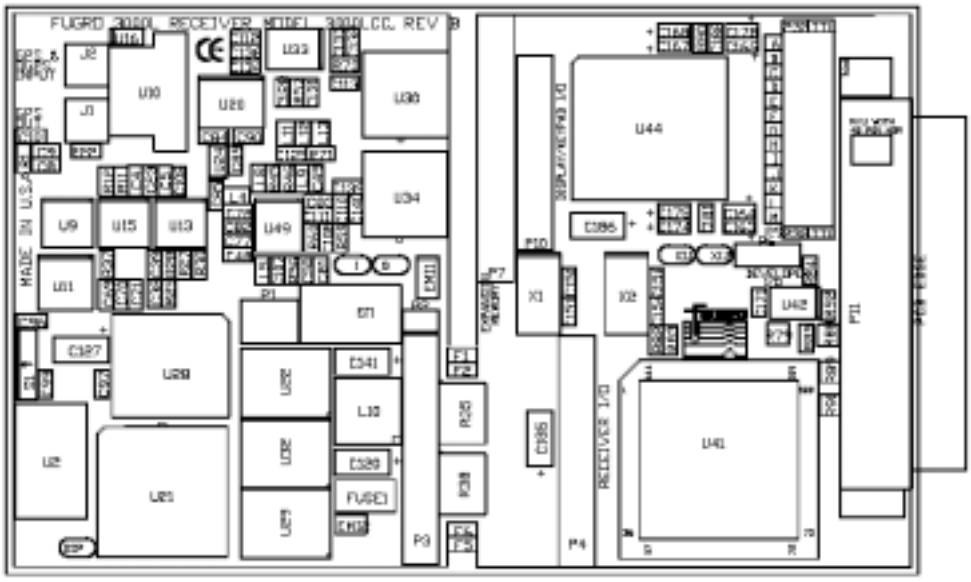
3000LCE DGPS Receiver



The Global Positioning System

Operator's Manual

Issue 30100-10-0204 March 2001

OmniSTAR 3000LCE DGPS Receiver
Operator's manual

On front cover

Photo 1 :The 3000LCE front view.

This warranty applies only to normal usage of the product. It does not apply to units or electronic circuit boards defective due to improper installation or handling. Physical damage due to lightning or other electrical discharge and units subjected to fresh or salt water contamination is not covered. OmniSTAR reserves the right not to warrant the product if, upon request, sufficient proof of recommended installation compliance as laid out in this manual is not provided. No other warranties are expressed or implied. No other warranties exist.

One-Year Limited Hardware Warranty

OmniSTAR reserves the right to repair and/or replace, at its option, any part or parts found to be defective, provided such defects, in their opinion, are due to faulty material or workmanship and are not caused by unauthorised or improper repair or abuse, or normal wear. Purchaser shall be responsible for shipping and insurance of the returned product for repair under this warranty. OmniSTAR will pay shipping and insurance for the product's return to purchaser provided that the product returned proves to be defective under this limited warranty.

OmniSTAR BV and its operating companies world-wide (Fugro NV), warrants this product to be free from defects in workmanship and material for a period of one year from the date of original sale by OmniSTAR or its authorised dealers, to the original purchaser or end user.

OmniSTAR assumes no responsibility for any consequential or incidental losses or damages of any nature with respect to the use of this product.

The manufacturer of the endproduct is responsible for compliance with European and USA EMI/EMC directives.

Specifications are subject to change without notice.

This manual is applicable to the following versions of operating software.

Version	compatible
02.09.02	
02.11.XX	

Table 1 :Software version compatibility

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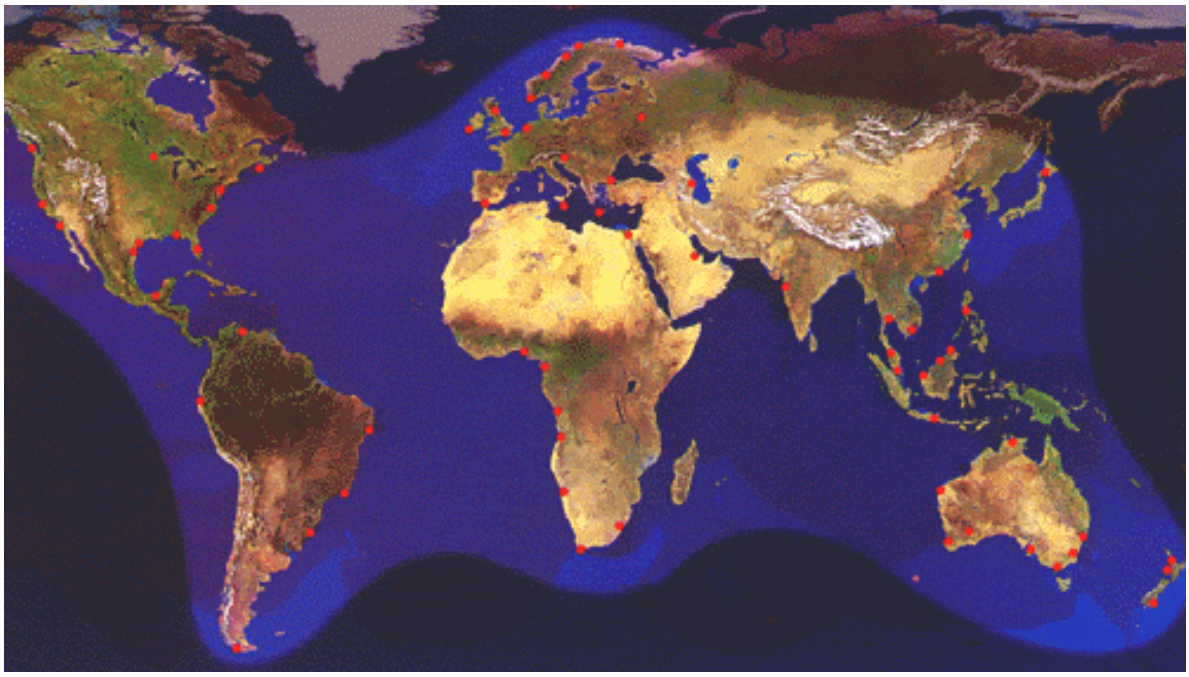

Photo 2 :World coverage map for the OmniSTAR service.

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Introduction

The Global Positioning System (GPS) is a satellite based navigation system, the GPS constellation consists of 27 satellites (at the moment of writing) providing world wide, 24 hour, three dimensional coverage. Differential GPS (DGPS) is a form of GPS navigation using an error correction signal to calculate a highly accurate position.

About This Manual

This manual has been produced to assist the typical user with the installation and operation of the 3000LCE DGPS Receiver.

System Features

The 3000LCE DGPS Receiver is a component part of the Fugro world-wide DGPS Service. The Fugro service is a full-time differential GPS (DGPS) broadcast system delivering corrections from an array of GPS reference stations located around the globe see photo 1 and 2 on page 2. Reference stations provide industry standard RTCM SC-104 version2 formatted corrections to Network Control Centres (NCC) at strategic geographic locations, where the corrections are decoded, checked, and repackaged in a highly efficient format for broadcast. The data is modulated onto a RF carrier that is then up-converted for transmission to an L-band communications satellite.

The signals are received at the user's location by an antenna and downconverter system, demodulated by a receiver, and are made available, after selection of the desired individual reference site's data set, as corrections for use in a GPS, differential-capable, receiver.

The 3000LCE receiver supports the following OmniSTAR services:

1. Virtual Base Station (VBS2000) where the data from multiple reference stations is used in processor software to produce enhanced corrections for the user's location. The resulting corrections are restructured as RTCM SC-104 version 2 corrections for direct application to the GPS engine. The accuracy is virtually constant for the selected space segments.

2. Restricted Zone (VBS200 or region / country), where the data from multiple reference stations is used to produce enhanced corrections for an user selected zone. The correction messages will not be applied in the GPS solution outside the selected zone.

3. Virtual Reference Cell (VRC), where the data from multiple reference stations is used to produce enhanced corrections for a virtual reference station. The resulting corrections are restructured as RTCM SC-104 version 2 corrections for direct application to the internal receiver. The accuracy will degrade gradually the farther the user is away from the virtual reference station location.

4. DGPS Services Stand alone differential GPS, where corrections from one selected site are extracted from the incoming data stream and are reformatted to the industry standard Format, RTCM SC-104 version2 supporting message types 1 and 3.

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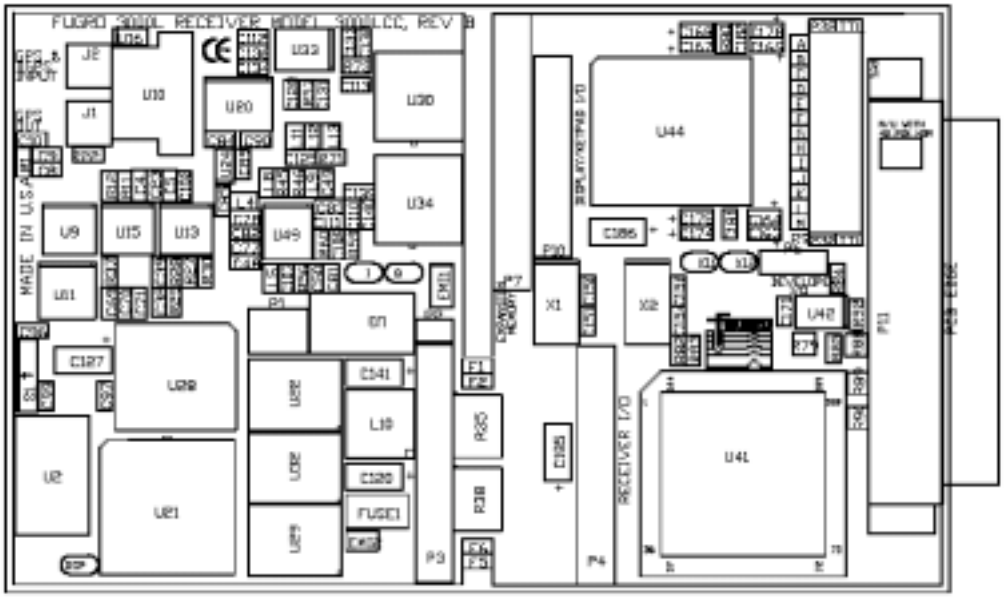
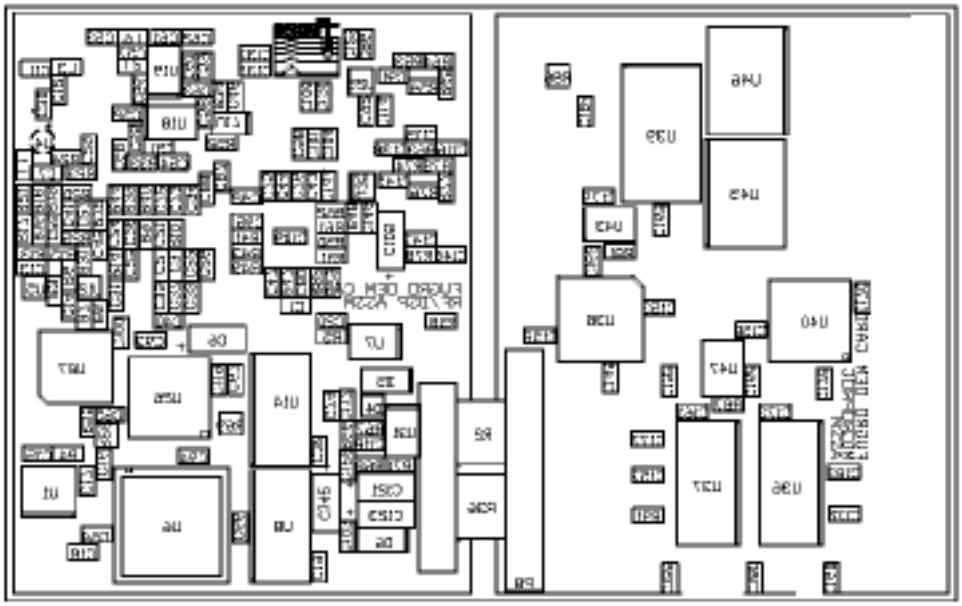
This manual describes in brief the 3000LCE OEM receiver.

As the product is designed for OEM (Original Equipment Manufacturers) and System Integrators, we have not documented the product in as much detail as for an end user product

The main area addressed in this manual are the connectors.

Top and Bottom view





Connector hardware

CON	HDR	FUNCTION	REMARKS	CON TYPE
P1	2X3	Xilinx Programming	Design purposes	
P2	1x3	LNA Voltage selection	5V / input V / none option shown on board	See note
P3	2x20	Interconnection	Stacked version	Samtec SLW
P4	2x20	Interconnection	Stacked version	Samtec FTSH
P5	2x3	Xilinx Programming	Design purposes	
P6	1x4	Spare	Reserved for 5V output	
P7	2x25	Expansion memory	Max 8 Meg Expansion memory	Samtec FTS
P8	2x20	Interconnection	Stacked version	Samtec TLW
P9	3x13	TTL 232 selection		
P10	2x15	Display / keypad / I/O	Compatible with 3000L series	Samtec FTS
P11	2x20	I/O connector	See underneath	Samtec TSW

Table 2 :Description of all the connectors on the 3000LCE card.

Note : The LNA power is directly connected to the input power when the switch is set to 12V. For the none option remove jumper. Maximum current for the antenna is 300 mA.

P7

PIN	FUNCTION
2, 50	GND
1	+5V
49	Reset
3 - 22	A0 – a19
23, 24, 25, 26	EMA 20 – 23 (effectively A20 –A23)
27	Write
28	Read
29, 30, 31, 32	CS
33 - 48	D0 – D15

Table 3 :Pin layout of memory expansion P7.

P10

PIN	FUNCTION
3, 25	+5V
29, 30	GND
27, 28	+12V
21	LCD Contrast
8, 10, 12, 14, 18	Keypad
4, 6, 9, 11, 12, 15, 17	LCD Displays
19, 20, 33, 24, 26,	LCD Displays
1, 2	GPS serial port
5, 7, 16, 23	Control lines

Table 4 :Pin layout of the standard display connection P10.

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P11

PIN	DESCRIPTION	FUNCTION
1	CMD port Tx	Command Port RS 232 C
2	CMD port Rx	Command Port RS 232 C
3	CMD port DTR	Command Port RS 232 C
4	CMD port DCD	Command Port RS 232 C
5	CMD port RTS	Command Port RS 232 C
6	CMD port CTS	Command Port RS 232 C
7	CMD port DSR	Command Port RS 232 C
8	DATA port Tx	Data Port RS 232 C
9	DATA port Rx	Data Port RS 232 C
10	AUX port Tx	Auxiliary Port RS 232 C
11	AUX port Rx	Auxiliary Port RS 232 C
12	GPS port Tx	GPS Port RS 232 C
13	GPS port Rx	GPS Port RS 232 C
14	LED 8	Received Power 2mA
15	LED 7	Unique Word 2mA
16	LED 6	Power 2mA
17	LED 5	Bit Error Rate 2mA
18	LED 4	Subscription 2mA
19	LED 3	Data Port TX Activity 2mA
20	LED 2	Aux Port RX Activity 2mA
21	LED 1	Aux Port TX Activity 2mA
22	CAN L	Can Bus Low 82C250 Transceiver
23	CAN H	Can Bus High 82C250 Transceiver
24	SPARE 1	See P6 above (reserved 5V)
25	SPARE 2	See P6 above
26	SPARE 3	See P6 above (reserved 5V)
27	SPARE 4	See P6 above
28	Alarm Sink	Fugro software function
29	Alarm Source	Fugro software function
30	Antenna Steering DSP	Antenna steering voltage
31	I Demon DSP	In Phase BPSK signal (debug function)
32	Q Demod DSP	QuadraPhase BPSK signal (debug function)
33	PB RST DSP	Test pin DSP
34	R69 – Temp Mon DSP	Test pin DSP
35	GND	Power supply Ground
36	+ 12 v	Power supply
37	GND	Power supply Ground
38	+12 v	Power supply
39	GND	Power supply Ground
40	+ 12 v	Power supply

Table 5 :Pin layout of the main I/O connector P11.

P9

Port	Jumper	Describtion
Command	A	Tx
	B	Rx
	C	DTR
	D	DCD
	E	RTS
	F	CTS
	G	DSR
Data	H	Tx
	I	Rx
Aux	J	Tx
	K	Rx
GPS	L	Tx
	M	Rx

Table 6 :OEM board jumpers for TTL/RS232 selection.

The row of jumpers labelled A to M are used to set voltage levels used by the serial ports. Note that the command port is the only one which has hardware handshake lines available.

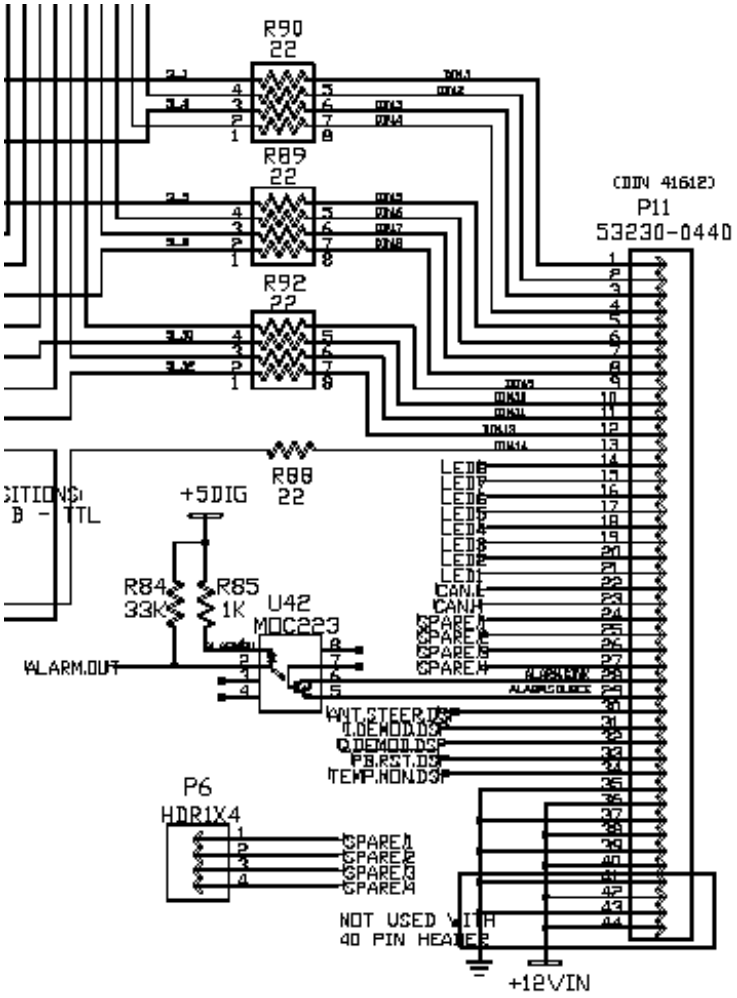


Figure 1 :The electrical interface of the 40 pin header.

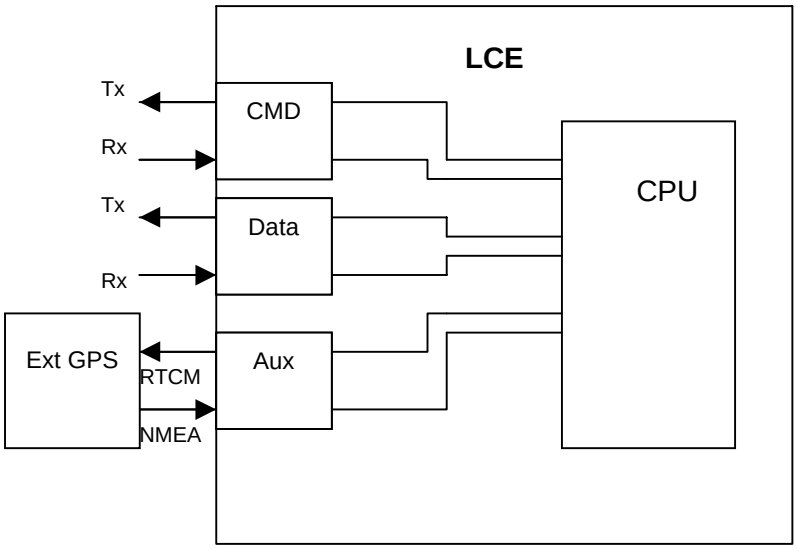
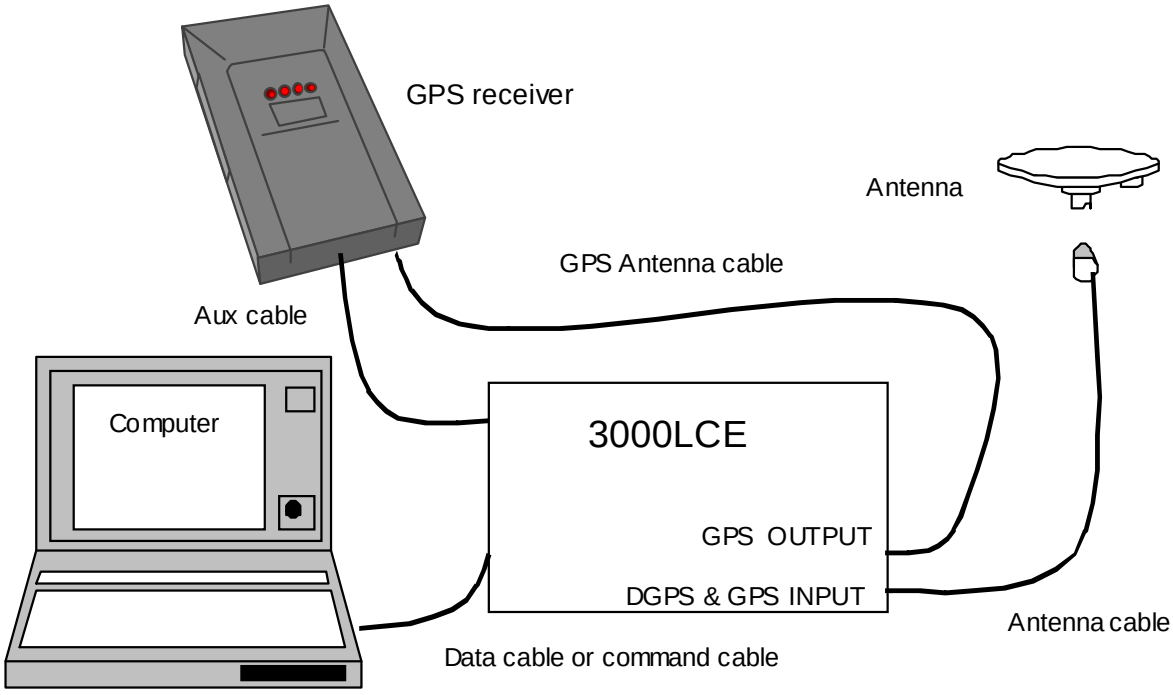


Figure 2 :Proposed connection diagram for connecting the 3000LCE card to a GPS engine.



Commands

Configuration is possible using the User Toolkit or sending commands to the 3000LCE via the command port using a terminal program. Connect the command cable from the command connection on P11 to a com port on the PC. The command port is usually set to 9600,8,N,1.
To acquire a value use the short form and then return, i.e. for acquiring the serial number:
Send SN
Response Serial Number = 321123

To change a setting i.e. the frequency
Send FR = 1531230000
Response Frequency = 1531230000

In the following list are the free commands described.

Command	Short Form	Description	Options	Type	CMD Port	NCC Link
Version	VR VR FULL	Returns Version number of firmware	N/A	Report	N/A	N/A
Actual Frequency	AF	Returns current frequency of the receiver	N/A	Report	N/A	N/A
Power	PR	Returns current receive power	N/A	Report	N/A	N/A
Signal Quality	SQ	Returns current receive signal quality	N/A	Report	N/A	N/A
CPU	CPU	Returns current CPU usage	N/A	Report	N/A	N/A
Serial Number	SN	Reports the Serial Number of the unit	N/A	Report	N/A	N/A
Group Number	GN	Reports the Group Number of the unit	N/A	Report	N/A	N/A
Service Identifier	SI	Repeats the Service Identifier from the most recently received packet.	N/A	Report	N/A	N/A
Time (Receiver)	TI	Displays Receiver current date and time	N/A	Report	N/A	N/A
Software Download	SD	Sets Receiver for Software Download	Use toolkit	Config / Report	Yes	No
Switch Software Version	SS	Switches software versions	0, 1, 2	Config / Report	Yes	Yes
Detector Mode	DM	Sets the receiver's operation mode	VBS/RTCM OFF	Config / Report	Yes	Yes
Frequency	FR	Sets the initial receive frequency	Frequency #	Config / Report	Yes	Yes
Up link	UP	Gives/sets the frequency by up link service name	string	Config / Report	Yes	Yes
Symbol Rate	SR	Sets the symbol rate for the receiver	Symbol rate #	Config / Report	Yes	Yes
Data Rate	DR	Sets the baud rate for the data port	Baud rate #	Config / Report	Yes	Yes

Command	Short Form	Description	Options	Type	CMD Port	NCC Link
Aux. Rate	AR	Sets the baud rate for the Aux. Port	Baud rate #	Config / Report	Yes	Yes
Command Rate	CR	Sets the baud rate for the Command Port	Baud rate #	Config / Report	Yes	Yes
Remote Sites Enable	RE	Sets the mask for the sites to be O/P in RTCM format	Use toolkit	Config / Report	Yes	Yes
Echo	EO	Turns command port chr. Echoing on or off	N/A	Config	Yes	N/A
VBS Position	VBSPOS	Sets the point of origin for the RTCM corrections for when the receiver is operated in stand alone config.	Lat & Lon	Config / Report	Yes	Yes
Internal GPS Program Mode	PM	Enables GPS Program Mode	On/Off	Config	Yes	Yes
Receiver config	CONFIG or ABOUT	Displays some information about the receiver	N/A	Report	Yes	N/A
Data Port Output Options	DO	Selects data output mode in VBS units	NMEA, ERTCM or NONE	Config / Report	Yes	Yes
Auxiliary port options	AO	Selects Aux output mode in VBS units where the Aux port is not dedicated to a GPS	ERTCM, EXT, GPS or NONE	Config / Report	Yes	Yes
Output data to Auxiliary Port	OA	Outputs the given string to the aux port when sent from a terminal via the command port or the NCC	string	Config	Yes	Yes
Output data to Data Port	OD	Outputs the given string to the data port as OA	string	Config	Yes	Yes
Output data to Command Port	OC	Outputs the given string to the command port as OA	string	Config	Yes	Yes
Set AUX port RTCM Termination Character(s)	RT	Sets the Aux port RTCM terminating character(s)	CR, LF or CR+LF or None	Config/ Report	Yes	Yes
VBS status	VS	Displays VBS and GPS status flags	N/A	Report	Yes	N/A
RTCM Auto Off	RA	Enables automatic shutoff of RTCM corrections if GPS input is lost.	ON / OFF	Config/ Report	Yes	Yes
Auto scan	AS	Enables / Disables autoscan facility	ON / OFF	Config/ Report	Yes	Yes
Autoscan delay in seconds	ASDELAY Lock_wait Scan_wait	Control period receiver will wait for signal lock before and during Autoscan	e.g. = 60 30	Config/ Report	Yes	Yes

Command	Short Form	Description	Options	Type	CMD Port	NCC Link
Subscription status	ST	Gives the subscription status	N/A	Report	Yes	N/A
Expiry time	ET	Gives the expiry or expired date and time	N/A	Report	Yes	N/A
Countdown time	CT	Gives the count down time left when in this mode	N/A	Report	Yes	N/A
Sites	Sites	Gives the list of ref. sites Dump is in csv format	DUMP or nothing	Report	Yes	N/A
Almanac	Almanac	Gives the GPS almanac Dump is in csv format	DUMP or nothing	Report	Yes	N/A
User message	UM	Gives the latest received User message	string	Report	Yes	Yes

Troubleshooting

Diagnostic Test Software

The 3000LCE DGPS Receiver has an inbuilt self test program which performs diagnostics on all the receiver subsystems. A full diagnostic report indicating the health of the receiver is output to the Command Port using the USER ToolKit software.

Receiver Service Procedure

If an 3000LCE Receiver unit fails to perform, contact the OmniSTAR office within the region, after following the procedural checks.

We wish to hear about frequently experienced problems, and your assistance will help by copying the form on the next page, filling in the details requested and faxing or mailing the form to the OmniSTAR office within the region for on-forwarding to Product Marketing.

The most common problems are interfacing, and usually occur at installation time. If you have a interfacing connection not covered, we would like to assist you and produce a technical bulletin that may assist other users in the future.

If a problem appears that you think may be caused by a system performance problem, contact the OmniSTAR office in your region for any system abnormalities that may have been experienced.

We are sensitive to our customers' needs and we want to assure specified system performance at all times. There could, however, be situations where conditions are below average, such as fringe area operations, radio communication disturbance etc., and, as 3000LCE Receiver monitors the system performance continuously, these conditions would be noted.

Helpdesk

If there are any further errors not described above then refer to the OmniSTAR office in The Netherlands under telephone number ++ 31 71 5814710.
Or return the receiver problem report form by mail or by fax ++ 31 71 5814719.

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3000LCE Receiver Problem Report Form

Please copy this form and report the problem with as much detail as possible.

Serial Number ZE

Time, date of failure

Company Name	_____
Contact Person	_____
Dealer Name	_____
Tel. Number	_____
Fax. Number	_____

Antenna(s) used	____
Application	____
Power source used	____
Outside air temperature	
	____

Physical location latitude _____ longitude _____

Interfaced to _____
If PC type _____Program _____
Static or Dynamic use _____ Approx. speed _____

Description of Problem.

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Technical specifications

Receive Frequency : 1525 MHz to 1559 MHz (L band)

Environment

Operating Temperature:	-20^{o} to 80^{o} C
Non-Operating:	-40^{o} to 85^{o} C
Humidity:	95% non-condensing
Vibration:	3G/30Hz/ x, y & z axes
Shock:	Max 7G, 5-20 msec zero rebound

Data inputs and outputs

Four serial ports:	Command, Data & Auxiliary or GPS
Electrical interface:	Selectable TTL or RS232
Data rates:	300, 600,1200,2400,4800,9600, 19200, 38400 Bd
Message Rate:	Typically 1-2 seconds output
Plug Types:	40 pin header

Connectors

DGPS antenna input	SMA on eurocard, MCX on stacked eurocard
GPS antenna output	SMA on eurocard, MCX on stacked eurocard
Interface	On 40 pin header

Power

Power Supply:	10 Vdc to 22 Vdc
Power consumption:	500 mA at 12Vdc
LNA Power supply:	5 VDC & **input voltage** or none selectable max 300 mA

Physical Characteristics

Weight (approx.):	130 gram
Dimensions (H W D)	18 x 100 x 160 mm

Approvals

This card complies with European and USA EMI/EMC directives.

The manufacturer of the end product is responsible for compliance with European and USA EMI/EMC directives.

Appendix A NMEA 0183

Introduction

NMEA 0183 is an interface protocol created by the National Marine Electronics Association. The latest release of NMEA 0183 is Version 2.1. This protocol was originally established to allow marine navigation equipment to share information. NMEA 0183 is a simple, yet comprehensive ASCII protocol, which defines both the communication interface and the data format.

This appendix provides a brief overview of the NMEA messages employed for this DGPS receiver.

NMEA 0183 Message Format

NMEA 0183 allows a single source (talker) to transmit serial data over a single twisted wire pair to one or more receivers (listeners). The MNEA 0183 protocol covers a broad array of navigational data. This is separated into discrete messages, which convey a specific set of information. The NMEA 0183 message structure is outlined below.

$IDMSG,D1,D2,D3,D4,……..,Dn*CS[CR][LF]

"$"	The "$" signifies the start of message.
ID	The Talker identification is a two letter mnemonic which describes the source of the navigation information. The GP identification signifies a GPS source.
MSG	The message identification is a three letter mnemonic which describes the message content and the number and order of the data fields.
","	Commas serve as deliminators for the data fields.
Dn	Each message contains multiple data fields (Dn) which are delimited by commas.
"*"	The asterisk serves as a checksum delimiter.
CS	The checksum field contains two ASCII characters which indicate the hexadecimal value of the checksum.
[CR][LF]	The carriage return [CR] and line feed [LF] combination terminate the message.

NMEA messages vary in length, but each message is limited to 79 characters or less. This length limitation excludes the "$" and the [CR] [LF]. The data field block, including delimiters, is limited to 74 characters or less.

NMEA 0183 Message Options

The OmniSTAR 3000LCE, when supplied with a Trimble Navigation "Lassen-SK8" GPS receiver is factory configured with 3 NMEA 0183 sentences. GGA, GSV, and VTG. Sentences can be added or removed by the factory to a maximum of four sentences. The output rate is fixed at a 1-second interval.

Message Sentence	Description
GGA	GPS Fix Data
GLL	Geographic Position – Latitude/Longitude
GSA	GPS DOP and Active Satellites
GSV	GPS Satellites in View
RMC	Recommended Minimum Specific GPS Data
VTG	Track Made Good and Ground Speed
ZDA	Time and Date

Table 7 :NMEA 0183 messages.

NMEA 0183 Message Formats

In this section each message is described in more detail.

GGA – GPS Fix Data

The GGA message includes time, position and fix related data for the GPS receiver.

GGA,hhmmss.s,llll.llll,a,yyyyy.yyyy,a,x,xx,x.x,x.x,M,x.x,M,x.x,xxxx

Field Number	Description
1	UTC of Position
2,3	Latitude, N (North) or S (South). *
4,5	Longitude, E(East) or W (West). *
6	GPS Quality Indicator: 0=No GPS, 1=GPS, 2=DGPS.
7	Number of Satellites in Use.
8	Horizontal Dilution of Precision (HDOP).
9,10	Antenna Altitude in Meters, M = Meters.
11,12	Geodial Separation in Meters, M = Meters. **
13	Age of Differential GPS Data. ***
14	Differential Reference Station ID (0000 – 1023)

Table 8 :Description of the GGA message.

NOTES:
* The GGA message provides 3 decimal points of precision in non-differential mode, and 4 decimal points of accuracy in differential mode.

** Geodial Separation is the difference between the WGS-84 earth ellipsoid and mean-sea-level (MSL).

*** Time in seconds since the last RTCM SC-104 message type 1 or type 9 update.

GLL – Geographic Position – Latitude/Longitude

The GLL message contains the latitude and longitude of the present position, the time of the position fix and the status.

GLL,llll.lll,a,yyyyy.yyy,a,hhmmss.s,A

Field Number	Description
1,2	Latitude, N (North) or S (South).
3,4	Longitude, E (East) or W (West).
5	UTC of Position.
6	Status: A = Valid, V = Invalid.

Table 9 :Description of the GLL message.

GSA – GPS DOP and Active Satellites

The GSA message indicates the GPS receivers operating mode and lists the satellites used for navigation and the DOP values of the position solution.

GSA,a,x,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,x.x,x.x,x.x

Field Number	Description
1	Mode: M = Manual, A = Automatic.
2	Current Mode 1 = Fix not available, 2 = 2D fix, 3 = 3D fix.
3 to 14	PRN numbers of the satellites used in the position solution. *
15	Position Dilution of Precision (PDOP).
16	Horizontal Dilution of Precision (HDOP).
17	Vertical Dilution of Precision (VDOP)

Table 10 :Description of the GSA message.

NOTES:
* When less than 12 satellites are used, the unused fields are null.

GSV – GPS Satellites in View

The GSV message identifies the GPS satellites in view, including their PRN number, elevation, azimuth, and SNR value. Each message contains data for four satellites. Second and third messages are sent when more than four satellites are in view. Fields 1 and 2 indicate the total number of messages being sent and the number of each message respectively.

GSV,x,x,xx,xx,xx,xxx,xx,xx,xx,xxx,xx,xx,xx,xxx,xx,xx,xx,xxx,xx

Field Number	Description
1	Total Number of GSV Messages.
2	Message Number: 1 – 3.
3	Total Number of Satellites in View.
4	Satellite PRN Number.
5	Satellite elevation in Degrees (90° Maximum)
6	Satellite Azimuth in Degrees True (000 – 359)
7	Satellite SNR, Null when not Tracking.
8,9,10,11	PRN, Elevation, Azimuth and SNR for Second Satellite.
12,13,14,15	PRN, Elevation, Azimuth and SNR for Third Satellite.
16,17,18,19	PRN, Elevation, Azimuth and SNR for Fourth Satellite.

Table 11 :Description of the GSV message.

RMC – Recommended Minimum Specific GPS Data

The RMC message contains the time, date, position, course and speed data provided by the GPS navigation receiver. A checksum is mandatory for this message and the transmission interval may not exceed 2 seconds. All data fields must be provided unless the data is temporarily unavailable. Null fields may be used when data is temporarily unavailable.

RMC,hhmmss.s,A,llll.lll,a,yyyyy.yyy,a,x.x,x.x,xxxxxx,x.x,a*hh

Field Number	Description
1	UTC of Position Fix.
2	Status: A = Valid, V = Navigation Receiver Warning.
3,4	Latitude, N (North) or S (South).
5,6	Longitude, W (West) or E (East).
7	Speed Over the Ground (SOG) in Knots.
8	Track Made Good in Degrees True.
9	Date: dd/mm/yy.
10,11	Magnetic Variation in Degrees, E = East W = West.
12	Checksum (Mandatory for RMC)

Table 12 :Description of the RMC message.

VTG – Track Made Good and Ground Speed

The VTG message conveys the actual track made good (COG) and the speed relative to the ground (SOG).

VTG,x.x,T,x.x,N,x.x,K

Field Number	Description
1	Track Made Good in Degrees True.
2	Track Made Good in Degrees Magnetic.
3,4	Speed Over the Ground in Knots.
5,6	Speed Over the Ground in Kilometer's per Hour.

Table 13 :Description of the VTG message.

ZDA – Time and Date

The ZDA message contains UTC, the day, the month and the year of the local time zone.

ZDA,hhmmss.s,xx,xx,xxxx,xx,xx

Field Number	Description
1	UTC.
2	Day (0 – 31).
3	Month (0 – 12).
4	Year.
5	Local Zone Description Hours (± 13 Hours). *
6	Local Zone Description Minutes.

Table 14 :Description of the ZDA message.

NOTES:
* Local zone description is the number of whole hours added to local time to obtain UTC. The zone description is always negative for eastern longitudes. A GPS receiver cannot independently identify the local time zone offsets.

This appendix contains information about the OmniSTAR network

L-Band communication satellites

The following table presents a list of L-band communication satellites which will enable you to use your receiver over the entire world (depending on your subscription type you might only be entitled to a certain area).

Satellite Channel	Frequency	Symbol Rate
EMS	1531230000	2438
EA-SAT	1535152500	2438
AM-SAT	1535137500	2438
AP-SAT	1535137500	2438

Table 15 : World-wide satellite frequencies and symbol rates

The position (marker), broadcasted reference stations (red dots) and coverage area of each satellite is displayed in the following figures.

Figure 3: EMS coverage

Figure 4: EA-SAT coverage

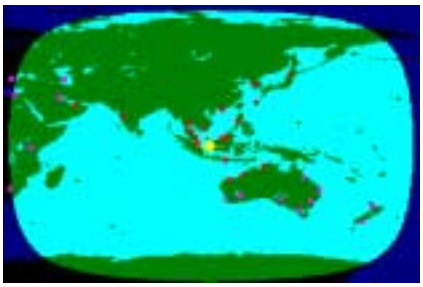

Figure 5: AP-SAT coverage

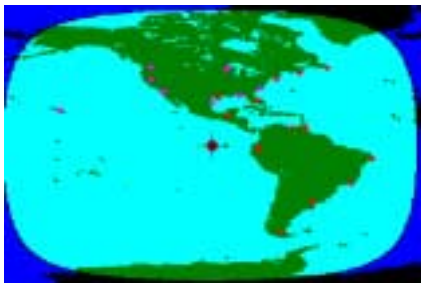

Figure 6: AM-SAT coverage

The following tables present the current list of reference stations, which are broadcast over communication satellites used by OmniSTAR. The list of reference stations change regularly to improve the network.

Table 16: Reference stations on EMS

Nr	Station	ID	Data
1	Tromso, Norway	690	YES
2	Orlandet, Norway	630	YES
3	Torshavn, Faroes	620	YES
4	Rogaland, Norway	580	YES
5	Aberdeen, Scotland	571	YES
6	Shannon, Ireland	530	YES
7	Leidschendam, The Netherlands	521	YES
8	Toulouse, France	431	YES
9	Vienna, Austria	480	YES
10	Istanbul, Turkey	410	YES
11	Baku, Azerbaijan	400	YES
12	Faro, Portugal	371	YES
13	Malta	351	YES
14	Crete, Greece	340	YES
15	Alexandria, Egypt	310	YES
16	Bodo, Norway	122	YES
17	Visby, Sweden	229	YES
	Ny Alesund, Spitsbergen	101	NO
	Vardo, Norway	114	NO
	Trondheim, Norway	126	NO

Table 17: Reference stations on EA-SAT

Nr	Station	ID	Data
1	Cape Town, South Africa	335	YES
2	Johannesburg, South Africa	262	YES
3	Walvis Bay, Namibia	235	YES
4	Luanda, Angola	095	YES
5	Pointe-Noire, Congo	045	YES
6	Nairobi, Kenia	015	YES
7	Sao Tome	011	YES
8	Douala, Cameroon	043	YES
9	Abidjan, Ivory Coast	050	YES
10	Lagos, Nigeria	060	YES
11	Blantyre, Malawi	155	YES
13	Abu Dhabi, UAE	016	YES
14	Kuwait	290	YES
15	Alexandria, Egypt	310	YES
16	Crete, Greece	340	YES
17	Las Palmas, Canaries	280	YES
18	Orlandet, Norway	630	YES
19	Rogaland, Norway	580	YES
22	Faro, Portugal	371	YES
23	Baku, Azerbaijan	400	YES
24	Durban, South Africa	305	YES
	Rio de Janeiro, Brazil	226	NO
	Rio de Janeiro, Brazil	225	NO
	Mumbai-Arvi, India	191	NO

Table 18: Reference stations on AP-Sat

Nr	Station	ID	Data
2	Karratha, Australia	215	YES
3	Darwin, Australia	125	YES
4	Broome, Australia	185	YES
9	Okinawa, Japan	261	YES
10	Singapore	010	yes
11	Miri, Malaysia	042	YES
12	Vung Tua, Vietnam	012	YES
13	Hong Kong	220	YES
14	Seoul, S. Korea	370	YES
15	Kota Kinabalu, Malaysia	061	YES
16	Bali, Indonesia	096	YES
17	Mumbai-Arvi, India	191	YES
19	Subic Bay, Phillipines	151	YES
20	Kuwait	290	YES
21	Abu Dhabi, UAE	016	YES
23	Kuantan, Malaysia	041	YES
24	Satun, Thailand	018	YES
25	Bangkok, Thailand	141	YES
27	Sapporo, Japan	430	YES

Table 19: Reference stations on AM-Sat

Nr	Station	ID	Data
1	Houston, Texas	100	YES
2	Cocoa Beach, Florida	120	YES
3	Long Island, New York	333	YES
4	Carmen, Mexico	110	YES
5	Punta Arenas, Chile	210	YES
6	Guayaquil, Ecuador	202	YES
7	Rio de Janeiro, Brazil	225	YES
8	St. Johns, Newfoundland	470	YES
9	Dartmouth, Nova Scotia	440	YES
10	Recife, Brazil	075	YES
11	Port Of Spain, Trinidad	111	YES
12	Caracas, Venezuela	112	YES
13	Buenos Aires	345	YES

Table 20: Reference stations on Optus

Nr	Station	ID	Data
1	Perth, Australia	325	YES
2	Karratha, Australia	215	YES
3	Darwin, Australia	125	YES
4	Townsville, Australia	195	YES
5	Brisbane, Australia	275	YES
6	Melbourne, Australia	385	YES
7	Pt Augusta, Australia	326	YES
8	Kalgoorlie, Australia	315	YES
9	Cobar, Australia	316	YES
16	Bali, Indonesia	096	YES
18	Bathurst, Australia	336	YES
22	Auckland. NZ	022	YES
26	Dunedin, NZ	026	YES
31	Broome, Australia	185	YES

Table 21: Reference stations on AMSC

Nr	Station	ID	Data
1	San Diego, Ca, USA	140	YES
2	Everrett, Wa, USA	555	YES
3	Mercedes, Tx, USA	160	YES
4	Houston, Tx, USA	100	YES
5	Pensacola, Fl, USA	150	YES
6	Cocoa Beach, FL, USA	120	YES
7	Fayetteville, NC, USA	130	YES
8	Long Island, NY, USA	333	YES
9	Duluth, Mn, USA	491	YES
10	Redding, Ca, USA	180	YES
11	Carmen, Mexico	110	YES