[redacted]

DRAFT

NAVSTAR
SYSTEMS

DR5-96S-III

UHF Telemetry Radio

User Manual

DRAFT

NAVSTAR SYSTEMS Ltd.
Mansard Close, Westgate, Northampton. England. NN5 5DL

DR5-96S-III

UHF Telemetry Radio

User Manual

Issue: 1.0

Including the operation of software Version 3.0

Document Number: 190-335 Issue 1.0
Date: 23/03/98

CONTENTS

APPENDICES

1.0 INTRODUCTION

The primary function of the NavSymm® DR5-96S-III UHF Telemetry Radio is to provide a radio frequency link for the distribution of GPS corrections in differential solutions. It can therefore be used to supply standard RTCM corrections when operated as part of a DGPS base station, or to supply raw data in Real Time Positioning (RTP) systems. Additionally, it has timing control features which the NavSymm® XR5/XR6 range of GPS receivers utilise to provide effective use of frequency allocations. The DR5-96S-III ***can also be used with any GPS receiver*** which is able to provide an RS232 data stream, and may also be employed for applications outside GPS.

Under normal joint operation with an XR5/XR6 receiver, the DR5-96S-III will transmit RTCM 104 differential corrections (the Industry Standard) to a number of mobile units. These mobiles will return corrected GPS position and status information using the same datalink. The link is able to use addressing and error checking to improve the reliability of the communication. In an advanced system, the mobiles may also be configured as repeaters to give extended coverage.

When the DR5-96S-III is used in an RTP system, raw measurements and base station location data are passed over the datalink every second, allowing the mobile unit to calculate a centimetric accuracy position.

The radio case is identical to the one used for XR5-M, and has been designed to meet the same stringent environmental specification. Interface to the DR5-96S-III is achieved using connectors again identical to those in the XR5-M, providing environmental and electrical sealing to the case.

The radio is supplied with an antenna suitable for short ranges, an antenna lead, together with electrical leads for connection to both an XR5/XR6 and a power supply. NavSymm® can also supply antennas suitable for use over longer ranges, and power amplifiers for use where by local regulations permit.

In addition, NavSymm® can supply appropriate leads for connection to a computer or other equipment.

2.0 INSTALLATION

Before installation, check the contents of the set of items supplied, by referring to the shipping list and to Appendix A. Mount the radio as required, using the mounting holes on the base of the unit. Make all necessary connections **before** applying power. Figures 2.1, 2.2, and 2.3, show typical installations.

Note:

DO NOT turn on the unit without an antenna or load connected.

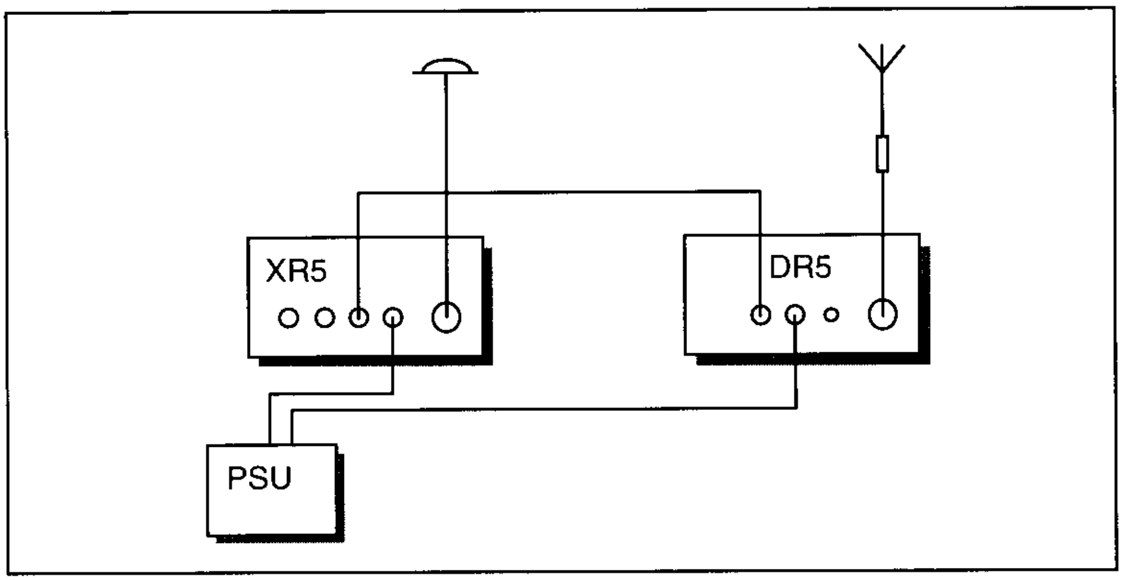


Figure 2.1 Differential GPS Configuration & RTP Base Station

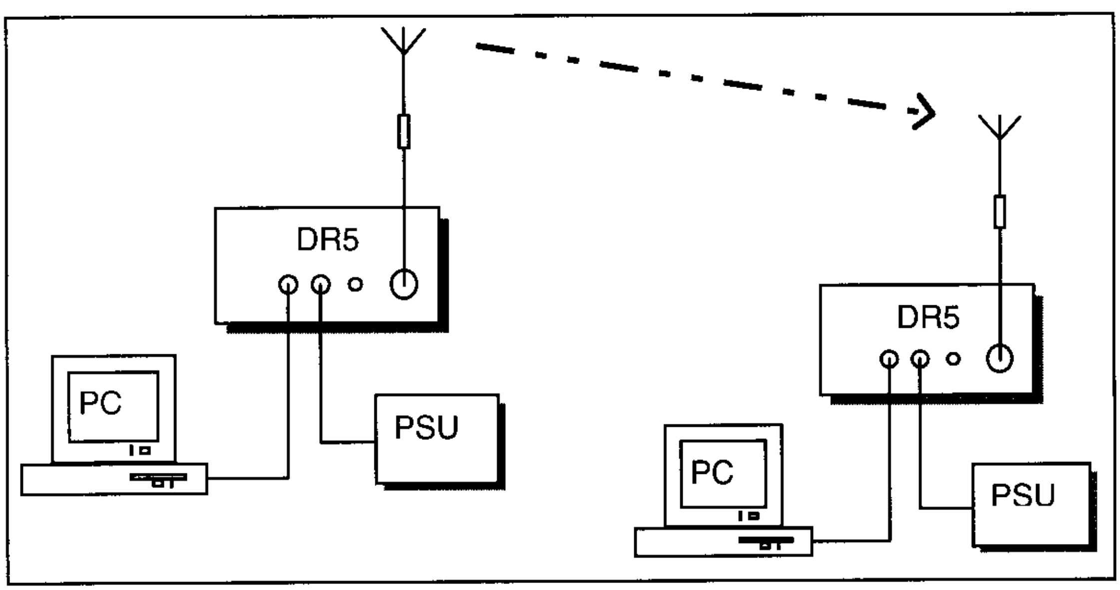


Figure 2.2 Radio Modem Configuration

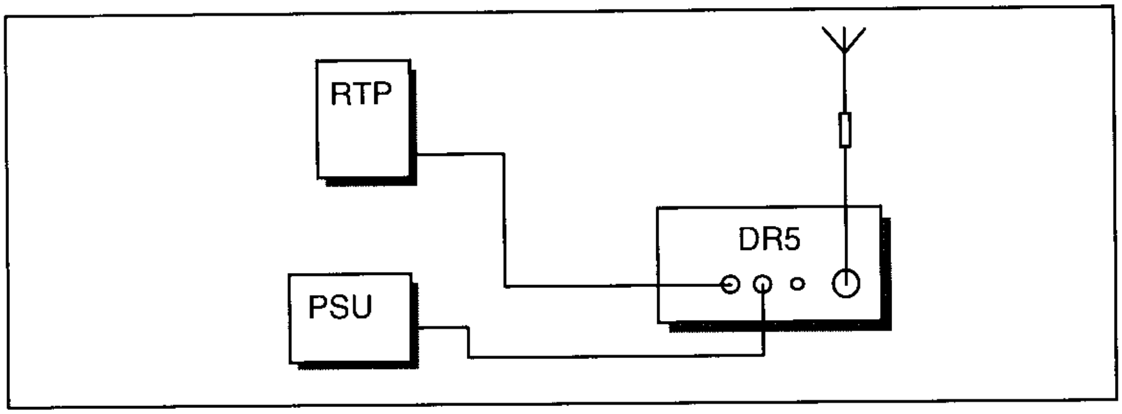


Figure 2.3 RTP Mobile Configuration

2.1 POWER SUPPLY

The power lead as supplied by NavSymm® is terminated at one end with a three pin DIN connector, and has bare ends of wire at the other. This is identical to the cable used to power the XR5-M. The DR5-96S-III will operate from the same battery or power supply as the associated XR5-M, and accepts the same range of input voltages, (eg. 11 - 32 Volts).

The correct lead **must** be used in order to maintain the power supply filtering, and water-resistance, of the DR5-96S-III. Both the RED and WHITE leads are connected to **positive,** and the BLACK lead to **negative**. The GREEN lead is the earth return for the unit, and **must** (in conjunction with the screen) be connected to a good earth point, or to the **negative** terminal of the power supply. Input power supply should be capable of providing 1.5A continuous, and 2A peak, in addition to any other loads attached to it.

2.2 DATA CONNECTION

Connection between the RTCM port of the XR5/XR6 and the DATA port of the DR5-96S-III is made via the 12-way to 12-way cable supplied. This cable connects both data and transmit timing control. A table of connections is given in Figure 3.1 (Section 3.2.2). The high quality cable supplied provides a shielded and water resistant connection between the XR5/XR6 and DR5-96S-III. If a longer connection is required, a suitable cable can be supplied by NavSymm®.

Connection to the 9-way serial port of a PC or RTP12 system (see Figures 2/3) is made via computer data cable supplied with the RTP system, or as a special part as required (See appendix A for parts lists). This cable has a RED cover on the D-Type connector cover.

Note: *This cable is NOT the same as the XR5/XR6 data cable and cannot be used on the XR5/XR6, nor can the XR5/XR6 data cable be used on the DR5-96S-III.*

2.3 BASE STATION ANTENNA

2.3.1 UHF ANTENNA CONNECTION

The UHF antenna supplied will normally be a quarter wave whip antenna. A mounting bracket system is provided, this should be assembled as shown in Figure 2.4. For base station applications, a colinear antenna may be supplied which will require different mounting arrangements.

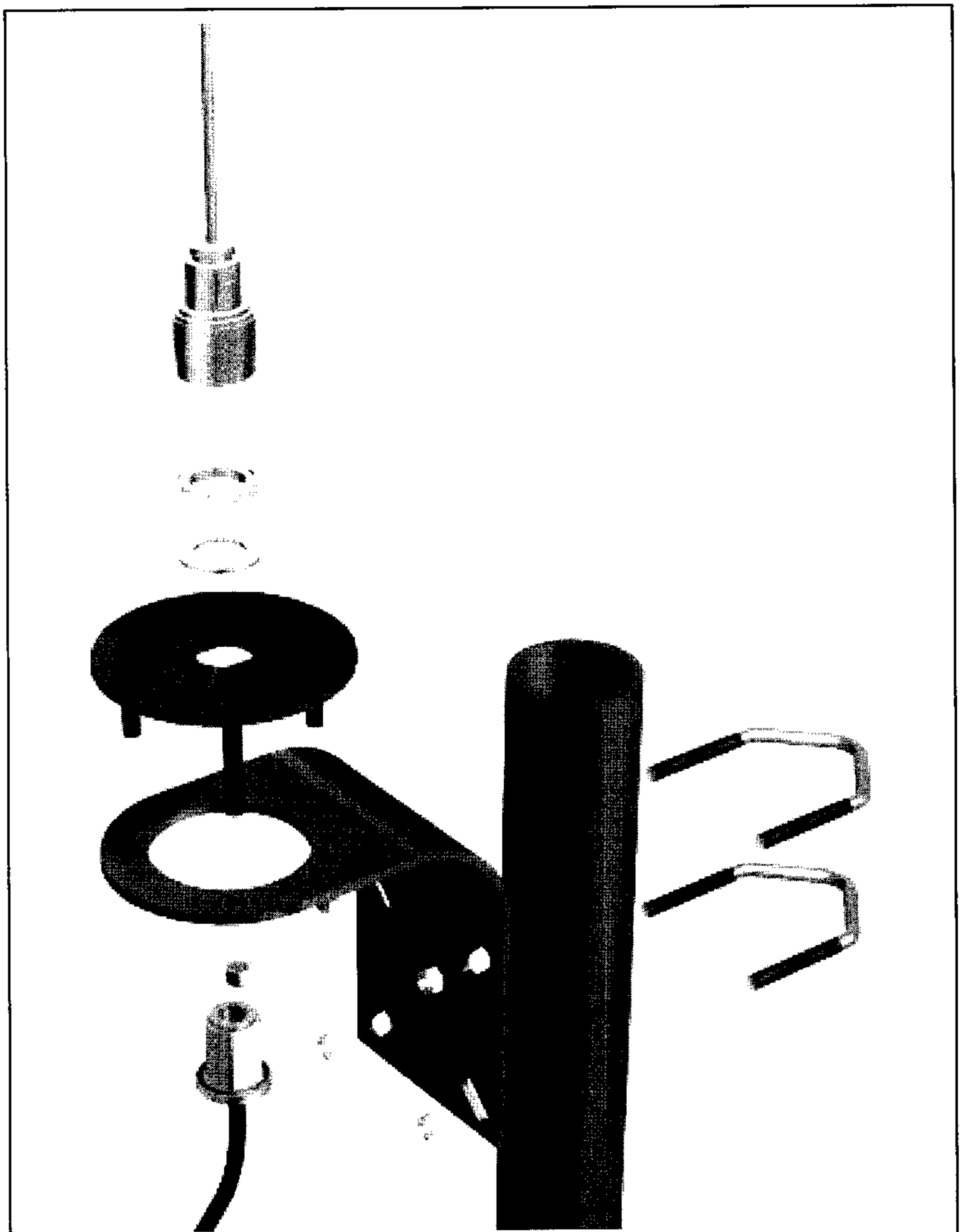


Figure 2.4 UHF Antenna Connection

2.3.2 GPS and UHF ANTENNA SPACING

Any UHF transmitting antenna should be mounted as high as possible. A suggested minimum height being 8 metres, which will give a radio horizon of 12km (assuming there are no obstacles whatsoever). The UHF antenna and the GPS antenna should be separated horizontally by a minimum of 5 metres, more if possible.

If this is not possible, the two antennas should **not** be at the same height. The GPS antenna should be higher, and the UHF antenna must be mounted at **least** 1.5metres from any adjacent metallic mast. In this situation, reduction of radio range from some directions is to be expected.

The radio horizon can be calculated from the charts given in Figures 2.5 and 2.6. Any expected range of the radio will be reduced from this value by environmental conditions or obstructions to the signal path. As a rule of thumb, range will be reduced over land by about 30-50%, and by a further 20% because of buildings or trees.

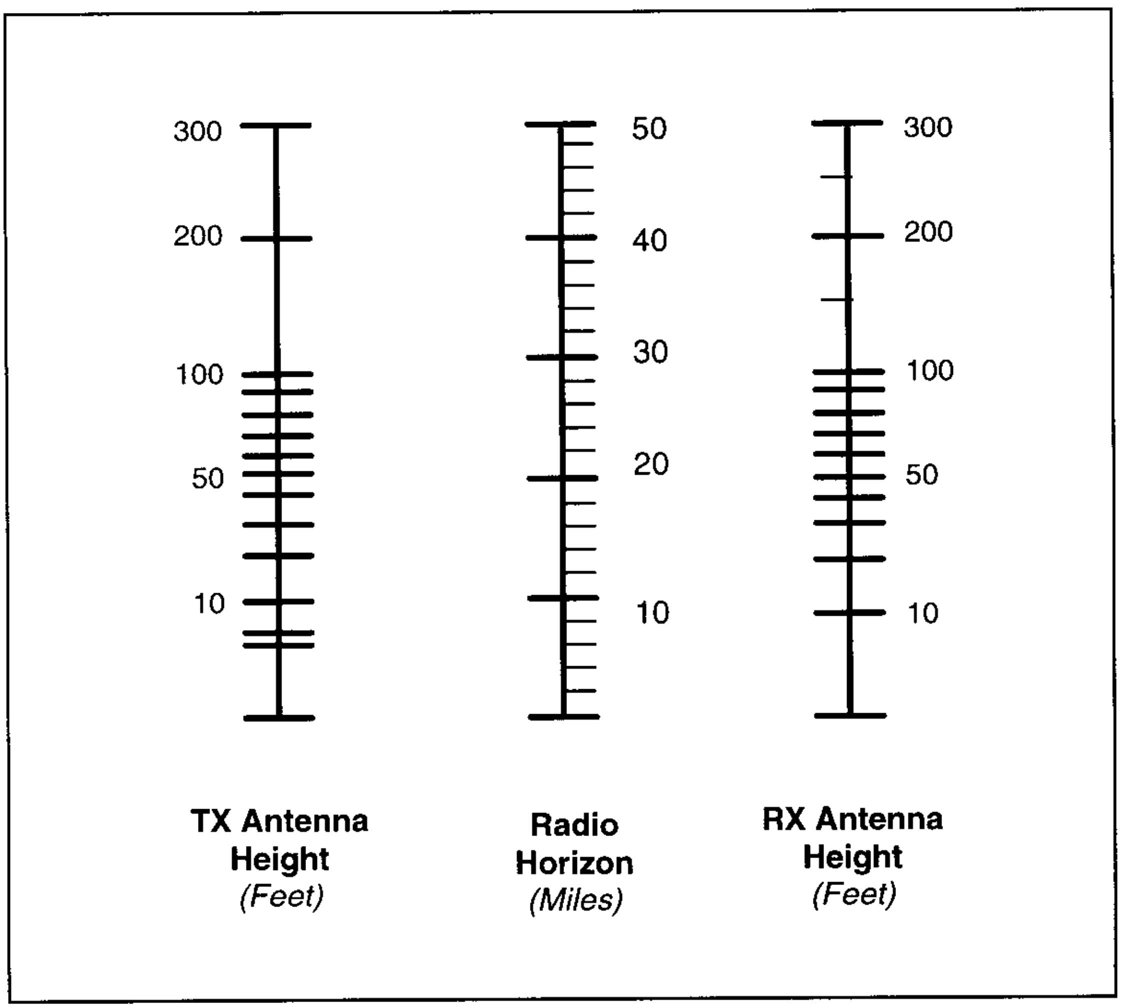


Figure 2.5 Radio Horizon (Feet/Miles)

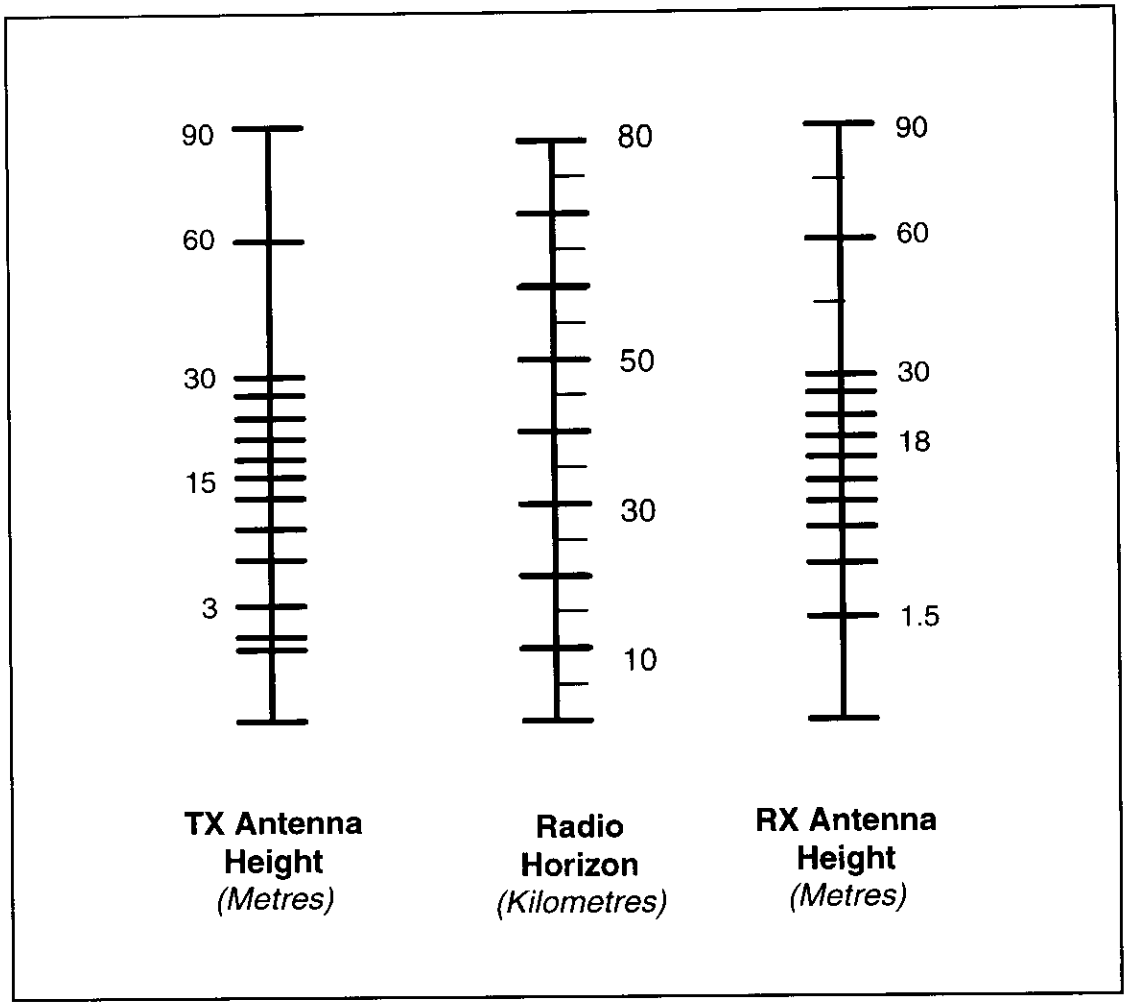


Figure 2.6 Radio Horizon (Metres/Kilometres)

Note:

A more detailed description of radio range is included in Application Note 3.

2.3.3 DR5-96S-III and UHF ANTENNA SEPARATION

The DR5-96S-III should be mounted as close as possible to the transmitting antenna. Maximum cable length is 10metres.

2.3.4 GPS RECEIVER and DR5-96S-III SEPARATION

The longest data cable between the XR5-M and the DR5-96S-III is 10metres. Standard cable supplied is 0.5metres long.

2.4 REMOTE STATION ANTENNA

The DR5-96S-III antenna and a GPS antenna should be separated as far as is practical. If the system is being used to send back status (or other) messages to the base station, this separation becomes more critical, since it is undesirable for the radio transmitter power to be coupled into the GPS receiver antenna. However, the XR5/XR6 GPS receiver features effective filtering, and should not suffer degradation in performance when the transmitting antenna is more than 1metres from the GPS antenna. The Radio and GPS units can be mounted together inside (or outside) the host platform, ensuring all connections to them are protected from mechanical damage.

2.5 RFI

The DR5-96S-III has been designed to meet all relevant specifications in transmit mode, and will receive signals in a satisfactory manner provided there are no other transmissions on the frequency chosen.

2.6 ENVIRONMENTAL

The DR5-96S-III meets sealing and temperature requirements provided each connector is used with the correct cable, and has the dust and sealing caps (supplied) properly fitted.

However, as with all electronic equipment, it will function most reliably when protected from environmental extremities. Ensure mounting is within weather-proof housings, vehicles, or other enclosures.

3.0 OPERATION

3.1 BASIC USE

The DR5-96S-III will be configured for use in the system as described by the customers order confirmation. It should only be necessary to connect the system as shown in the diagrams, correct operation should then begin. LED's are used to indicate correct operation. Power-on is shown by AMBER, correct transmit by RED, and received signal by GREEN.

Reference to Application Note 2 will provide the user with more detailed information on TDMA and RTP applications.

3.1.1 RTCM DISTRIBUTION, with STATUS RETURN

The serial interface of the DR5-96S-III is pre-set during manufacture to 19200,N,8,1. As supplied, the DR5-96S-III will have the transmit control handled by the XR5/XR6. A 'Y'-lead is required at the base station to separate the returning status messages from the outgoing data. This lead should be ordered as an optional extra from NavSymm®.

3.1.2 RTCM DISTRIBUTION with TDMA MULTIPLE STATUS RETURN

A mobile DR5-96S-III is supplied with the serial interface set to 19200,N,8,1 to allow connection to an XR5/XR6. Base station interfaces will be set to 19200,N,8,1 to allow most efficient transfer of data from the radio. The 'Y'-lead is used to split the outgoing RTCM messages from the returning status messages. NavSymm® will supply any DR5-96S-III which is intended for use as a base station pre- marked with "BASE" on its label. Both the base station and the mobiles are set-up to use binary compression, thereby providing effective radio transmission and addressing, which ensures that a mobile will ignore any data sent from another mobile.

See Appendix C, Application Note 2 for details of the capabilities of the TDMA system.

3.1.3 RTP or Data Transfer

All DR5-96S-III's are supplied set to 19200,N,8,1 with software transmission control. The transmitter will send data when it is presented at the serial port, even though it may be receiving data at the same time. This requires the communication programs to make their own allowances for ensuring there are no conflicting transmissions. For data transfer applications, it is recommended that a half duplex transfer protocol such as "Kermit" is employed.

3.1.4 General Operation

Assuming all connections to have been correctly made, and the XR5-M has been configured for correct operation using the XR5-M programme, base station and remote operation becomes totally automatic.

In a TDMA system the transmission periods will need to be set using the XR5-M, paying special attention to ensure that the various mobiles will not interfere with each other *(Appendix C, Application Note 2)*. An XR5-M transmission can take place at pre-set times within any given second. With other systems, transmission usually occurs as soon as data becomes available.

3.2 ADVANCED USE

3.2.1 Radio Description

The DR5-96S-III Radio Modem transmits and receives half duplex serial data at either 9600 bits/sec, or 4800 bits/sec, depending on the users setting. A buffer RAM is provided enabling data to be passed asynchronously to the host at Baud rates from 150 to 38400. Parity and stop bits are all adjustable over the usual values. An error detecting algorithm can be selected to maintain the integrity of the data transmission at high speed or over interrupted paths.

It is possible to configure the DR5-96S-III whereby it will automatically repeat the data it receives, consequently extending the range of transmission, or as an echo back configuration.

3.2.2 Connections

Power is supplied to the unit via a 3 way DIN connector as described in section 2.1. The unit has a switching regulator which requires a 2A start-up current, but once running, the DR5-96S-III uses only 1.4A to transmit, and 25mA to receive. The power supply does not need to be specially regulated provided it meets the current requirements of the units.

All data port cables supplied will connect directly to an XR5/XR6, RTP12 unit, or a PC. Cable specifically for use with an RTP12 system, or a PC, will have a **RED** cover. The pins used are shown in Figure 3.1.

Normal connection will only use the data and return connections, the XR5/XR6 uses the transmit control line. All the other connections are used for configuration purposes.

DR5-96S-III Pin	*Cable Colour*	*Data port*	*XR5-M*	*PC or RTP12*	*Control Port*
A (1)	GREEN	+8v out	-	-	
B (2)	GRN / BLK	Tx Control	Radio Control	-	-
C (3)	ORANGE	Spare	-	-	-
D (4)	OR / BLK	RSSI	-	RSSI out	-
E (5)	BLUE	Prog Data Out	-	-	Transmit Data
F (6)	BLUE / BLK	Data In	Transmit Data	TxD	-
G (7)	RED	Prog Data In	-	-	Receive Data
H (8)	RED / BLK	Data Out	Receive Data	RxD	-
J (9)	WHITE	CTS	-	CTS	
K (10)	RED / WHITE	RTS	-	RTS	
L (11)	WHITE / BLK BLACK	Ov	Ov	Sig Gnd	Gnd
M (12)	SCREEN & DRAIN	Screen	Screen	Screen	-

Figure 3.1 Data Port Connections DR5-96S-III

3.2.3 Configuration of DR5-96S-III

The DR5-96S-III is delivered already configured for the application specified by the customer. Changing this configuration involves opening the DR5-96S-III, making connection to the internal control port, and utilising a terminal programme to change the settings of the DR5-96S-III.

Users must ensure that they have read and understood **all** sections of the manuals (for both the DR5-96S-III, and the XR5/XR6) **before** beginning to make any changes. Once disturbed, the settings must be correctly reset before the link will begin to work again (Section 3.4).

Appendix C contains several Application Notes describing the Setup Parameters and use of the DR5-96S-III in a range of systems. It is advised that these are used as starting points for any attempts at re-configuration.

3.3 MODEM PORTS and CONTROL

This section describes the commands used to control the radio data ports. The DR5-96S-III has four ports: the RTCM Data Port, Frequency Programming Port, Control Port, and a Radio Interface Port. Detailed descriptions for use by applications engineers are given in Application Note 1.

3.3.1 The RTCM Data Port

The RTCM Data Port is available at the 12-way connector on the outside of the DR5-96S-III. This port transmits and receives data from the XR5/XR6, RTP12 unit, or a PC.

Any data presented at the port will be transmitted and received unchanged at either end of a mobile link, provided that the data rate is matched to the port setting.

3.3.2 The Control Port

The Control Port is also available via the 12 way connector marked 'DATA' on the DR5-96S-III. It requires a special serial cable to connection to a PC (BLUE 9-way D cover).

This Control Port allows the resetting of all the Data Port and Radio Interface Port parameters. Normally, the DR5-96S-III will have been supplied with the two frequencies pre-set to the values requested by the purchaser. However, it is possible to change these frequencies when required, using the Control Port.

This feature is password protected. Contact NavSymm® for further details.

3.3.3 The Radio Interface Port

The Radio Interface Port controls the transmission and reception of the data over the airwaves, together with the hardware use of compression, correction, addressing, data-rates and simple frequency switching.

Direct connection is not possible, the port is contained within the unit. Configuration is via the Control Port.

Figure 3.2 Top PCB Layout (upper surface)

Figure 3.3 Top PCB Layout (lower surface)

3.4 THE CONTROL PORT COMMAND SET

To access the Control Port, connect the 'Control Port Serial Cable' (BLUE 9-way D cover) to the 'DATA' port.

The other end of the cable connects into the 9-way RS232 port of a PC. Using a terminal program (such as Windows Terminal), set the communication parameters to 9600 baud, 8 data bits, no parity, no handshaking, and one stop bit. When power is applied to the radio, the terminal should display:

DR5-96S-III HDLC Modem Ver 1.0

Press return, the modem should reply something like, (but not exactly):

Command failed

MODE COM1: 9600,N,8,1

MODE COM2: 9600,S,F,A,U,0

MODE COM3: 4800,N,8,1

MODE FRQ1: 456.9250,456.9250

MODE FRQ2: 462.0000,462.0000

This shows the present settings of the modem.

It is strongly suggested that careful note is made of the exact wording of this reply, so that original settings may be restored should the changes fail.

The parameters refer to:

COM1	-	The Control Port
COM2	-	Radio Interface Port
COM3	-	RTCM Data Port
FRQ1	-	Frequency 1
FRQ2	-	Frequency 2

These ports may be re-configured by entering commands from the PC terminal to the radio. It is important to follow the **case** and **form** of the commands **exactly**. When commands have been executed correctly, the radio will reply (thereby confirming the correct reception of the new command) which will be implemented immediately.

The Data Port and Control Port are both asynchronous ports for RS232 communication and have identical command sets.

The Radio control Port is a synchronous port, controlling the data format over the radio channel. This has a different command format.

Radio frequencies are pre-set, the data is displayed for information only.

3.4.1 Setting the RTCM Data Port and the Control Port

Setting the data and control ports is a similar procedure to setting serial communication ports on a PC.

The format of the command is as follows :-

MODE COMv:w,x,y,z <cr>

where:-

v	=	the port number 1 or 3
w	=	the baud rate 150, 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200
x	=	parity O, E, 0, 1, N for odd, even, zero, one or none parity
y	=	length 7 or 8 data bits
z	=	stop bit 1 or 2
<cr>	=	carriage return

The manufacturing defaults are :-*

MODE COM 1: 9600,N,8,1 <CR>

MODE COM 3: 4800,N,8,1 <CR>

All parameters have to be included and typed in upper case. No characters can be shortened or omitted.

***** NOTE:***

These examples may not show the same settings as the radios supplied by NavSymm®.

During manufacture, radios are individually adjusted to give best possible performance for the application described in a customers purchase order.

3.4.2 Setting the Radio Interface Port

The radio interface port uses a similar basic format to the other ports, but different parameters.

MODE COM2:a, b, c, d, e, f <cr>

where:-

a = Baud Rate
Set to 4800 or 9600 bits per second over the radio channel.

b = Transmit Initiation Control
S = Software - Idle gap of 10 characters, or more than 320 characters received.
H = Hardware - Pulse on RTS line or transmit control line

c = Error checking
C = Clear - No error checking on received messages
F = Filtered - CRC, Overflow, Abort, Frame length and Non Octet Aligned checking. A message which has any errors will not be passed out of data port.

d = Message format
A = ASCII - No compression
B = Binary - Packed standard status messages for minimum transmit time

e = Network addressing
A = Addressed - Network addressing switched on
U = Unaddressed - No address checking, all messages relayed
R= Repeating - received messages are immediately re-transmitted

f = Frequency
0 = Select Frequency 1
1 = Select Frequency 2

<cr> = carriage return

The manufacturing defaults are :-*

MODE COM2: 4800, H, F, A, A, 0 <CR>

**** NOTE:***

These examples may not show the same settings as the radios supplied by NavSymm®. During manufacture, radios are individually adjusted to give best possible performance for the application described in a customers purchase order.

After <cr> the radio modem replies

Command OK MODE COM2: 4800, H, F, A, A, 0

This shows the new values of the control for the ports.

3.5 USER CONFIGURABLE CONTROLS

There are four DIP switches mounted on the radio modem board (See Figure 3.1), labelled as SW1 (1-4).

Switch 1 unconnected.

Switch 2 the reset switch for the processor, used only to download new software. Both these switches should be left open (off).

Switch 3 connects the RTS line from the XR5/XR6 to the RTS line of the DR5-96S-III.

Switch 4 connects the Tx control line to the RTS line of the DR5-96S-III. The default setting for both switches 3 and 4 is closed (on) and provided NavSymm® cables are used this setting will work for all applications. However, if different cables are used, these may have to be changed to allow the DR5-96S-III to select handshaking or hardware control of transmit.

The RV1 (Figure 3.1) potentiometer sets the level of the receiver detection circuit. It should not be necessary to adjust this potentiometer.

If persistent data break up is occurring without an obvious cause, turn the potentiometer one tenth turn **clockwise**, then turn it back again to its original setting. If necessary, reset again by one further tenth turn **anti-clockwise**. Do this whilst transmitting and monitoring the data. Leave the potentiometer set to the position which gives best quality of reception.

If there is no change in the data break-up, return the potentiometer to its original setting.

4.0 FAULT FINDING GUIDE FOR DR5-96S-III

Fault-finding on the DR5-96S-III radio is accomplished mainly by using the LED's on the top of the case.

This displays:

GREEN	for quiescent (neither sending or receiving).
AMBER	for receiving.
RED	for transmitting.

An XR5, SHARPE XR6, or a PC, which is connected correctly, will cause the transmitter to function the moment data is ready for transmission, and to go off the moment all available data has been sent. When incoming data is received, it is passed immediately from the radio to the remote GPS unit or computer. Refer to Figure 4.1 for the most obvious problems and their solutions.

If you are still having problems, call the NavSymm® technical help line on +44-1604-585588.

Symptom	***Occurs***	***Solution***
No LED:		Check power leads, fuses, voltage supply.
Green LED:	When expecting to transmit.	Check antenna connections on transmitter. Check data rate and port settings.
Green LED:	When expecting to receive.	Check antenna connections and receive frequency.
Amber LED:	When expecting to transmit.	Channel is in use or blocked by interference from electrical equipment. Try re-locating receiver and or antenna.
Amber LED:	When expecting to receive.	Channel is blocked by interference. Try moving the receiver and or the antenna to get the LED to blink in time with the transmitted signal. Channel is in use by another user. Use a monitor receiver to listen to the signals on the frequency.
No Red LED:	When expecting to transmit.	If the radio current is increasing and falling in time with the expected transmission, then the antenna is incorrectly fitted, or the cable is faulty. If there is no increase in current when transmission is expected, the baud-rate on the GPS and radio do not match, or the radio is set up to have transmission controlled by the GPS and the transmit control line is not connected.
LED blinks Amber *in time with transmitted data but only rubbish is received:*		Data rate over the air is sent differently at transmitter and receiver. Set COM2 parameters to match at receiver and transmitter. Parity or data bits is set incorrectly at transmitter or receiver.
LED blinks Amber *in time with transmitted data but there are occasional errors in the data stream:*		Adjust RV1 +/- 1/10 turn to set detection threshold. RV1 is factory set for best performance with all radios. Making this adjustment will set receiver to work only with transmitter used to set up receiver.
LED blinks Amber *in time with Data on transmit, but no data is received:*		Computer or modem is not set to the correct baud rate. Some or all settings on COM2 do not match between transmitter and receiver.

Figure 4.1 Fault Finding Checklist

APPENDIX A

	PART NO.
DR5-96S-III	A190-000G1
A complete product comprising:	
2W UHF Transceiver	A190-001G1
5m Antenna Cable (FM58)	A141-024G1
Antenna Mounting Bracket	M35099/06
UHF Antenna Mounting Ring	M141-205/02
Power Cable (2m)	A110-024/A
Data Cable to XR5-M	A141-020G1
Frequency Programming Cable	A141-039G1
User Manual	A190-032G1
Screw Pack	A61-103G1
Warranty Card **??**	141-303/01A **??**

OPTIONS

RTCM or TDMA Base station Y lead	A141-042G1
10m Antenna Cable (RG213)	A141-025G1
Data Cable to 9 way D-type (PC/RTP12 use - RED cover)	A141-027G1
Data Cable to 9 way D-type (Kernel use)	A141-029G1
25W Amplifier	A141-035G1

ANTENNA OPTIONS

Whip / Colinear (6db)	A141-209
Base Station Colinear a (3db)	A141-210
Base Station Colinear b (6db)	A141-211
Yagi (Reference Only)	A141-213

APPENDIX C

Radio Application Notes

- Application Note 1 -

DR5-96S-III SET-UP PARAMETERS

This application note covers the setup parameters for the DR5-96S-III in greater detail. It discusses some of the implications of the available settings, and how the radio is to be used to best effect in a system.

PORT SETTINGS

The settings of the ports are changed using the programming adapter cable supplied with the radio. Using a PC together with a standard terminal program, all the facilities of the DR5-96S-III can be accessed and changed. Parameters are stored in an EPROM and are saved when power is disconnected from the DR5-96S-III.

Port 1 - Control Port

Command Form

MODE COM1: 9600,N,8,1

Port 1 is the loader and control port, accessed via the 10 way internal connector (J8). Settings are variable, but under most circumstances there is no need to change them from the default values of 9600,N,8,1. This setting gives effective control of the DR5-96S-III, without interfering with the operation of the unit.

Port 2 - Radio Interface Port

Command Form

MODE COM2: 9600,H,F,A,U,O

Port 2 is the interface port for the radio. The parameters control the mode and frequency of transmission. It is accessed via the 10 way internal connector (J8).

Bits Per Second

MODE COM2: **9600**,H,F,A,U,O

The BPS parameter is 9600 or 4800, the rate is expressed as bits per second. Data is transmitted continuously within an HDLC packet, this means that the rate of data and times occupied depend upon the data lengths. For example, comparing data rates of RS232 defined as 9600 Baud and 9600 BPS there are some interesting effects.

Message Length (Bytes)	***RS232 (Bits)***	***Time (mS)***	***Radio Link (Bits)***	***Fixed Time (mS)***	***Total Time (mS)***	***Saving (mS)***
10.00	100.00	10.42	80.00	30.00	38.33	-27.92
100.00	1000.00	104.17	800.00	30.00	113.33	-9.17
256.00	2560.00	266.67	2048.00	30.00	243.33	23.33
320.00	3200.00	333.33	2560.00	30.00	269.67	36.67

Figure A1. Message Length and Timings

The radio link requires a fixed time to switch from receive to transmit and to set up the datalink. This means that for short packets, the radio takes longer than the RS232 to transfer the data. For longer packets, the radio is more effective at transferring data than the RS232. Therefore, most systems should accumulate data into larger bursts, rather than sending a larger number of smaller bursts.

Using a transmission data-rate of 4800 BPS results in a slightly more reliable link for difficult paths (eg. from fixed station to fixed station). The increased length of the transmission will also increase the likelihood of a mobile experiencing signal fade. The lower data-rate changes the data shaping value, whilst the occupied bandwidth on the radio channel remains constant.

Transmission Control

MODE COM2: 9600, **H**, F,A,U,0

The modem constantly monitors the data port, storing data as it is received. Under software transmit control, where a pause of 10 characters length occurs in the data, the stored data will be transmitted. Under hardware control, the transmit control line causes all the characters stored in the buffer to be transmitted at once. In both cases the transmitter is activated without reference to the radio channel being clear. This is intended to prevent external interference (from local sources) preventing operation of the system.

To ensure data is not lost (because of several stations in a TDMA system transmitting at the same time) the GPS is programmed to cause transmission only in the correct time-slot. (See Application Note 2 for more details).

With software control, either a one way link must be established, or a software method employed which ensures data is being correctly transferred. This is the basis of a packet system. The radios having been utilised as dumb-modems in such a system.

On some occasions it may be possible to make use of the data itself as a handshaking control. For example: (1) in an RTP mobile system which is receiving a long base station message once per second, (2) by cross connecting the received data into the handshaking lines of the mobile, (3) a short status message can be returned, (4) and transmitted by the radio.

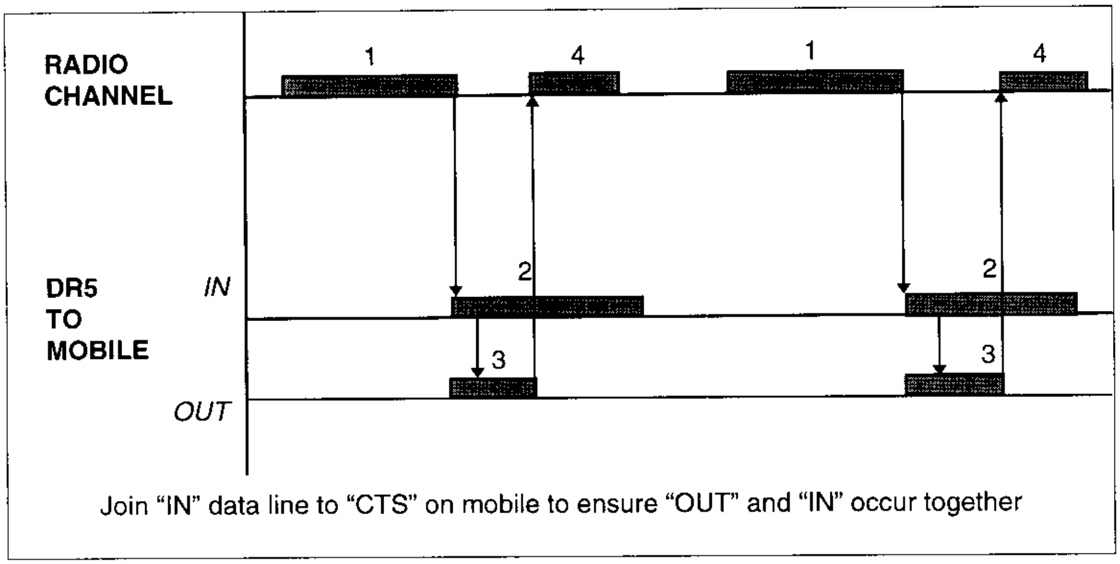


Figure A2. Handshaking Control

When data is being passed from the DR5-96S-III to the mobile RTP, the radio channel must be inactive. At this time it is possible to return transmission from the mobile to the base station (4). The hardware transmit control in the PC based system may also be used to gather data on the DR5-96S-III from a number of completely separated periods, and to transmit them together under software control. This increases the efficiency of operation. (See the previous section).

MODE COM2: 9600, H,**F**,A,U,0

This ensures that the data delivered to the XR5/XR6 (or PC) is completely correct. However, there is no reason why software using the modem should not use its own error correction routines. In this case, the modem can be set to transfer all received data out of the data port. This is clear mode. In addition this mode can be used to determine if data is being corrupted by pulse interference. It has been noted that an apparently clear radio channel can be blocked by very short bursts of noise, which cause single and double character errors.

MODE COM2: 9600,H,F,**A**,U,0

ASCII is a generalised term for the data sent to the DR5-96S-III. With ASCII selected, all the data will be transmitted exactly as was received into the data port. This is the most common mode of operation. The exception being

TDMA, which uses Binary mode. In Binary mode, the modem examines the incoming data. If the first received character is # (Hash or Pound), on transmission the data is passed to a compression routine which compresses Navstar status messages into a binary format. On receipt, the data is decompressed and passed out of the data port. Currently, the compression is specific to the XR5/XR6 status messages, and can be used in TDMA or software controlled transmit code.

MODE COM2: 9600,H,F,A,**U**,0

In un-addressed mode the data will be passed out of the data port and received by all radios. In addressed mode the radio examines the incoming data on the data port from the XR5/XR6 to determine its address. If the first four characters of the incoming data are #NNN (as they are with status messages), where NNN can be any number from 0 to 254, the radio takes that number as its address. If the first characters of the data are not '#000' but an RTCM message from a base station, then the radio assumes an address of 255.

Receiving of messages therefore depends on the message address received over the radio channel, and the address of the receiving DR5-96S-III.

Message Address	***Receiving Station Address***		
	0	***1 - 254***	***255***
0	✓	x	✓
1 - 254	✓	x	✓
255	✓	✓	x

Figure A3. Addressing Truth Table

✓ = Message passed out of data port

x = Message not passed out of data port

Station address 0 acts as a monitor for all messages for test purposes.

Frequency Selection

MODE COM2: 9600,H,F,A,U,**0**

The frequency selection parameter can take the values **0** or **1** for the primary and secondary frequencies. The radio has two frequencies pre-programmed as requested by the customer. If new frequencies are later required, the Frequency Programming Kit must also be supplied. More details are given in Application Note 3.

Port 3 - DATA Port (RTCM)

Command Form

MODE COM3: 9600,N,8,1

Port 3 is the data port, and is accessed via the 12 way connector marked DATA on the DR5-96S-III. This sets the parameters needed to communicate with the terminal equipment, be it an XR5/XR6, RTP 12, or PC.

The data rate and data size need to be considered in relation to the data rate over the transmission. In general, the data rate can be anything the user requires, provided that there are sufficient breaks in the data to allow transmission.

For example, if the data rate over the air is 9600 BPS, and the data port is set to 19200, the data port may only transmit data to the DR5-96S-III 50% of the time. If this percentage is exceeded, the internal memory of the DR5-96S-III will fill up and transmission will eventually stop.

The internal memory can store approximately 300mS of data at 9600 Baud. Setting 9600,N,8,1 is suitable for RTP systems, but for use with a TDMA system, the mobiles are set to 4800 Baud and the base station set to 19,200 baud.

- Application Note 2 -

DR5 - 96S - II TDMA and RTP APPLICATIONS

The DR5-96S-III is designed to provide efficient, reliable transmission of GPS data between base stations and mobile receivers. To achieve this, the DR5-96S-III radio uses addressing, error detection, and data compression. This application note describes the setup of a Time Division Multiple Access (TDMA) vehicle tracking system with broadcast RTCM distribution, together with the Real Time Positioning (RTP) system.

RADIO SYSTEM CONFIGURATION

A thorough understanding of the operation of both the DR5-96S-III and the XR5/XR6 is needed to configure a system. This is due to the flexibility of the systems which permit a working system to be prepared under the most adverse conditions. These application notes assume the user is familiar with both the XR5/XR6 and the DR5-96S-III product manuals.

These application notes seek to explain the logic behind each type of operation, and to describe how to achieve the most efficient use of the radio channel by using Time Division Multiple Access (TDMA) under the control of an XR5/XR6.

Development of the DR5-96S-III has specifically focused on the design of a unit which will effectively track a large number of RTCM corrected mobiles, ensuring that the XR5/XR6 and DR5-96S-III will give optimum performance in this mode.

There are a number of special features encapsulated within the DR5-96S-III and XR5/XR6 which are specific to this requirement. A clear understanding of these features will allow the capabilities of this system to be fully exploited.

TIME DIVISION MULTIPLE ACCESS APPLICATION

Radio systems communicate by transmitting data over a radio channel. The DR5-96S-III is a half-duplex radio, meaning that it can either transmit or receive at any one instant. In fact, it takes a finite amount of time to change from transmission to reception.

To make effective use of time, some external control of transmission is required. The XR5/XR6 provides this external control by allowing the user to set the time and duration of the transmission control output from the RTCM port. This allows every second to be divided into small parts, each of which is used to communicate data.

In a TDMA system, the base station transmits RTCM information in the first part of the second, and the mobiles return their information in the subsequent parts. An XR5/XR6 will control transmissions to make sure that signals do not interfere with each other.

In addition, the DR5-96S-III is able to compress standard status messages into a compact form which further reduces the amount of time required for transmission. The DR5-96S-III also uses addressing derived from the XR5/XR6 ID numbers, directing messages to the correct destinations. By deriving this addressing from the attached XR5/XR6, the radios are dynamic and do not need to be individually programmed.

The XR5 and SHARPE XR6 Setup

When programmed to operate as a base station, the XR5/XR6 will provide RTCM corrections to SC104, types 1, 2 and 9.

Type 1 provides a full set of corrections for all the satellites visible at the base station.

Type 2 provides an overlap for satellites whose Ephemeris has changed at the top of the hour, for a period of five minutes after the hour.

Type 9 messages only have data for three of the visible satellites, and cycles round all the visible satellites to send a full set of corrections. This occurs over a longer period and is useful in a heavily occupied channel, or over a slow data link.

Each of these corrections is prepared at the top of the second, and sent out of the RTCM port at the half-second mark. When in base station mode the communication can take place at 19,200 baud which allows the data to be communicated quickly and effectively from the XR5/XR6 to the DR5-96S-III.

At the mobiles, the received RTCM data is used to calculate position. A status message is generated about half a second after the top of second, and passed out of the GPS unit at the top of the following second. Status messages contain information on the mobiles position, speed, heading, and satellites used in the solution. Messages also have a unit identification number which is used within the radio to prevent a mobile from receiving other mobiles data.

Control of timing in a TDMA system is the key to achieving efficient data transfer. It is essential to decide on the time allocations before beginning to set up a system. The amount of time required for different messages is detailed in Figure B1. This assumes that the base station is set to 19,200 Baud, the mobiles are set to 4800 Baud, and the on air rate is set to 9600 BPS. These are the optimum settings for a TDMA system.

Message Type	ASCII Length	Binary Length	Data Time	Radio Time *
Type 1 RTCM	120 Bytes		60 mS	170 mS
Type 2 RTCM	70 Bytes		40 mS	130 mS (50 + 80mS)
Type 9 RTCM	35 Bytes		17 mS	80 mS
Standard Status	78 Bytes	40 Bytes		90 mS
Reduced Status	63 Bytes	35 Bytes		85 mS
Minimum Status	45 Bytes	17 Bytes		70 mS

Figure B1. Message Timing

* All radio times include 50mS setup time. This is not required twice if sending both type 1 and type 2, thus type 1 and type 2 duration = 250mS.

The numbers of mobiles per second is determined by simple mathematics. Figure B2 shows the outline of a typical basic system.

Status Message Type	RTCM Message Type			
	Type 1 & 2	Type 1	Type 9	None
Standard Status	8	9	10	11
Reduced Status	8*	9*	10*	11*
Minimum Status	10*	11*	13	14

Figure B2. Number of mobiles returned per second under different conditions

** Note these are minimum values. It is possible to increase these numbers by 1, using fine adjustment of tx offset and duration.*

The RTCM function selected depends on the trade-off of accuracy against recovery of numbers of vehicles. If a full, accurate RTCM solution is required, then the initial 250 mS of each second needs to be set aside for the transmission of both type 1 and type 2 messages. For a marginal reduction in accuracy at the top of the hour (5 - 20% for 5 minutes per hour), only type 1 messages can be sent, this allows one extra mobile to be returned each second, by needing only 170 mS for RTCM distribution. If type 9 messages are used, the accuracy is further reduced by 20 - 50%, but two additional mobiles can return their data each second.

Having chosen the RTCM format using the XR5/XR6 setup, (and selecting 19200,N,8,1 as the communications parameters) it is now possible to assign the mobile IDs and message update rates. Take the total number of mobiles required, divide by the number of mobiles per second possible (using the data and RTCM formats chosen from Figure B2). This gives the number of seconds required between updates.

ID Number	***35***	***34***	***33***	***32***	***31***	***30***	***29***	***28***	***27***	***26***	***25***	***24***
Second Offset	3	3	3	3	3	3	2	2	2	2	2	2
Millisecond Offset	600	530	460	390	320	250	880	810	740	670	600	530
Duration	70	70	70	70	70	70	70	70	70	70	70	70
Delay	4	4	4	4	4	4	4	4	4	4	4	4

ID Number	***23***	***22***	***21***	***20***	***19***	***18***	***17***	***16***	***15***	***14***	***13***	***12***
Second Offset	2	2	2	2	1	1	1	1	1	1	1	1
Millisecond Offset	460	390	320	250	880	810	740	670	600	530	460	390
Duration	70	70	70	70	70	70	70	70	70	70	70	70
Delay	4	4	4	4	4	4	4	4	4	4	4	4

ID Number	***11***	***10***	***9***	***8***	***7***	***6***	***5***	***4***	***3***	***2***	***1***	***0***
Second Offset	1	1	0	0	0	0	0	0	0	0	0	0
Millisecond Offset	320	250	880	810	740	670	600	530	460	390	320	250
Duration	70	70	70	70	70	70	70	70	70	70	70	70
Delay	4	4	4	4	4	4	4	4	4	4	4	4

Figure B3. Example TDMA configuration chart

In this example there are 36 mobiles, all receiving RTCM messages (1 and 2) every second which takes up 250mS. Each XR5-M has been set to output the minimum status message, having a length of 70mS each. Using table 2, all the 35 mobiles can report back in 4 seconds, and the time slice allocations are given in Figure B3. Thus, for mobile number 21, the ID is set to 021, the seconds interval is set to 4, the second offset is set to 2, millisecond offset is set to 320, and the duration to 70. When all the mobile XR5/XR6s have been programmed, they can be connected to DR5-96S-III's.

The DR5-96S-III Setup

Setting parameters for the DR5-96S-III using mobiles is different to base station applications. This is due to the fact that the XR5/XR6 is unable to receive data any faster than 4800 Baud.

Suggested settings are:

MOBILE	***BASE***
MODE COM2: 9600,H,F,B,A,0	MODE COM2: 9600,H,F,B,A,0
MODE COM3: 4800,N,8,1	MODE COM3: 19200,N,8,1

Figure B4. Comm port setting for TDMA application

For the mobiles, the hardware transmit control option is selected to ensure the DR5-96S-III controls the transmission. Filtering is turned on to prevent corrupted data being delivered to the XR5/XR6, binary compression is selected to get maximum efficiency on the radio channel, and addressing is used to prevent mobiles from receiving other mobiles status messages.

In operation, the timings of the various signals are shown in Figure B5. The RTCM messages and the mobile returns are all separated from one another by 5-10 mS gaps which are caused by the turn-on delay of the transmitter. If it is possible to examine the channel occupancy using a monitor receiver, it may be possible to adjust the timings to give slight performance improvements in signal timing.

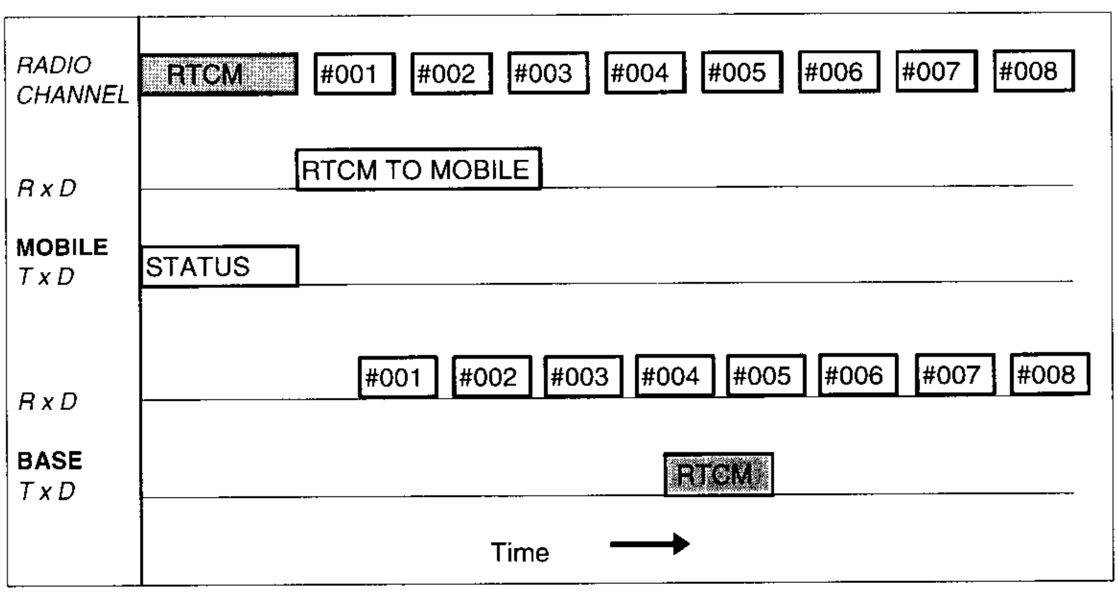
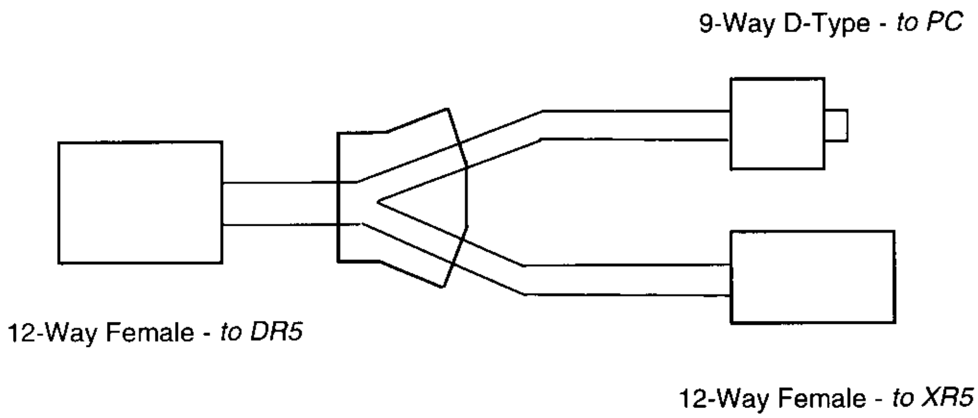


Figure B5. Signal Timing

These data flows can all be checked using a storage oscilloscope and monitor receiver, but the design of the DR5-96S-III/XR5/XR6 combination is such that this should not be necessary.

DR5-96S-III TDMA System Y-Lead

A 'Y'-lead can be supplied for the base station, this will enable outgoing RTCM messages and returning status messages to be seperated. Details of the pin connectors are given in Figure B6. The connections in brackets [ ] are optional.



DR5-96S-III 12 Way	***D Type to PC (female) 9 Way***	***XR5/XR6 12 Way***
F (6)		F (6)
H (8)	2	
L (11)	5	L (11)
[M] (12)	[5]	[M] (12)

Figure B6. TDMA 'Y' lead pin connection details

REAL TIME POSITIONING APPLICATION

The NavSymm® RTP12 system requires data to be transferred from the base station (a 12 channel XR5-M) to the RTP12 unit (which is a cased PC with built-in XR5-PC). This data consists of a burst of up to 320 Bytes, to be repeated once or twice a second.

Configuration for the XR5/XR6 will be as for an RTCM Base Station. However, the RTP Base Station message is specified as per one of the RTP output messages. These are stipulated in the XR5 RTP software (screen 5).

The DR5-96S-III is configured for maximum data throughput rate (9600 Baud N,8,1) to ensure most effective transfer of data. This RTP-DR5-96S-III combination is capable of transferring either 2 data bursts per second, or 1 data burst per second (as appropriate to the application).

DR5-96S-III settings for use with an RTP system, applicable to both base station and mobile:

COM1:	9600,N,8,1
COM2:	9600,S,F,A,U,0
COM3:	9600,N,8,1

Connection cables are supplied with the unit, and the system should operate without any further modification. It is possible to increase the Port 3 rate to 19,200 Baud, which will give less occupied time on the RS232 link, but have no real effect on the efficiency of data transfer.

- Application Note 3 -

RADIO RANGE ESTIMATING

Estimating radio path distances is often regarded as a black art. This section is intended to familiarise NavSymm® customers with the basic principles of DGPS data links and range.

RADIO WAVE PROPAGATION

Radio waves travel (propagate) by various means:

Low frequency radio signals (such as the 150-350KHz beacon band) can travel up to several hundred miles because they are able to pass between the atmosphere and earth's surface.

High frequency (HF) radio signals can travel long distances (possibly several thousand miles) by reflecting between the upper atmosphere and the earth's surface. This may occur a number of times, until the signal is attenuated beyond use.

Radio waves in VHF/UHF bands travel from point to point in straight lines. The signals are not reflected by the atmosphere, nor are they propagated in any way other than direct line-of-sight. Most DGPS links use VHF/UHF frequencies.

The phrase *"line-of-sight"* must not be taken absolutely literally. It implies that both the transmitting and receiving antennas must be in clear view of each other. While this is a highly desirable situation (and essential when planning long range links), it is not always essential to have a completely clear radio path between the DGPS base station and the mobiles.

The majority of DGPS links will employ UHF signals. These perform very well over water and open flat land, and adequately so in urban areas. In many situations it is difficult to provide a continuously clear path between the DGPS base station and mobiles. Provided that the range is not excessive, most DGPS radio links at VHF, and UHF, will give good range coverage without true line-of-sight conditions.

DGPS RADIO LINK DISTANCE

The distance over which the DGPS radio signal carries is determined by many factors, including:

- **Transmitter power**
- **Height of transmitter antenna**
- **Gain of transmitter antenna**
- **Length and type of coaxial cable**
- **Height of receiving antenna**
- **Gain of receiving antenna**
- **Frequency**
- **Surrounding topography**
- **Weather**
- **Obstructions**

From the above list, it will be apparent that DGPS radio link distance is not easy to determine, particularly for long paths. The overall DGPS radio system performance will be only as effective as the weakest link in the chain. Some of the factors are beyond the users control, such as FCC restrictions, weather, overall antenna height, and physical obstructions.

Generally, in planning a DGPS radio link, users must always strive for the best possible operating signal strength. In the majority of situations, this is best accomplished by:

- **Paying special attention to the antennas being used**.
- Position the antennas at both ends of the DGPS radio path as **high** as possible.
- Use good quality low loss cable and connectors.
- Ensure professional installation of the antenna, cable, and connectors.
- Remember that all cable has inherent losses, each additional length of cable (beyond which is essential for the connection) will degrade the overall performance.

Radio range should be the **first** calculation when planning a DGPS radio link, even the most temporary one. The radio horizon (optical + 33%) has to be checked in order to determine whether or not the link is generally possible.

Radio transmitter power, and heights of both the antennas (DGPS reference and mobile), must be sufficient to ensure that the radio signal has the clearest possible signal between them.

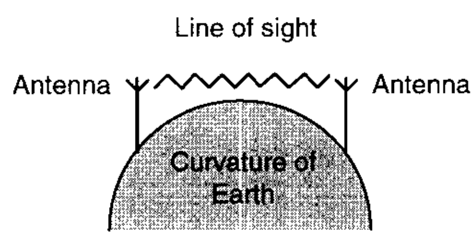
DGPS RANGE DETERMINATION

The design of the transmit and receive antenna system is very important, it determines how well radio energy is transferred between antennas. Some of the factors which require careful consideration are:-

- Gain
- Direction
- Polarisation
- Height above Ground

ANTENNA HEIGHT VERSUS RANGE

Antenna height is simply a matter of *'the higher the better'*. Increasing the height extends the line of sight distance and reduces the blocking effects of objects on the ground. View of the horizon is dependent on the antenna height above the surface of the earth as shown below. It can be seen that because of the curvature of the earth, the distance to the horizon is greater when viewed from an elevated angle.



Radio waves are similar to light waves in that they tend to travel in straight lines. However, radio waves also tend to refract (or bend) as they follow the curvature of the earth. This extends the radio horizon beyond the optical horizon. Bending of the wave is caused by the tendency of the radio wave to travel slower as the density of the air increases. Since part of the radio wave travels near the ground where the air is more dense, this bending will always occur.

When studying the behaviour of radio waves in space, it is more convenient to use a path that is a straight line instead of a curve. This requires that the radius of earth curvature be simultaneously readjusted to preserve the correct relationship.

For the standard atmosphere, this equivalent radius is 4/3 or 1.3 times the actual radius of the earth as determined by experience. As previously stated, the optical and radio wave paths differ.

The distance in miles from an antenna to the optical and radio wave horizons is determined as follows:

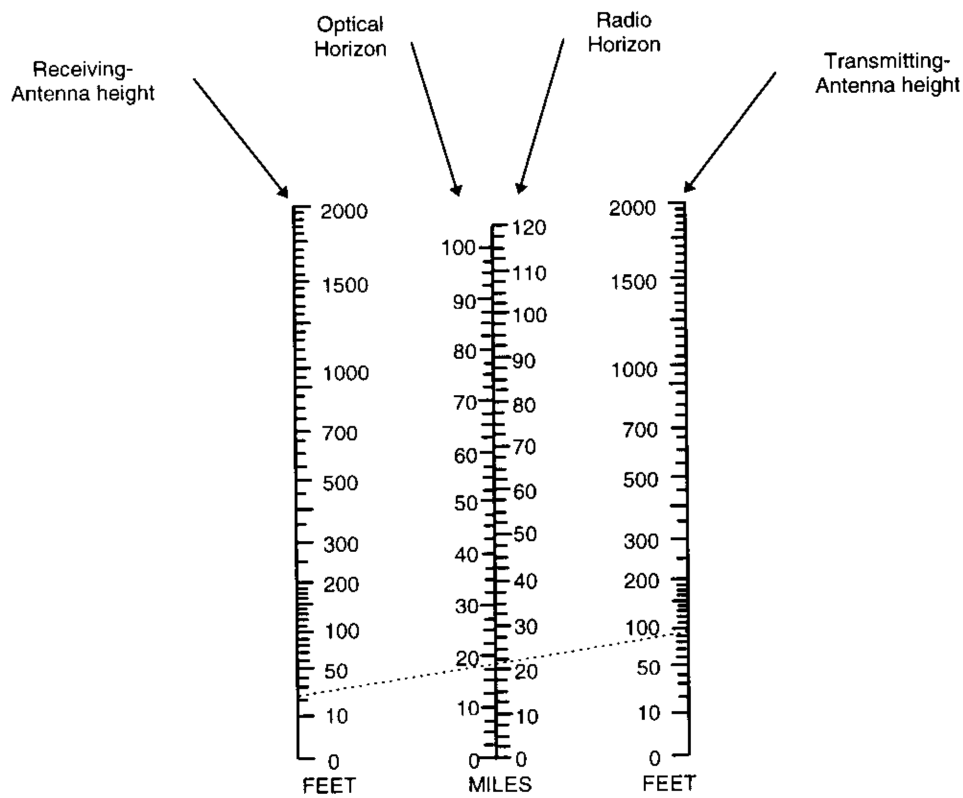
Optical Horizon Distance = Square root of 2h.

Radio Horizon Distance = 1.33 * Square root of 2h

(where 'h' is dimension in feet)

The maximum possible distance at which direct-wave transmission is possible between transmitting and receiving antennas, at given heights (the line of sight distance), is equal to the sum of the horizontal distances calculated separately for the individual antenna heights.

When the distance involved is less than line of sight, the path is sometimes referred to as the optical path. The nomogram below shows the relationship.



As the distance between the transmitting and receiving antennas increases, the energy concentration for a given area decreases. Therefore, the distance from the transmitting antenna also determines how much energy an antenna intercepts. This loss of signal strength due to increased distance is known as path attenuation and is expressed in decibels (dB).

The amount of power available at the receiving antenna is dependent on the amount of energy it intercepts. An electrically large antenna will intercept more energy than an electrically small one. The actual dimensions of the antenna are related to wavelength. Because a smaller antenna intercepts less energy, there is a decrease in useable range as frequency increases. It is possible to increase the size (in terms of wavelength) of higher frequency antennas so that they intercept more power. These antennas are referred to as 'gain' antennas.

Communication range is calculated by determining the path attenuation and relating it to the power output of the transmitting antenna. Path attenuation places a practical limit on maximum useable range because a point is reached where it is impractical to radiate sufficient power to overcome path loss. While antenna height establishes the maximum possible range, the radiated power determines the practical limit, since that determines the signal level at the receiving antenna. Even though base station power could be increased to several thousand watts, the system 'talk back' range would still be limited by the power output capability of the remote units.

CALCULATING RADIO RANGE

Determination of radio range is a complex matter which has many variables, some of which were described in the preceding section. Here, it is not intended to cover all the variables, but an outline is given covering the basic approach. This can be used to determine the distance over which a telemetry link will operate whilst providing reliable communication. The following steps may be taken:

Determine the line of sight transmission distance

1. Select the antenna height above the terrain.
2. Calculate the transmitter and receiver transmission line losses at the operating frequency.
3. Determine transmitter power output and receiver sensitivity in dBm.
4. Determine transmitter and receiver antenna gain.
5. Calculate path loss at the operating frequency.

Once these parameters have been determined, an estimate of the RF link range can be determined over smooth terrain. Obviously, if there are major obstacles in the signal path, designing a useable radio link may be difficult.

For example:

if there is a 10,000 foot high mountain between the base station and a remote site, whose antenna are only 100 feet above the average terrain.

The following information describes how these parameters may be calculated.

Line Of Sight Distance

The line of sight distance can be determined by the following equation:

$$D(\text{optical}) = \sqrt{2h_r} + \sqrt{2h_t}$$

$$D1\ (\text{radio}) = 1.3 * D$$

Where

D = *Distance in miles to optical horizon*

D1 = *Distance in miles to radio horizon*

h_t = *Transmitter antenna height*

h_r = *Receiver antenna height*

For example:

assume that the antenna heights about the spherical earth are 25 feet for the receiver, and 100 feet for the transmitter. Line of sight distance would then be

$$D = \sqrt{2(25)} + \sqrt{2(100)} = 21.2 \text{ miles}$$

$$D1 = 1.3 * 21.2 = 27.5 \text{ miles}$$

Path Loss

Determining (by calculation) the line of sight distance, does not guarantee that same range in reality. The transmitter power, receiver sensitivity, transmission line loss, antenna gain or loss, and operating frequency must also be considered. The line of sight distance only means that the curvature of the earth does not block the signal. To determine path loss with these factors, assume that the RF system has the following fixed parameters:

- Transmitter RF Power Output - 2.0 Watts (33dBm)
- Operating Frequency = 450MHz
- Total Tx Transmission Line Loss (heliax, 100ft) = 0.85dB
- Total Rx Transmission Line Loss (RG/U, 25ft) = 1.25dB
- Receiver 12dB SINADE Sensitivity = 116dB
- Transmit and receive antennas (7 element Yagi) = 10dB

Determine the path loss (PL) at radio line of sight of 27.5 miles using 100 and 25 foot antennas at 450MHz by using the following general equation:

$PL = 117 + 20 \log_{10} f\,MHz - 20 \log_{10} h_t h_r + 40 \log_{10} D$

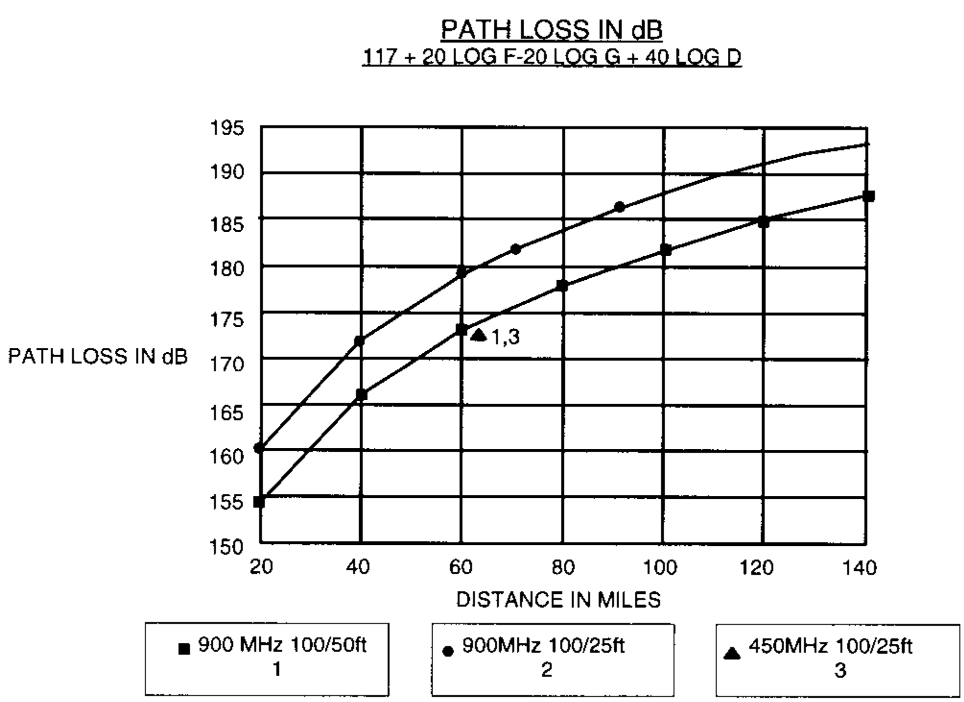
Where:

PL	=	*Path loss in dBm*
117		*is a constant*
f	=	*Operating frequency*
ht	=	*Transmitter antenna height in feet*
hr	=	*Receiver antenna height in feet*
D	=	*Distance between antennas in miles*

$PL = 117 + 20 \log_{10} 450 - 20 \log_{10} (100')(25') + 40 \log_{10} 27.5$

$PL = 117 + 53.06 - 67.9 + 57.5 = 159.6dB$

Therefore, the path loss at radio line of sight is 159.6dB at 450 MHz, with a receiver antenna height of 25 feet and a transmitting antenna height of 100 feet. The figure below shows the relationship between path loss and radio range over smooth earth with the above listed conditions.



PATH LOSS CHART

Path Margin

Path margin is the effective amount of transmitted power available before path loss is subtracted. If path margin is **greater** than path loss, communication is possible across the radio system. The formula for path margin is as follows:

Path Margin = Power Out - Rx Sensitivity - Cable loss + Antenna gain

Assume the following conditions exist:

Transmitter Power	= +33dBm (2 Watts)
Receiver Sensitivity	= -116dB (12dB SINAD)
Cable Loss	= 0.85dB (Tx) 1.25dB (Rx)
Antenna Gain	= 10dB (each antenna)
Path Margin	= 33 -(-116) - 0.85 - 1.25 + 10 + 10
	= 166.9dB

Therefore, from this example:

with a path margin of 166.9dB, minus a path loss of 159.6dB, equals 7.3dB of margin at the receiver.

ALTERNATIVE TYPES of DGPS RADIO LINK ANTENNAS

The subject of selecting antennas for communication purposes is complex. This section attempts to simplify this process, and to assist users in identifying the correct antenna for specific applications.

Antennas for DGPS radio links will fall into one of two categories:- either Omni-Directional, or Directional.

Omni-Directional antennas can both transmit and receive radio signals in a horizontal circular plane **all around** the antenna (i.e. 360 degrees).

Directional antennas (as the term implies) are designed to transmit (radiate) or receive signals, **only** in the direction in which the antenna is pointing.

Directionality is accomplished by focusing the radio signal within the antenna, a process which effectively amplifies the signal. The analogy here is similar to a flashlight, where a reflector placed around the bulb intensifies the light beam by focusing the light rays from the bulb. Due to this phenomenon, a directional antenna (eg. Yagi type) has gain, due to the increase in signal focusing. Omni-Direction antennas can also be designed to focus signals (include gain) in a circular pattern.

The choice of antenna, together with its physical location, will greatly effect the overall operation of the DGPS radio link. Any improvements (i.e. using an antenna with higher gain) made at one end of a DGPS radio link, will enhance the overall performance of the entire link.

There are many manufacturers and suppliers of radio antennas, with the differences between them being in type, gain, and mechanical factors. Mechanical factors include material, construction, and quality of finish. Users are reminded that the old saying "*you get what you pay for*" is particularly true with antennas. Antennas are a vital component part of the DGPS system, and are constantly exposed to adverse conditions. Purchase only the best quality.

The following is intended to assist in deciding which type of antenna will best suit the users DGPS radio link requirements.

Omni-Directional Antennas (Omni's)

This type has a 360 degree radiation pattern. Is it a good choice for DGPS links where the base station has to communicate with mobile receivers which keep changing their azimuth position, or where the base station is transmitting to a number of mobiles in different directions.

Omni's can vary from a couple of inches in height up to several feet, depending on frequency and gain. Unless the omni is a gain type, it will normally have unity gain (i.e. OdB or no gain). In other words, the antenna will neither increase, nor decrease, the signals passing through it. For many DGPS applications the unity gain antenna is quite acceptable, being a low cost, compact, and strong antenna, which is simple to mount.

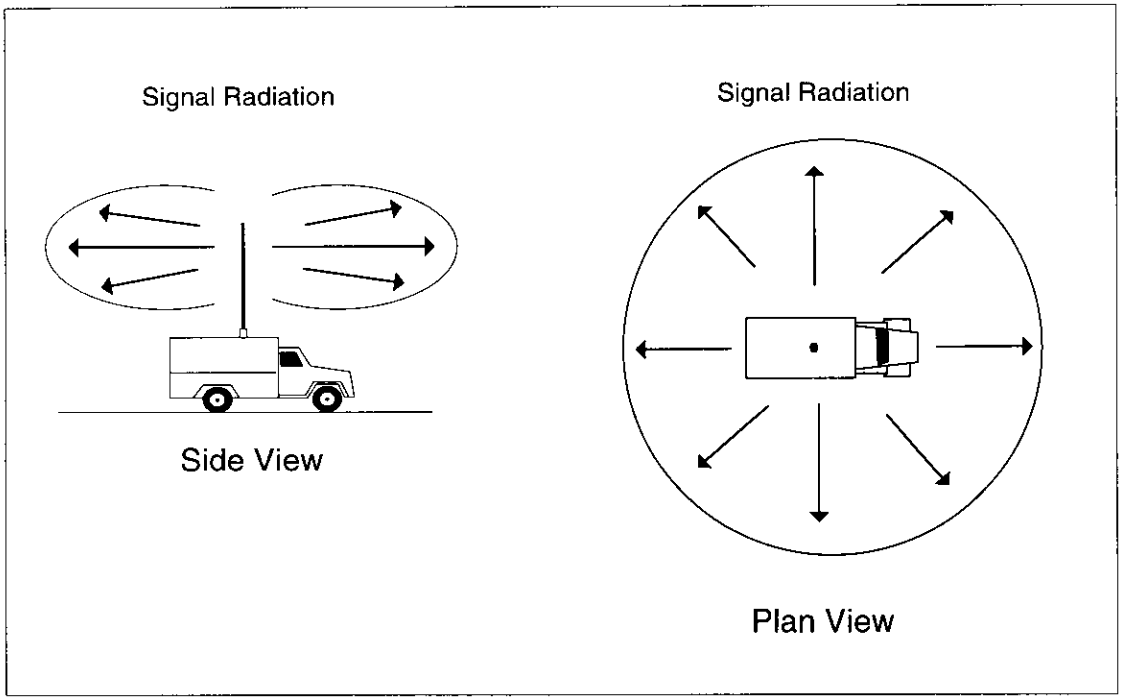


Figure C6. Omni-Directional Antenna

Half-Wave Dipole Antennas

This is a significant and fundamental type of antenna, providing the basis for a large number of other omni and directional antenna designs.

A very simple half-wave dipole antenna could be made from two pieces of stiff wire, placed one above the other in a vertical plane. The RF signal connection is made to the inner ends of each piece of wire at the centre of the antenna. One feed to the upper wire, and one to the lower. If the length of each piece of wire is then cut to be exactly *one quarter* of the radio signal wavelength (eg. the wave length is 70cm for a typical UHF signal), the whole assembly will function as a half-wave dipole antenna.

Antenna length is directly related to the frequency of operation. The higher the frequency, the shorter the antenna becomes.

A half-wave dipole is said to be balanced, its two component parts (the upper and lower sections) are equal in all respects. Not all antennas are balanced, as will be explained later.

When a half-wave dipole is mounted in the vertical position, the signal radiated from it is also vertical. The antenna is then described as being vertically polarised, or a "Vertical Antenna". Horizontal polarisation is also possible.

Antenna manufacturers product data leaflets will probably show a graph that gives the pattern of radiation for the specific antenna. In the case of the half-wave dipole, the electrical radiation pattern will be the shape of a circle around a centre point. There will be no, or little, radiation directly above or directly below the half-wave vertical antenna. The radiation will be a continuous circle around the antenna. This gives rise to the designation of "Omni-Directions", and unity gain can be expected.

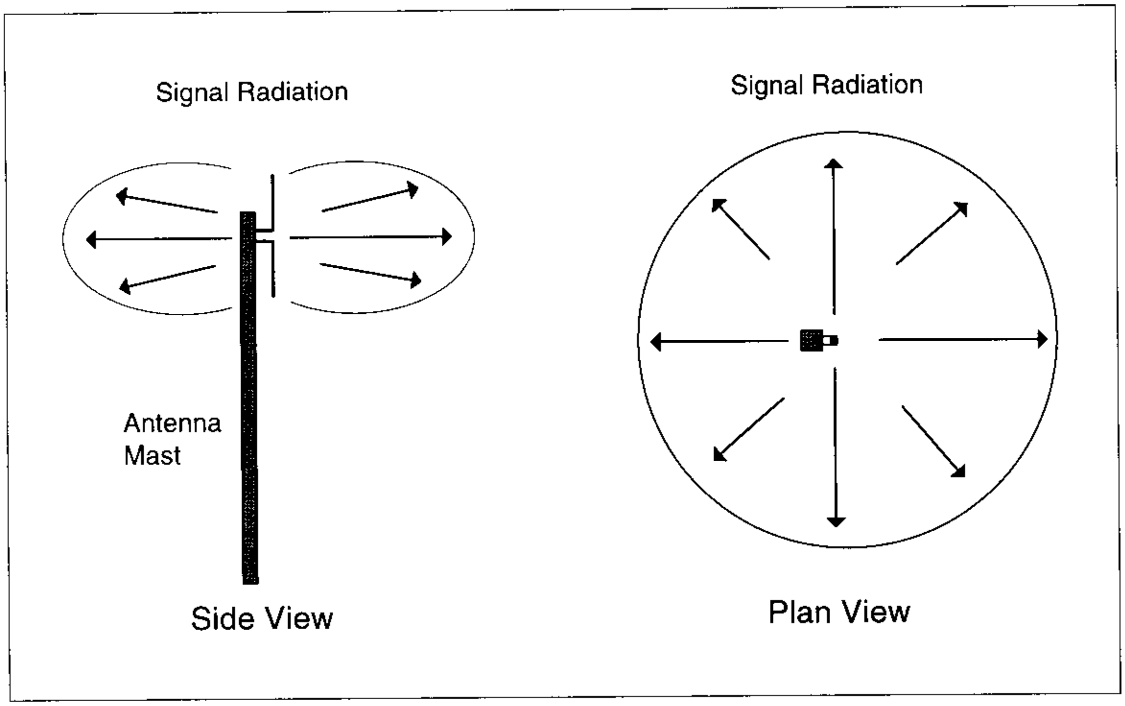


Figure C7. Half-Wave Dipole Antenna

Quarter-Wave Whip Antennas

Derivatives of the half-wave dipole antenna have been developed to meet specific requirements. For example, the quarter-wave whip antenna is designed to meet applications calling for a physically small antenna. This antenna having been made smaller by removing the lower section (used on the vertical half-wave dipole). This leaving only a shorter single element, measuring a quarter of a wave length. The quarter-wave radiating element is often constructed from small diameter stiff wire, hence the name "whip".

How does the quarter-wave whip operate with only a single element ?

This is achieved by using the ground plane around and below the quarter-wave element. For example, a ground plane can be formed by mounting the quarter-wave whip on the metal roof of a vehicle. Radio signals see this metal surface as being the second (lower) element of the half-wave vertical dipole. A ground plane can also be created by mounting the antenna to a metal enclosure, hereby achieving the same effect as the vehicle roof. In theory, any ground plane should have a radius of at least a quarter wavelength in order for the antenna to operate at maximum efficiency. Some designs incorporate 3, 4, or more, horizontal rods at the base of the antenna to establish the ground plane where none exists. (eg. when the antenna is mounted to a pole clear of the ground). Such an antenna is called a Ground Plane.

Zero, or negative gain, is a feature of quarter-wave whip antennas.

Helical Antennas

With the introduction of the hand-held walkie-talkie radio, a refinement of the quarter-wave vertical antenna came into being. This development is referred to as the Helical Antenna. As the name implies, the radiating element is wound is a helical path around a vertical former. The result is an antenna significantly shorter in length compared to the quarter-wave vertical.

The advantages of the helical include low cost and small physical size. It is mainly used for short range (up to a few hundred feet) links. Gain is much less than unity.

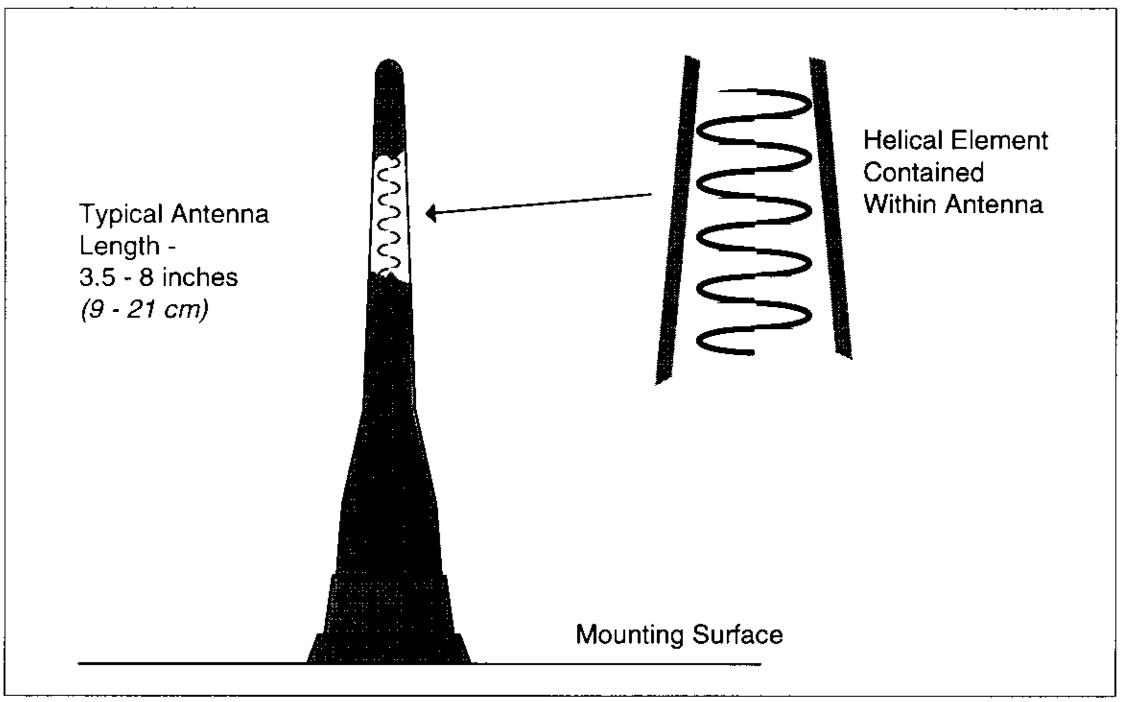


Figure C8. Helical Antenna

Co-Linear Dipole Antennas

This antenna is a good choice for DGPS base stations, and also for high mobility units such as vehicles or ships.

Such antennas is made up of interconnected half-wave dipoles stacked vertically. This configuration provides 'antenna gain' over a single half-wave vertical dipole antenna, and can be used to cover long distance DGPS links.

The increase in gain is derived from the stacking of vertical dipole elements, whereby the electrical signals are compressed in the vertical plane. This forces the signals to extend in the horizontal plane, effectively creating an increase in the gain of the antenna.

Another way to explain this increase in gain is to imagine an inflated balloon lying on a flat surface. If you apply downward pressure, the balloon expands sideways. The volume of the air inside the balloon still remains the same. It has simply been forced into a different direction.

Gain is usually from about 3 to 10dB. This is equivalent to a Yagi antenna, but retaining the 360 degree omni pattern.

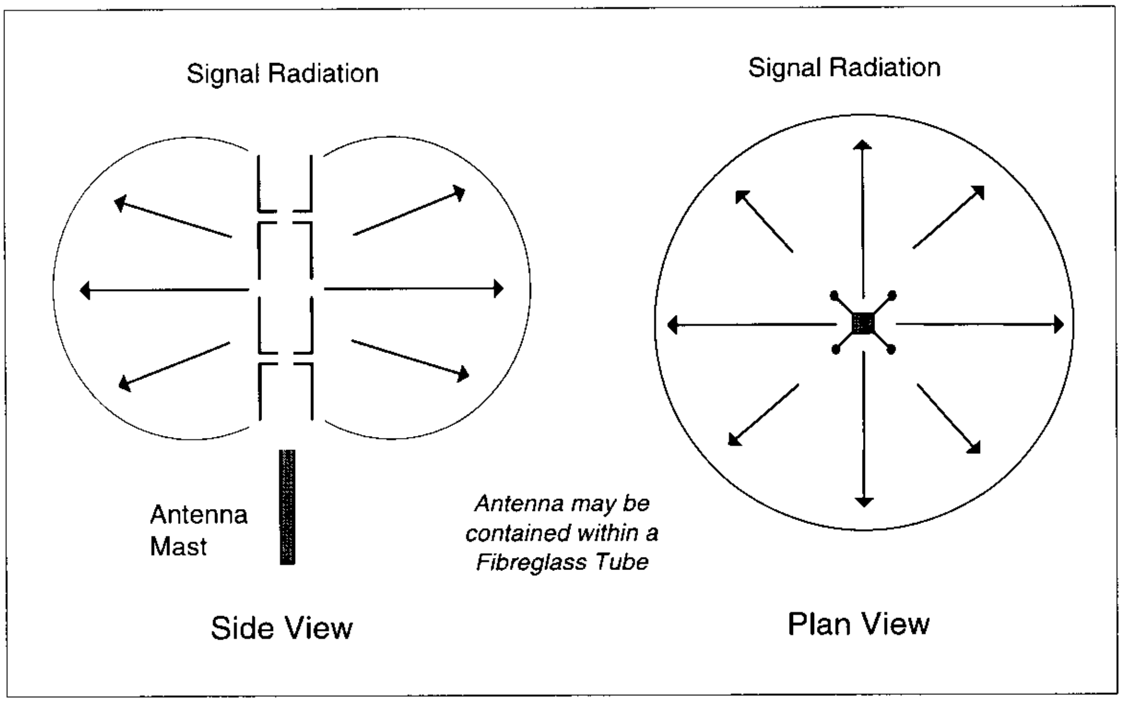


Figure C9. Co-Linear Dipole

Directional Yagi Antennas

This is the best choice of antenna for use in long range DGPS links (named after its inventor). It is also commonly used as a TV antenna, with the familiar long horizontal boom and small perpendicular elements. As a general rule, the more elements on the boom, the more gain the Yagi antenna will produce.

Any antenna having gain (co-linear or Yagi) will increase the output power of any transmitter connected to it. In other words, a transmitter giving an RF output of 2 watts coupled to a Yagi antenna rated at 3dB gain, would have its effective (or actual) radiated RF power doubled to 4 watts. The effective radiated power (ERP) is the important factor. Use of a Yagi antenna can also reduce DC current consumption of the transmitter. This could be an important advantage to users of battery powered DGPS links. In practice, this is achieved by reducing the transmitter power (and consequently, the DC current), whilst increasing the antenna gain to meet the required ERP level.

As the Yagi is directional, it will also reject/reduce unwanted radio signals from other users on the same radio frequency, (eg. where the other stations are in a different azimuth direction from the DGPS base station/mobiles).

When installing the Yagi antenna, care must be taken to ensure that it faces in the correct direction, and that the elements are correctly polarised. Note that the Yagi elements become progressively shorter towards the front of the antenna. The installed **must** point towards the appropriate DGPS station, although it can be mounted with its elements either horizontally or vertically polarised. **It is essential to ensure that all of the radio links DGPS station(s) Yagi antennas have the same orientation.**

Typically, the Yagi antenna is used at fixed base stations when directing signals in a particular direction. For example, on a shore mounted base station transmitting signals directed towards mobile receivers at sea. The width of the beam decreases with the increase in gain (as the antenna becomes more focused). Referring back to the torch analogy, this is equivalent to the difference between a floodlight and a spotlight. For high gain, the beam width can reduce to just a few degrees.

MIXED ANTENNA WORKING

It is perfectly acceptable to mix different types of antennas in order to engineer the best possible link. Where communication is needed between a Yagi antenna and any of the vertically polarised types (such as a whip), the user **must** mount the Yagi with the elements vertically aligned to correspond with the vertical orientation of the whip. A significant signal loss will result if this basic precaution is not followed.

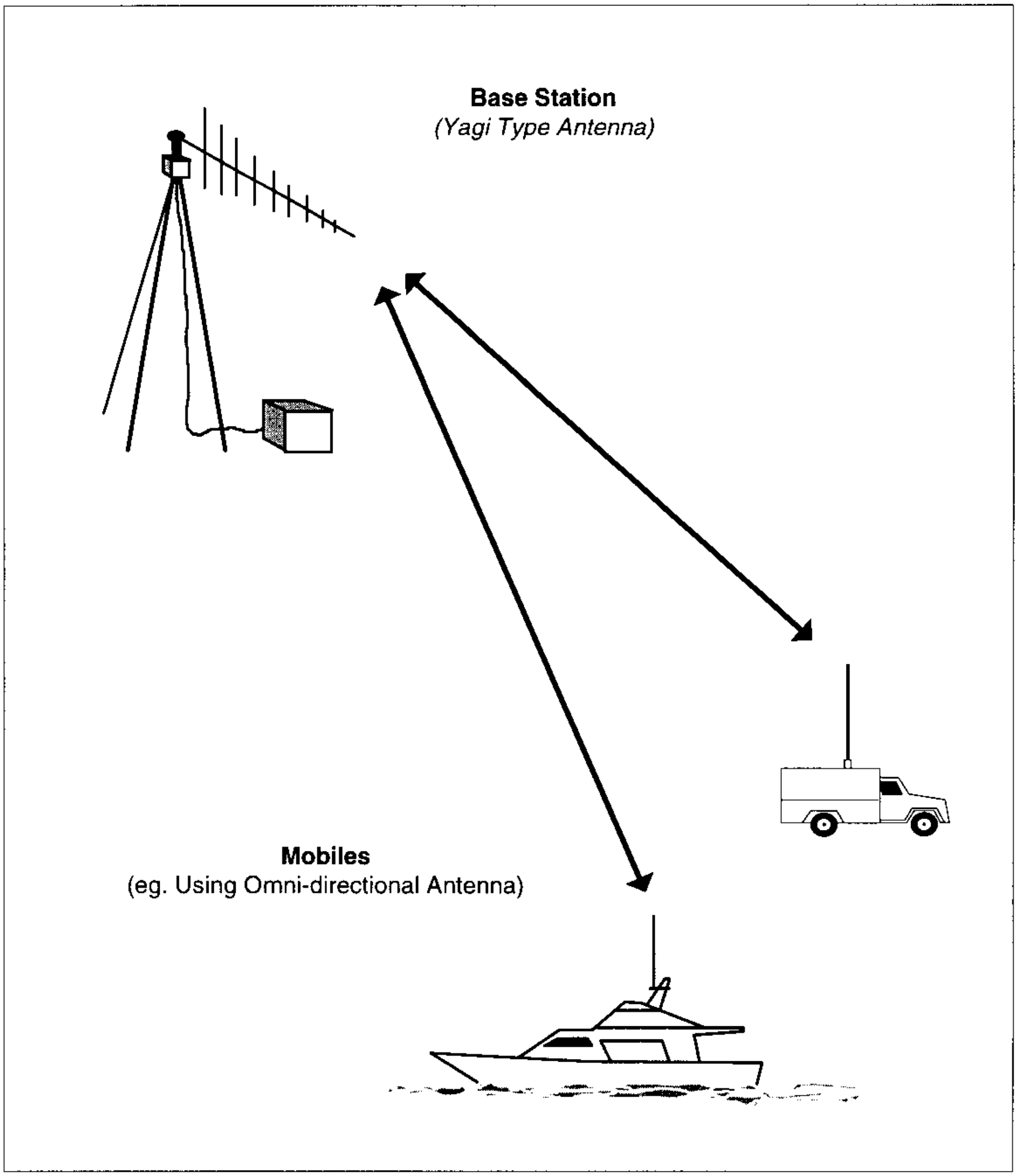


Figure C10. Transmitter and Receiver

THE DECIBEL (dB)

The dB is not a unit of measurement such as the volt or amp. It is the ratio between two distinct values and is commonly used in RF engineering. Users should have a basic understanding of this term.

Example 1:

if 2 watts of RF power is applied to an amplifier having an output of 4 watts, it would have a gain of +3dB, that is, a doubling of the original power level.

Conversely, if a 1 watt RF signal was connected into a filter network, and the measured output is 0.5 watts, it would have experienced a loss of -3dB in the filter.

The dB is a logarithmic function, which means that it is possible to directly add (or subtract) dB values as whole numbers when calculating problems associated with radio engineering.

Example 2:

a 3dB increase in transmitter power, when coupled into a 10dB gain antenna, will yield a 13dB overall increase in effective radiated power (eg. an increase of 20 times).

ANTENNA GAIN and THE dB

As previously mentioned, the amount of gain provided by a Yagi antenna is basically dependent on the number of elements used in the design. Therefore, a 12 element Yagi antenna will have greater gain than an 8 element design. When discussing dB and antenna gain, it is usual to express the gain of an individual antenna in dBd, relative to a half-wave dipole. This is taken as the unity (0dB) reference point. Some antenna manufacturers will quote their gain levels in dB isotropic (dBi), in which case, simply deduct 2.16 to convert to dBd.

Common reference points in radio engineering are +3dB and -3dB. These represent double and half power respectively. Note also that 1dB loss is equivalent to a factor of 20% power reduction.

Users remember the ratios for 1dB, 3dB and 10dB, it becomes very easy to calculate most dB relationships.

Number Of Elements	***Gain dB***	***Length Of Boom***
4	+ 8.5dB	1.2m
8	+ 10dB	2.6m
12	+ 12dB	3.2m
18	+ 14dB	4.3m

CONNECTING THE ANTENNA

Great care must be taken to minimise signal losses when antennas are connected to DGPS radio link transmitters and receivers.

A coaxial feeder cable is required to connect a radio transmitter or receiver to an antenna. Whenever a radio signal is passed down any cable, there will be losses in signal strength due to the attenuating effect of the cable. The degree of attenuation will vary depending on the type of cable employed, and the frequency of the signal. At higher frequencies, a cable will have a greater effect on the signal passing through it.

A comparison test between a 10 metre, and a 25 metre length, of medium quality RG-58 cable (a standard, widely used type of coaxial feeder cable) demonstrates just how much signal strength can be lost at UHF.

> *The 10 meter cable:* will show that a 450MHz signal passing through it will have a loss of 1dB. In practice, this would mean that the output of a 0.5 watt transmitted signal is reduced to 0.4 watts before it reaches the antenna.
>
> *The 25 meter cable:* transmitting a 0.5 watt signal will have a loss of 3dB overall, which would leave less than 0.2 watts at the input to the antenna.

Figure C11. Cable Losses (see cable Mfr.)

IT IS VITAL TO KEEP CABLE LENGTHS AS SHORT AS POSSIBLE.

Use only the highest quality cable and connectors.
Cable and connector joints are the most common cause of excessively high signal losses.

LICENSING INFORMATION

All users of DGPS radio link equipment operating within the USA or Canada must obtain a radio license from either the FCC, or the DOC, respectively.

Additionally, all DGPS radio link equipment (either made, imported to, or used) in the United States and Canada must meet the approval of appropriate legislation.

Similar regulations apply internationally.

Customers requiring assistance to obtain a license should contact NavSymm® at the address found at the back of this manual.

APPENDIX D

1.1 GLOBAL POSITIONING SYSTEM (GPS)

The Global Positioning System (GPS) is a military satellite based navigation system developed by the U.S. Department of Defence, which is also made freely available to civil users.

Civilian use of GPS is made available at the users own risk, subject to the prevailing DoD policy or limitations, and to individuals understanding of how to use the GPS.

In today's satellite constellation there are a minimum of 24 operational satellites (plus several operational spares) in 6 orbital planes, at an altitude of about 22,000 km. The GPS system can give accurate 3-D position, velocity, time, and frequency, 24 hours a day, anywhere around the world.

GPS satellites transmit a code for timing purposes, and also a 'Navigation message' which includes their exact orbital location and system integrity data. Receivers use this information, together with data from their internal almanacs, to precisely establish the satellite location. The receiver determines position by measuring the time taken for these signals to arrive. At least three satellites are required to determine latitude and longitude if your altitude is known (eg. a ship at sea), and at least a fourth to obtain a 3-D fix.

However, the U.S. Department of Defence deliberately degrades signals from the constellation of GPS satellites by applying errors in the form of Selective Availability (SA), thereby reducing the accuracy obtainable by civilian GPS receivers. DoD policy is to set the level of SA degradation to give a horizontal accuracy of 100 metres (95% of the time). Most of the effects of SA can be eliminated by utilising Differential GPS (DGPS) techniques.

1.2 GPS POSITIONING and NAVIGATION

The NavSymm® XR5 or SHARPE XR6 GPS Receivers need to be able to see at least 4 satellite vehicles (SV's) to obtain an accurate 3-D position fix. When travelling in a valley or built-up area, or under heavy tree cover, users will experience difficulty acquiring and maintaining a coherent satellite lock. Complete satellite lock may be lost, or only enough satellites (3) tracked to be able to compute a 2-D position fix, or even a poor 3D fix due to insufficient satellite geometry (ie. poor DOP). Note also, that inside a building or beneath a bridge, it probably will not be possible to update a position fix. The Receiver can operate in 2-D mode if it goes down to seeing only 3 satellites by assuming its height remains constant. But this assumption can lead to very large errors, especially when a change in height does occur. A 2-D position fix is not to be considered a good or accurate fix, it is simply "better than nothing".

The receivers **antenna** must have a clear view of the sky to acquire satellite lock. Remember always, it is the **location of the antenna** which will be given as the position fix. If the antenna is mounted on a vehicle, survey pole, or backpack, allowance for this must be made when using the solution.

To measure the range from the satellite to the receiver, two criteria are required: signal transmission time, and signal reception time. All GPS satellites have several atomic clocks which keep precise time and these are used to time-tag the message (ie. code the transmission time onto the signal) and to control the transmission sequence of the coded signal. The receiver has an internal clock to precisely identify the arrival time of the signal. Transit speed of the signal is a known constant (the speed of light), therefore: time x speed of light = distance.

Once the receiver calculates the range to a satellite, it knows that it lies somewhere on an imaginary sphere whose radius is equal to this range. If a second satellite is then found, a second sphere can again be calculated from this range information. The receiver will now know that it lies somewhere on the circle of points produced where these two spheres intersect.

When a third satellite is detected and a range determined, a third sphere would intersect the area formed by the other two. This intersection occurs at just two points. The correct point is apparent to the user, who will at least have a very rough idea of position. A fourth satellite is then used to synchronise the receiver clock to the satellite clocks.

In practice, just 4 satellite measurements are sufficient for the receiver to determine a position, as one of the two points will be totally unreasonable (possibly many kilometres out into space).

This assumes the satellite and receiver timing to be identical. In reality, when the NavSymm® GPS Receiver compares the incoming signal with its own internal copy of the code and clock, the two will no longer be synchronised. Timing error in the satellite clocks, the Receiver, and other anomalies, mean that the measurement of the signals transit time is in error. This effectively, is a constant for all satellites, since each measurement is made simultaneously on parallel tracking channels. Because of this, the resultant ranges calculated are known as "pseudo-ranges".

To overcome these errors, the NavSymm® GPS Receiver then matches or "skews" its own code to become synchronous with the satellite signal. This is repeated for all satellites in turn, thus measuring the relative transit times of individual signals. By accurately knowing all satellite positions, and measuring the signal transit times, the user's position can be accurately determined.

Utilising its considerable processing power, the NavSymm® GPS Receiver rapidly updates these calculations from satellite data to provide a real time position fix. Memory options allow storage of navigation and position data for subsequent post-processing or post-mission analysis, all within a single unit.

1.3 STANDARD POSITIONING SERVICE (SPS)

Civil users world-wide are able to use the SPS without restriction or charge. Accuracy of the system is intentionally degraded by the DoD through the application of Selective Availability (SA). This degradation is achieved by the system deliberately broadcasting extra errors into the satellite orbit information, and by 'dithering' the satellite clocks.

A predicted accuracy for the SPS has been published in the 1994 Federal Radionavigation Plan as:-

- 100 metre horizontal accuracy
- 156 metre vertical accuracy
- 340 nanosecond time accuracy

The figures refer to 95% position fix accuracies, expressing the value of two standard deviations of radial error from the actual **antenna** position, this position being an estimate made under specified satellite elevation angle and PDOP conditions.

Dilution Of Precision (DOP) is a measure of the satellite geometry, and is an indicator of the potential quality of the solutions. The lower the numerical value, the better the potential accuracy (for example, a PDOP below 3 indicates good satellite geometry). For 3-D positioning, fluctuations in DOP can be harmful to the solution, especially in Kinematic/Dynamic modes.

For example, the following DOP terms are computed by the SHARPE XR6:

HDOP	Horizontal Dilution of Precision	(Latitude, Longitude)
VDOP	Vertical Dilution of Precision	(Height)
TDOP	Time Dilution of Precision	(Timing errors)
PDOP	Position Dilution of Precision	(3-D positioning)
GDOP	Geometric Dilution of Precision	(3-D position & Time)

Estimated accuracy = DOP x measurement accuracy

While each of these terms can be individually computed, they are formed from co-variances, and are not independent of each other. For example, a high TDOP will cause receiver clock errors which will eventually result in increased position errors.

Horizontal accuracy figure of 95% is the equivalent to 2RMS (twice root-mean-square), or twice the standard deviation radial error.

Similarly, for vertical and time errors, a figure of 95% is the value of 2 standard-deviations of vertical or time error.

- Root-mean-square (RMS) error is the value of one standard deviation (67%) of error.

- Circular Error Probability (CEP) is the value of the radius of a circle, centred at a position containing 50% of the position estimates.

- Spherical Error Probability (SEP) is the spherical equivalent of CEP, which is centred at a position containing 50% of the position estimates.

CEP and SEP are not affected by large errors which could make the values an overly optimistic measurement. These probability statistics are not suitable for use in a high accuracy positioning system. The SHARPE XR6 reports all accuracy's in the form of a standard deviation (RMS) value.

1.4 PRECISE POSITIONING SERVICE (PPS)

This service is only available to authorised users with cryptographic equipment and special receivers. Access is limited to the U.S. and Allied military, U.S. Government agencies, and selected civil users specifically approved by the U.S. Government.

1.5 DIFFERENTIAL GPS

Differential GPS (or DGPS) is a method of removing errors common to several nearby receivers (eg. satellite orbit, clocks, SA, and also those caused by atmospheric distortion of the satellite signal).

The basis of the system is to position a GPS receiver at a known location, and to tell this receiver where it is. Once this fixed GPS receiver (or Base Station) is operating, it is then able to calculate the expected ranges from the satellites using its known location, and make a comparison with data received directly from each of the satellites in view. Any errors (differential) in the measurements are calculated, and transmitted to the mobile receivers.

A mobile receiver operates in the same manner as the Base Station, by taking data from all satellites in view. However, before calculating its own position, the mobile receiver adjusts its own measurements using the corrections supplied from the Base Station.

Utilising this DGPS technique in survey operation, the NavSymm® SHARPE XR6 GPS Receiver will output real time positions to an accuracy ranging from 3 metres down to 2 centimetres, depending on the DGPS mode of operation.

1.6 REAL-TIME KINEMATIC (RTK) POSITIONING

RTK GPS is a differential technique which makes use of both pseudorange and carrier phase measurements to compute the position of the mobile receiver, relative to that of the base station. This highest accuracy mode relies on having differentially corrected carrier phase measurements at the millimetre level, which can in turn, lead to positioning accuracies down to 2cm.

There are many operational considerations associated with RTK positioning, which can determine the accuracy obtained. These are covered in more detail in the advanced section of the SHARPE XR6 manual.

1.7 GEODETIC DATUMS

The default geodetic datum of the NavSymm® XR5 and SHARPE XR6 is WGS 84 (World Geodetic System 1984). To establish a position based on a local land map, it is necessary to select the corresponding local map datum.

For example: in the UK the mapping datum is OSGB 36.

A full list of datum's supported is given in the SHARPE XR6 manual.

Note:

1) it is vitally important to use the **correct** geodetic datum as there may be differences of several hundreds of metres between datum's. This is probably the largest cause of error and problems to users of precise GPS equipment.

2) the Base Station position must be set to the same datum co-ordinate value in which the end solution is required.

3) ensure the same datum transformation parameters are used at both ends in the DGPS operations. Although the same name may be used by different equipment or software suppliers, different values may have been used by the different sources.

USER NOTES

USER NOTES

NavSymm® CONTACT DETAILS

For further details and hot-line support please contact:

Sales, International Customer Support, and Service

Navstar Systems Ltd
Mansard Close
Westgate
Northamptonshire   NN5 5DL
England

Telephone:	+44 1604 585588
Facsimile:	+44 1604 585599
E-Mail:	navstar@telecom.com
Web Site:	http://www.telecom.com/navstar

Sales office in the USA

NavSymm®
2300 Orchard Parkway
San Jose
California 95131-1017
USA

Telephone:	1-888-367-7966
Facsimilie:	1-408-428-7998
E-Mail:	navsymm@telecom.com

DR5-96S MkIII

NAVSTAR SYSTEMS

Frequency Programming User Interface

The frequency programming user interface allows the user to change the operating frequency of the transceiver through a series of ASCII Commands. The frequency programming user interface is entered by sending a control sequence from an attached terminal e.g. Procomm or Windows Terminal. This will prevent general users from changing the frequency.

Connect the PC to the data port using the Control Serial Cable (Blue Marker). The interface defaults to 9600 baud NO parity.

Enter the password (**Hold *CTRL* and type *navstar***) followed by <Enter>. Note if using Windows Terminal it is necessary to set the Control Keys to be used by the Program not by Windows, this is done under Settings, Terminal Preferences.

When the correct authorisation word has been sent to the radio an acknowledgement is returned (Access OK). This will add two extra controls to the user interface. The user will enter a command to set the frequency. The microprocessor will calculate the relevant synthesiser values and set the synthesiser accordingly. An acknowledgement is sent to the user reporting the new frequency.. Once the transceiver has been authorised using the password it will remain authorised until the unit is switched off.

The command structure to change the frequency is as follows:

MODE FRQ1:456.5000,456.5000

where FRQ1 is the frequency to change i.e. FRQ1 or FRQ2. The frequencies are in MHz and must be entered to 4 decimal places (to give enough resolution for 12.5kHz channel spacing) They are the transmit and receive frequencies respectively. If the user enters an invalid frequency an error message is returned. Note the radio checks that the frequencies entered are within the transmit band of the radio and will return an error message if either frequency is out of range.

If the radio has not been authorised by using the above password sequence 'ACCESS DENIED' will be returned from the radio when trying to set a new frequency. The new frequency settings are remembered at power down and only need to be set once.

NOTE: When setting the transceiver to new frequencies that have not been used before it is advisable to check that no one else is using the frequency before transmitting data.