM DEFINITION

3.1 General Functional Description

The 6-channel Trimble Acutime GPS Sensor Antenna/Receiver is designed as a GPS SPS (Standard Positioning Service) unit which uses the C/A code on the L1 frequency carrier. The GPS Acutime internally calculates position , velocity and time worldwide, day-and-night, and in all weathers. Position accuracy is specified at 25 meters spherical error probability (SEP) and velocity accuracy is specified at 0.02 meters/second under moderate dynamic conditions. The DoD , however reserves the right to implement selective availability (SA) of accuracy. Under these conditions, position accuracy is degraded to 100 meters (2 dRMS) and velocity accuracy will also be reduced.

The system receives GPS satellite signals using a fixed-pattern crossed dipole antenna mounted above the receiver board . The sensor uses six processing channels to compute three-dimensional position and velocity and to manage and maintain the satellite tracking process. The GPS Acutime interfaces for data output with other equipment provided by the customer using the digital protocols described below. The GPS Acutime automatically selects the satellites which it tracks and is completely self-initializing from a cold start, loading almanac data from the first satellite available. An option is provided to allow the memory to be supported externally during power-off periods. Startup from power-on is then 30 - 45 seconds.

The Acutime GPS Sensor Antenna/Receiver provides interfaces for data input and output with other equipment provided by the customer using either:

Electrical -	RS232 RS422
Data Protocols -	Trimble Standard Interface Protocol (TSIP) NMEA0183 (ASCII) Trimble ASCII Interface Protocol (TAIP)

The primary output of Acutime is time-tagged position and velocity at intervals of approximately one second. Other available information includes satellite status, dilution of precision factors (PDOP, HDOP, VDOP, etc.), and diagnostics of sensor operational status, depending on the protocol chosen; the default protocol is TSIP. Output information is communicated digitally via one EIA RS - 422 or optionally RS - 232 serial data channels. Note that the main serial channel is bi-directional in either case; the second RS - 232 channel is receive only and is normally dedicated to DGPS corrections using the RTCM 104 protocol.

Acutime automatically selects the satellites which it tracks, but the operator optionally may mask (exclude from selection) satellites which provide less than a specified received signal level, or are lower than a specified elevation above the horizon, or are in poor health. The operator may specify minimum acceptable dilution's of precision and may specify position solutions in either 2 or 3 dimensions.

While the Acutime is completely self-initializing from a cold start, on board memory may be used to store information to speed the initialization, but the operator optionally may input new information (e.g., approximate location following a long move after Acutime last was used) to speed the initialization further. To do this the on board memory needs to be supported when Acutime is not operating by an external feed from a battery or other source taking less than 100 micro amps. Where the user does not wish to provide battery backup it is also feasible to upload the last stored almanac, approximate time and initial position into the on-board memory, again to reduce the time to first fix.

3.2 Abbreviated Specifications

1 PPS accuracy: 10 microseconds nominal, ± 1 microseconds normal. A dwell time of 2 - 3 minutes after satellite lock-on is needed before the 1 PPS output is within specification.

Position accuracy: 25 meters spherical error probability (SEP), 100 meters (2 dRMS) if selective availability (SA) is enabled.

Datum: WGS-84 standard. Others datum's available to special order.

Velocity accuracy: 0.02 m/sec without SA

Reaction time: 2.5 - 3.5 minutes (average)
30 -45 seconds with memory backup

Data I/O:

Option 1	(TSIP) Trimble Standard Interface Protocol (TANS)
Option 2	TAIP Trimble ASCII Interface Protocol
Option 3	NMEA talker only Flexible Messaging
Option 4	NMEA talker/listener (special order)

Electrical I/O: RS-422
RS-232

Differential GPS: RTCM SC104 protocol input (Acutime equipped with RS-232)
See below for connections.

Dynamic capability: (Electrical only)

Velocity	Acceleration	Jerk
400 m/sec	4 g (39.2 m/sec^2)	20 m/sec^3

Please note that the unit will not give fully accurate 1PPS output unless it is installed in a static environment;

Temperature:

Operating:	- 40°C to + 71°C
Non-operating:	- 55°C to + 85°C

Humidity: 100% condensing

Prime power: 10 /32 VDC - 2 watts nominal - Inline fuse (3A Quick Blow - to be supplied by customer externally)

The GPS Acutime is compatible with both 12 and 24 volt DC systems. The GPS Acutime has an over-voltage protection circuit designed to trip at voltages exceeding 36 volts. Over-voltage conditions may cause the in-line fuse to blow. The protection circuit automatically resets upon removal of the over-voltage condition, but the fuse may need to be replaced.

Standard Cable Arrangement - RS 422 *

I / O Cable Color Code

Acutime Connection	Wire Color	Function
Pin 1	Orange	Receive +
Pin 2	Brown	Transmit -
Pin 3	Yellow	Transmit +
Pin 4	Violet	Receive -
Pin 5	Blue	1 PPS / Memory Backup
Pin 6	Black	Ground
Pin 7	Red	Power

* A 15 meter, 7 conductor cable (P/N 19360-50) is supplied, terminated one end with a Conxall Mini-con Socket (Conxall P/N 6280-7SG-523), the other end unterminated for connection by the user.

Note 1) DGPS correction inputs can be input through the receive lines. This method, however, can lead to excessive complexity of the external system since some form of interleaving of the RTCM corrections with other commands sent to the Acutime unit is required. The TAIP protocol is designed to provide this interleaving function and should be considered if there are otherwise strong reasons to use an RS422 version of the Acutime with real time RTCM corrections. The RS-232 version is the preferred choice for DGPS operation.

TTL Connection

Many data collection devices that do not accept a true RS-422 signal, will accept a TTL compatible signal. To approximate a TTL signal, connect the BROWN "Transmit -" to the "Receive +" pin of the input connector and a jumper wire from the BLACK "Ground" wire to the "Receive -" pin of the connector.

Computer Interfacing -- RS422

For connection to the RS232 serial ports of most computers it is possible to wire the Acutime unit through an RS422-RS232 converter. It is also possible for short runs to use a single ended RS 422 wired in the following manner to a DB-25S plug.

Color	Function	DB-25S Pin
Violet	RX -	14
Brown	TX -	3
Orange	RX +	2
Yellow	TX +	16
Black	Ground	7 (also power ground)
DC connection		
Red		Power +ve

This combination will operate both with and without the RS422- RS232 converter in most cases. The exceptions are found with computers having UARTS with marginal voltage thresholds.

Standard Cable Arrangement - RS 232

I / O Cable Color Code

Acutime Connection	Wire Color	Function
Pin 1	Orange	RXD (Receive Data)
Pin 2	Brown	RXD (DGPS corrections I / P)
Pin 3	Yellow	TXD (Transmit Data)
Pin 4	Violet	Signal Ground
Pin 5	Blue	1 PPS / Memory Backup
Pin 6	Black	Power ground
Pin 7	Red	Power

Note 1) Connector cable via standard Conxall screw fitting (Conxall P/N 6280-7SG-523) mounted in the base of the housing.

2) 1 PPS output is by pulldown of external voltage provided to open collector circuit through Pin 5. Pulse synchronized to the integer second on the falling edge. Leakage current of 100 micro amps nominal taken to maintain internal memory

Dimensions:

Spigot Mount Antenna/Receiver: 18637-XX Series	147 mm dia x 100 mm high (5.8" dia x 3.9" high) 3/4" NPT female spigot on bottom surface for mounting Volume 1700 cc maximum (103 cubic inches) including dead space around mounting spigot.

Weight:

0.41 Kg (0.9 pound)

4.0 SYSTEM COMPONENT DESCRIPTION

The Acutime GPS Antenna/Receiver system consists of 3 sub-assemblies, the Antenna/Receiver board, a Polycarbonate housing, and a 15 meter connecting cable.

4.1 Antenna:

The antenna unit consists of a double dipole antenna element mounted together with the Receiver Board in a heavy duty Polycarbonate housing complete with mounting cone (spigot mount).

4.2 Receiver Board:

The Board consists of the necessary hardware and firmware required for satellite signal processing and solution computation. The receiver has six processing channels, operating on the L1 frequency using the C/A code. Prime DC power is supplied from an external source, with isolation against major in-line interference. The power supply module can tolerate variations between 10 and 32 volts.

The GPS Acutime board receives the satellite signal through the antenna feed line connector. The complete process, from signal processing to digital output control, is performed by the components on the receiver board. The reference oscillator is a high-stability crystal oscillator operating at 16.368 MHz. The synthesizer module generates several signals for use on the board. One output is the local oscillator for the mixer. Two other frequencies are generated for use by the custom integrated circuits (ICs) tracking hardware. An additional signal is used as the microprocessor clock. The mixer has additional circuitry for coupling in the antenna signal. The IF module processes the IF signal, amplifying it and limiting its bandwidth. The resulting signal is fed to the signal processing circuits.

The GPS tracking hardware is based on Trimble custom gate arrays. They contain satellite tracking circuitry, plus support circuitry for the microprocessor. The GPS Acutime has a single 16-bit microprocessor to perform both functions.

The channel signal processing circuits contain hardware for tracking the GPS satellite signals and for extracting the carrier code information as well as the navigation data at 50 bits per second. The signal processor controls the operation of the tracking hardware. The receiver continuously tracks the four satellites used for a solution and the remaining channels track up to 4 other satellites. The signal processor collects measurements and data which are passed to the navigation processor module. The processor uses the measurements and data to compute the GPS-based position and velocity solution. The navigation processor also controls the selection of which satellites are tracked and manages the orbital information data and almanac for all of the satellites.

4.3 Radio Frequency Interface

GPS Acutime is designed to be functionally compatible with the L1 GPS satellite navigation signals as described in the GPS Specification SS-GPS-300B and ICD-GPS-200. GPS Acutime operates with the experimental Block I satellites as well as the operational Block II satellites or a combination thereof.

GPS Acutime has burn-out protection which prevents damage by RF signals at frequencies which are 100 MHz or more from the L1 frequency (1575.42 MHz), with received power up to one watt at the antenna.

4.4 Differential GPS

Acutime has the capability to configure digital data channel "B" (or 2) into an input port for differential GPS corrections in the Radio Technical Commission for Maritime Services (RTCM) Version 1.0 or 2.0 format (RS-232 version only). The differential corrections are generated from a reference GPS receiver at a known location and can be made available to remote GPS receivers in the area via a data link. The Trimble Standard Interface Protocol describes the data packets associated with differential correction incorporation. Contact Trimble Navigation for further information about available GPS reference stations and details concerning differential GPS operation.

4.5 Mechanical Interface - Antenna Mounting

Choose a location for the Acutime antenna/receiver as close as possible to vertical, which has a relatively unobstructed view of the horizon, and which will be safe from damage during normal operation of the host vehicle. Dense wood or metal structures will shield Acutime from satellite signals. Acutime can receive satellite signals though glass, canvas and thin fiberglass. If you plan to install Acutime in a partially enclosed environment, test the ability of Acutime to receive satellite signals before committing to a permanent mount. The Acutime unit is designed, however, to withstand the full rigors of the elements and can therefore be mounted in an exposed external location. The only limitation is that the unit's extended performance at temperatures below -40 degrees (C or F) is not warranted. The unit will perform also when partially snow covered providing the snow is dry; ice accumulations will eventually shut off performance, only if the ice sheet is continuous. The shape of the unit has however been selected partially to minimize rain, snow and ice accumulation.

The Acutime antenna/receiver is an active head antenna. For optimal performance, avoid locating Acutime within two feet (60cm) of other antennas, near high vibration areas like engine housings, or near radar installations. If there is a limitation on available mounting locations ensure at least that Acutime is positioned outside the radar's cone of transmission. Follow the same guidelines when installing the Acutime near a satellite communication equipment (e.g. Inmarsat A or C) or microwave dishes. For best results, mount the Acutime below and at least ten feet (3 meters) away from satellite communication equipment.

If the unit is being mounted permanently in a microwave installation, e.g. for timing purposes, then care should be exercised to shield the unit from random back-scatter from microwave dishes. Difficulties will be immediately apparent if the unit cannot lock on to satellites or shows a poor ability to track. Protection is afforded by use of a ground plane, a metallic shield which is mounted below the desired minimum viewing angle of the antenna unit. In extreme cases a cone shield extending up to a 10 degree horizontal viewing angle may be tried (make allowance for snow and rain drainage!). This takes advantage of the fact that low elevation satellites have lower signal/noise ratios due to increased ionospheric absorption and therefore are less desirable for timing purposes. Such a cone shield will not work well on a moving vehicle such as a vessel because of its rolling and pitching motion.

Acutime is designed for a pole mount. The threaded socket at the base of Acutime will accept both a 1"-14 threads per inch (TPI) straight thread, and a standard 3/4"-14 TPI (NPT) pipe thread. Acutime only requires hand tightening on the pole mount. For temporary installations on a metallic surface a magnetic mount may be used (Part No. 12920-00) together with an adapter

(Part No 17030). The adapter is threaded 5/8 11 (TPI), the standard survey instrument mounting thread.

The connector cable should be firmly secured to the support using cable ties so that there is little or no mechanical strain on the 7 pin connector.

Note: Acutime is a valuable instrument and for permanent installations it may be prudent to drill and pin the Acutime mount to discourage theft and prevent accidental loosening. If Acutime is easily removed, store it in a secure location when not in use.

4.6 Electrical Interface

System Power:

The Acutime electrical interface is via pins 6 (Ground) and 7 (Positive) on the 7 pin Conxall connector; these correspond to the black and red conductors respectively of the connecting cable. The power requirement is nominally 2 Watts for a supply voltage of 12 Volts DC. The maximum voltage is 32 VDC. Input circuits are provided to protect Acutime inputs and outputs from off-nominal power conditions. The input is protected against over-voltage by means of an external client supplied 3A fast blow fuse. The power supply is set to blow this at 36 V DC. If Acutime encounters low voltage conditions, it degrades gracefully and returns to full operation upon the restoration of power.

Lightning surge protection is built into the Acutime; the unit is tested to 25kV on the antenna case, as well as 25kV applied to each pin using an industry standard test procedure of a 150 pf capacitor discharging through a 10k ohm resistor.

Pulse-Per-Second Output:

A 1-microsecond pulse per second is output on pin 5 of the main connector which is also used for battery backup of the on-board RAM. The circuit is open collector and should be connected to the battery or other source through a 10k external resistor. The falling edge of the pulse is synchronized with UTC (Universal Coordinated Time). The pulse will be shaped by the distributed impedance of the attached cabling and input circuit. If it is intended that the Acutime unit be mounted in a location remote from the accompanying system then the system designer should make arrangements to provide a local RS422 interface for the 1PPS signal to overcome the attenuation effects of long cable runs.

The timing accuracy is ±1 microsecond and is valid only when computing position fixes, or in static, one-satellite, time-only, mode. Repeatability checks show that 10 sets of 100 1 second samples taken over a period of 20 minutes showed an average variation of 100 nanoseconds approximately (SA not allowed for).

RAM Support:

The random-access-memory (RAM) and real time clock are held up by the same external, user-supplied voltage via Pin 5 as for the 1PPS output. If the Acutime is being used for position outputs only there is no need for the 10k resistor noted above. The required voltage range is 3.5 to 32 VDC. Supplying external voltage for memory hold-up during a power outage period will ensure rapid acquisition upon re-starting.

Digital Communication Interface

The following description applies when the unit is operating electrically as an RS422 protocol and supporting TSIP. Variations occur when operating under different protocols, shown in the attached Appendices. Digital communication is accomplished via a single bi-directional EIA RS-422, optionally a 1 1/2 channel (1 TX/RX and 1 RX only) RS232 serial interface with a default 9,600 baud setting, but switchable between 50 and 38,400 baud.. The data channels are transmitted through the 7 pin connector. The signals conform to the electrical specifications of EIA RS-422 or RS-232D. Inputs are not terminated within Acutime.

Transmit Data and Receive Data are asynchronous 9,600 baud (default) serial data signals with 8 data bits, 1 stop-bit, and odd parity. Idle, "Mark," or Logic 1 occurs when the (+) signal is more positive than the (-) signal.

See Appendix 4 for RS-232 connections

5.0 TIME OPERATION

Acutime makes an excellent source of accurate time for a system such as environmental data acquisition or communications networks. The electrical connections are discussed in Section 4.6 above. Digitally the timing functions of the Acutime unit are supported in the TSIP and TAIP protocols. The following description of the special time function packets is derived from the TSIP protocol. Please see the introduction to the TSIP protocol for a description of the packet structure.

Special hex packets are available as follows for time information

22 Position Fix Mode Select

This packet commands the Acutime to operate in a specific position fix mode. This packet contains one data byte indicating the mode, as follows:

Mode	Data byte value
Automatic	0 (default value)
1-satellite (0-D)	1
3-satellite (2-D)	3
4-satellite (3-D)	4

This selection is held in battery-backed memory

The 1-satellite (0-D) mode uses a single satellite to determine receiver clock error (time) and error rate (frequency) when the position is known precisely. In this mode, the Acutime computes no positions or velocities. Instead, the Acutime sends packet 54 hex with the clock bias and bias rate. This can be used for time transfer applications and to enable the Acutime to maintain the accuracy of the one PPS (Pulse Per Second) output even if a full position fix cannot be done.

41 GPS Time

This packet provides the current GPS time of week and the week number. The Acutime sends this packet in response to packet 21 hex and during an update cycle. Update cycles occur every 15 seconds when not doing fixes and occur every 150 seconds when doing fixes.

It is sent promptly after reading the internal time clock. The moment of transmission is not synchronized to the 1 PPS.

The data format is shown below.

Byte #	Item	Type	Units
0-3	GPS time of week	SINGLE	seconds
4-5	GPS week number	INTEGER	weeks
6-9	GPS/UTC offset	SINGLE	seconds

Note that GPS time differs from UTC by a variable integral number of seconds. UTC = (GPS time) - (GPS/UTC offset). The offset is presently 8 seconds (July 1992) and increases by 1 second approximately every 18 months. The system designer should therefore plan to read this data element as part of the timing interface to obtain UTC. The GPS week number reference is Week # 0 starting January 6, 1980.

The seconds count begins with "0" each Sunday morning at midnight. A negative indicated time-of-week indicates that time is not yet known; in that case, the packet is sent only on request. The following table shows the relationship between the information in packet 41, and the packet 46 status code.

approx. time accuracy	time source	sign (TOW)	packet 46 status code
none	no time at all	-	01 hex
unknown	approximate time from real-time clock or packet 2E	+	01 hex
20 to 50 msec + clock drift	time from satellite	+	not 01 hex
full accuracy	time from GPS solution	+	00 hex

The recommended technique for PPS/Packet 41 synchronization is to check the received time value and do not process messages that occur too close to the PPS or overlap it. Packet 41 is handled quickly so that PPS time synchronization can be done. It is sent normally less than 5 milliseconds after the time contained in the packet. By allowing 10 milliseconds plus the data transmission time plus the processing delay one has an estimate of the total delay. If the time of week contained in Packet 41 is closer than this delay to the next integer second, then it should not be used. If it is greater than the delay then the next 1PPS will mark the next whole second.

As an example if the time of week is N seconds plus 456 milliseconds, then the next PPS will be at N+1 seconds exactly. If the time is N + 990 milliseconds a second Packet 41 should be requested since the next pulse cannot be trusted.. Further Packet 41' s should be requested until the time received allows for proper synchronization. Subsequent Packet 41's can then be used to check time and synchronization.

A software DOS routine, GPSTIME1.EXE is available for clock setting on PC computers.

The Acutime has no real-time clock hardware. For the most accurate GPS time, before using the GPS time from packet 41, verify that the packet 46 status code is 00 hex ("Doing position fixes") or that the unit has a good reference position and can operate in one (1) satellite mode.

54 One-Satellite Bias and Bias Rate

The Acutime sends this packet to provide the computed clock-only solution when the Acutime is in the manual or automatic one-satellite mode.

Byte	Item	Type	Units
0-3	Bias	SINGLE	meters
4-7	Bias rate	SINGLE	meters/second
8-11	Time of fix	SINGLE	seconds

The bias is the offset of the Acutime internal time clock from GPS time. Bias is expressed as meters of apparent range from the satellites. It is used to correct the one PPS output. The user should avoid using the bias and bias rate figures for second to second correction of the 1PPS output since the on board crystal oscillator drift is of the order of 1 - 2 microseconds per second and is temperature dependent.

6.0 ACUTIME PART NUMBERS

The 18637-XX part number series includes:

18636-XX - Acutime Antenna/Receiver
19360-50 - 15 meter connection cable
21250-00 - Acutime Specification and User's Manual

Data Protocol	RS - 232	RS - 422
TSIP	18637-02	18637-00
TAIP	18637-62	18637-60
NMEA*	18637-72	18637-70
NMEA**	18637-82	

* NMEA sentences GGA and VTG only at 1 second intervals.
** NMEA sentences GGA and GSA at 1 second intervals.

APPENDIX 1

Trimble Standard Interface Protocol (TSIP)

Version 1.15

1.0 INTRODUCTION

Depending how the system designer uses Trimble Standard Interface Protocol (TSIP) to configure the GPS receiver, final system performance can be optimized for any number of applications. For example, an aircraft or vessel operating with an unobstructed view of the sky, will most likely have different GPS operating requirements than vehicle operations in a downtown "urban canyon" environment, where frequent satellite blockages are the rule rather than the exception.

TSIP gives the system designer and unprecedented degree of freedom in choosing settings most appropriate to the task at hand; however, along with this flexibility, comes the responsibility of making intelligent selections which are consistent with each other and the overall system objective.

The GPS receiver is provided with certain factory default settings, which will suffice for a great number of applications. For those requiring customization, application hints are provided for each packet, in the sections that follow. The key operative is to make judicious use of the powerful features TSIP has to offer the system designer. The system designer will greatly enhance overall system performance while reducing development time.

1.1 INTERFACE SCOPE

The Trimble Standard Interface Protocol is used in a large number of Trimble 3 and 6 channel board and navigation sensor designs. The protocol was originally defined for the Trimble Advanced Navigation Sensor (TANS) and is colloquially known as the TANS protocol even though applying to many other devices. References in this document to the TANS protocol should not thus be taken to apply to the TANS unit only, but to the whole range of Acutime sensors with the exception of those devices operating with an ASCII interface only. One important difference is that the RS422 version has one bi-directional port only.

For the RS232 Acutime range of sensors there are some particular considerations for the setup of Serial Channel A and Channel B (or Channels 1 & 2).Channel 1 operates in the same way as for all other Trimble 2, 3 and 6 satellite channel sensors, i.e. there is a series of automatic outputs described in the attached Table. Do not confuse the number of satellite channels with the number of serial channels (or ports) - there is no relationship between the two; reference is often made to serial channel or port interchangeably.

The second serial channel is a receive only, i.e. it is intended normally for receipt of RTCM corrections. The default setting on start-up is 9600 baud, 8 bit, odd parity, and 1 stop bit.

This document describes in detail the format of the transmitted data, the packet identification codes, and all available information over the output channel to allow the user to choose the data required for his particular application. As will be discussed, the Acutime transmits some of the information (position and velocity solutions, etc.) automatically when it is available, while other information is transmitted only on request. Additional packets may be defined for particular products and these will be covered in the specifications for those products as necessary.

Some knowledge of the theory of the GPS system is assumed; those readers wishing to refresh their knowledge of the theory are directed to Section 2 of this document for references. The bi-directional channel is the interface for command, control, and data output, for integration with control systems, vehicle tracking and management systems, navigation processors, displays, and other user equipment. The channel protocol is based on the transmission of packets of information between the user equipment and the unit. Each packet includes an identification code (1 byte, representing 2 hexadecimal digits) that identifies the meaning and format of the data that follows. Each packet begins and ends with ASCII control characters.

The PKTMON utility, part of the GPS Software Toolkit, is designed to exercise many of the TSIP packets. The system integrator can use the utility to test the reaction of the sensor to these commands.

1.2 KEY ACUTIME SETUP PARAMETERS

Correct selection of the right operating parameters is a major factor in getting the best performance from the sensor. Packets 22 (set fix mode), 2C (set operating parameters), 35 (set I/O options), and packet 62 (set DGPS mode) are provided to change the receiver setup to the specific conditions of a particular user. The default values for the parameters in these packets are chosen to allow the receiver to operate well under the most varied and demanding conditions. A user may choose to change the default parameters if the receiver is only required to perform in a specific or limited environment. The user should be warned that when the receiver is exposed to operating conditions which are different from the conditions described by the user setup, then the performance may be degraded. A brief description of the main parameters in these packets is given below so that a designer may understand the trade-off involved with a particular setup.

Initially the system designer needs to consider carefully the environment in which the receiver is expected to operate. There is a trade-off between how frequently a position fix is output versus the absolute accuracy of the fix. The system designer needs to decide which takes priority and then make the appropriate selections. This becomes increasingly important when frequent satellite blockages are expected, as in downtown "urban canyon" environments and heavily foliated areas.

If one contrasts the sensor performance required for an aircraft, flying level, or a marine vessel, in a calm sea, with that of a truck or bus being driven in an area of partial or complete blockage due to buildings and trees, then it is clear that different demands are being made on the sensor. Accuracy of the position fix is optimized when the 'Synchronized Measurements' (Packet 35) option is ON. By so doing, the GPS will only output a position fix when it has continuous lock on three or more satellites simultaneously.

In a downtown urban canyon, however, it is difficult to maintain continuous lock on a given satellite constellation for any length of time. The sensor may find it almost impossible to pick up signals simultaneously from 3 or 4 satellites and will also be subject to continuous constellation shifts, since the satellites are frequently blocked from view by tall buildings. Other limitations are also set by the masks for PDOP, elevation and signal strength (SNR). Therefore, the system designer would be satisfied with a lower accuracy provided that fix density (or frequency) is at an acceptable level. Switching the 'Synchronized Measurements' options to OFF, gives the receiver more latitude in selecting and propagating old measurements to yield a position fix, albeit with less accuracy than one which maintained continuous lock.

The user can check for this condition occurring by setting the Additional Fix Status ON. Packet 5E will identify the number of old measurements being used. Such data is most useful where the sensor is being used as part of a DR system; checking the independence of measurements can be used as a weighting parameter in computing the overall solution from the combined sensor suite. Note also that Minimize Projection is set ON by default; in this case where obscuration occurs, new positions will be computed for 3-4 seconds using the last velocity vector before obscuration occurred. This may not be desirable in combined sensor systems and should therefore be set OFF.

One should also resist the temptation to set the elevation and SNR masks too low. The satellite geometry is sometimes improved considerably by selecting low elevation satellites. They are, however, subject to significant signal degradation by the greater ionospheric and tropospheric attenuation that occurs. They are also subject to more obscuration by the passing scenery when the sensor is in a moving vehicle. The code phase data from those satellites is therefore more difficult to decode and therefore has more noise. If possible the elevation mask should set between 5 and 10 degrees minimum.

The Vehicle Dynamics should also be correctly set so that the search algorithm for satellites operates in optimum fashion if there has been a complete loss of lock with the satellites due to short periods of obscuration. A more detailed discussion of the effects of the various parameters is set out below.

1. <u>Fix Mode</u> The preferable fix mode is 3-D, where altitude is calculated along with the latitude, longitude, and time. However, this requires four satellites with a PDOP below the PDOP mask set in packet 2C in order to obtain a position. Normally, this will provide the most accurate solution. Thus, if only 3-D solutions are desired, then the user should request 3-D manual mode. Depending on how the PDOP mask is set, this may be restrictive when the receiver is subjected to frequent obscuration, or when the geometry is poor due to an incomplete constellation.

   Alternatively, if the user only wants a 2-D solution, then 2-D manual should be requested. In this case, the sensor uses either the last altitude obtained in a 3-D fix, or the altitude supplied by the user. However, any error in the assumed altitude will effect the accuracy of the latitude and longitude solution. High accuracy users should avoid this mode and should expect fixes with accuracy's which are at best as accurate as the supplied altitude. If a marine user enters sea-level as the altitude, then small errors in the horizontal solution will occur when the sea state is rough or there are high tidal variations. However, these errors may be smaller than the altitude errors induces by SA, so 2-D may be preferable for a marine user who does not want to observe "unusual" altitudes.

   The default mode is AUTO 2-D/3-D, where the receiver first attempts to obtain a 3-D solution with a PDOP below both the PDOP mask and PDOP switch. If this is not possible, then the receiver attempts to obtain a 2-D solution with a PDOP less than the PDOP mask. This mode supplies fairly continuous position fixes even when there is frequent obscuration. This mode is preferable for most land or air applications, where altitude changes are occurring and there is occasional obscuration.

2. <u>Operating Parameters</u> These parameters are used to define the maximum dynamics the user expects to experience, and also to define the set of satellites which are usable based on the satellite geometry at the user's position.

   (a) <u>Dynamics Code</u> The default is AIR mode, where the receiver assumes a high dynamic environment. In this case, the satellite search and reacquisition routines are optimized to tolerate high accelerations. A user which is subject to only benign accelerations (less than 1g) may benefit by selection of LAND or SEA mode where the search and reacquisition routines assume a low acceleration environment. In this case, satellite loss-of-lock is due more often to obscuration rather than extreme dynamics.

(b) Elevation Mask This is the minimum elevation angle for satellites to be used in a solution output by the receiver. Satellites which are near the horizon are typically more difficult to track due to signal attenuation and are also generally less accurate due to higher variability in the ionospheric and tropospheric corruption of the signal. When there are no obstructions, the receiver can generally track a satellite down to near the horizon. However, when this mask is set to low, the receiver may experience frequent constellation switching due to low elevation satellites being obscured. Frequent constellation switching is undesirable because small position jumps may be experienced when SA is present and DGPS is not available to remove these effects. The benefit of a low elevation mask is that more satellites are available for use in a solution and a better PDOP may be yielded. The current mask is set to five degrees and provides a reasonable tradeoff of the benefits and drawbacks. High accuracy users may prefer a mask angle around ten degrees, where the ionosphere and troposphere begin to be more predictable.

(c) Signal Level Mask This mask defines the minimum signal strength for a satellite to be used in a solution. There is some internal hysteresis on this threshold which allows brief excursions below the threshold if lock is maintained and the signal was previously above the mask. The mask has been set to 4.0 in V1.14 and higher versions due to increased tracking capability now included. The mask should only be lowered cautiously since this mask is also used to minimize the effects of jammers on the receiver. High accuracy users may use a slightly higher mask of 5.0-6.0 since weaker measurements may be slightly noisier. However, good performance is available with the default setting.

(d) PDOP Mask and Switch The PDOP mask is the maximum PDOP for which any 2-D or 3-D solution will be made. The switch is the level at which the receiver stops attempting a 3-D solution, and tries for a 2-D solution when in automatic 2-D, 3-D mode. The switch level has no affect on either manual mode. Raising the PDOP mask will generally increase the fix density during obscuration, but the fixes with the higher PDOP will be less accurate (especially with SA present). Lowering the mask will improve the average accuracy at the risk of lowering the fix density.

3. Time of Fix Parameters There are basically three options available for specifying the time of the GPS solution. When a satellite is in a normal continuous tracking mode, the time-of-applicability of the measurements is at 0.25 seconds and 0.75 seconds within each GPS second.

(a) Default Mode In the default mode, the time of solution is the time at which the GPS solution is computed. Thus, all measurements are projected by an interval which is roughly the amount of time it takes to compute the solution. The benefit of this approach is that the receiver provides a solution which is applicable as close to the time of transmission as possible, which minimizes the burden on the user's computer. The drawback is that the measurement projection (which is exactly the same as dead-reckoning with velocity) may induce some error during high accelerations.

(b) Integer Second In the integer second mode, the most recent measurements are projected to next integer second, and the solution is then valid at this time. The benefit of this mode is obviously the standard fix time. The drawbacks are that some measurement projection is performed and that the fix may be slightly older than with the default option.

(c) Minimized Projection In this mode, the time of solution is the time of the most recent measurements. Thus, if all measurements are taken at exactly the same time, then there is no measurement projection. If a selected satellite's measurement time is lagging the most recent measurement, then it is projected to this time. The only penalty is that the fix will be older than a fix provided with the above timing options. This is the best choice for users performing non real-time error analysis, or non real-time DGPS solution-space corrections. This is also the preferable mode for users integrating GPS with other sensors, where communication lags are the dominant latencies, and thus the time lag between the applicability and availability of the fix is small. This option is only available in version 1.14 and higher.

4. Synchronized Measurements In this mode, all measurements are required to have the same time tag. This only applies to a six channel receiver, where selected satellites are tracked continuously on their own channel. If a satellite is lost which is in the selected set for the solution, then no fix will be made until a new selection is made. In the usual case (when the Synchronized measurement if off), slightly older measurements are tolerated (on the order of 3-5 seconds) in order to provide solutions when obscurations make it impossible to obtain exactly concurrent measurements from each satellite. The Synchronized measurement mode combined with the minimized projection timing mode allows absolutely no measurement projection. This mode is ideal for vehicles which experience high accelerations and want the highest accuracy. However, obscurations may reduce the fix density when there are limited satellites, so this mode should be used cautiously.

5. Additional Fix Status Setting bit three of the auxiliary byte in packet 35 will cause packet 5E to be output with each fix. Packet 5E has been added to give additional information about the fix concerning measurement latency. Packet 3E can be used to request packet 5E. These packets are in versions 1.14 and higher.

   The least significant three bits of byte one of this packet contain the number of measurements used in the fix which were considered old. (Use of an old measurement will immediately cause a new satellite selection.) It turns out that some latency is desirable to "self-aid" the receiver, since a solution which has some projection error is probably good enough to help re-acquisition of lost satellites, and is probably better than no fix at all. These fixes are now flagged as containing old measurements with this packet.

   The least significant three bits (Bits 0-2) of byte zero of packet 5E contain the number of measurements used in the current solution that were also used in a previous solution. This gives an indication of how much independent information is contained in each fix. (NB for a three channel sequencing receiver, the channel allocation and fix rate may make it impossible for a new measurement to be taken from each satellite between fixes which are less than a second apart. Thus, it is possible to re-use a measurement in consecutive fixes even though the measurement is not considered old based on the current satellite distribution on sequencing channels). This information is useful when integrating the receiver with additional sensors. The fourth bit (Bit 3) of this byte flags fixes whether Differential Doppler velocity was available.

The fifth bit (Bit 4) of byte zero is used to flag fixes which are computed but are not output since the receiver is converging after being in an approximate position mode. In this case, the receiver says that it is doing fixes but no positions are being output. This condition is now flagged with this bit.

6. DGPS Mode In manual DGPS mode, the receiver only computes solutions if corrections are available for the satellites which are selected. This is the most accurate mode, but it is also the most selective, since the fix density is dependent on the availability of corrections. The auto mode avoids the fix density problem but opens the door to the possibility of going in and out of DGPS mode, which will cause position and velocity jumps. If accuracy is critical, one should stick with manual mode. On the other hand, if fix density is critical, auto DGPS is probably safer.

   In summary, the default parameters chosen allow the receiver to perform well in almost any environment. The user can optimize the receiver to a particular application if the vehicle dynamics and expected level of obscuration are understood. If the receiver is then taken out of this environment, then a specifically tuned receiver may not operate as well a receiver with the default options. Table 1 shows some possible parameter selections as a function of the dynamics, obscuration, and whether accuracy or fix density is important. (NA: not applicable, DC. don't care, i.e., could be set either way)

Table 1: Suggested Parameter Settings

	High Obscuration		Low Obscuration	
Parameter	Accuracy	Fixes	Accuracy	Fixes
Fix mode	man 3D	Auto	man 3D	Auto
Elevation mask	10	5	10	5
Signal mask	6.0	4.0	6.0	4.0
PDOP mask	6.0	12.0	6.0	12.0
PDOP switch	NA	8.0	NA	8.0
Timing mode	min proj	DC	min proj	DC
Sync meas.	OFF	OFF	ON	ON
Min. projection	ON	DC	ON	DC
DGPS mode	man ON	DC	man ON	DC

2.0 APPLICABLE DOCUMENTS

Unless otherwise indicated, the issue of each document which was in effect on 1 May 1987, is the issue to be used.

SS-GPS-300B	System Specification for the NAVSTAR Global Positioning System
ICD-GPS-200	NAVSTAR GPS Space Segment/Navigation User Interfaces
17035	Trimble Advanced Navigation Sensor, Specification and User's Manual, Rev. A, October 1990
RTCM (SC-104)	RTCM Recommended Standards For Differential NAVSTAR GPS Service, Version 2.0. RTCM Special Committee No. 104. Published by the Radio Technical Commission For Maritime Services, Washington, D.C. January 1, 1990.

GPS - A Guide to the Next Utility - Trimble 1990 - an introduction in non-mathematical terms to the GPS system.

Proceedings - Institute of Navigation Washington DC - A series of 3 abstracts published between 1980 & 1986 of papers from the Journal of the Institute of Navigation. Essential source material for any system designer.

3.0 SIGNAL CHARACTERISTICS

3.1 General

The user interface signals are EIA RS-422 balanced conductor pairs. For the short line lengths anticipated, the user's receive-end need not be terminated. The format is standard serial, sent least-significant-bit first, at 9,600 baud, with 8 data bits, odd parity, and one stop-bit. "Clear to send" flow control signals are included in the design and should be used to eliminate the possibility of over-run. For details, see Section 3.7 of the manual, *Digital Communication Interface*.

TSIP will also operate with RS-232 configurations.

Note: Several packets have significant effects on the operation of the Acutime sensor where an external battery back-up is used for the internal memory. These are noted in the text and the system designer should be aware of these effects in the structure of the software.

3.2 Packet Data Format

Each packet type is described below. Where necessary, specific data formats are given.

The INTEGER data type is a 16-bit signed number sent in 2s-complement format, most significant byte first.

A floating-point number, sometimes called "scientific notation" (for decimal numbers), or a REAL number, consists of a signed mantissa and a signed exponent. The precision is determined by the number of digits in the mantissa, and the range of expressible values is determined by the number of digits in the exponent. In a non-zero binary floating-point number, the mantissa consists of a "1," followed by the binary point, followed by the fractional part of the mantissa. Note that the leading binary "1" is redundant.

For floating-point numbers, the Acutime uses the ANSI/IEEE Std 754 *IEEE Standard for Binary Floating-Point Arithmetic*, in which the formatted exponent is biased to avoid the use of an exponent sign, the mantissa's redundant leading "1" is omitted, and various special cases are specified. The IEEE 754 standard specifies two degrees of precision, "SINGLE" and "DOUBLE," both of which are used in the Acutime; the DOUBLE-precision format uses more bits both in the mantissa (for greater precision) and in the exponent (for greater range). The IEEE 754 format is described briefly below.

The sign-bit is 1 for a negative number and is 0 for a positive number.

To ensure that the formatted exponent is non-negative, and thus to avoid the use of an exponent sign, the formatted exponent (the *biased exponent*) is the sum of the actual (signed, unbiased) exponent plus a constant (the bias).

The redundant leading "1" is not included; only the fractional part of the mantissa is included and is called the "fraction."

The value *zero* is formatted by setting both the biased exponent and the fraction to zero. Note that this special case must be recognized as zero and not interpreted as described above for a non-zero number.

The IEEE 754 standard specifies various other special cases. For programming and for detailed data analysis, the user should consult the IEEE standard.

The Acutime "SINGLE" data type is a 32-bit (4-byte) single-precision floating-point number in the ANSI/IEEE Std 754 SINGLE (short) format. The first byte sent contains the sign-bit of the mantissa and the 7 most-significant bits of the biased exponent. The second byte contains the least-significant bit of the biased exponent, followed by the 7 most-significant bits of the fraction (the part of the mantissa to the right of the binary point). The remaining 2 bytes complete the fraction. The exponent bias is +127; i.e., the biased exponent is the actual exponent +127. With the implied (unformatted) leading "1," the single-precision mantissa contains 24 significant bits.

The Acutime "DOUBLE" data type is a 64-bit (8-byte) double-precision floating-point number in the ANSI/IEEE Std 754 DOUBLE (long) format. The first byte sent contains the sign-bit of the mantissa and the 7 most-significant bits of the biased exponent. The second byte contains the 4 least-significant bits of the biased exponent, followed by the 4 most-significant bits of the fraction. The remaining 6 bytes complete the fraction. The exponent bias is +1,023. With the implied (unformatted) leading "1," the double-precision mantissa contains 52 significant bits.

3.3 Packet Structure

In both directions of information transmission, the data format conforms to a packet structure as follows. Each packet starts with the two-character sequence.

<DLE>	the ASCII "data link escape" character, 1 byte, value 10 hex
<id>	the packet type identification number, 1 byte, expressed as 2 hexadecimal digits. This byte can have any value other than 10 hex (ASCII <DLE>) or 03 hex (ASCII <ETX>). The values and their meanings are given in the remainder of this appendix.

Each packet ends with the two-character sequence.

<DLE>	the ASCII "data link escape" character, 1 byte, value 10 hex
<ETX>	the ASCII "end-of-text" character, 1 byte, value 03 hex.

The packet format is shown below.

```
-----------------------------------------------------------
<DLE>  <id>   ... data bytes ...  <DLE>  <ETX>
-----------------------------------------------------------
```

Each packet data byte can have any 8-bit value, with the one requirement that any data byte of value 10 hex (<DLE>) must be sent twice. The receiving devices (in both the Acutime and the user's data terminal) must compress all occurrences of two <DLE> characters into one <DLE> data byte. The data portion of the packet may be from 0 to 255 bytes long, not counting <DLE> stuffing.

3.3.1 Packets Sent By The User To Acutime

The table below provides the packet ID numbers sent by the user to Acutime, a short description of each packet, and the identities of the packets which Acutime sends in response. In some cases, the response packets depend on user-selected options. These selections are covered in the packet descriptions below. Details are provided for each packet type in the following sections. Descriptions of some packets assume availability of battery-backed memory; the battery has to be provided externally through pin 5 if required.

<id> (hex)	Description	Response Packet Sent By Acutime
1D	clear oscillator offset	--
1E	clear battery back-up, then reset	--
1F	request software versions	45
20	request almanac	40
21	request current time	41
22	mode select (2-D, 3-D, auto)	--
23	initial position (XYZ ECEF)	--
24	request Acutime position fix mode	44
25	initiate soft reset & self-test (equivalent to cycling power)	45,46, 4B, 42 or 83 4A or 84
26	request health	46, 4B
27	request signal levels	47
28	request GPS system message	48
29	request almanac health page	49
2A	altitude for 2-D mode	--
2B	initial position (Lat, Lon, Alt)	--
2C	set/request operating parameters	4C
2D	request oscillator offset	4D
2E	set GPS time	4E
31	accurate initial position (XYZ Cartesian ECEF)	--
32	accurate initial position (lat, lon, alt)	
34	satellite number for 1-sat mode	--
35	set/request I/O options	55
36	velocity aiding of acquisition	--
37	request status and values of last pos & vel	57; 42 or 83 or 4A or 84; 43 or 56
38	request/load satellite system data	58
39	set/request satellite disable or ignore health	59
3A	request last raw measurement	5A
3B	request satellite ephemeris status	5B
3C	request tracking status	5C
3D	configure channel A for RTCM (SC-104) differential GPS	3D
3E	request additional fix parameters	5D
62	set/request differential GPS position fix mode	82
65	request differential correction status	85

3.3.1.1 1D Clear Oscillator Offset

This packet commands the Acutime to clear the oscillator offset stored in battery-backed memory. This packet contains one data byte equal to the ASCII letter "C," 43 hex. Note that packet 2D hex can be used to request the current value of the offset; this information is used mainly for service. In normal use, there is no need to send this packet.

3.3.1.2 1E Clear Battery Back-up, then Reset

This packet commands the Acutime to clear all battery back-up data and to perform a software reset. This packet contains one data byte equal to the ASCII letter "K," 4B hex.

> **CAUTION**
>
> All almanac, ephemeris, current position, mode, and calibration, information is lost by the execution of this command. In normal use this packet should not be sent.

3.3.1.3 1F Request Software Versions

This packet requests information about the version of software running in the Navigation and Signal Processors. This packet contains no data bytes. The Acutime returns packet 45 hex.

3.3.1.4 20 Request Almanac

This packet requests almanac data for one satellite from the Acutime. This packet contains one data byte specifying the satellite PRN number. The Acutime returns packet 40 hex.

3.3.1.5 21 Request Current Time

This packet requests current GPS time. This packet contains no data. The Acutime returns packet 41 hex.

3.3.1.6 22 Position Fix Mode Select

This packet commands the Acutime to operate in a specific position fix mode. This packet contains one data byte indicating the mode, as follows:

Mode	Data byte value	PKTMON key command
Automatic	0 (default value)	^N
1-satellite (0-D)	1	^T
3-satellite (2-D)	3	n
4-satellite (3-D)	4	N

This selection is held in battery-backed memory

The 1-satellite (0-D) mode uses a single satellite to determine receiver clock error (time) and error rate (frequency) when the position is known precisely. In this mode, the Acutime computes no positions or velocities. Instead, the Acutime sends packet 54 hex with the clock bias and bias rate. This can be used for time transfer applications and to enable the Acutime to maintain the accuracy of the one PPS (Pulse Per Second) output even if a full position fix cannot be done.

3.3.1.7 23 Initial Position (XYZ Cartesian ECEF)

This packet provides the Acutime with an approximate initial position in Cartesian ECEF (Earth Centered, Earth Fixed) WGS-84 coordinates. This packet causes a world-wide search for the user's position, starting at the position entered via this packet. That takes about 6 to 10 seconds before the Acutime can provide more fixes. This packet is useful if the user has moved more than about 1,000 miles after the previous fix. (Note that the Acutime can initialize itself without any data from the user; this packet merely reduces the time required for initialization.) This packet does not cause a software reset.

The data format is shown below.

The X-axis points toward the intersection of the equator and the Greenwich meridian, the Y-axis points toward the intersection of the equator and the 90o meridian, and the Z-axis points toward the North Pole.

Byte #	Item	Type	Units
0-3	X	SINGLE	meters
4-7	Y	SINGLE	meters
8-11	Z	SINGLE	meters

3.3.1.8 24 Request Acutime Position Fix Mode

This packet requests current position fix mode of the Acutime. This packet contains no data. The Acutime returns packet 44 hex.

3.3.1.9 25 Initiate Soft Reset & Self Test

This packet commands the Acutime to perform a software reset. This is equivalent to cycling the power. The Acutime performs a self-test as part of the reset operation. This packet contains no data. The Acutime returns packets 41, 45, 46, 4B, (42 and 4A) or (83 and 84), all hex. The Acutime sends packet 45 hex only on power-up and reset (or on request); thus if packet 45 appears unrequested, then either the Acutime power was cycled or the Acutime was reset.

3.3.1.10 26 Request Health

This packet requests health and status information from the Acutime. This packet contains no data. The Acutime returns packet 46 hex and 4B hex.

3.3.1.11 27 Request Signal Levels

This packet requests signal levels for all satellites currently being tracked. This packet contains no data. The Acutime returns packet 47 hex.

3.3.1.12 28 Request GPS System Message

This packet requests the GPS system ASCII message sent with the navigation data by each satellite. This packet contains no data. The Acutime returns packet 48 hex.

3.3.1.13 29 Request Almanac Health Page

This packet requests the Acutime to send the health page from the almanac. This packet contains no data. The Acutime returns packet 49 hex.

3.3.1.14 2A Altitude for 2-D Mode

This packet provides the altitude to be used for Manual 2-dimensional (3 satellite) mode. This altitude is used for Auto 2-D mode until a 3-D fix is performed. This packet contains one SINGLE number (4 bytes) specifying the altitude in meters, using the WGS-84 model of the earth or MSL geoid altitude depending on I/O options (set by packet 35). This altitude value is held in battery-backed memory.

3.3.1.15 2B Initial Position (Latitude, Longitude, Altitude)

This packet provides the Acutime with an approximate initial position in latitude and longitude coordinates (WGS-84). This packet causes a world-wide search for the user's position, starting at the position entered via this packet. That takes about 6 to 10 seconds before the Acutime can provide more fixes. This packet is useful if the user has moved more than about 1,000 miles after the previous fix. (Note that the Acutime can initialize itself without any data from the user; it merely requires more time.) This packet does not cause a software reset.

The data format is shown below.

Byte #	Item	Type	Units
0-3	latitude	SINGLE	radians, north
4-7	longitude	SINGLE	radians, east
8-11	altitude	SINGLE	meters

3.3.1.16 2C Set/Request Operating Parameters

This packet optionally sets the operating parameters of the Acutime receiver and requests the current values after setting them. The data format is shown below. The Acutime returns packet 4C hex.

The dynamics code indicates the expected vehicle dynamics and is used to assist the initial solution.

The elevation angle mask determines the lowest angle at which the Acutime tries to track a satellite.

The signal level mask sets the required signal level for a satellite to be used for position fixes.

The PDOP mask sets the maximum PDOP with which position fixes are calculated. The PDOP switch selects the 2-D and 3-D mode. If 4 or more satellites are available and the resulting PDOP is not greater than the PDOP switch value, then 3-dimensional fixes are calculated. The PDOP switch is effective only in the automatic 2-D/3-D mode.

Byte #	Item	Type	Units	Default value
0	Dynamics code	BYTE		3 (see table)

Value	Meaning	Assumed velocity
0	Current value is left unchanged.	
1	land	< 120 knots
2	sea	< 50 knots
3	air (default)	< 800 knots
4	static	stationary

1-4	Elevation angle mask	SINGLE	radians	0.1745 (10 degrees)
5-8	Signal level mask	SINGLE	---	6
9-12	PDOP mask	SINGLE	---	12
13-16	PDOP switch (3-D or 2-D)	SINGLE	---	8

A negative value in a SINGLE field leaves that current setting unchanged.

This information is held in memory.

Mode 4 selection informs the Acutime that it is stationary. Any position fix computed or provided via the data channels is assumed to be accurate indefinitely. When the dynamics code is set to static (byte value = 4) and the fix mode is automatic (set by packet 22 hex), then the Acutime enters automatic 1-satellite mode when a position fix cannot be performed but there is at least one usable satellite. In this mode, no positions or velocities are computed. Instead, the Acutime sends packet 54 hex with the clock bias and bias rate. As long as the Acutime is truly stationary, this mode can be used for time transfer applications and to enable the Acutime to maintain the accuracy of the one PPS (Pulse Per Second) output even if a full position fix cannot be done.

3.3.1.17 2D Request Oscillator Offset

This packet requests the calculated offset of the Acutime master oscillator. This packet contains no data. The Acutime returns packet 4D hex. This packet is used mainly for service. The permissible oscillator offset varies with the particular Acutime unit.

3.3.1.18 2E Set GPS Time

This packet provides the approximate GPS time of week and the week number to the Acutime. The Acutime returns packet 4E hex. The data format is shown below. The GPS week number reference is Week # 0 starting January 6, 1980. The seconds count begins at the midnight which begins each Sunday morning.

Byte #	Item	Type	Units
0-3	GPS time of week	SINGLE	seconds
4-5	GPS week number	INTEGER	weeks

This packet normally is not needed as the internal battery-powered clock keeps time to sufficient accuracy for finding position rapidly.

3.3.1.19 31 Accurate Initial Position (XYZ Cartesian ECEF)

This packet is identical in content to packet 23 hex. This packet provides an initial position to the Acutime in XYZ coordinates. However, the Acutime assumes the position provided in this packet to be accurate. This packet is used for satellite acquisition aiding in systems where another source of position is available and in time transfer (one-satellite mode) applications. For acquisition aiding, the position provided by the user to the Acutime in this packet should be accurate to a few kilometers. For high-accuracy time transfer, position should be accurate to a few meters.

3.3.1.20 32 Accurate Initial Position (Latitude, Longitude, Altitude)

This packet is identical in content to packet 2B hex. This packet provides the Acutime with an approximate initial position in latitude, longitude, and altitude coordinates. However, the Acutime assumes the position provided in this packet to be accurate. This packet is used for satellite acquisition aiding in systems where another source of position is available and in time transfer (one-satellite mode) applications. For acquisition aiding, the position provided by the user to the Acutime in this packet should be accurate to a few kilometers. For high-accuracy time transfer, position should be accurate to a few meters.

3.3.1.21 33 Request A-to-D Readings

Since the Acutime does not have an internal A-to-D chip, this function is not supported.

3.3.1.22 34 Satellite Number For One-Satellite Mode

This packet allows the user to control the choice of the satellite to be used for the one-satellite mode. This packet contains one byte. If the byte value is 0, the Acutime chooses the usable satellite with the highest elevation above the horizon. This automatic selection of the highest satellite is the default action, and the Acutime does this unless it receives this packet. If the byte value is from 1 to 32, the packet specifies the PRN number of the satellite to be used. This selection is not kept in battery-backed memory.

3.3.1.23 35 Set/Request I/O Options

This packet requests the current I/O option states and optionally allows the I/O option states to be set as desired. Please review the discussion in Section 1.2 to help in selection of the right settings. To request the option states without changing them, the user sends only the packet "<DLE> (35 hex) <DLE> <ETX>" with no data bytes included. To change any option states, the user includes 4 data bytes with the values indicated below in the packet. The I/O options, their default states, and the byte values for all possible states are shown below. A glossary is given at the end of the table. These option states are held in battery-backed memory. The Acutime returns packet 55 hex.

Byte #	Parameter Name	Bit Position	Default Bit Value	Option	Associated Packet
0	position	0 (LSB)	1	XYZ ECEF Output 0: off 1: on	42 or 83
		1	0	LLA Output 0: off 1: on	4A or 84
		2	0	LLA ALT Output 0: HAE WGS-84 1: MSL geoid	4A or 84 or 8F-01 or 8F-02
		3	0	ALT input 0: HAE WGS-84 1: MSL geoid	2A
		4	0	precision-of-position output 0: Send single-precision packet 42 and/or 4A. 1: Send double-precision packet 83 and/or 84.	
		5	0	Superpacket output 0: off 1: on	
		6	0	Superpacket format 0: binary 1: ASCII	
		7	0	unused	

Note: If bit 5 is 0 then no Superpackets are output. If bit 5 and 6 are 1 then packet 8E-01 is output. If bit 5 is 1 and 6 is 0 then packet 8F-02 is. If Superpacket output is selected then 8F-01 or 8F-02 packets are output instead of the standard 4A or 84 packets.

Byte #	Parameter Name	Bit Position	Default Bit Value	Option	Associated Packet
1	velocity	0	1	XYZ ECEF Output 0: off 1: on	43
		1	0	ENU Output 0: off 1: on	56
		2-7	0	unused	
2	timing	0	0	time type 0: GPS time 1: UTC	
		1	0	fix computation time 0: ASAP 1: next integer sec	
		2	0	output time 0: when computed 1: only on request	37
		3	0	Synchronized measurements 0: off 1: on	
		4	0	Minimize Projection (V1.14 onwards) 0: on 1: off	
		5-7	0	unused	

Byte #	Parameter Name	Bit Position	Default Bit Value	Option	Associated Packet
3	Auxiliary	0	0	raw measurements 0: off 1: on	5A
		1	0	Doppler smoothed codephase (V1.12 onwards) 0: raw 1: smoothed	
		2	0	Additional Fix Status(V1.14 onwards) 0: off 1: on	5E
		3 - 7		unused	

Glossary for the table above:

ALT:	Altitude
ECEF:	Earth-centered, Earth-fixed
XYZ:	Cartesian coordinates
LLA:	latitude, longitude, altitude
HAE:	height above ellipsoid
WGS-84:	Earth model (ellipsoid)
MSL geoid:	Earth (mean sea level) mode
UTC:	coordinated universal time

3.3.1.24 36 Velocity Aiding of Acquisition

In this packet the user provides velocity information to the Acutime from an external source to aid in satellite acquisition and reacquisition.

Byte	Item	Type	Units
0	Coordinate select	BYTE	

Byte Value	Meaning
0	XYZ
1	ENU (East, North, Up)

Byte	Item	Type	Units
1	Velocity aiding enable flag	BYTE	

Byte Value	Meaning
0	disable velocity aiding
1	enable velocity aiding (See note below.)

Byte Value	Meaning		
2-5	X or East velocity	SINGLE	meters/second
6-9	Y or North velocity	SINGLE	meters/second
10-13	Z or Up velocity	SINGLE	meters/second

If the velocity aiding enable flag is set to "1," the Acutime assumes that the velocity data is accurate to 25 meters per second or better and that it can be used for aiding. The Acutime continues to use this data until another packet 36 hex is sent with the aiding enable flag set to "0" (to disable velocity aiding). Once aiding has begun, the Acutime must be informed (via a new packet 36) of any velocity changes greater than 25 meters per second until velocity aiding is disabled. Once acquisition occurs, the aiding data is ignored; but if acquisition later is lost, then the aiding data is used again.

3.3.1.25 37 Request Status and Values of Last Position and Velocity

This packet requests information regarding the source codes, time of last fix, and GPS week and UTC offset. The Acutime returns packet 57 and the appropriate position packet 42 or 4A, or 83 or 84, and the appropriate velocity packet 43 or 56, based on the I/O options in effect.

3.3.1.26 38 Request/Load Satellite System Data

This packet is not supported by the GPS Software Toolkit - PKTMON. This packet requests current satellite data (almanac, ephemeris, etc.) or permits loading initialization data from an external source (for example, by extracting initialization data from an operating Acutime unit via a data logger or computer and then using that data to initialize a second Acutime unit). The Acutime returns packet 58. (Note that the Acutime can initialize itself without any data from the user; it merely requires more time.)

To request data without loading data, use only bytes 0 through 2; to load data, use all bytes. Before loading data, observe the caution notice below.

Byte #	Item	Type	Byte value	Meaning
0	Operation	BYTE		
			1	Request data from Acutime
			2	Load data into Acutime
1	Type of data	BYTE		
			1	not used
			2	Almanac
			3	Health page, T_oa, WN_oa
			4	Ionosphere
			5	UTC
			6	Ephemeris
2	Sat PRN #	BYTE		
			0	data that is not satellite-ID-specific
			1 to 32	satellite PRN number
3	length (n)		BYTE	number of bytes of data to be loaded
4 to n+3	data		n BYTES	

CAUTION

Proper structure of satellite data is critical to Acutime operation. Dataformat, content, and protocol should be obtained through consultation with Trimble Navigation before use of this feature.

Improper data can cause the Acutime software to lock up immediately after turn on, so that any battery-backed memory cannot be cleared except by removing the battery backup voltage. (The Acutime is not damaged physically by improper data, but it may be unusable until it is serviced.) *Requesting* data is *not* hazardous; *Loading* data improperly *is* hazardous. Use this packet only with extreme caution.

3.3.1.27 39 Set/Request Satellite Disable or Ignore Health

Normally the Acutime selects satellites for use in GPS solution according to whether the candidate satellites are in good health and whether they satisfy the mask values for elevation angle, signal level, and PDOP. This packet allows the user to tell the Acutime either to disable unconditionally the selection of any particular satellite or to ignore the health of any particular satellite that otherwise is acceptable for selection. The Acutime returns packet 59.

It should be noted that when viewing the satellite disables list, the satellites are not numbered but are in numerical order. The disabled satellites are signified by a "1" and enabled satellites are signified by a "0".

Byte #	Item	Type	Byte value	Meaning
0	Operation	BYTE	1	Enable for selection (default)
			2	Disable for selection
			3	Request enable-or-disable status of all 32 satellites
			4	Heed health on satellite (default)
			5	Ignore health on satellite
			6	Request heed-or-ignore status on all 32 satellites
1	Satellite #	BYTE	0	all 32 satellites
			1 to 32	any one satellite PRN number

This information is not held in battery-backed memory. At power-on and after a reset the default values are set for all satellites.

CAUTION

Improperly ignoring health can cause the Acutime software to lock up, as an unhealthy satellite may contain defective data. Generally, such software lock-up is cleared by the Acutime user, although improper data can cause the Acutime software to lock up immediately after turn-on, so that the battery-backed memory cannot be cleared except by instrument service. (The Acutime is not damaged physically by this, but it may be unusable until it is serviced). Use extreme caution in ignoring satellite health.

3.3.1.28 3A Request Last Raw Measurement

This packet requests the most recent raw measurement data for one specified satellite. The Acutime returns packet 5A hex.

Byte #	Item	Type	Byte value	Meaning
0	Satellite #	BYTE	0	All satellites in the current tracking set
			1-32	Desired satellite

3.3.1.29 3B Request Current Status Of Satellite Ephemeris Data

This packet requests the current status of satellite ephemeris data. The Acutime returns packet 5 B hex.

Byte #	Item	Type	Byte value	Meaning
0	Satellite #	BYTE	0	All satellites in the current tracking set
			1-32	Desired satellite

3.3.1.30 3C Request Current Satellite Tracking Status

This packet requests the current satellite tracking status. The Acutime returns packet 5C hex.

Byte #	Item	Type	Byte value	Meaning
0	Satellite #	BYTE	0	All satellites in the current tracking set
			1-32	Desired satellite

3.3.1.31 3D Request or Set Data Channel A Configuration for Differential Corrections

This packet is not supported by the GPS Software Toolkit - PKTMON. This packet requests, and optionally sets, the data channel A configuration for differential corrections. This configuration includes the baud rate, number of bits, parity, and number of stop bits for channel A and also the language mode. When this packet is used only to request the configuration the packet contains no data bytes. When this packet is used to set the configuration, the packet contains the data bytes shown below.

The language mode is defined as follows. For transmission, the language mode specifies whether packets are output on channel A. For reception, the language mode specifies whether packets or RTCM data are received on channel A.(1)

The baud rate for the transmitter and the receiver can be set independently; but the number of bits, parity, and the stop bits are common between them. The default mode is packets for both transmission and reception at 9,600 baud with 8 data bits, odd parity, and one stop bit.

When the language mode for reception is set to RTCM (SC-104), raw RTCM (SC-104) data is accepted on channel A for differential GPS corrections. These corrections are used only if the GPD mode is set to manual GPD or automatic with packet 62.

When a Acutime receives a packet 3D with no data bytes, it responds with packet 3D with current settings.

(1) Note: The default of byte 5 is set to RTCM automatically on start-up, with default settings for the port at; 9600, 8, o, and 1.

Byte	Item	Type	Units			
0	XMT Baud Rate code	BYTE	0:	50	8:	2400
			1:	110	9:	4800
			4:	300	11:	9600
			5:	600	12:	38.4K
			6:	1200	28:	19.2K
1	RCV Baud Rate code	BYTE	0:	50	8:	2400
			1:	110	9:	4800
			4:	300	11:	9600
			5:	600	12:	38.4K
			6:	1200	28:	19.2K

Byte	Item	Type	Units		
2	Parity and # bits/char code	BYTE	xxxpppbb		
			ppp:		
				0:	even parity
				1:	odd parity
				4:	no parity
			bb:		
				2:	7
				3:	8
3	Stop bits code	BYTE	7:	1 stop bit	
			15:	2 stop bits	
4	Language mode for Transmission	BYTE	0:	Packets	
			1:	off	
			5:	NMEA	
5	Language mode for Reception	BYTE	0:	Packets	
			1:	RTCM (SC-104)	

Notes: 1) In most RS232 versions of the sensor, RTCM input for the second channel is the default mode at power-on to allow for direct connection to a radio modem. Note that the default speed is 9600,8,o,1.

2) If the bit is set to 5, then output is standard NMEA ASCII, GGA + VTG. See Appendix 3 for syntax.

This information is held in battery-backed memory. After loss of battery-backed memory, the default values are set.

3.3.1.32 3E Request Additional Fix Parameters

This packet is sent to request the attributes of a position fix, i.e. the number of old measurements used in the fix, whether differential Doppler velocity is available, and whether the fix has converged. The response is Packet 5E. Note also that Packet 35 can be set to request Packet 5E automatically.

3.3.1.33 62 Request/Set Differential Position Fix Mode

This packet requests and optionally sets the differential position fix mode of the Acutime. When this packet is used to request the mode the packet contains no data bytes. When this packet is used to set the mode the packet contains only one data byte to specify the mode. In response, the Acutime always sends packet 82 which contains the current mode.

The following modes can be set:

0	Manual GPS (Differential off) (default)
1	Manual GPD (Differential on)
2 or 3	Automatic

"Manual GPS" (mode 0) sets the Acutime to do position solutions without differential corrections, even if the differential corrections are available.

"Manual GPD" (mode 1) sets the Acutime to do position solutions only if valid differential correction data are available.

"Automatic" (data byte value = either 2 or 3): The Acutime automatically sets itself to mode 2 (differential currently off) if the Acutime is not receiving differential correction data for all satellites in a constellation which meets all other masks; and the Acutime automatically sets itself to mode 3 (differential currently on) if the Acutime is receiving differential correction data for all satellites in a constellation which meets all other masks. Packet 82 which the Acutime sends in response to receiving packet 62, indicates whether the Acutime currently is in mode 2 or 3.

An attempt to set a mode outside this set results in simply requesting packet 82.

The selected mode (manual GPS, manual GPD, or automatic) is held in battery-backed memory.

3.3.1.34 65 Request Differential Correction Status

This packet requests the status of differential corrections for a specific satellite or for all satellites for which data is available. This packet contains only one byte specifying the PRN number of the desired satellite or zero to request all available. The response is a packet 85 for each satellite.

3.3.2 Packets Sent By Acutime To The User

The table below provides the packet ID numbers sent by the Acutime to the user, a short description of each packet, and an indication of when the packet is sent. Details are provided for each packet type in the following sections.

Id (hex)	Description	When Sent			
		Power-up	Automatic	If selected	Response to Packet Number
40	almanac data for specified sat		X		20
41	GPS time	X (1)	X (1)		21
42	single-precision XYZ position	X (2)		X	25, 37
43	velocity fix (XYZ ECEF)			X	37
44	satellite selection, PDOP, mode			X	24
45	software version information	X			1F, 25
46	health of Acutime		X	X	25, 26
47	signal level for all satellites				27
48	GPS system message				28
49	almanac health page for all sats			X	29
4A	single-precision LLA position	X (2)		X	25, 37
4B	machine code/status	X	X		25, 26
4C	report operating parameters				2C
4D	oscillator offset			X	2D
4E	response to set GPS time				2E
54	one-satellite bias & bias rate		X		22
55	I/O options				35
56	velocity fix (ENU)			X	37
57	information about last computed fix				37
58	GPS system data/acknowledge				38
59	sat enable/disable & health heed				39
5A	raw measurement data		X		3A
5B	satellite ephemeris status		X		3B
5C	satellite tracking status				3C
5E	additional fix status			X	3E, 35
5F	severe failure report		X		
82	differential position fix mode				62
83	double-precision XYZ position	X (2)		X	25, 37
84	double-precision LLA position	X (2)		X	25, 37
85	differential correction status				65

Notes: (1) If the current GPS time is not known, this packet is not sent at power-up or automatically.

(2) At turn-on, the Acutime sends packets 42 and 4A if the I/O single-precision-of-position option is selected and sends packets 83 and 84 if the I/O double-precision-of-position option is selected. At power-up, these packets are sent with negative time-of-fix.

3) Channel A is silent unless a request for data is received. The automatic outputs shown above apply only to Channel B.

3.3.2.1 40 Almanac Data Page

This packet provides almanac data for a single satellite. The Acutime sends this packet on request (packet 20 hex) and when the data is received from a satellite. The data format is shown below.

Byte #	Item	Type	Units
0	satellite	BYTE	(identification number)
1	T_zc	SINGLE	seconds
5	week number	INTEGER	weeks
7	eccentricity	SINGLE	(dimensionless)
11	T_oa	SINGLE	seconds
15	i_o	SINGLE	radians
19	OMEGA_dot	SINGLE	radians/second
23	square root A	SINGLE	(meters)1/2
27	OMEGA o	SINGLE	radians
31	omega	SINGLE	radians
35	M o	SINGLE	radians

These symbols are defined in ICD-GPS-200.

T_zc is normally positive. If no almanac data is available for this satellite, then T_zc is negative. T_zc and the week number in this packet refer to the Z-count time and week number at the time the almanac was received. The remaining items are described in the ICD-GPS-200.

3.3.2.2 41 GPS Time

This packet provides the current GPS time of week and the week number. The Acutime sends this packet in response to packet 21 hex and during an update cycle. Update cycles occur every 15 seconds when not doing fixes and occur every 150 seconds when doing fixes.

The data format is shown below.

Byte #	Item	Type	Units
0-3	GPS time of week	SINGLE	seconds
4-5	GPS week number	INTEGER	weeks
6-9	GPS/UTC offset	SINGLE	seconds

Note that GPS time differs from UTC by a variable integral number of seconds. UTC = (GPS time) - (GPS/UTC offset).

The GPS week number reference is Week # 0 starting January 6, 1980.

The seconds count begins with "0" each Sunday morning at midnight. A negative indicated time-of-week indicates that time is not yet known; in that case, the packet is sent only on request. The following table shows the relationship between the information in packet 41, and the packet 46 status code.

approx. time accuracy	time source	sign (TOW)	packet 46 status code
none	no time at all	-	01 hex
unknown	approximate time from real-time clock or packet 2E	+	01 hex
20 to 50 msec + clock drift	time from satellite	+	not 01 hex
full accuracy	time from GPS solution	+	00 hex

Application note:

Acutime has no real-time clock hardware. For the most accurate GPS time, before using the GPS time from packet 41, verify that the packet 46 status code is 00 hex ("Doing position fixes").

3.3.2.3 42 Single-precision Position Fix, XYZ ECEF

This packet provides current GPS position fix in XYZ ECEF coordinates. If the I/O "position" option is set to "XYZ ECEF" and the I/O "precision-of-position output" is set to single-precision, then the Acutime sends this packet each time a fix is computed. The data format is shown below.

Byte #	Item	Type	Units
0-3	X	SINGLE	meters
4-7	Y	SINGLE	meters
8-11	Z	SINGLE	meters
12-15	time-of-fix	SINGLE	seconds

The time-of-fix is in GPS time or UTC as selected by the I/O "timing" option. At start-up, this packet or packet 83 is also sent with a negative time-of-fix to report the current known position. Packet 83 provides a double-precision version of this information.

3.3.2.4 43 Velocity Fix, XYZ ECEF

This packet provides current GPS velocity fix in XYZ ECEF coordinates. If the I/O "position" option is set to "XYZ ECEF, then the Acutime sends this packet each time a fix is computed if selected by the I/O "timing" option. The data format is shown below.

Byte #	Item	Type	Units
0-3	X velocity	SINGLE	meters/second
4-7	Y velocity	SINGLE	meters/second
8-11	Z velocity	SINGLE	meters/second
12-15	bias rate	SINGLE	meters/second
16-19	time-of-fix	SINGLE	seconds

The time-of-fix is in GPS time or UTC as selected by the I/O "timing" option.

3.3.2.5 44 Satellite Selection

This packet provides a list of satellites used for position fixes by the Acutime; the packet also provides the PDOP, HDOP, and VDOP of that set and provides the current mode (automatic or manual, 3-D or 2-D). The Acutime sends this packet in response to packet 24 hex and whenever a new satellite selection is attempted. The Acutime attempts a new selection every 30 seconds and whenever satellite availability and tracking status change. The data format is shown below.

Byte #	Item	Type	Value	Meaning
0	Mode	BYTE	01 hex	Auto, 1-satellite, 0-D
			03 hex	Auto, 3-satellite, 2-D
			04 hex	Auto, 4-satellite, 3-D
			11 hex	Manual, 1-satellite, 0-D
			13 hex	Manual, 3-satellite, 2-D
			14 hex	Manual, 4-satellite, 3-D
1-4	4 satellite numbers	4 BYTES		4 satellite numbers
5-8	PDOP	SINGLE		PDOP
9-12	HDOP	SINGLE		HDOP
13-16	VDOP	SINGLE		VDOP
17-20	TDOP	SINGLE		TDOP

PDOP value of zero indicates that the Acutime is not doing fixes, usually because there are not enough healthy usable satellites for position fixes. In this case, the satellite number list contains up to four of the satellites which are usable. Empty satellite number-bytes contain zero. Negative PDOP values indicate that the PDOP is greater than the PDOP mask value and therefore the Acutime is not performing fixes.

3.3.2.6 45 Software Version Information

This packet provides information about the version of software in the Navigation and Signal Processors. The Acutime sends this packet after power-on and in response to packet 1F hex. The data format is two 5-byte sequences, each of which has the format shown below.

Byte #	Item	Type
0	Major version number	BYTE
1	Minor version number	BYTE
2	Month	BYTE
3	Day	BYTE
4	Year number minus 1900	BYTE

The first 5 bytes refer to the Navigation Processor and the second 5 bytes refer to the Signal Processor.

3.3.2.7 46 Health of Acutime

This packet provides information about the satellite tracking status and the operational health of the Acutime. The Acutime sends this packet after power-on or software-initiated resets, in response to packet 26 hex, during an update cycle, when a new satellite selection is attempted, and when the Acutime detects a change in its health. Packet 4B hex is always sent with this packet. The data format is given in the following table.

Byte #	Item	Type	Byte value	Meaning
0	Status code	BYTE		
			00 hex	Doing position fixes
			01 hex	Don't have GPS time yet
			02 hex	Not used
			03 hex	PDOP is too high
			08 hex	No usable satellites
			09 hex	Only 1 usable satellite
			0A hex	Only 2 usable satellites
			0B hex	Only 3 usable satellites
			0C hex	The chosen satellite is unusable (4)
1	Error codes	BYTE		

The error codes are encoded into individual bits within the byte. The bit positions and their meanings are shown below.

Bit Position	Meaning if bit value = 1
0 (LSB)	Battery back-up failed (1)
1	Signal Processor error (1)
2	Alignment error, channel or chip 1 (1)
3	Alignment error, channel or chip 2 (1)
4	Antenna feed line fault (2)
5	Excessive ref freq. error (3)
6	(Unused)
7 (MSB)	(Unused)

Notes: (1) After this error is detected, its bit remains set until the Acutime is reset.

(2) This bit follows the current status of the antenna feed line fault-detection circuitry. Since Acutime has an integral antenna assembly, this information is of itself of little import; it is only shown here for sake of completeness, being important for sensors with separate antennas.

(3) This bit is "1" if the last computed reference frequency error indicated that the reference oscillator is out of tolerance. (Packet 2D requests the oscillator offset and packet 4D returns the oscillator offset to the user.)

(4) This message occurs when the one-satellite mode is in effect and a specific satellite has been chosen with packet 34 hex but that satellite is unusable.

3.3.2.8 47 Signal Levels for all Satellites

This packet provides received signal levels for all satellites currently being tracked or on which tracking is being attempted (i.e., above the elevation mask and healthy according to the almanac). The Acutime sends this packet only in response to packet 27 hex. The data format is shown below

Byte #	Item	Type
0	Count	BYTE
1	Satellite number 1	BYTE
2- 5	Signal level 1	SINGLE
6	Satellite number 2	BYTE
7-10	Signal level 2	SINGLE
(etc.)	(etc.)	(etc.)

Up to 12 satellite number/signal level pairs may be sent, indicated by the count field. Signal level is normally positive. If it is zero then that satellite has not yet been acquired. If it is negative then that satellite is not currently in lock. The absolute value of signal level field is the last known signal level of that satellite.

The signal level provided in this packet is a linear measure of the signal strength after correlation or de spreading.

3.3.2.9 48 GPS System Message

This packet provides the 22-byte ASCII message carried in the GPS satellite navigation message. The Acutime sends this packet in response to packet 28 hex and when this data is received from a satellite.

The message effectively is a bulletin board from the Air Force to GPS users. The format is free-form ASCII. The message may be blank.

3.3.2.10 49 Almanac Health Page

This packet provides health information on 32 satellites. Packet data consists of 32 bytes each containing the 6-bit health from almanac page 25. First byte is for satellite #1, and so on. The Acutime sends this packet in response to packet 29 hex and when this data is received from a satellite.

Byte #	Item
1	health of satellite # 1
2	health of satellite # 2
.	.
.	.
.	.
32	health of satellite # 32

In each data byte of this packet, a value "0" indicates that the satellite is healthy; all other values indicate that the satellite is unhealthy.

3.3.2.11 4A Single-precision LLA Position Fix

This packet provides current GPS position fix in LLA (latitude, longitude, and altitude) coordinates. If the I/O "position" option is set to "LLA" and the I/O "precision-of-position output" is set to single-precision, then the Acutime sends this packet each time a fix is computed. The data format is shown below

Byte #	Item	Type	Units
0-3	Latitude	SINGLE	radians; + for north, - for south
4-7	Longitude	SINGLE	radians; + for east, - for west
8-11	Altitude	SINGLE	meters
12-15	Clock Bias	SINGLE	meters
16-19	Time-of-Fix	SINGLE	seconds

Altitude is referred to the WGS-84 ellipsoid or the MSL Geoid, depending on which I/O "LLA altitude" option is selected.

The time-of-fix is in GPS time or UTC, depending on which I/O "timing" option is selected.

This packet also is sent at start-up with a negative time-of-fix to report the current known position.

Packet 84 provides a double-precision version of this information.

CAUTION

When converting from radians to degrees, significant and readily visible errors will be introduced by use of an insufficiently precise approximation for the constant p(PI). The value of the constant PI as specified in ICD-GPS-200 is 3.1415926535898.

3.3.2.12 4B Machine/Code ID and Additional Status

The Acutime transmits this packet in response to packets 25 and 26 and following a change in state. In conjunction with packet 46, "health of Acutime," this packet identifies the Acutime and may present error messages. The machine ID can be used by equipment communicating with the Acutime to determine the type of Acutime to which the equipment is connected. Then the interpretation and use of packets can be adjusted accordingly.

Byte #	Item	Type	Value	Meaning
0	Machine ID	BYTE	20	6-channel Acutime
1	Status 1	BYTE		

The error codes are encoded into individual bits within the byte. The bit positions and their meanings are shown below.

Bit Position	Meaning if bit value = 1
0 (LSB)	Synthesizer Fault
1	Battery Powered Time Clock Fault
2	A-to-D Converter Fault (Not Used)
3	The almanac stored in the Acutime, is not complete and current.
4-7	Not used

Byte #	Item	Type	Value	Meaning
2	Status 2	BYTE		Superpackets supported

3.3.2.13 4C Report Operating Parameters

This packet provides several operating parameter values of the Acutime. The Acutime sends this packet in response to packet 2C hex. The data format is shown below.

The dynamics code indicates the expected vehicle dynamics and is used to assist the initial solution.

The elevation angle mask determines the lowest angle at which the Acutime tries to track a satellite.

The signal level mask sets the required signal level for a satellite to be used for position fixes.

The PDOP mask sets the maximum PDOP with which position fixes are calculated. The PDOP switch sets the threshold for automatic 3-D/2-D mode. If 4 or more satellites are available and the resulting PDOP is not greater than the PDOP mask value, then 3-dimensional fixes are calculated.

Byte #	Item	Type	Units	Default
0	Dynamics code	BYTE		

Value	Meaning	Assumed velocity
0	Current value is left unchanged.	
1	land	< 120 knots
2	sea	< 50 knots
3	air (default)	< 800 knots
4	static	stationary

Byte #	Item	Type	Units	Default
1-4	Elevation angle mask	SINGLE	radians	0.1745 or 10°
5-8	Signal level mask	SINGLE	---	6
9-12	PDOP mask	SINGLE	---	12
13-16	PDOP switch (3-D or 2-D)	SINGLE	---	8

A negative value in a SINGLE field leaves that current setting unchanged.

This information is held in battery-backed memory.

3.3.2.14 4D Oscillator Offset

This packet provides the current value of the Acutime master oscillator offset in Hertz at carrier. This packet contains one SINGLE number. The Acutime sends this packet in response to packet 2D hex. The permissible offset varies with the Acutime unit.

3.3.2.15 4E Response to Set GPS Time

Indicates whether the Acutime accepted the time given in a Set GPS time packet. The Acutime sends this packet in response to packet 2E hex. This packet contains one byte.

Value	Meaning
ASCII "Y"	The Acutime accepts the time entered via packet 2E. The Acutime has not yet received the time from a satellite.
ASCII "N"	The Acutime does not accept the time entered via packet 2E. The Acutime has received the time from a satellite and uses that time. The Acutime disregards the time in packet 2E.

3.3.2.17 54 One-Satellite Bias and Bias Rate

The Acutime sends this packet to provide the computed clock-only solution when the Acutime is in the manual or automatic one-satellite mode.

Byte	Item	Type	Units
0-3	Bias	SINGLE	meters
4-7	Bias rate	SINGLE	meters/second
8-11	Time of fix	SINGLE	seconds

The bias is the offset of the Acutime internal time clock from GPS time. Bias is expressed as meters of apparent range from the satellites. It is used to correct the one PPS output. Bias rate is the frequency error of the Acutime internal oscillator. It is expressed as apparent range rate.

CAUTION

For accurate interpretation of the propagation delay, the precise constant for the speed of light must be used. The WGS-84 value for the speed of light is 299,792,458 meters per second.

3.3.2.18 55 I/O Options

This packet provides current I/O options in effect in response to packet 35 request. The data format is the same as for packet 35 hex and is repeated below for convenience.

Byte #	Parameter Name	Bit Position	Bit Value	Default Option	Associated Packet
0	position	0 (LSB)	1	XYZ ECEF Output 0: off 1: on	42 or 83
		1	0	LLA Output 0: off 1: on	4A or 84 or 8F-01 or 8F-02
		2	0	LLA ALT Output 0: HAE WGS-84 1: MSL geoid	4A or 84
		3	0	ALT input 0: HAE WGS-84 1: MSL geoid	2A
		4	0	precision-of-position output 0: Send single-precision packet 42 and/or 4A. 1: Send double-precision packet 83 and/or 84.	
		5	0	Superpacket output 0: off 1: on	
		6	0	Superpacket format 0: binary 1: ASCII	
		7	0	unused	

Note: If bit 5 is 0 then no Superpackets are output. If bit 5 and 6 are 1 then packet 8E-01 is output. If bit 5 is 1 and 6 is 0 then packet 8F-02 is. If Superpacket output is selected then 8F-01 or 8F-02 packets are output instead of the standard 4A or 84 packets.

Byte #	Parameter Name	Bit Position	Bit Value	Default Option	Associated Packet
1	velocity	0	1	XYZ ECEF Output 0: off 1: on	43
		1	0	ENU Output 0: off 1: on	56
		2 - 7	0	unused	
2	timing	0	0	time type 0: GPS time 1: UTC	
		1	0	fix computation time 0: ASAP 1: next integer sec	
		2	0	output time 0: when computed 1: only on request	37
		3	0	Synchronized measurements (V1.14 onwards) 0: off 1: on	

Byte #	Parameter Name	Bit Position	Bit Value	Default Option	Associated Packet
		4	0	Minimize Projection (V1.14 onwards) 0: on 1: off	
		5-7	0	unused	
3	Auxiliary	0	0	raw measurements 0: off 1: on	5A
		1	0	Doppler smoothed codephase (V1.14 onwards) 0: raw 1: smoothed	
		2	0	Additional Fix Status (V1.12 onwards) 0: off 1: on	
		3 - 7		unused	

Glossary for the table above:(from 3.3.2.18)

ALT:	Altitude
ECEF:	Earth-centered, Earth-fixed
XYZ:	Cartesian coordinates
LLA:	latitude, longitude, altitude
HAE:	height above ellipsoid
WGS-84:	Earth model (ellipsoid)
MSL geoid:	Earth (mean sea level) model
ENU:	East-North-up (same as LLA)
UTC:	coordinated universal time

3.3.2.19 56 Velocity Fix, East-North-Up (ENU)

If East-North-Up (ENU) coordinates have been selected for the I/O "position" option, the Acutime sends this packet under the following conditions: (1) each time that a fix is computed; (2) in response to packet 37 hex (last known fix). The data format is shown below.

Byte #	Item	Type	Units
0-3	East Velocity	SINGLE	m/s; + for east, - for west
4-7	North Velocity	SINGLE	m/s; + for north, - for south
8-11	Up Velocity	Single	m/s; + for up, - for down
12-15	Clock Bias Rate	SINGLE	m/s
16-19	Time-of-Fix	SINGLE	seconds

The time-of-fix is in GPS or UTC time as selected by the I/O "timing" option.

3.3.2.20 57 Information About Last Computed Fix

This packet provides information concerning the time and origin of the previous position fix. The Acutime sends this packet, among others, in response to packet 37 hex.

The data format is shown below.

Byte #	Item	Type	Units
0	Source of information	BYTE	---

Value	Meaning
00 hex	none
01 hex	regular fix
02 hex	initialization diagnostic
04 hex	initialization diagnostic
05 hex	entered by packet 23 or 2B
06 hex	entered by packet 31 or 32
08 hex	default position after RAM battery fail

Byte #	Item	Type	Units
1	Manuf. diagnostic	BYTE	---
2-5	Time of last fix	SINGLE	seconds, GPS time
6-7	Week of last fix	INTEGER	weeks, GPS time

3.3.2.21 58 Satellite System Data/Acknowledge from Acutime

This packet provides GPS data (almanac, ephemeris, etc.). The Acutime sends this packet under the following conditions: (1) on request; (2) in response to packet 38 hex (acknowledges the loading of data). The data format is shown below.

Byte #	Item	Type	Byte Value	Meaning
0	Operation	BYTE		
			0	Acknowledge, can't use
			1	Acknowledge
			2	Data Out
			3	No Data on SV
1	Type of data	BYTE		
			1	not used
			2	Almanac
			3	Health page, T_oa, WN_oa
			4	Ionosphere
			5	UTC
			6	Ephemeris
2	Sat PRN #	BYTE		
			0	data that is not satellite-ID-specific
			1 to 32	satellite PRN number
3	length *(n)*	BYTE		number of bytes of data to be loaded
4 to n+3 dat	*n* BYTES			

3.3.2.22 59 Status of Satellite Disable or Ignore Health

Normally the Acutime selects satellites for use in GPS solution according to whether the candidate satellites are in good health and whether they satisfy the mask values for elevation angle, signal level, and PDOP. This packet reads back whether the user has told the Acutime to disable unconditionally the selection of any particular satellite and whether the user has told the Acutime to ignore the health of any particular satellite that otherwise is acceptable for selection. The Acutime sends this packet in response to packet 39 hex. The data format is shown below.

Byte #	Item	Type	Byte Value	Meaning
0	Operation	BYTE		
			3	The remaining bytes tell whether Acutime is allowed to select each satellite.
			6	The remaining bytes tell whether Acutime heeds or ignores each satellite's health as a criterion for selection.
1 to 32	Satellite #	32 BYTES (1 byte per satellite)		(Depends on byte 0 value.)
			0	Enable satellite selection or heed satellite's health. Default value.
			1	Disable satellite selection or ignore satellite's health.

This information is not held in battery-backed memory. At power-on and after a reset, the default values are set for all satellites.

3.3.2.23 5A Raw Measurement Data

This packet provides raw GPS measurement data. If the I/O "auxiliary" option has been selected, the Acutime sends this data automatically as measurements are taken. The Acutime also sends this packet in response to packet 3A hex. The data format is shown below.

Byte #	Item	Type	Units
0	Satellite PRN Number	BYTE	-----
1	Sample Length	SINGLE	msec
5	Signal Level	SINGLE	
9	Code phase	SINGLE	1/16th chip
13	Doppler	SINGLE	Hertz
17	Time of Measurement	DOUBLE	sec

Application Note:

Packet 5A provides the raw satellite signal measurement information used in computing a fix.

The satellite PRN (Byte 0) number is a unique identification for each of the 32 GPS satellites.

The sample length (Byte 1) is the number of milliseconds over which the measurement was averaged. thus if the sample length is 428, then the receiver tracked the satellite and collected the measurement over a 428 millisecond period. Acutime uses a 500 millisecond dwell time per satellite, however, if the channel is sequencing on several satellites, the sample length will be closer to 400 milliseconds due to reacquisition and loop setting times.

The signal level (Byte 5) is a linear approximation of C/N_0 which is stated in antenna amplitude measurement units (AMU's), a Trimble devised unit. An approximate correlation of AMU levels to C/N_0 follows:

5 AMU's ≈ -20 dB SNR

16 AMU's ≈ -10 dB SNR ⇒ or $\text{AMU's} \cong 51 * \sqrt{10^{(\text{SNR} / 10)}}$

26 AMU's ≈ - 5 dB SNR

The C/N_0 is affected by five basic parameters: 1) signal strength from the GPS satellite, 2) receiver/antenna gain, 3) pre-amplifier noise figure, 4) receiver noise bandwidth, and 5) accumulator sample rate and statistics. The approximation is very accurate from 0 to 25 AMU's.

The codephase (Byte 9) value is the average delay over the sample interval of the received C/A code and is measured with respect to the receiver's millisecond timing reference. Thus, it includes all receiver, satellite, and propagation biases and errors. It is expressed in 1/16th of a C/A code chip.

The doppler (Byte 13) value is apparent carrier frequency offset averaged over the sample interval. It is measured with respect to the nominal GPS L1 frequency of 1575.42 MHz, referenced to the receiver's internal oscillator (TCXO). Thus, it includes all receiver and satellite clock frequency errors. It is expressed in Hertz at the L1 carrier.

The time of measurement (Byte 17) is the center of the sample interval and measured by adding the Acutime supplied codephase (modulo mS) to a user determined integer number of mS between user and satellite.

Since the Acutime codephase resolution is 1/16th of a C/A code chip, this corresponds to:

1/16 * C/A code chip ≈ 977.517ns/16 ≈ 61.0948 ns

≈ 61.0948* speed of light, m/s

≈ 18.3158 meter

The integer millisecond portion of the pseudo-range must then be derived by utilizing the approximate user and satellite positions. Rough user position (within a few hundred kilometers) must be known; the satellite position can be found in its almanac / ephemeris data.

Each mS integer corresponds to:

C/A code epoch * speed of light = 1 ms* speed of light, m/s

≈ 300km (approx.)

≈ 299.792458 km (precise)

3.3.2.24 5B Satellite Ephemeris Status

This packet is sent in response to packet 3B and when a new ephemeris (based on IODE) is received. It contains information on the status of the ephemeris in the receiver for a given satellite. The structure of packet 5B is as follows.

Byte #	Item	Type	Meaning or Units
0	SV PRN Number	BYTE	
1-4	Time of Collection	REAL	seconds
5	Health	BYTE	
6	IODE	BYTE	
7	toe	REAL	seconds
11	Fit Interval Flag	BYTE	
12-15	SV Accuracy (URA)	REAL	meters

SV PRN Number is from 1 to 32 representing the satellite PRN number. Time of Collection is the GPS time when this ephemeris data was collected from the satellite. Health is the 6-bit ephemeris health. IODE, toe, and Fit Interval Flag are as described in ICD-GPS-200. SV Accuracy (URA) is converted to meters from the 4-bit code as described in ICD-GPS-200.

3.3.2.25 5C Satellite Tracking Status

This packet provides tracking status data for a specified satellite. Some of the information is very implementation-dependent and is provided mainly for diagnostic purposes. The Acutime sends this packet in response to packet 3C hex. The data format is shown below.

Byte #	Item	Type	Units
0	satellite PRN number	BYTE	number, 1 to 32
1	channel and slot code	BYTE	

This is an internal coding of the hardware tracking channel and of the slot within the channel to which the specified satellite currently is assigned.

Bit Position	Value	Meaning
2 to 0 (LSB)	210	
	000 (LSB)	slot 1
	001	slot 2
	010	slot 3
	011	slot 4
	100	slot 5
	101	slot 6

7(MSB) to 3: channel number, starting with zero

Bits 7-3	Channel	Used by
00000	1	all Acutime
00001	2	6-channel Acutime only
00010	3	6-channel Acutime only
00011	4	6-channel Acutime only
00100	5	6-channel Acutime only
00101	6	6-channel Acutime only
76543		

Byte #	Item	Type	Units
2	acquisition flag	BYTE	

Byte Value	Meaning
0	never acquired
1	acquired
2	re-opened search

3	ephemeris flag	BYTE	

Byte Value	Meaning
0	flag not set
≠0	good ephemeris for this satellite (< 4 hours old, good health)

4-7	signal level	SINGLE	same as in packet 46 hex
8-11	GPS time of last msmt	SINGLE	seconds

Byte Value	Meaning
<0	no measurements have been taken
≥0	center of the last measurement taken from this satellite

12-15	elevation	SINGLE	radians

Approximate elevation of this satellite above the horizon. Updated about every 15 seconds. Used for searching and computing measurement correction factors.

16-19	azimuth	SINGLE	radians

Approximate azimuth from true north to this satellite. Updated typically about every 3 to 5 minutes. Used for computing measurement correction factors.

20	old measurement flag	BYTE	

Byte Value	Meaning
0	flag not set
>0	The last measurement is too old to use for a fix computation.

21	integer msec flag	BYTE	

Byte Value	Meaning
0	don't have good knowledge of integer millisecond range to this satellite
1	msec from sub-frame data collection
2	verified by a bit crossing time
3	verified by a successful position fix
4	suspected msec error

22	bad data flag	BYTE	

Byte Value	Meaning
0	flag not set
1	bad parity
2	bad ephemeris health

23	data collect flag	BYTE

Byte Value	Meaning
0	flag not set
>0	The Acutime currently is trying to collect data from this satellite.

3.3.2.25.5 5E Additional Fix Status

This packet describes attributes of a position fix. The information is requested by packet 3E or sent after each fix if bit 2 of AUX BYTE in packet 35 is set.

BYTE	BIT	Meaning
0	0-2	# of measurements in current fix that were used in a previous fix.
	3	1: No differential doppler velocity available 0: Differential doppler velocity available
	4	1: Fix still converging (when status code = 0, i.e. doing fixes) 0: Fix converged
	5-7	Unused
1	0-2	# of measurements in current fix that are old (3-5 s)
	3-7	Unused

3.3.2.26 5F Failure Report

If a severe failure prevents the Acutime from operating, the Acutime sends this packet at turn-on if the failure does not preclude doing so. Generally, the Acutime sends nothing following this packet. The packet data bytes consist of "02" followed by an ASCII text message which describes the failure.

3.3.2.27 82 Differential Position Fix Mode

This packet provides the differential position fix mode of the Acutime. This packet contains only one data byte to specify the mode.

This packet is sent in response to packet 62 and whenever a satellite selection is made and the mode is Auto GPS/GPD (modes 2 and 3).

The Acutime switches automatically between modes 2 and 3 based on the availability of differential corrections for a constellation which meets all other masks. If such a constellation is not available, then the Acutime stays in its current automatic mode (2 or 3), and does not do position solutions.

Valid modes are:

0	Manual GPS (Differential off)
1	Manual GPD (Differential on)
2	Auto GPS (Differential currently off)
3	Auto GPD (Differential currently on)

"Manual GPS" (mode 0) means that the Acutime does position solutions without differential corrections, even if the differential corrections are available.

"Manual GPD" (mode 1) means that the Acutime only does position solutions if valid differential correction data are available.

"Automatic GPS" (mode 2) means that the Acutime is not receiving differential correction data for all satellites in constellation which meets all other masks, and is doing non-differential position solutions.

"Automatic GPD" (mode 3) means that the Acutime is receiving differential correction data for all satellites in a constellation which meets all other masks, and is doing differential position solutions.

3.3.2.28 83 Double-precision XYZ Position Fix And Bias Information

This packet provides current GPS position fix in XYZ ECEF coordinates. If the I/O "position" option is set to "XYZ ECEF" and the I/O double-precision-of-position option is selected, the Acutime sends this packet each time a fix is computed. The data format is shown below.

Byte #	Item	Type	Units
0-7	X	DOUBLE	meters
8-15	Y	DOUBLE	meters
16-23	Z	DOUBLE	meters
24-31	clock bias	DOUBLE	meters
32-35	time-of-fix	SINGLE	seconds

The time-of-fix is in GPS time or UTC, as selected by the I/O "timing" option. At start-up, if the I/O double-precision-of-position option is selected, this packet is also sent with a negative time-of-fix to report the current known position.

Packet 42 provides a single-precision version of this information.

3.3.2.29 84 Double-precision LLA Position Fix And Bias Information

This packet provides current GPS position fix in LLA coordinates. If the I/O "position" option is set to "LLA" and the double-precision-of-position option is selected, the Acutime sends this packet each time a fix is computed. The data format is shown below.

Byte #	Item	Type	Units
0-7	latitude	DOUBLE	radians; + for north, - for south
8-15	longitude	DOUBLE	radians; + for east, - for west
16-23	altitude	DOUBLE	meters
24-31	clock bias	DOUBLE	meters
32-35	time-of-fix	SINGLE	seconds

The time-of-fix is in GPS time or UTC, as selected by the I/O "timing" option. At start-up, this packet is also sent with a negative time-of-fix to report the current known position.

Packet 4A provides a single-precision version of this information.

CAUTION

When converting from radians to degrees, significant and readily visible errors will be introduced by use of an insufficiently precise approximation for the constant p (PI). The value of the constant PI as specified in ICD-GPS-200 is 3.1415926535898.

3.3.2.30 85 Differential Corrections Status

This packet provides the status of differential corrections for a specific satellite. It is sent in response to packet 65. The format of this packet is as follows:

Byte	Item	Type	Units
0	Satellite PRN number	BYTE	
1	Summary status code	BYTE	
2	Station health	BYTE	
3	Satellite health (UDRE)	BYTE	
4	IODE 1	BYTE	
5	IODE 2	BYTE	
6	Z-count as Time-of-Week	SINGLE	seconds
10	Range correction	SINGLE	meters
14	Range-rate correction	SINGLE	m/sec
18	Delta range correction	SINGLE	meters

The summary status code is encoded as follows:

0	good correction data
1	good delta correction data
2	station health bad (5 or 7)
3	data too old (60 seconds)
4	UDRE too high (>4)
5	IODE mismatch with ephemeris

APPENDIX 1.1

Trimble Standard Interface Protocol (TSIP) Superpackets

1.0 General

Superpackets describes those packets which reduce the I/O traffic with the receiver and facilitate interpretation to a modem or data acquisition device with limited programming facilities.

Note: (1) TSIP Superpackets is incorporated into the firmware revisions 1.14 or newer.
(2) Superpackets are not supported in the PKTMON software kit.

There are two versions of the Superpacket: one ASCII and one binary. The order and contents of the fields are the same in both packets. There is a method for asking the receiver to automatically send Superpackets rather than the current position packet (4A or 84) when a new position is calculated. This is bits 5 and 6 of byte 0 of packets 35 and 55 (set/request I/O options), along with the other position output options. There is also a method for determining whether a receiver supports Superpackets; this is bit 0 of byte 2 of packet 4B.

The packets are:

8E-01	Request last fix with extra information (ASCII)
8E-02	Request last fix with extra information (binary)
8F-01	Last fix with extra information (ASCII)
8F-02	Last fix with extra information (binary)

1.1 Detail

8E-01 Request last fix with extra information

This packet requests packet 8F-01. The data format is shown below.

Byte #	Item	Type	Meaning
0	Sub-packet id	BYTE	Id for this sub-packet (always 01x)

Total length of data in packet is 1 byte.

8F-01 Last fix with extra information

This packet provides information concerning the time and origin of the previous position fix. This is the last-calculated fix; it could be quite old. The Acutime sends this packet in response to packet 8E-01. The data format is shown below.

Byte #	Item	Type	Meaning		
0	Sub-packet id	BYTE	Id for this sub-packet (always 01x)		
1	Info	BYTE	Type of fix. This is a set of bit flags.		
			0 (LSB)	0:	Fix was available
				1:	No fix available
			1	0:	Fix is autonomous
				1:	Fix was corrected with RTCM
			2	0:	3D fix
				1:	2D fix
3				0:	2D fix used last-calc'ed altitude
				1:	2D fix used entered altitude
4-7			unused (always zero)		
2-19	Latitude	ASCII (18)	WGS-84 latitude. Format is left-justified, decimal point included, trailing spaces, units radians. Example: "0.6524622520372 " for a latitude of approximately 37°23'00"N. Southern latitudes would have a leading '-' sign.		
20-37	Longitude	ASCII (18)	WGS-84 longitude. Format is left-justified, decimal point included, trailing spaces, units radians. Example: "-2.12988346385 " for a longitude of approximately 122°02'00"W. Acceptable range is -180 to +180.		
38-55	Altitude	ASCII (18)	Altitude above WGS-84 ellipsoid. Format is left-justified, decimal point included, trailing spaces, units meters. Negative values are allowed.		
56-73	Time	ASCII (18)	Time of fix. Format is left-justified, decimal point included, trailing spaces, units GPS seconds. Negative values are not allowed.		
74-75	Week	INTEGER	GPS time of fix, weeks.		
76-80	PDOP	ASCII (5)	PDOP when fix was calculated. Format is left-justified, decimal point included, trailing spaces, no units. Negative values are not allowed. Example: "5.2 "		
81	SVs	BYTE	Number of satellites used for fix. Will be zero if no fix was available.		
82-end			Repeated groups of 3 bytes, one for each satellite. There may be none of these groups, if no position fix was available. Each group contains:		
0	PRN	BYTE	Satellite number. It is very important to note that this is the number of a satellite that was used in the calculation of the fix. This satellite may or may not currently be being tracked, or may not be reported by packet 44 (satellite selection).		
1-2	IODC	WORD	The low-order byte is thus the IODE. It is very important to note that this is the IODC that was used for the calculation of the position, which is not necessarily the IODC that is now current for the satellite.		

Total length of data in packet is thus 83 + 3*n* bytes, where *n* is the number of satellites.
Note: ASCII has been chosen because it greatly speeds up operation with certain handheld data recording, which use BCD numbers internally.

8E-02 Request last fix with extra information (binary)

This packet requests packet 8F-02. The data format is shown below.

Byte #	Item	Type	Meaning
0	Sub-packet id	BYTE	Id for this sub-packet (always 02x)

Total length of data in packet is 1 byte.

8F-02 Last fix with extra information (binary)

This packet provides information concerning the time and origin of the previous position fix. This is the last-calculated fix; it could be quite old. Acutime sends this packet in response to packet 8E-02. This packet is the same as packet 8F-01, except that the fields are all binary rather than ASCII. The data format is shown below.

Byte #	Item	Type	Meaning
0	Sub-packet id	BYTE	Id for this sub-packet (always 02x)
1	Info	BYTE	Type of fix. This is a set of bit flags. 0 (LSB) 0: Fix was available 1: No fix available 1 0: Fix is autonomous 1: Fix was corrected with RTCM 2 0: 3D fix 1: 2D fix 3 0: 2D fix used last-calc'ed altitude 1: 2D fix used entered altitude 4-7 unused (always zero)
2-9	Latitude	DOUBLE	WGS-84 latitude, units radians.
10-17	Longitude	DOUBLE	WGS-84 longitude, units radians.
18-25	Altitude	DOUBLE	Altitude above WGS-84 ellipsoid, units meters.
26-33	Time	DOUBLE	Time of fix, units GPS seconds.
34-35	Week	INTEGER	GPS time of fix, weeks.
36-39	PDOP	REAL	PDOP when fix was calculated.
40	SVs	BYTE	Number of satellites used for fix. Will be zero if no fix was available.
41-end			Repeated groups of 3 bytes, one for each satellite. There may be none of these groups, if no position fix was available. Each group contains:
0	PRN	BYTE	Satellite number. It is very important to note that this is the number of a satellite that was used in the calculation of the fix. This satellite may or may not currently be being tracked, or may not be reported by packet 44 (satellite selection).
1-2	IODC	WORD	The low-order byte is thus the IODE. It is very important to note that this is the IODC that was used for the calculation of the position, which is not necessarily the IODC that is now current for the satellite.

Total length of data in packet is thus 41 + 3*n* bytes, where *n* is the number of satellites.

Appendix 2

Trimble ASCII Interface Protocol (TAIP) Version 1.02

1.0 General

Trimble ASCII Interface Protocol is a Trimble-specified digital communication interface, based on printable ASCII characters over a serial data link. It supports scheduled and polled responses. Messages may be scheduled for output at a user specified rate starting on a given epoch from top of the hour. For communication robustness, the protocol optionally supports checksum on all messages. It also provides the user with the option of tagging all messages with the unit's previously specified vehicle identification number (ID). This greatly enhances the functional capability of the unit in a network environment. Additionally, given the printable ASCII format of all communication, TAIP is ideal for use with mobile data terminals, seven bit modems and portable computers. Although, sensors incorporating this protocol are shipped from the factory with a specific serial port setting, the port characteristics are fully programmable through TAIP messages. Please refer to the interfacing section of the Operator's Manual for specific default settings.

2.0 Message Format

All communication is done using printable ASCII characters. The interface provides the means to configure the unit to output various sentences in response to query or on a scheduled basis. Each sentence has the following general format:

`>ABB{C}[;ID=DDDD][;*FF]<`

where

>	start of new message,
A	message qualifier,
BB	a two character message ID,
C	data string,
DDDD	optional 4 character vehicle ID,
FF	optional 2 character checksum,
<	the delimiting character.

Notation:

{x}	signifies that x can occur any number of times.
[x]	signifies that x may optionally occur once.

Start of new message

A '>' is used to specify the start of a new sentence.

Message Qualifier

A one character message qualifier is used to describe the action to be taken on the message. The following table lists the valid qualifiers:

Qualifier	Action
Q	Query for a single sentence.
R	Response to a query or scheduled report
F	Scheduled reporting frequency interval in seconds
S	Set command

Message ID

A unique two character message ID consisting of letters of alphabet is used to identify different type messages. Valid message IDs are presented in the tables of section 3.

Data String

The format and length of the data string are dictated by the message qualifier and the message ID. It can consist of any printable ASCII character with the exception of ('>', '<', and ';'). See section 3 for detailed descriptions of message formats. Most messages are length sensitive and unless otherwise specified, field separators including space are not used.

Vehicle ID

A vehicle identifier may optionally be used in all the communications with the unit. Each vehicle may be assigned a four digit ID and be forced to use that in all correspondence. The default vehicle ID is '0000' and the default mode of operation is not to use vehicle ID.

CheckSum

The checksum field provides for an optional two digit hex checksum value, which is computed as XOR of all characters from the beginning of the sentence up to and including the '*'. If provided, the checksum is always the last element of the sentence before the message delimiter. The default mode of operation is to include checksum in sentences.

Message Delimiter

A '<' signifies end of a sentence and is used as message delimiter.

3.0 Message Types

The following table lists all the messages currently supported:

Message ID	Message Name
AL	Altitude/Vertical Velocity
CP	Compact Position Solution
DC	Differential Corrections
DD	Delta Differential Corrections
ID	Vehicle ID
IP	Initial Position
PT	Port characteristic
PV	Position/Velocity Solution
RM	Reporting Mode
ST	Status
VR	Version Number

Each message is described in detail in the following pages.

AL Altitude/Up Velocity

Data String Format:

AAAAABBBBBBCCCCDE

Item	# of Char	UNITS	Format
GPS Time of day	5	Sec	*AAAAA*
Altitude	6	Meters	*BBBBBB*
Vertical Velocity	4	MPH	*CCCC*
Source	1	N/A	*D*
Possible Values:			
GPS 2D	0		
GPS 3D	1		
DGPS 2D	2		
DGPS 3D	3		
Unknown	9		
Age of Data Indicator	1	N/A	*E*
Possible Values:			
Fresh(< 10 sec)	2		
Old (>= 10 sec)	1		
Not available	0		
Total	17		

Altitude is above mean sea level in WGS-84. The GPS time of day is the time of fix rounded to the nearest second. This message contains data obtained from the last 3 dimensional fix and my not be current.

Note:
The data in this message is to be considered invalid and should not be used, if the "Age of Data Indicator" is equal to 0 (signifying data not available).

CP Compact Position Solution

Data String Format:

AAAAABBBCCCCDDDDEEEEFG

Item	# of Char	UNITS	Format
GPS Time of day	5	Sec	*AAAAA*
Latitude	7	Deg	*BBB.CCCC*
Longitude	8	Deg	*DDDD.EEEE*
Source	1	N/A	*F*
Possible Values:			
GPS 2D	0		
GPS 3D	1		
DGPS 2D	2		
DGPS 3D	3		
Unknown	9		
Age of Data Indicator	1	N/A	*G*
Possible Values:			
Fresh(< 10 sec)	2		
Old (>= 10 sec)	1		
Not available	0		
Total	22		

Position is in latitude (positive north) and longitude (positive east) WGS-84. The GPS time of day is the time of fix rounded to the nearest second.

Note:
The data in this message is to be considered invalid and should not be used, if the "Age of Data Indicator" is equal to 0 (signifying data not available).

DC Differential Corrections

This message provides the sensor with differential corrections from RTCM-104 record types 1 and 9. The values are numerical values written out in hex format. So for each byte of data there is a two digit hex number. The format of the data String is as follows:

AAAABBCC{DDEEEEFFGG}

Item	# of Char	Type	UNITS	Format
Modified Z-count	4	WORD	.6 sec	*AAAA*
Station health	2	BYTE	N/A	*BB*
Number of SVs	2	BYTE	N/A	*CC*
The next 5 bytes (10 characters) are repeated for each SV				
SV PRN & health(UDRE)	2	BYTE	N/A	*DD*
Range Correction	4	WORD	RTCM-104	*EEEE*
Range-rate correction	2	BYTE	RTCM-104	*FF*
IODE	2	BYTE	N/A	*GG*

The units and scale factors are as defined by RTCM-104 version 1. The SV PRN and health contains the SV PRN in the lower 5 bits and the health/UDRE/scale factor in the upper 3 bits. Range corrections are scaled by 0.02 meters times 2 raised to the "health" power. Range-rate corrections are scaled by 0.002 meters per second times 2 raised to the "health" power.

DD Delta Differential Corrections

This message provides the sensor with delta differential corrections from RTCM-104 record type 2. The values are numerical values written out in hex format. So for each byte of data there is a two digit hex number. The format of the data String is as follows:

AAAABB{CCDDDD}

Item	# of Char	Type	UNITS	Format
Modified Z-count	4	WORD	.6 sec	*AAAA*
Number of SVs	2	BYTE	N/A	*BB*
The next 3 bytes (6 characters) are repeated for each SV				
SV PRN	2	BYTE	N/A	*CC*
Delta Range Correction	4	WORD	RTCM-104	*DDDD*

The units and scale factors are as defined by RTCM-104 version 1. The health/UDRE/scale factor given for the specific SV in the most recent message "DC" is used. Delta range corrections are scaled by 0.02 meters times 2 raised to the "health" power.

ID Vehicle ID

Data String Format:

AAAA

Item	# of Char	UNITS	Format
Vehicle ID	4	N/A	*AAAA*
Total	4		

Vehicle's unique four character ID. The default at cold start is '0000'.

IP Initial Position

Data String Format:

AAABBBBCCCCC

Item	# of Char	UNITS	Format
Initial Latitude	3	Deg	*AAA*
Initial Longitude	4	Deg	*BBBB*
Initial Altitude	5	10 Meters	*CCCCC*
Total	12		

This is a very coarse initial position that the user can provide to aid the receiver in obtaining its first fix. This is specially useful with receivers that do not have non-volatile (Battery Backed-up) memory. In such cases, every time the unit is powered up, it goes through a complete cold-start and it has absolutely no knowledge of where it is. Providing this message improves performance by decreasing the time to first fix and enhances the accuracy of the initial two dimensional navigation solutions by providing a reference altitude. In case of units with non-volatile memory, sending this message is only helpful if the unit has moved more than 1,000 miles since its previous fix. In either case, the receiver can initialize itself appropriately without any data from the user; It merely requires more time.

Note:
For all the above values, the first character specifies the sign (+/-).

PT Port Characteristic

Data String Format:

AAAA,B,C,D

Item	# of Char	UNITS	Format
Baud Rate (9600,4800,2400,1200,0300)	4	N/A	*AAAA*
# of data bits	1	N/A	*B*: (7 or 8)
# of stop bits	1	N/A	*C*: (1 or 2)
Parity	1	N/A	*D*: N (None); O (Odd); E (Even)
Total	10		

PV Position/Velocity Solution

Data String Format:

AAAAABBBCCCCCDDDDEEEEEFFFGGGHI

Item	# of Char	UNITS	Format
GPS Time of day	5	Sec	*AAAAA*
Latitude	8	Deg	*BBB.CCCCC*
Longitude	9	Deg	*DDDD.EEEEE*
Speed	3	MPH	*FFF*
Heading	3	Deg	*GGG*
Source	1	N/A	*H*
Possible Values:			
GPS 2D	0		
GPS 3D	1		
DGPS 2D	2		
DGPS 3D	3		
Unknown	9		
Age of Data Indicator	1	N/A	
Possible Values:			
Fresh(< 10 sec)	2		
Old (>= 10 sec)	1		
Not available	0		
Total	30		

Position is in latitude (positive north) and longitude (positive east) WGS-84. Heading is in degrees from True North increasing eastwardly. The GPS time of day is the time of fix rounded to the nearest second.

Note:
The data in this message is to be considered invalid and should not be used, if the "Age of Data Indicator" is equal to 0 (signifying data not available).

RM Reporting Mode

Data String Format:

[;ID_FLAG=*A*][;CS_FLAG=*B*][;EC_FLAG=*C*]

Item	# of Char	UNITS	Format
ID Flag	1	N/A	*A*: T (TRUE) or F (False)
CS Flag	1	N/A	*B*: T (TRUE) or F (False)
EC Flag	1	N/A	*C*: T (TRUE) or F (False)

ID Flag dictates whether the unit is to include the vehicles ID with each report. CS FLAG dictates whether the unit is to include a checksum as part of each message.

When the EC Flag is set, the unit will echo back all complete and properly formatted set commands, except for DC and DD, with a "Response" qualifier. This provides an easy way to verify that the unit did in fact receive the intended data. The default value at start-up for ID flag is false and for CS and EC flags is true.

ST Status

Data String Format:

AABBCCDDEE

This message provides information about the satellite tracking status and the operational health of the receiver. This information is contained in five status bytes which are output as five 2 digit hexadecimal values. The data format is given in the following table.

Byte #	Item	Byte Value	Meaning
1	Tracking Status Code		
		00 hex	Doing position fixes
		01 hex	Don't have GPS time yet
		02 hex	Not used
		03 hex	PDOP is too high
		08 hex	No usable satellites
		09 hex	Only 1 usable satellite
		0A hex	Only 2 usable satellites
		0B hex	Only 3 usable satellites
		0C hex	6-Ch units only: The chosen
satellite			is unusable.

2 Error Codes-- Byte 1

The error codes are encoded into individual bits within the byte. The bit positions and their meanings are shown below.

	Bit Position	Meaning if bit value = 1
	0 (LSB)	Battery back-up failed (Note 1)
	1	Signal Processor error (Note 1)
	2	Alignment error, channel or chip 1 (Note
1)		
	3	Alignment error, channel or chip 2 (Note
1)		
	4	Antenna feed line fault (Note 2)
	5	Excessive ref. freq. error (Note 3)
	6	(Unused)
	7 (MSB)	(Unused)

3 Machine ID

4 Error codes -- Byte 2

The error codes are encoded into individual bits within the byte. The bit

positions and their meanings are shown below.

Bit Position	Meaning if bit value = 1
0 (LSB)	Synthesizer Fault
1	Battery Powered Timer/Clock Fault
2	A-to-D Converter Fault
3	The stored almanac is not complete and current.
4-7	Not used

5 Not used; for future expansion

Total message length 10 characters

Notes: (1) After this error is detected, its bit remains set until the receiver is reset.

(2) This bit follows the current status of the antenna feed line fault-detection circuitry, if fitted. The normal configuration of the Acutime excludes this option.

(3) This bit is "1" if the last computed reference frequency error indicated that the reference oscillator is out of tolerance.

(4) A-to-D Converter is not normally fitted; the unit will therefore always be set to 1.

VR Version Number

Data String Format:

XXXXXXX VERSION *A.BB (CC/CC/CC)*

Item	# of Char	UNITS	Format
Product Name	n	N/A	N/A
Major version number	1	N/A	*A*
Minor version number	2	N/A	*BB*
Release Date	8	N/A	*CC/CC/CC*

Note: The length of this message may change in later revisions and therefore should not be assumed fixed.

4.0 Communication Using TAIP

Communication with the unit takes place in four different ways. Message qualifiers are used to differentiate between these.

Query for a single sentence

The format is

>Q*AA*[;ID=*BBBB*][;**CC*]<

Sending this sentence to the unit queries the unit for an immediate response with message specified by the two digit message ID *AA*. Messages supported by this qualifier are AL, CP, IP, PT, PV, RM, ST, and VR.

Scheduled reporting frequency interval

The format is

>F*AABBBBCCCC*[;ID=*DDDD*][;**FF*]<

Sending this sentence to the unit tells the unit to report message specified by the two digit ID *AA* at the time interval of *BBBB* seconds with time epoch at *CCCC* seconds from top of the hour. Specifying time interval of 0000 stops scheduled reporting of the message. The default is 0000 time interval for all messages except PV. The output frequency for PV at cold-start is set at once every five seconds, zero seconds from top of the hour. Messages supported by this qualifier are AL, CP, IP, PT, PV, RM, ST, and VR.

Note that what is specified by this qualifier is the timing of the message output and may be different from the time tag of the data in the message.

The Response to a query or scheduled report

The response(R) qualifier carry various types of data between the unit and the user equipment. It's format is

>R*AA*[{*B*}][;ID=*CCCC*][;*DD]<

where *AA* is the two character message ID and {*B*} specifies the data string within the message. For the format of {*B*}, please refer to the message definitions in the previous section. Messages supported by the response qualifier are AL, CP, IP, PT, PV, RM, ST, and VR.

The Set qualifier

The set (S) qualifier enables the user equipment to initialize/set-up various types of data in the GPS unit. The format is

>S*AA*[{B}][;ID=CCCC][;*DD]<

where AA is the two character message ID and {B} specifies the data string within the message. For the format of {B}, please refer to the message definitions in the previous section. Note that all the messages have very specific formats and are length dependent. Messages supported by the set qualifier are AL, CP, DC, DD, ID, IP, PT, PV, and RM.

Appendix 3

NMEA Protocol

1.0 Introduction

The NMEA 0183 Standard is produced by the National Marine Electronics Association, the latest of which is Version 2.00, published January 1992. The NMEA 0183 Standard is therefore primarily designed for marine instrumentation to communicate with each other using an ASCII sentence library with one TALKER and one or more LISTENERS. The Standard also implies the use of EIA RS-422 serial protocol with talker and listeners in parallel on a twisted pair line.

NMEA 0183 has also been partially adopted by other industries requiring a simple data protocol. It is therefore possible to find NMEA 0183 sentences being used for data transmission of position and direction using either RS-422 or RS-232 electrical protocols, as well as other more specialized telemetry links.

The standard transmission protocol for NMEA is as follows:

Baud Rate:	4800
Data Bits:	8 (d7=0; MSB)
Parity:	None
Stop Bits:	1

NB. TSIP uses Odd parity.

NMEA 0183 protocol is available therefore with the Acutime unit as well as the Acutis 6 series of GPS sensors. The Acutime uses the GGA and VTG or GSA sentences and normally acts as a TALKER , i.e. it will produce the GGA and VTG (18637-70 or -72) or GSA (18637-82) sentences automatically once per second or better. External NMEA control (LISTENER) over the output is available to special order. The possible range of sentences covers the following:

ALM
GGA
GSA
GSV
RMC
VTG
ZDA

Certain TSIP packets may be sent also through the second serial channel. These can be used for instance to switch the Acutime into 2-D mode using hex packet 22 or to change the baud rate (Packet 3D). Since the Acutime has no internal battery backed memory the TSIP settings should be loaded every time the unit is powered up. Similarly the RS-232 version of Acutime may optionally receive DGPS corrections using RTCM SC104 formats.

2.0 NMEA 0183 Supported Sentences (18637-70/72)

2.1 GGA - GPS Fix Data

GGA provides the most comprehensive information for a GPS fix within the Standard, hence its choice. Format is as follows:-

$GPGGA,hhmmss.ss,llll.lll,a,yyyyy.yyy,a,Q,NN,H.H,A.A,M,G.G,,M,T.T,RSID*CS<CR><LF>

Where:

Field	Description	Fixed/Var.
$	Start of Sentence	Fix
,	Field delimiter	Fix
.	Decimal point	Fix
*	Checksum delimiter	Fix
CS	Checksum of sentence - hex value*	Fix
<CR><LF>	End of Sentence	Fix
GPGGA	GGA address field	Fix
hhmmss.ss	UTC of position fix	Fix- secs only
llll.lll	Latitude - degrees/decimal degrees	Fix
a	N/S or E/W marker	Fix
yyyyy.yyy	Longitude - degrees/decimal degrees	Fix
Q	Quality Indicator	Fix
	0 Fix not available or invalid	
	1 GPS fix	
	2 DGPS fix	
NN	No. of satellites used in the fix	Fix
H.H	HDOP (3 satellites),PDOP (4 satellites)	Fix
A.A	Antenna Altitude (aboveMean Sea Level - MSL)	Var
M	Units of altitude (meters)	Fix
G.G	Geoid - ellipsoid separation (meters)	Var
T.T	Age of DGPS correction data - seconds	Var
RSID	DGPS Reference Station ID (0000 - 1023)	Fix

Notes:

1) Some fields are fixed and others are variable; if the data is being input via serial port to a data acquisition device and the serial port buffer may get overloaded from time to time, then the checksum should be used as a method of verifying good data being received.

2) The checksum is computed by exclusive OR of the 8 data bits (no start or stop bits) of each character in the sentence between, and not including, $ and *. The exclusive OR is itself computed by successive comparisons of the 8 data bits of each character with the result from the previous comparison. The process is started by exclusive OR result of the first two characters being computed, and is then carried out with the third character, and so on through the character string until the process is complete. The end result is then divided into the four most significant and least significant 4 bits which are then converted to two ASCII characters (0 to 9 and A to F)

3) Always parse the sentence identifier (GGA for instance) to check the right sentence is being read. There may be occasions where identical sentences are sent in succession due to the interrupt handling structure of the Acutime.

4) Some simpler NMEA listener devices are not always able to cope with 1 second input data rates ; a 5 second option is available with the standard Acutis 6 unit (18637-10) and this should be considered as an alternative specification in the event of difficulty.

2.2 VTG - Track Made Good and Ground Speed

$GPVTG,t.t,T,m.m,M,s.s,N,k.k,K*CS<CR><LF>

Where:

Field	Description	Fixed/Var.
$	Start of Sentence	Fix
,	Field delimiter	Fix
.	Decimal point	
*	Checksum delimiter	Fix
CS	Checksum of sentence - hex value	Fix
<CR><LF>	End of Sentence	Fix
t.t	Track - degrees true	Var
T	True indicator	Fix
m.m	Track - degrees magnetic	Var
M	Magnetic indicator	Fix
s.s	Speed over ground - knots	Var
N	Knots indicator	Fix
k.k	Speed over ground - km/hr	Var
K	Km/hr indicator	Fix

Appendix 4

Acutime RS-422 / RS-232 Connection Table

Introduction

The Acutime antenna / receiver is provided with a Conxall cable connector (P/N 19360-50) with the connections shown as below. The RS422 version has one bi-directional serial data channel whereas the RS232 version has one and a half channels, the second being a receive only for DGPS corrections, etc. No flow control is available on either the RS422 or RS232 versions. Each channel responds to the TSIP protocol (see Appendix 1 for definition).

The connections are detailed for the Conxall cable connector (P/N 19360-50); this is designed with 7 conductors which can be terminated in any convenient manner, e.g. either DB-9 or DB-25 connectors for interfacing. The 5th and 7th connector provide access to DC power and external memory backup voltage to maintain almanac when the main power is disconnected.

Standard Cable Arrangement - RS 422

I / O Cable Color Code

Acutime Connection	Wire Color	Function
Pin 1	Orange	Receive +
Pin 2	Brown	Transmit -
Pin 3	Yellow	Transmit +
Pin 4	Violet	Receive -
Pin 5	Blue	1 PPS / Memory Backup
Pin 6	Black	Ground
Pin 7	Red	Power

Standard Cable Arrangement - RS 232

I / O Cable Color Code

Acutime Connection	Wire Color	Function
Pin 1	Orange	RXD (Receive Data)
Pin 2	Brown	RXD (DGPS corrections I / P)
Pin 3	Yellow	TXD (Transmit Data)
Pin 4	Violet	Signal Ground
Pin 5	Blue	1 PPS / Memory Backup
Pin 6	Black	Power ground
Pin 7	Red	Power

APPENDIX 5

Functional Characteristics

1 Acquisition

The Acutime acquisition and tracking process features the ability to determine position without any position initialization. The receiver tracks up to 8 satellites and automatically selects the best 4 of those satellites for computing position. As the satellites move, Acutime automatically begins tracking new satellites and continues to select the best satellites for computing position.

The following sections describe the acquisition, tracking, and GPS solutions performance of the Acutime receiver / antenna . These assume the availability of an external battery back up being connected. Where no backup is available then the unit must first acquire time and then almanacs and ephemerides from the satellites. This may take up to 12.5 minutes (see below), but an average time is 2.5 - 3.5 minutes.

Upon applying power to the system, the sensor begins a search for satellites that are expected to be above the horizon. This calculation is based on the battery-backed almanac of satellite orbits, an estimate of current position (using the receiver's last calculated fix or manual user input), and the current time from the self-contained, real-time clock. If this information is reasonably accurate (position within 1,000 km, time within 5 to 10 minutes), then rapid acquisition of the available satellites occurs. Once locked, if the elapsed time from the previous fix taken by the Acutime unit is more than one hour, current satellite ephemeris must be collected from the data message of each satellite. If the required number of satellites is being tracked and the ephemeris data for each is current, then the user position and velocity solution is performed. (For 3-dimensional positioning a minimum of 4 satellites are required and 3 satellites are required for 2-dimensional positioning.)

The time required for Acutime to acquire satellites, and to calculate position and velocity, is dependent upon a number of factors. Primarily, it depends on whether the unit has a representative satellite almanac in battery-backed memory, the time elapsed since the previous operating fix, and the distance the unit has been moved since the last operating fix.

If Acutime has current almanac and current ephemeris (collected from the GPS satellites being tracked) and has not been moved a great distance (approximately 1,000 km) since its last fix, then, after power-up, Acutime acquires the satellite and position and velocity solution occur, all within 1 minute.

The subsequent paragraphs describe processes that lengthen time to first fix, the circumstances under which they are required, and the approximate time impact.

Almanac:

The satellite almanac consists of approximate orbit parameter data to aid the sensor in satellite acquisition. This data is held in battery-backed random access memory (RAM) in the sensor. Initial turn-on after manufacture, back-up battery failure or non connection, or usage after a significant constellation change are circumstances that would require collection of a new almanac via the satellite data message. This process requires 30 seconds for each satellite and 12.5 minutes for all 32 satellites. (This is because some 30-second data frames contain 2 satellite almanacs.) However, depending on the order of satellite almanacs in the data message, the almanacs for satellites currently above the horizon may be obtained before cycling through all existing satellites. Therefore, collection of almanac data to allow acquisition requires from 2 to 12.5 minutes.

Note that a complete almanac is not required for the Acutime to do position and velocity fixes.

Ephemeris:

The satellite ephemeris provides an accurate estimate of satellite position at any given time. This data, like the almanac, is held in battery-backed RAM and is collected from the satellites on roughly an hourly basis during operation. Should the satellite tracking be interrupted for more than an hour (due to either signal blockage or the Acutime being turned off), the sensor requires the collection of new ephemeris before a solution is made. Collection of this data requires 30 seconds for 4 satellites (the number required for a 3-D solution).

Receiver Initial Reference Position: At power-on, to estimate the proper frequencies and determine which satellites are above the horizon, Acutime uses the almanac, time, and an estimate of current position. By default, the sensor uses the last calculated position stored in memory. Alternatively, the user can input a position estimate. If the initial reference position is sufficiently accurate, the satellite doppler frequency shifts are accounted for correctly and acquisition occurs rapidly (in a matter of seconds). However, if the search does not yield acquisition at the expected frequencies, the frequency search is expanded around the expected frequency for each of the satellites that the sensor believes is above the horizon.

The receiver does not require an initial position to acquire satellites and to perform GPS solutions. A completely uninitialized Acutime has the ability to determine its position autonomously. Under certain circumstances, the processor executes a special acquisition algorithm. This is a process whereby the receiver uses the initial position stored in memory only as a starting place for doppler search calculations, but the position is not implicitly trusted. This process is invoked whenever the position stored in memory is not a GPS-calculated position (i.e., was user-entered) or when sufficient time has passed since the last fix such that, based on expected host vehicle velocity, the receiver could have moved more than 150 km.

This process searches the expected satellite doppler shifts based on the initial position estimates. If the expected satellites are not found, then the effective elevation mask is lowered to allow the receiver to search for other PRN codes for satellites supposedly below the horizon. (The term "PRN" refers to "pseudo-random noise." Each GPS satellite generates its own distinctive PRN code, which is modulated onto its carrier. The PRN code serves as identification of the satellite, as a timing signal, and as a subcarrier for the navigation data.) This mode does not have a significant impact on the time to first fix if indeed the initial position in memory is a reasonable estimate of true position. If no satellite is acquired after the Acutime has searched for 5 minutes, then other satellites are substituted into the satellite search set. Each satellite is given 5 minutes before another is tried. Eventually all 32 satellites are tried, and the process starts again. After one satellite is acquired, it can provide accurate time, rough position, and updated almanac data if needed. If the position is in extreme error, then the search process could add up to 15 minutes to the time to first fix.

Signal Interruption:

During Acutime operation, should the signal be interrupted (by antenna blockage or disconnect, etc.), the reacquisition time is dependent on events during the interruption.

When tracking lock has been lost on a satellite for more than 15 seconds, then a frequency search is begun. Acutime makes use of the information that it has about the user and the satellite to direct the center and width of the search. Every 15 seconds until lock is reacquired, a new center and maximum width is computed, and the search range is expanded in 300 Hz steps towards this maximum width. Code search at a given frequency takes about one second and occurs automatically.

If the Acutime internal clock oscillator error is known, it is compensated for. If not, then the maximum search width is set large enough to allow for oscillator tolerance, aging, and temperature errors.

If ephemeris or almanac data is available for the satellite, then its velocity is incorporated into the center frequency. The reduced accuracy of the almanac data is accounted for in the width. If neither is available, then the doppler at last lock is used for 2 minutes. After that, the maximum doppler at last lock is used for 2 minutes. After that, the maximum doppler expected due to a satellite motion is used.

If Acutime is doing velocity fixes or velocity aiding is being provided, then doppler due to this motion is used. If not, the dynamics code is used to determine the maximum doppler expected. In addition, if position is not known accurately, the search width is increased appropriately.

The user should realize that obstructions, shading, and satellite transmission interruptions can degrade the signal reception and lengthen acquisition times.

2 Position and Velocity Solution

The position and velocity, along with the time tag of the measurement, are digitally output over the communication channel in the formats described in the TSIP protocol (which see). The position data is 3-dimensional and is available in X-Y-Z or latitude-longitude-altitude (LLA) coordinate frames. Velocity data also is 3-dimensional, available in X-Y-Z or East-North-Up coordinate systems. Position and velocity time tags can be output as GPS time or UTC (Coordinated Universal Time) at user specification. The GPS solutions are computed at typically less than one second intervals. Position and velocity solutions are independent and do not undergo Kalman filtering.

3 Dynamic Capability

The following specifications are the operational dynamic limits Acutime operation (please note that these may exceed the mechanical limitations of the boardset or housing in some versions)

Velocity:	The velocity of the user is limited to 400 m/s (~800 knots) for proper Acutime operation.
Acceleration:	4 g or 39.2 m/s/s
Jerk:	The rate of change of acceleration is not to exceed 2 g/s.

Please refer to Trimble Navigation Engineering Dept. if power spectral densities of greater than 0.01g2/sec of vibration in any plane are foreseen during normal operation.

APPENDIX 6

DIFFERENTIAL GPS BACKGROUND

INTRODUCTION

This appendix gives the essential background to the GPS system, discusses the error sources and corrections, as well as a general insight into the communications needs.

Differential GPS has been conceived as a method of providing increased accuracy from the system; it is simply the measurement of the errors at a reference station and making them available to correct the readings of a mobile station. The idea of differential operation of a navigation system is not new; it has been used with every earlier generation of radio positioning systems such as Loran and Omega. It is particularly appropriate for the GPS system, however, since the signals are derived from distant satellites; thus the errors over a wide area will remain common to a first approximation.

SATELLITE INFORMATION

Each satellite in orbit broadcasts a continuous stream of information which can be summarized as:

- The Satellite Position
- Position and Health of Other Satellites
- Satellite Time
- Satellite Clock Errors
- Ionospheric Corrections

The first stage in the navigation process is to measure the distance between the satellite and the receiver; crudely the receiver does this by measuring the time delay between the transmission of a signal from the satellite and its reception and converting it to a distance. If the position of the satellite is known then a rough measure of the range from the satellite is obtained. Theoretically if three ranges are available from three satellites then it should be possible to fix the position of the receiver in three dimensions, but this ignores the fact that the receiver itself is made by man and has its own arbitrary time error. Thus we have 4 unknowns, X, Y, Z, and the Receiver Time Error. One needs therefore information from 4 satellites to solve the instantaneous position of the receiver satisfactorily. If one is at sea or some other environment where the height is known accurately then it is possible to obtain the position with 3 satellites only.

SATELLITE POSITION

Each satellite is a body orbiting in space and subject to the laws of gravity and planetary motion first laid out by Johannes Kepler, the great German astronomer nearly four hundred years ago. His methods are still used today to describe satellite orbits. The information on satellite orbits is divided into two parts:

- Almanac Data - The approximate orbit parameters for each satellite

- Ephemeris - Detailed orbit parameters

Almanac data is broadcast by each satellite for all other satellites in orbit and Ephemeris Data is broadcast by each satellite periodically, usually updated every hour. If the receiver has up to date information then it can calculate the instantaneous position of that satellite to a high degree of precision, normally within 40 meters (disregarding the effects of Selective Availability), a remarkable feat considering that each satellite is moving at 4,500 meters per second.

SATELLITE CLOCKS

All of the satellite clocks are synchronized by reference to a master standard based at the U.S. Naval Observatory in Washington. Again, because the satellite clocks are made by human hand there are inconsistencies and errors between satellites. The ground station at Colorado Springs monitors the performance of the satellite clocks continuously and periodically sends the corrections back to each satellite which in turn broadcasts the new corrections to every receiver. Satellite clocks are a source of error and will lead to loss of accuracy unless these corrections are made. There is still a certain level of error and DGPS helps in removing it.

ATMOSPHERIC ERRORS

The signals from each satellite are transmitted a distance of approximately 20,000 kilometers to the GPS receivers on or near the surface of the Earth. During their passage they are affected by the ionosphere and troposphere. The ionosphere is the most tenuous part of the atmosphere surrounding the earth and has a major effect on all radio transmissions, e.g. fading on short-wave radios. Satellite signals are equally affected, the practical result being that the signal is refracted, i.e. it effectively takes a longer path through the ionosphere than the direct line of sight. This effect may be up to 10 meters of error.

The reason for this is due to the solar wind, the practical effect of which we see in northern latitudes as the Aurora Borealis. Charged particles are emitted from the sun's surface and are ejected into space, being attracted to the Earth by its magnetic field. The particle streams appear high over the North Pole and are dispersed through the ionosphere along the lines of magnetic force, rather like iron filings aligning themselves to a magnet. The streams of charged particles are extremely variable in quantity even over short periods of time and the physicists have found that the total electron content (TEC) in any area is a good measure of the delay due to the ionosphere. The GPS system is extremely clever in that it attempts to predict the effects of the ionosphere and part of the information broadcast by the satellite is the correction which needs to be made for this. However, the broadcast corrections are not 100% effective and it has been found particularly over the last year with high sun spot activity that the pseudoranges (the approximate distance to the satellite) can be more than 10 meters in error.

The troposphere is the lower part of the atmosphere, dense enough to contain substantial amounts of water vapor. Water vapor has an influence on the signals from satellites, appearing to refract them so they take a longer path. The water content of the troposphere, can be measured but it is not homogeneous; it is possible however to model the effect in a straight forward way. Hence the troposphere is not a significant source of error, being significant only for high precision surveying.

SELECTIVE AVAILABILITY

As if natural phenomena were not enough, the DOD has helped along the process by introducing Selective Availability which adds to the errors in two ways:

1. Modify the apparent position of the satellite
2. Introduce some noise into the satellite clock

In the extreme these errors, natural and man made, can add up to many tens of meters if they were all to work in the same sense at the same time. The DoD definition of accuracy is 100 meters 2 dimensional 95% of the time. The errors for the other 5% of the time are not defined! At present (August 1992) the satellite constellation is not complete and therefore periods of significantly greater error can occur due to less than perfect geometry, leading to high PDOP's (a measure of the satellite constellation geometry at any instant for a given location). Differential GPS was conceived in order to get around these problems by monitoring these errors and making the corrections available.

ERROR CORRECTIONS

How therefore, do we get around the errors? The principle is very simple; if a receiver is mounted at a point with known coordinates, the difference between the position measured at any instant and the reference information will give an error figure. The errors can be set off against the measurements at the mobile stations to give a better measurement. The simplest method is to calculate the difference in latitude and longitude and height; there are several restrictions to this, the most important of which is that the reference and mobile stations must be using the same satellites for the errors to be applicable. A more correct method is to calculate the difference in the measured pseudorange and the reference pseudorange for each satellite, making available that error to correct the readings at each of the mobile stations.

The decision on how and when these corrections are applied to the mobile station becomes economic; if they are required soon after they are available at the reference station in order to correct the navigation position of the mobile stations, then a telemetry system is required with concomitant costs and organizational needs. If they are not needed at that instant in time then the data at each point has to be recorded and brought together afterwards in some form of post-processing operation. The cost of the second method of approach is obviously much less than the first. We shall refer to real time and post processing as handy acronyms for each of the methods.

The distance between the reference station and the mobile station is a major consideration; a good initial assumption is that the errors at both stations are the same and this is largely true over short distances. Over longer distances (50 km) the picture becomes more complicated and we need to look at the various sources of error in more detail.

Satellite clock errors will remain the same however far the reference and mobile stations are apart. Errors in the satellite position or ephemeris will depend on the direction in which the satellite is traveling with respect to the reference and mobile stations; if it is traveling in a direction which lies roughly along the axis between the two then the effect will be very little; if it is at right angles then the effect will be considerable.

Both the ionosphere and the troposphere will add errors into the measurement; in periods of high ionospheric activity the error can vary very rapidly. This variation is more difficult to cope with because it depends not only on the time but on the slice of the ionosphere through which the signals are received. If at a given time the observer is using satellites which are low in both the northern and southern sectors of the sky, the signals are received through parts of the ionosphere which may be quite different in their characteristics. If one is after the highest precision for critical operations in the offshore industry for instance it may be necessary to use more than one reference station to minimize the effects of the ionosphere.

SELECTIVE AVAILABILITY CORRECTION

We have now lived with the full effects of Selective Availability; it was used for 5 months in 1990 and has been in full operation for nearly a year. The U.S. Air Force has stated that the GPS System is experimental until it is declared operational in 1993; position errors of well over 100 meters and residual velocities of up to 2 meters per second have been observed . From the discussion thus far one can, however, draw comfort from the conclusion that deliberately induced clock errors will be effectively removed by the use of DGPS.

GPS RECEIVERS

The precision obtained is dependent in part on the choice of GPS equipment used. The lowest cost GPS equipment such as the Trimble Acutime, SVeeSix or Navtrac XL unit is a 6 channel parallel/sequencing type of receiver where the four satellites used in the current navigation solution each occupy one channel and up to 4 more satellites are switched successively to the remaining two channels of the receiver. Higher capacity receivers such as the Trimble 4000 DL II unit, are fitted with multiple channels (either 9 or 12) which allow a channel to remain dedicated to a satellite for long periods of time. The pseudorange measurements are therefore more accurate. These units contain more hardware and firmware (the software required to drive the receiver) and therefore cost more, consume more power, and are bulkier.

The lowest cost installations therefore use parallel / sequencing receivers and the higher cost units use multiple channel receivers. As a rule of thumb a pair of parallel/sequencing receivers operating at both the reference and mobile stations will give results of between 5 and 15 meters with a separation of 100 kilometers, whereas a pair of parallel channel receivers will give an error of between 2 and 5 meters at the same distance.

To provide a real time service is a balance between cost precision and timeliness. From the analysis above it is clear that a multi-channel receiver will normally provide better accuracy than a sequencing receiver. Therefore they are the receiver type of choice where precision is the main criterion. Multi-channel receivers such as the Trimble 4000 DL II are therefore widely used in the offshore industry and increasingly for hydrographic and environmental work, being used for both mobile and reference stations. Most receivers , including all Trimble units, are now designed to take in DGPS corrections using the RTCM protocol and provide a corrected position.

DATA COMMUNICATIONS

Data communications is the art of getting the information you require from one point to another with the highest reliability and the lowest possible cost. In practice most of the work associated with a real-time DGPS system is concerned with the organization and infra-structure for communicating the data; it is an area with a plethora of conflicting cost, technical and regulatory factors caused for the most part by the restricted frequency spectrum available and the many competing potential users. As soon as a satisfactory solution has been worked out for a given area of the world one finds that, because of different government regulations, it sometimes has little relevance in another area.

One is concerned therefore with the what - what data has to be communicated, and the how - the method and speed of transmission.

WHAT

We only make real advances once standards for a certain area have been agreed, and this is as true of DGPS as for any other field. Fortunately for us, several years' work has already been undertaken by the Radio Technical Commission to Maritime Services (RTCM) Special Committee 104 to define such a standard for DGPS. Version II of the RTCM Recommended Standards for Differential Navstar GPS service was published in January 1990. In contrast to most standards this paper is readable and understandable and is highly recommended for further study to those interested. The standard defines a total of 60 message types, only a few of which are used so far. Most receivers such as those in the Trimble range, respond to type 1, 2, 3.6 and 16 messages. The basic message is the measured error in pseudorange for each satellite, as well as its rate of change with time.

A further consideration of accuracy of a DGPS system is the time delay between detecting errors at the reference station and their effective use by the mobile receivers. The technical term for this is latency and it becomes important where the errors are rapidly varying in time. This applies partially to the ionospheric effect and, to a greater extent, to Selective Availability. Thus the designer of the data communications link must take into account the longest delay that he can tolerate to keep within an acceptable level of error at the mobile stations. The problem is not as bad as it seems at first since the type 1 message which is the normal transmission, is the rate of change with time of the error. Thus the receiver can determine how old the message is and use the time difference to calculate the most likely error at a particular instant. During the extensive field operation in the North Sea in 1989 when the initial tests of Selective Availability were undertaken it was found that the errors could be kept to less than 2 meters if a full update of the type 1 messages for all satellites was sent every 8-10 seconds. The full effects of Selective Availability suggest that the update rate must be increased to once every 5 seconds.

The RTCM standard is designed to operate with a data rate of 50 bits per second (50 baud). The information for one satellite can therefore be sent each second approximately. One has to distinguish between the theoretical and effective rates of sending data due to noise, fading, etc.; errors will be introduced into the stream of data and the effective rate will be significantly less than the nominal rate. Much ingenuity has been devoted over the last 15 years to devising methods of sending data via a radio system; the goal is to send as much clean data as possible in the noisiest environment with the least power available at the transmitter.

The receiver will take the rate of change data and use it to calculate the most likely correction for a given satellite in the event that a subsequent transmission is blocked or fades. Thus the DGPS accuracy is said to degrade gracefully in the absence of usable transmissions. Fortunately DGPS corrections are like the proverbial London bus; if you miss one, there's another one along soon!

The Type 1 message is in two parts:

- The pseudorange correction
- The rate of change of the corrections

At this point it is prudent to distinguish between a wide area DGPS System and a dedicated DGPS System. Wide area systems are designed to transmit the errors from a given reference station to many users. Typical applications would be precise navigation of vehicles or offshore vessels in an oil patch area. A dedicated DGPS System would be one set up for local operation such as a hydrographic survey of a small stretch of coast or river using a temporary reference station established for the purpose.

HOW

When dealing with any form of radio transmission one often hears the expression "frequency spectrum"; this is a convenient shorthand for the range of radio frequencies which cover the entire range of possibilities for broadcasting information. The detailed characteristics are discussed in the next section, but as already noted, broadcasting time is a scarce commodity and is subject to government regulation worldwide in order to ration out the available frequencies for all the potential users. Any potential user of DGPS in real time must therefore be aware of the importance of the regulatory authorities in their deliberations. Their policies and attitude can quite literally make the difference between success and failure of a DGPS scheme.

Regulatory Authorities

In the United States the Federal Communications Commission is the responsible body. They are based in Washington and application should be made to them for permission to operate on any particular frequency. A regulation manual is published by them; however, it has been found easier to operate through specialized consultant agencies and law firms to obtain licenses and if the potential scheme is unusual or complex then it is usually better to operate through one of these firms in making an application.

In other countries there is either a Ministry of Communications or a division of the PTT who are responsible. Very often certain applications have their own specialized regulatory authority, e.g. Maritime Radio which may be under the control of the Coast Guard or shipping authorities. In order to avoid an excessive level of bureaucracy several countries have provided blanket permission to operate on certain frequencies on low power, generally less than half a watt. This is particularly relevant with VHF and UHF transmissions and, where one is operating with line-of-sight conditions, the possibility should be actively investigated. The regulatory freedom is matched by the ready availability of equipment from vendors for such frequencies. A similar procedure is the use of spread spectrum techniques, similar to those used for GPS itself. The signal is modulated over a very wide frequency range and the power level at any frequency is so low as to be virtually undetectable except by a receiver designed to pick up the special type of transmission.

There are several methods of coding information, of which spread spectrum is probably the most advanced. Most radio transmission use either amplitude modulation (AM) or frequency modulation (FM) about a single base frequency. Each of these methods has its advantages and disadvantages, depending on the frequency and application and these are laid out in detail in the standard radio transmission texts.

Appendix 7

GPS GLOSSARY

2-D, 3-D - Refers to two-dimensional and three-dimensional positions. A 2-D position fix provides latitude and longitude. Altitude is assumed to be fixed. Only three satellites are required to provide a 2-D position with a user-supplied altitude. A 3-D position provides the altitude in addition to LAT/LON and requires four satellites.

Almanac - Data transmitted by a GPS satellite which includes orbit information on all the satellites, clock correction, and atmospheric delay parameters. These data are used to facilitate rapid SV acquisition. The orbit information is a subset of the ephemeris data with reduced accuracy.

Ambiguity - The unknown integer number of cycles of the reconstructed carrier phase contained in an unbroken set of measurements from a single satellite pass at a single receiver.

Argument of latitude - The sum of the true anomaly and the argument of perigee.

Argument of perigee - The angle or arc from the ascending node to the closest approach of the orbiting body to the focus or perigee point, as measured at the focus of an elliptical orbit, in the orbital plane in the direction of motion of the orbiting body.

Ascending node - The point at which an object's orbit crosses the reference plane (e.g., equatorial plane) from south to north.

Azimuth - A horizontal direction expressed as the angular distance between a fixed direction, say North, and the direction of the object.

Bandwidth - A measure of the information-carrying capacity of a signal, expressed as the width of the spectrum of that signal (frequency domain representation) in Hertz.

Baseline - The three-dimensional vector distance between a pair of stations for which simultaneous GPS data has been collected and processed with differential techniques. The most accurate GPS result.

Beat frequency - Either of the two additional frequencies obtained when signals of two frequencies are mixed. The beat frequencies are equal to the sum or difference of the original frequencies.

Bias - See Integer Bias Terms.

Binary biphase modulation - Phase changes of either 0 or 180 degrees on a constant frequency carrier (representing a binary 0 or 1 respectively). GPS signals are biphase modulated.

Binary pulse code modulation - Pulse modulation using a string of binary numbers (codes). This coding is usually represented by ones and zeros with definite meanings assigned to them, such as changes in phase or direction of a wave.

C/A code - The Coarse/Acquisition (or Clear/Acquisition) code modulated onto the GPS L1 signal. This code is a sequence of 1023 pseudo random binary biphase modulations on the GPS carrier at a chipping rate of 1.023 MHz, thus having a code repetition period of one millisecond. This code was selected to provide good acquisition properties.

Carrier - A radio wave having at least one characteristic (such as frequency, amplitude, phase) which may be varied from a known reference value by modulation.

Carrier beat phase - The phase of the signal which remains when the incoming Doppler-shifted satellite carrier signal is beat (the difference frequency signal is generated) with the nominally constant reference frequency generated in the receiver.

Carrier frequency - The frequency of the unmodulated fundamental output of a radio transmitter. The GPS L1 carrier frequency is 1575.42 MHz.

Celestial equator - The great circle that is the projection of the Earth's geographical equator of rotation onto the celestial sphere. Its poles are the North and South Celestial Poles.

Celestial meridian - That vertical circle through the elevated celestial pole. It also passes through the other celestial pole, the astronomical zenith, and the nadir

Channel - The receiver hardware that is required to lock to a satellite, make the range measurements and collect data from the satellite.

Chip - The length of time to transmit either a zero or a one in a binary pulse code.

Chip rate - Number of chips per second (e.g., C/A code = 1.023 MHz).

Clock offset - Constant difference in the time reading between two clocks.

Code division multiple access (CDMA) - A method of frequency reuse whereby many radios use the same frequency but with each one having a separate and unique code. GPS uses CDMA techniques with Gold's codes for their unique cross-correlation properties.

Conventional international origin (CIO) - Average position of Earth's rotation axis during the years 1900 - 1905.

Correlation-type channel - A GPS receiver channel which uses a delay lock loop to maintain an alignment (correlation peak) between the replica of the GPS code generated in the receiver and the received code.

Datum - A mathematical model of the earth. Many local datum's model the earth for a small region: e.g., Tokyo datum, OSGB-36 (Ordnance Survey of Great Britain 1936), NAD-27 (North American). Others, WGS-84, for example, model the whole earth.

See also Geodetic Datum

Deflection of the vertical - The angle between the normal to the ellipsoid and the vertical (true plumb line). Since this angle has both a magnitude and a direction, it is usually resolved into two components: one in the meridian and the other perpendicular to it in the prime vertical.

Delay lock - The technique whereby the received code (generated by the satellite clock) is compared with the internal code (generated by the receiver clock) and the latter is shifted in time until the two codes match. Delay lock loops can be implemented in several ways; tau dither and early-minus-late gating.

Delta pseudorange - See reconstructed carrier phase.

DGPS - Differential GPS operation. The use of a reference station to provide corrections using the RTCM SC-104 protocol for one or more mobile receivers. This may be carried out in real time over a telemetry link or by storing the data and post processing (see below). The accuracy of position measurement may be improved from 100 meters 2dRMs under Selective Availability conditions to 1 - 15 meters depending on the choice of sensors and telemetry.

Differential processing - GPS measurements can be differenced between receivers, satellites, and epochs. Although many combinations are possible, the present convention for differential processing of GPS phase measurements is to take differences between receivers (single difference), then between satellites (double difference), then between measurement epochs (triple difference).

A single-difference measurement between receivers is the instantaneous difference in phase of the signal from the same satellite, measured by two receivers simultaneously.

A double-difference measurement is obtained by differencing the single difference for one satellite with respect to the corresponding single difference for a chosen reference satellite.

A triple-difference measurement is the difference between a double difference at one epoch of time and the same double difference at the previous epoch of time.

Differential (relative) positioning - Determination of relative coordinates of two or more receivers which are simultaneously tracking the same satellites. Static differential GPS involves determining baseline vectors between pairs of receivers. See also DGPS.

Dilution of precision (DOP) - A description of the purely geometrical contribution to the uncertainty in a position fix, given by the expression DOP = SQRT TRACE (A A) where A A is the design matrix for the instantaneous position solution (dependent on satellite-receiver geometry). The DOP factor depends on the parameters of the position-fix solution. Standard terms for the GPS application are:

GDOF	Geometric (three position coordinates plus clock offset in the solution)
PDOP	Position (three coordinates)
HDOP	Horizontal (two horizontal coordinates)
VDOP	Vertical (height only)
TDOP	Time (clock offset only)
RDOP	Relative (normalized to 60 seconds)

Doppler aiding - The use of Doppler carrier-phase measurements to smooth code-phase position measurements.

Doppler shift - The apparent change in frequency of a received signal due to the rate of change of the range between the transmitter and receiver. See reconstructed carrier phase.

Double-difference method - A method to determine that set of ambiguity values which minimizes the variance of the solution for a receiver pair baseline vector.

Dynamic positioning - Determination of a timed series of sets of coordinates for a moving receiver, each set of coordinates being determined from a single data sample, and usually computed in real time.

Earth-centered earth-fixed - (ECEF) Cartesian coordinate system where the X direction is the intersection of the prime meridian (Greenwich) with the equator. The vectors rotate with the earth. Z is the direction of the spin axis.

Eccentric anomaly E - The regularizing variable in the two-body problem. E is related to the mean anomaly M by Kepler's equation: M = E - e.sinE (e stands for eccentricity).

Eccentricity - The ratio of the distance from the center of an ellipse to its focus to the semimajor axis. e = (l - b2/a2)-1/2 where a and b are the semimajor and semiminor axes of the ellipse.

Ecliptic - The earth-sun orbital plane. North is the direction of the system's angular momentum. Also called the ecliptic pole.

Elevation - Height above mean sea level. Vertical distance above the geoid.

Elevation Mask Angle - That angle below which satellites should not be tracked. This varies according to the task and location, e.g. for land surveying it is normally set to 15 degrees to avoid interference problems caused by buildings, trees and multipath errors. For marine navigation on the other hand, the angle can be lowered to 5 degrees. Please note that, because of the greater thickness of the ionosphere and troposphere traversed by the signal at low angles together with the increased distance of the satellite, the signal is weaker.

Ellipsoid - In geodesy, unless otherwise specified, a mathematical figure formed by revolving an ellipse about its minor axis. It is often used interchangeably with spheroid. Two quantities define an ellipsoid; these are usually given as the length of the semimajor axis, a, and the flattening, f = (a - b)/a, where b is the length of the semiminor axis. Prolate and triaxial ellipsoids are invariably described as such.

Ellipsoid height - The measure of vertical distance above the ellipsoid. Not the same as elevation above sea level. GPS receivers output position-fix height in the WGS-84 datum.

Ephemeris - A list of (accurate) positions or locations of a celestial object as a function of time. Available as "broadcast ephemeris" or as post processed "precise ephemeris." For GPS navigation purposes the broadcast ephemeris is always used and is updated every hour. It is sent as a set of 8 elements of the Keplerian orbital equation (qv) and used by the receiver to compute the instantaneous position of that satellite..

Epoch - Measurement interval or data frequency, as in making observations every 15 seconds. Loading data using 30-second epochs means loading every other measurement.

Fast switching channel - A switching channel with a sequence time short enough to recover (through software prediction) the integer part of the carrier beat phase.

Flattening - f = (a - b)/a = l -(l - e2)1/2 where:

a = Semimajor axis
b = Semiminor axis
e = Eccentricity

Frequency band - A range of frequencies in a particular region of the electromagnetic spectrum.

Frequency spectrum - The distribution of amplitudes as a function of frequency of the constituent waves in a signal.

Fullwave - Term used to differentiate between measurements made with signal-squared (codeless) and code-tracking receivers. Specifically, a receiver tracking L2 P-code can make measurement using the whole L2 wavelength (23 cm): the full wave.

Fundamental frequency - The fundamental frequency used in GPS is 10.23 MHz. The carrier frequencies L1 and L2 are integer multiples of this fundamental frequency.
L1 = 154F = 1575.42 MHz L2 = 120F = 1227.60 MHz

GDOP - Geometric Dilution of Precision. The relationship between errors in user position and time and in satellite range. GDOP2=PDOP2 + TDOP2

Geocenter - The center of the earth.

Geodetic datum - A mathematical model designed to best fit part or all of the geoid. It is defined by an ellipsoid and the relationship between the ellipsoid and a point on the topographic surface established as the origin of datum. This relationship can be defined by six quantities, generally (but not necessarily) the geodetic latitude, longitude, and the height of the origin, the two components of the deflection of the vertical at the origin, and the geodetic azimuth of a line from the origin to some other point. The GPS uses WGS-84, which see.

Geoid - The actual physical shape of the earth which is hard to describe mathematically because of the local surface irregularities and sea-land variations. In geodetic terms it is the particular equipotential surface which coincides with mean sea level, and which may be imagined to extend through the continents. This surface is everywhere perpendicular to the force of gravity.

Geoid height - The height above the geoid is often called elevation above mean sea level.

GPS - Global Positioning System, consisting of:

1) A Space Segment (up to 24 NAVSTAR satellites in 6 different orbits)

2) The control segment (5 monitor stations, 1 master control station and 3 upload stations)

3) The user segment (GPS receivers)

NAVSTAR satellites carry extremely accurate atomic clocks and broadcast coherent simultaneous signals.

GPS ICD-200 - The GPS Interface Control Document is a government document that contains the full technical description of the interface between the satellites and the user. GPS receivers must comply with this specification if they are to receive and process GPS signals properly.

GPS Time - The length of the second is fixed and is determined by primary atomic frequency standards. Leap-seconds are not used, as they are in UTC. Therefore, GPS time and UTC differ by a variable whole number of seconds.
See also Universal Time

Gravitational constant - The proportionality constant in Newton's Law of Gravitation: G=6.672 x 10-11 Nm2/Kg2.

Greenwich mean time - (GMT) See Universal Time. They are often used interchangeably, although Universal Time is now defined as the accepted standard.

Halfwave - Measurements made using L2-squared measurements. The squaring process results in only half of the original L2 wavelength being available.

HDOP - Horizontal Dilution of Precision. See DOP and PDOP.

HOW - Handover word. The word in the GPS message that contains time synchronization information for the transfer from the C/A code to the P-code.

Inclination - The angle between the orbital plane of a body and some reference plane (e.g., equatorial plane).

INS - Inertial navigation system, which contains an inertial measurement unit (IMU).

Integer Bias Terms - The receiver counts the radio waves from the satellite, as they pass the antenna, to a high degree of accuracy. However, it has no information on the number of waves to the satellite at the time it started counting. This unknown number of wavelengths between the satellite and the antenna is the integer bias term.

Integrated Doppler - A measurement of Doppler shift frequency or phase over time.

IODE - Issue Of Data, Ephemeris. Part of the navigation data. It is the issue number of the ephemeris information. A new ephemeris is available usually on the hour. Especially important for Differential GPS operation that the IODE change is tracked at both the reference station and mobile stations.

Ionospheric delay - A wave propagating through the ionosphere [which is a non homogeneous (in space and time) and dispersive medium] experiences delay. Phase delay depends on electron content and affects carrier signals. Group delay depends on dispersion in the ionosphere as well, and affects signal modulation (codes). The phase and group delay are of the same magnitude but opposite sign.

ipar soln - Values giving the difference in each of delta X, delta Y, delta Z vector components.

JPO - Joint Program Office for GPS located at the USAF Space Division at El Segundo, California. The JPO consists of the USAF Program Manager and Deputy Program Managers representing the Army, Navy, Marine Corps, Coast Guard, Defense Mapping Agency and NATO.

Kalman Filter - A numerical method used to track a time-varying signal in the presence of noise. If the signal can be characterized by some number of parameters that vary slowly with time, then Kalman filtering can be used to tell how incoming raw measurements should be processed to best estimate those parameters as a function of time.

Kinematic surveying - A form of continuous differential carrier-phase surveying requiring only short periods of data observations. Operational constraints include starting from or determining a known baseline, and tracking a minimum of four satellites. One receiver is statically located at a control point, while others are moved between points to be measured.

Keplerian orbital elements - Allow description of any astronomical orbit:

a: semimajor axis
e: eccentricity
o: argument of perigee
I: right ascension of ascending node
i: inclination
t: true anomaly

L1 - The primary L-band signal radiated by each NAVSTAR satellite at 1575.42 MHz. The L1 beacon is modulated with the C/A and P-codes, and with the NAV message. L2 is centered at 1227.60 MHz and is modulated with the P-code and the NAV message.

Lane - The area (or volume) enclosed by adjacent lines (or surfaces) of zero phase of either the carrier beat phase signal, or of the difference between two carrier beat phase signals. On the earth's surface a line of zero phase is the locus of all points for which the observed value would be an exact integer for the complete instantaneous phase measurement. In three dimensions, this locus becomes a surface. Lane counts are used extensively also in terrestrial radio navigation systems such as Loran or Decca to define position.

L band - The radio-frequency band extending from 390 MHz to (nominally) 1550 MHz.

LLA - A topocentric spherical coordinate system, whose coordinates are latitude, longitude, and altitude. Note that altitude can be expressed with respect to any particular ellipsoid or geoid model and generally depends on the model.

MCX - A small RF coaxial cable antenna connector system produced by several companies, e.g. Huber & Suhner.

Mean anomaly - $M = n\,(t - T)$ where: n is the mean motion, t is the time and T is the instant of perigee passage.

Mean motion - $n = 2\,/P$ where P is the period of revolution.

Microstrip antenna - A two-dimensional, flat, precisely cut piece of metal foil glued to a substrate.

Monitor station - Worldwide group of stations used in the GPS control segment to monitor satellite clock and orbital parameters. Data collected here is linked to a Master Station where corrections are calculated and controlled. These data are uploaded to each satellite at least once per day from an Upload Station.

Multichannel receiver - A receiver containing many independent channels. Such a receiver offers highest SNR because each channel tracks one satellite continuously.

Multipath - Interference similar to "ghosts" on a television screen which occurs when GPS signals arrive at an antenna having traversed different paths. The signal traversing the longer path will yield a larger pseudo range estimate and increase the error. Multiple paths may arise from reflections from structures near the antenna.

Multipath error - A positioning error resulting from interference between radio waves which have traveled between the transmitter and the receiver by two paths of different electrical lengths.

Multiplexing channel - A receiver channel which is sequenced through several satellite signals (each from a specific satellite and at a specific frequency) at a rate which is synchronous with the satellite message bit-rate (50 bits per second, or 20 milliseconds per bit). Thus, one complete sequence is completed in a multiple of 20 milliseconds.

NAD-83 - North American Datum, 1983.

NAVDATA - The 1500-bit Navigation Message broadcast by each satellite at 50 bps on both L1 or L2 beacons. This message contains system time, clock correction parameters, ionospheric delay model parameters, and the vehicle's ephemeris and health. This information is used to process GPS signals to obtain user position and velocity.

NAVSTAR - The name given to GPS satellites, built by Rockwell International (Block I) or GE (Block II), which is an acronym formed from NAVigation System with Time And Ranging.

N-type - A large diameter screwed coaxial antenna connector, normally used with RF cables such as RG213 or RG58 where the mechanical strain relief is taken through the connector.

Observing session - The period of time over which GPS data is collected simultaneously by two or more receivers.

Outage - The occurrence in time and space of a GPS dilution of precision value exceeding a specified maximum.

P-code - The protected or precise code used on both L1 and L2 GPS beacons. This code will be made available by the DoD only to authorized users. The P-code is a very long (about 1014 bits) sequence of pseudo random binary biphase modulations on the GPS carrier at a chipping rate of 10.23 MHz which does not repeat itself for about 38 weeks. Each satellite uses a one-week segment of this code which is unique to each GPS satellite, and is reset each week.

PDOP - Position Dilution of Precision, a unitless figure of merit expressing the relationship between the error in user position and the error in satellite position. Geometrically, PDOP is proportional to 1 divided by the volume of the pyramid formed by lines running from the receiver to four satellites observed. Values considered "good" for positioning are small, say 3. Values greater than 7 are considered poor. Thus, small PDOP is associated with widely separated satellites. Small PDOP is important in navigation and positioning, but much less so in surveying.

PDOP is related to horizontal and vertical DOP by PDOP2 = HDOP2 + VDOP2.

Parity error - A digital message is composed of 1s and 0s. Parity can be defined as the sum of these bits within a word unit. A parity error results when one of the bits is changed so that the parity calculated at reception is not the same as it was at transmission of the message.

PCB - Printed Circuit Board. Reference is also made to flexible PCBs, a method of providing flexible connector ribbons to normal PCBs.

Perigee - That point in a geocentric orbit when the geometric distance is a minimum. The closest approach of a body.

Phase lock - The technique whereby the phase of an oscillator signal is made to follow exactly the phase of a reference signal by first comparing the phases of the two signals, and then using the resulting phase difference signal to adjust the reference oscillator frequency to eliminate phase difference when the two signals are next compared.

Phase observable - See reconstructed carrier phase.

Point positioning - A geographic position produced from one receiver in a stand-alone mode. At best, position accuracy obtained from a stand-alone receiver is 15-25 meters, depending on the geometry of the satellites. With Selective Availability in operation the best that can be expected is 100 meters 2dRMS.

Polar motion - Motion of the instantaneous axis of the rotation of the Earth with respect to the solid body of the Earth. Irregular but more or less circular motion with an amplitude of about 15m and a main period of about 430 days (called Chandler Wobble).

Precise positioning service (PPS) - The highest level of military dynamic positioning accuracy that will be provided by GPS, based on the dual-frequency P-code and having high anti-jam and anti-spoof qualities.

Prime vertical - The vertical circle perpendicular to the celestial meridian.

PRN - Pseudorandom noise, a sequence of digital 1s and 0s which appears to be randomly distributed like noise, but which can be exactly reproduced. The important property of PRN codes is that they have a low autocorrelation value for all delays or lags except when they are exactly coincident. Each NAVSTAR satellite has its own unique C/A and P pseudorandom-noise codes.

Pseudolite - A ground-based GPS transmitter station which broadcasts a signal with a structure similar to that of an actual GPS satellite.

Pseudorange - A measure of the apparent propagation time from the satellite to the receiver antenna, expressed as a distance. Pseudorange is obtained by multiplying the apparent signal-propagation time by the speed of light. Pseudorange differs from the actual range by the amount that the satellite and user clocks are offset, by propagation delays, and other errors.

The apparent propagation time is determined from the time shift required to align (correlate) a replica of the GPS code generated in the receiver with the received GPS code. The time shift is the difference between the time of signal reception (measured in the receiver time frame) and the time of emission (measured in the satellite time frame).

Pseudorange difference - See reconstructed carrier phase.

Range rate - The rate of change of range between the satellite and receiver. The range to a satellite changes due to satellite and observer motions. Range rate is determined by measuring the Doppler shift of the satellite beacon carrier.

RDOP - Relative Dilution of Precision. Defined as:

$$\frac{(\_DX2 + \_DY2 + \_DZ2)1/2}{\_DD}$$

usually in units of m/cycle. Multiplying RDOP by the uncertainty of a double-difference measurement yields the spherical relative-position error.

Reconstructed carrier phase - The difference between the phase of the incoming Doppler-shifted GPS carrier and the phase of a nominally constant reference frequency generated in the receiver. For static positioning, the reconstructed carrier phase is sampled at epochs determined by a clock in the receiver.

The reconstructed carrier phase changes according to the continuously integrated Doppler shift of the incoming signal, biased by the integral of the frequency offset between the satellite and receiver reference oscillators.

The reconstructed carrier phase can be related to the satellite-to-receiver range, once the initial range (or phase ambiguity) has been determined. A change in the satellite-to-receiver range of one wavelength of the GPS carrier (19 cm for L1) will result in a one-cycle change in the phase of the reconstructed carrier.

Relative navigation - A technique similar to relative positioning except that one or both, of the points may be moving. The pilot of a ship or aircraft may need to know his position relative to a harbor or runway. A data link is used to relay the error terms to the moving vessel to allow real-time navigation.

Relative positioning - The process of determining the relative difference in position between two marks with greater precision than that to which the position of a single point can be determined. Here, a receiver (antenna) is placed over each spot and measurements are made by observing the same satellite at the same time. This technique allows cancellation (during computations) of all errors which are common to both observers, such as satellite clock errors, propagation delays, etc. See also Translocation and Differential Navigation.

Right ascension of ascending node - The angular distance measured from the vernal equinox, positive to the east, along the celestial equator to the ascending node. Typically denoted by a capital omega. Used to discriminate between orbital planes.

RTCM - Radio Technical Commission for Maritime Services. Commission set up to define a differential data link to relay GPS correction messages from a monitor station to a field user. RTCM SC-104 recommendations define the correction message format and 16 different correction message types.

SA - See Selective Availability

SATNAV - A local term referring to use of the older TRANSIT system for satellite navigation. One major difference between TRANSIT and GPS is that the TRANSIT satellites are in low-altitude polar orbits with a 90-minute period.

Selective Availability - (SA) A DoD program to control the accuracy of pseudorange measurements, whereby the user receives a false pseudorange which is in error by a controlled amount. Differential GPS techniques can reduce these effects for local applications.

Semimajor axis - One half of the major axis of an ellipse.

SEP - Spherical Error Probable, a statistical measure of precision defined as the 50th percentile value of the three-dimensional position error statistics. Thus, half of the results are within a 3-D SEP value.

Sidereal day - Time between two successive upper transits of the vernal equinox.

Simultaneous measurements - Measurements referenced to time-frame epochs which are either exactly equal, or else so closely spaced in time that the time misalignment can be accommodated by correction terms in the observation equation, rather than by parameter estimation.

Slope distance - The three-dimensional vector distance from station one to station two. The shortest distance (a chord) between two points.

Slow switching channel - A switching channel with a sequencing period which is too long to allow recovery of the integer part of the carrier beat phase.

SMA, SMB, SMC.- Small diameter RF coaxial cable connectors with various fastening mechanisms. See manufacturers' catalogues for details.

Solar day - Time between two successive upper transits of the sun.

Spheroid - See ellipsoid.

Spread spectrum - The received GPS signal is a wide bandwidth, low-power signal (-160dBW). This property results from modulating the L-band signal with a PRN code in order to spread the signal energy over a bandwidth which is much greater than the signal information bandwidth. This is done to provide the ability to receive all satellites unambiguously and to provide some resistance to noise and multipath.

Spread spectrum systems - A system in which the transmitted signal is spread over a frequency band much wider than the minimum bandwidth needed to transmit the information being sent.

Squaring-type channel - A GPS receiver channel which multiplies the received signal by itself to obtain a second harmonic of the carrier which does not contain the code modulation. Used in so-called codeless receiver channels.

Standard positioning service (SPS) - The level of dynamic- or static-positioning capability that will be provided by GPS, based on the single-frequency C/A-code. The accuracy of this service will be set at a level consistent with national security.

Static positioning - Positioning applications in which the positions of static or near static points are determined.

SV - Satellite vehicle or space vehicle.

Switching channel - A receiver channel which is sequenced through a number of satellite signals (each from a specific satellite and at a specific frequency) at a rate which is slower than, and asynchronous with, the message data rate.

TAIP - Trimble ASCII Interface Protocol. A protocol used to interface with Trimble vehicle navigation sensors such as the Starfinder and Acutime. It is designed for bi-directional use with communication modems and radio data telemetry systems which have problems with binary or hexadecimal data packets.

Each packet is preceded by two letters, followed by a sequence of alphanumeric information. A full specification of the protocol is contained in Appendix 2 , q.v.

TANS - Trimble Advanced Navigation Sensor. A family of rugged 6 channel GPS sensors. Used also to refer to the protocol, also known as TSIP, Trimble Standard Interface Protocol (q.v.).

TDOP - Time Dilution of Precision. See DOP.

TOW - Time of week, in seconds, from midnight Sunday UTC.

Translocation - A version of relative positioning which makes use of a known position, such as a national survey authority mark, to aid in the accurate positioning of a desired point. Here, the position of the mark, determined using GPS, is compared with the accepted value. The three-dimensional differences are then used in the calculations for the second point.

Trop - Tropospheric correction. The correction applied to the measurement to account for tropospheric delay. This value is obtained from the modified Hopfield model.

True anomaly - The angular distance, measured in the orbital plane from the earth's center (occupied focus) from the perigee to the current location of the satellite (orbital body).

TSIP - Trimble Standard Interface Protocol. A binary/hex packet bi-directional protocol, also known as the TANS protocol. Used by a large number of Trimble sensors. TSIP is the subset of TANS which is recognized by all sensors except those of the 4000 series. The protocol is defined in full in the TSIP Document , published November 1991 and derived from Document 17035 Appendix A of March 1991.

Universal time - Local solar mean time at Greenwich Meridian. Some commonly used versions of Universal Time are:

UT0 - Universal Time as deduced directly from observations of stars and the fixed numerical relationship between Universal and Sidereal Time; 3 minutes 56.555 seconds.

UTI - UT0 corrected for polar motion.
UT2 - UTI corrected for seasonal variations in the earth's rotation rate.
UTC - Universal Time Coordinated; uniform atomic time system kept very close to UT2 by offsets. Maintained by the US. Naval Observatory. GPS time can be directly related to UTC.
UTC - GPS = seconds. (changing constant = 7 seconds in 1991).

User range accuracy (URA) - The contribution to the range-measurement error from an individual error source (apparent clock and ephemeris prediction accuracy's), converted into range units, assuming that the error source is uncorrelated with all other error sources. Values less than 10 are preferred. Block II satellites operating under Selective Availability are usually set to 32.

UTM - Universal Transverse Mercator Map Projection. A special case of the Transverse Mercator projection. Abbreviated as the UTM Grid, it consists of 60 north-south zones, each 6 degrees wide in longitude.

VDOP - Vertical Dilution of Precision. See DOP and PDOP.

Vernal equinox - The intersection of the celestial equator with the ecliptic, with the positive sense being from the earth to the sun, as the sun crosses the equator from south to north.

Vertical - The line perpendicular to the geoid at any point. The direction of the force of gravity at that point. Plumb line.

WGS-72 - World Geodetic System (1972); the mathematical reference ellipsoid previously used by GPS, having a semimajor axis of 6378.135 km and a flattening of 1/298.26.

WGS-84 - World Geodetic System (1984); the mathematical ellipsoid used by GPS since January 1987. The shift from WGS-72 to WGS-84 in Sunnyvale CA (37o N, 122o W) is about 13.6 meters east, 45 meters north and 2.7 meters up.

Widelane - A linear combination of L1 and L2 observations (L1-L2) used to partially remove ionospheric errors. This combination yields a solution in about one-third the time of a complete ionosphere-free solution.

Z-count - The GPS satellite clock time at the leading edge of the next data subframe of the transmitted GPS message (usually expressed as an integer number of 6 seconds).

Appendix 8

GPS Software Toolkit

Sample C programs are provided free of charge and without warranty to TNL customers as programming aids for developing software for ACUTIME GPS receivers and are subject to change without notice.

READ.ME	The text of this Appendix
GPSMON	Software for monitoring channel A of an ACUTIME,
GPSREC	A simple program for recording ACUTIME data from channel B to a file. Syntax is "GPSREC filename.ext".
GPSPLAY	A program that will send a file recorded by GPSREC to the communications port, allowing a PC to emulate a ACUTIME. Syntax is "GPSPLAY filename.ext".
GPSLSTLL	A program to list latitude and longitude from data recorded by GPSREC. Syntax is "GPSLSTLL inputname.ext > outputname.ext" Omitting the outputname.exe will echo the data to the screen.
GPSLST	Same as GPSLSTLL plus list all messages sent from the ACUTIME. Syntax is the same as GPSLSTLL.
PKTMON	PKTMON provides a simple user interface to a ACUTIME GPS receiver when connected to an IBM PC compatible with a math co-processor. PKTMON's help screen displays the keystroke command list whenever the "?" key is hit.
WARNING:	Function "^O" in PKTMON requires that the user input each of the four configuration bytes. If return is hit without any values, PKTMON will zero the values and not set them at the previous or default values. The default values for the four bytes is: 01 01 00 00 Please refer to ACUTIME manual Appendix 1 paragraph 3.3.1.20 for configuring the ACUTIME to your application.
WARNING:	FUNCTION "P" in PKTMON requires values to be entered. Failure to do so will zero the current values in the ACUTIME and will cause erratic performance.

The default values are as follows:

Dynamics code = 1
Elevation mask = 10
SNR mask = 6
PDOP mask = 12
PDOP switch = 8

PKTMON command list: (key - pkt ID - description)

a	29	almanac health	A	20	almanac data	^A	2A	altitude for 2-D
d	39	disable/ign hlth	D	62	set DGPS mode	e	3B	ephemeris info
h	26	receiver health	i	23	input XYZ pos	I	2B	input LLA pos
^K	1E	clear battery RAM	^L	3F	00 low level	m	28	GPS sys message
M	24	show 2-D/3-D mode	n	22	set manual 2-D	N	22	set manual 3-D
^N	22	set auto 2-D/3-D	o	2D	show osc offset	O	35	show I/O options
^O	35	set I/O options	p	2C	show mask parms	P	2C	set mask parms
^R	25	reset receiver	s	27	show sig. levels	S	34	set SV for 1-SV
t	21	show current time	T	2E	set time from PC	^T	22	set 1SV time mode
u	2F	show UTC info	v	1F	show S/W version	V	33	show A-to-D volt
^V	36	velocity input	w	37	show last fix	>	3C	show track status
<	3A	show raw meas	/	65	show DGPS info			

QKDISP	Trimble Navigation quick display library routines.
SVP	A satellite visibility program.
ALMGETB	Support program with source for SVP. ALMGETB reads the almanac data from channel B then writes it to the file "GPSALM.DAT".
ALMPUTB	Support program. ALMPUTB writes the almanac data to channel B from the file "GPSALM.DAT".
GPSALM	Almanac data file for SVP.
SPDRIVE	SPDRIVE provides high speed interrupt driven serial port services. Once installed, it remains resident until the computer is rebooted. It is required by several programs, including GPSMON and GPSMF. It is recommended that SPDRIVE be run from the AUTOEXEC.BAT file to ensure that it is installed prior to running any of the programs that require it. If the ACUTIME channel B is connected to the PC's COM:2, run SPDRIVE /2 . If channel B is connected to COM:1 use SPDRIVE /1.

Usage is:	SPDRIVE	(installs on port COM1)
or:	SPDRIVE /2	(installs on port COM2)

APPENDIX 9

Sources of Supply

Amphenol Products Headquarters

4300 Commerce Court
Lisle, IL 60532
Tel (312) 983-3500

Thanet Way
Whitstable, Kent CT5 3JF
England
Tel (44) 227 264411

Room 513-514
World Commerce Centre
Harbour City, 11 Canton Rd.
TST Kowloon, Hong Kong
Tel (852-3) 681283,681284

Applied Engineering Products - AEP

104 John Murphy Drive
PO Box 510
New Haven, CT 06513
Tel (203) 776-2813
Fax (203) 776-8294

Belden

OEM Sales Office
PO Box 1980
Richmond, IN 47375
Tel (317) 983-5200
Fax (317) 983-5294

Cooper Energy Services
Chester House, 86 Chertsey Rd.
Woking, Surrey, GU21 5BJ
Great Britain
Tel (44) 4862 28511/26818
Fax (44) 4862 27745

Belden Electronics GMBH
Fuggerstrasse 2
4040 Neuss 1
West Germany
Tel (02101) 35041
Fax (02101) 32222

Elco Corporation

8611 Balboa Ave
San Diego, CA 92123
Tel (619) 576-2600
Fax (619) 492-1456

Huntingdon Industrial Park
Huntingdon, PA 16652
Tel (814) 643-0700
Fax (814) 643-0426

Conxall - The Connector Company

601 E. Wildwood
Villa Park, IL 60181
Tel (708) 834-7504

DC Electronics

1800 Bering Drive
San Jose, CA 95112
Tel (408) 453-2400
Fax (408) 453-3970

15032 Redhill #A
Tustin, CA 92680
Tel (714) 259-9066
Fax (714) 259-9078

2211 South 48th Street #H
Tempe, AZ 85682
Tel (602) 438-1234
Fax (602) 438-0892

Gilbert Engineering

5310 West Camelback Road
Glendale, AZ 85301-7595
Tel (602) 245-1050
Fax (602) 939-3538

Huber + Suhner, Inc.

500 West Cummings Park
Wobuton, MA 02254
Tel (617) 938-1335
Fax (617) 938-3796

Optical Transmission Division
CH-9100 Herisau, Switzerland
Tel (41) 71/534111
Fax (41) 71/534590

Telford Road, Oxon 0x6 OLA
UK / England
Tel (44) 869 244676
Fax (44) 869 249046

Sources of Supply (cont.)

ITT Cannon

666 East Dyer Road
Santa Ana, CA 92705
Tel (714) 557-4700
Fax (714) 754-2142

Viables Estate
Basingstoke, Hants RG22 4BW
England
Tel (44) 256 473 171
Fax 44) 256 23356

King Wire & Cable Corp.

179-45 110th Ave
Jamaica, NY 11433
Tel (800) 221-0144
Tel (718) 657-4422 (call collect)

2525 Royal Lane
Dallas, TX 75229 France
Tel (800) 527-5207
Tel (214) 484-8600 (call collect)

2930 East Northern
Phoenix, AZ 85028
Tel (800) 528-0449
Tel (602) 867-1222 (call collect)

Omni - Spectra

77 Milford Road
Waltham, MA 02254
Tel (617) 890-4750
Fax (617) 890-2381

140 Fourth Avenue
Reading Berks
RG1 8LG England
Tel (44) 734/534111
Fax (44) 734/534590

Palco (Pheonix Connector)

555 Pond Drive
Woodlake, IL 60190
Tel (800) 323-19562
Fax (708) 595-6579

Pasternack Enterprises

PO Box 16759
Irvine, CA 92713
Tel (714) 261-1920
Fax (714) 261-7451

Remtek Corporation

4601 Landing Parkway
Fremont, CA 94538-6471
Tel (415) 490-3999
Fax (415) 659-1849

Fairford, Gloucestershire GL7 4DW
England
Tel (44) 285/712129
Fax (44) 285/713427

Radiall Inc.

150 Long Beach Blvd.
Stratford, CT 06497
Tel (203) 386-1030
Fax (203) 375-3808

101 RUX PH Hoffman
93116 Rosny, France
Tel (33)149 353 35
Fax (33) 148 546 363

Solitron Devices, Inc.

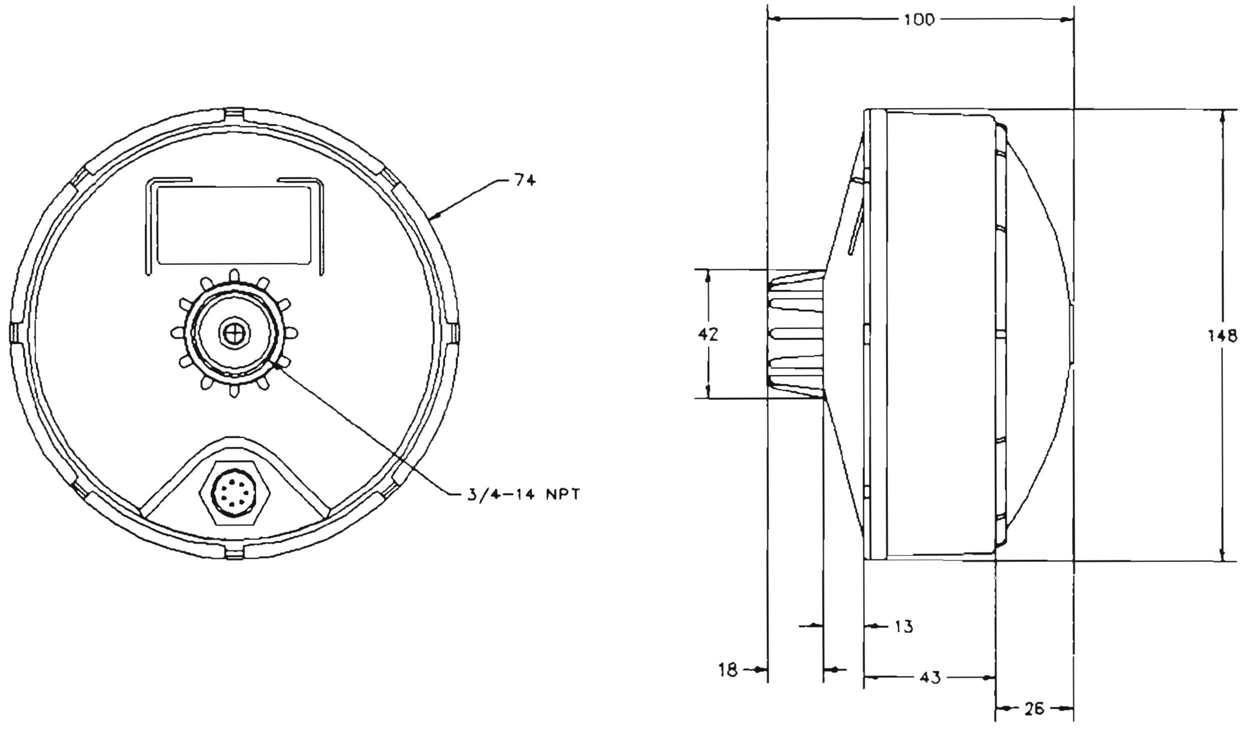
1177 Blue Heron Blvd. .
Riviera Beach, FL 33404
Tel (407) 848-4311
Fax (407) 848-4311 ext. 116

Appendix 10

Mechanical Drawings

Title	Drawing Number	Revision
1 - Acutime Antenna/Receiver - Dimensions	18636-XX	1
2 - Cable Assembly -50 feet	19360-50	B
3 - Acutime RS-422 Connections (Typical)	18637-X0	A
4 - Acutime RS-232 Connections (Typical)	18637-X2	A

Notes



NOTE: DIMENSIONS ARE IN MILIMETERS

PARTS LIST

Trimble Navigation

GPS Acutime Antenna/Receiver

3/4" NPT mounting

DWG NO. 18636-XX

REV 1

SCALE NONE

B. Duffy 1-10-92

DO NOT SCALE DRAWING

APPLICATION

19360-50	1	B

2477	A	RELEASE TO PRODUCTION	——	4-22-92	GBT
2636	B	BLUNT CUT CABLE			

NOTES: UNLESS OTHERWISE SPECIFIED

1 CABLE CONSTRUCTION: 3 TWISTED PAIRS PLUS 1 INDIV. CONDUCTOR, 22 AWG PVC INSULATION, OVERALL ALUMINIZED MYLAR SHIELD WITH 22 AWG DRAIN WIRE. OVERALL BLACK PVC JACKET, SEE PINOUT TABLE FOR COLORS.

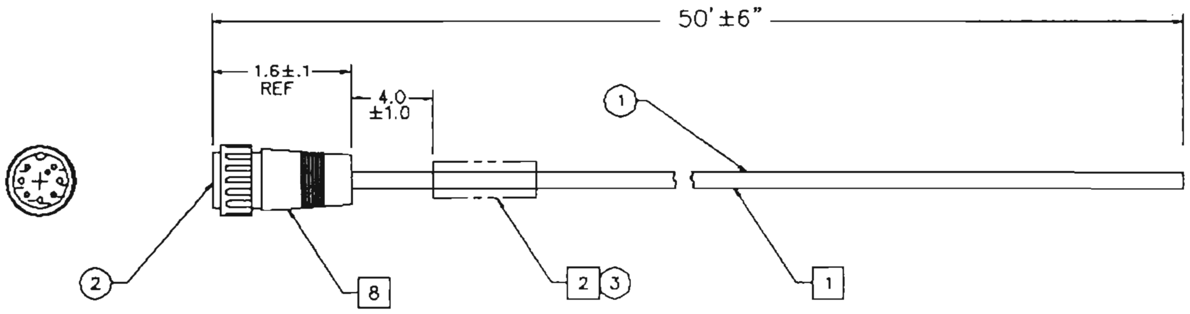
2 APPLY TRIMBLE NAVIGATION PART NO., REV LEVEL, VENDOR IDENT. AND DATE CODE APPROX. WHERE SHOWN. THE LETTERING MUST BE IN A PERMANENT CONTRASTING COLOR AND SHOULD BE LEGIBLE.

3. AFTER ASSY, THE FOLLOWING TEST WILL BE PERFORMED ON EACH CABLE TERMINATION, 100% TESTING (NOT AQL SAMPLING).
   A. PULL TEST, THE CABLE TERMINATION WILL WITHSTAND A PULL OF 35±2 POUNDS.

4. COIL CABLE INTO MAX 8" DIA COIL WITH TWO WIRE TIES.

6. CERTIFICATION OF COMPLIANCE MUST ACCOMPANY EACH SHIPMENT.

8 "BULLET" TAPERED BOOT TO BE MOLDED TO CABLE JACKET AND CONNECTOR (2) WITH POLYPROPYLENE.



PIN OUT TABLE

WIRES	SIGNAL	PIN #	COLOR
PAIRED	RECEIVE +	1	ORANGE
	(RECEIVE –)	4	VIOLET
PAIRED	(TRANSMIT –)	2	BROWN
	(TRANSMIT +)	3	YELLOW
PAIRED	(GROUND)	6	BLACK
	(POWER)	7	RED
DRAIN WIRE	NC	NC	UNINS.
——	(ONE PULSE PER SEC)	5	BLU

	3	A/R			TUBING, HEATSHRINK		
	2	1		[illegible]	7 SOC CONN [illegible] (FEMALE CONTACTS)		
1	1	A/R			CBL, 3 TWTD PAIRS W/SHLD & DRAIN WIRE, BLK PVC JACKET		

1

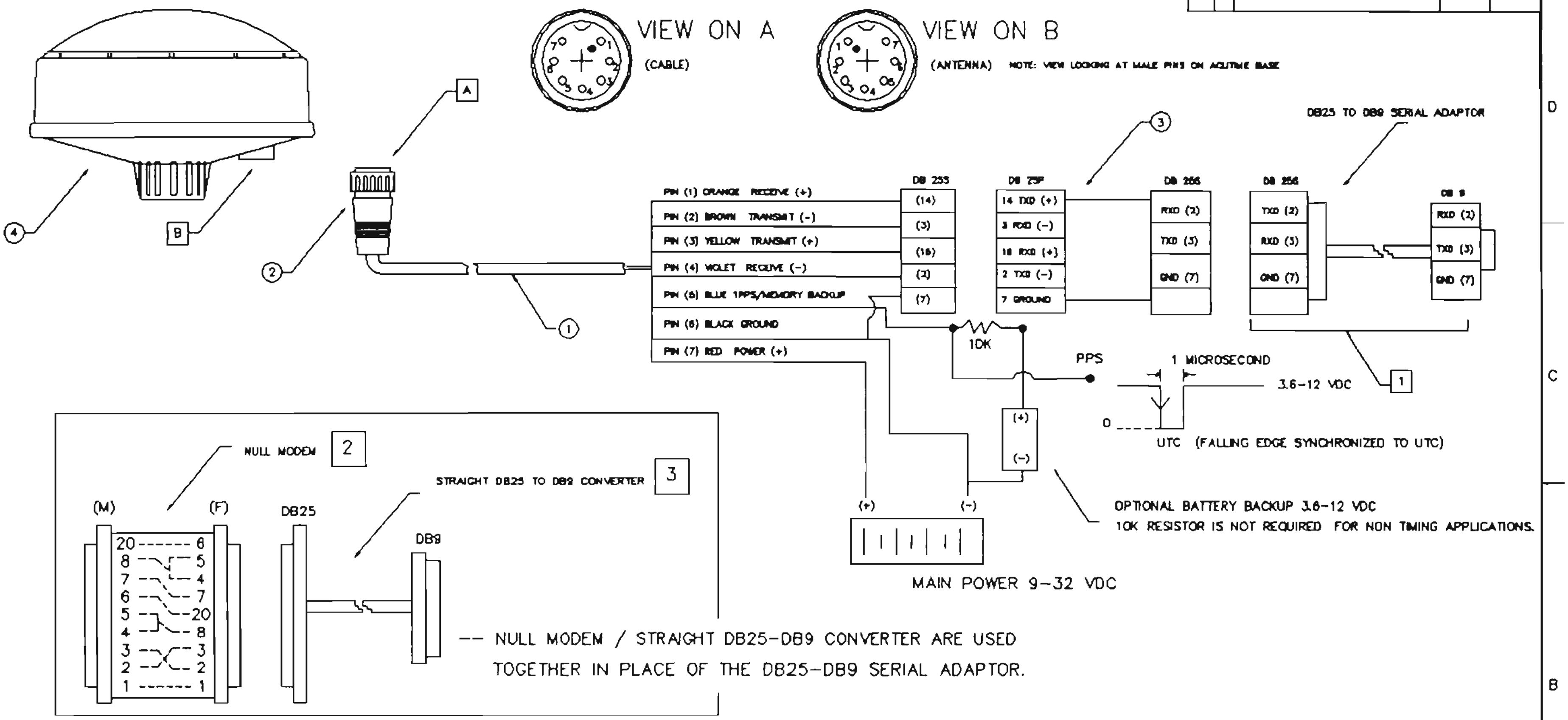
P. MOTONE

Navigation

CABLE ASSEMBLY
50 FEET, 7 CONDS, J6

19360-50 B

1/1 1 OF 1



NOTE PROVIDING A TTL CONNCECTION:

MANY DATA COLLECTION DEVICES THAT DO NOT ACCEPT A TRUE RS-4SS SIGNAL, WILL ACCEPT A TTL COMPATIBLE SIGNAL. TO APPROXIMATE A TTL SIGNAL, CONNECT THE BROWN "TRANSMIT -" TO THE "RECEIVE +" PIN OF THE INPUT CONNECTOR AND A JUMPER WIRE FORM THE BLACK "GROUND" WIRE TO THE "RECEIVE -" PIN OF THE CONNECTOR. .

1 SERIAL ADAPTOR INCLUDES NULL MODEM. CONNECT DB9 TO SERIAL PORT ON PC.

2 IF STRAIGHT DB25 TO DB9 CONVERTER IS USED IT MAY BE REQUIRED TO USE A NULL MODEM. NULL MODEM CONNECTS DIRECTLY TO RS422-RS232 ADAPTOR (P/N 18637-00).

3 CONNECT DB9 SERIAL PORT ON PC. NOTE: IF COMMUNICATION IS NOT ALLOWED, REMOVE NULL MODEM.

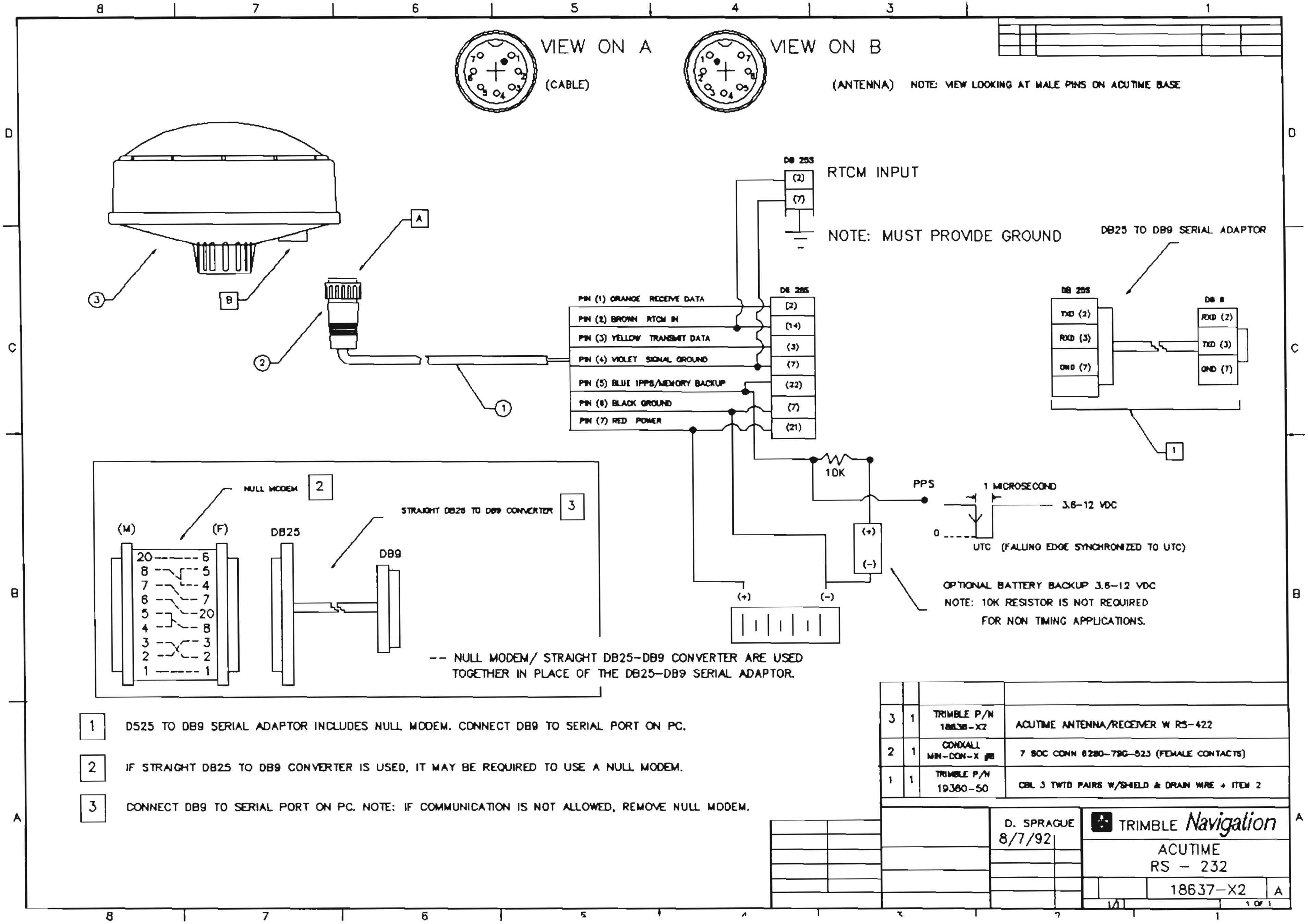
4	1	TRIMBLE P/N 18638-X0	ACUTIME ANTENNA/RECEIVER W RS-422
3	1	TRIMBLE P/N 18637-00	RS-422 / RS-232 CONVERTER
2	1	CONXALL MIN-CON-X #8	7 SOC CONN 6280-7S0-523 (FEMALE CONTACTS)
1	1	TRIMBLE P/N 19360-50	CBL 3 TWTD PAIRS W/SHIELD & DRAIN WIRE + ITEM 2

D. SPRAGUE
8/7/92

TRIMBLE Navigation

ACUTIME
RS - 422

1/1
18637-X0
A
1 OF 1



1 D525 TO DB9 SERIAL ADAPTOR INCLUDES NULL MODEM. CONNECT DB9 TO SERIAL PORT ON PC.

2 IF STRAIGHT DB25 TO DB9 CONVERTER IS USED, IT MAY BE REQUIRED TO USE A NULL MODEM.

3 CONNECT DB9 TO SERIAL PORT ON PC. NOTE: IF COMMUNICATION IS NOT ALLOWED, REMOVE NULL MODEM.

3	1	TRIMBLE P/N 18638-X2	ACUTIME ANTENNA/RECEIVER W RS-422
2	1	CONXALL MIN-CON-X	7 SOC CONN 6280-7SG-523 (FEMALE CONTACTS)
1	1	TRIMBLE P/N 19360-50	CBL 3 TWTD PAIRS W/SHIELD & DRAIN WIRE + ITEM 2

D. SPRAGUE
8/7/92

TRIMBLE *Navigation*

ACUTIME
RS – 232

18637–X2 A

1/1

1 OF 1