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Enhanced Position Location Reporting System (EPLRS) Positioning Capability

Gary Fielke

Electronic Warfare and Radar Division
Defence Science and Technology Organisation

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ABSTRACT

The Enhanced Position Location Reporting System (EPLRS) is a network of wireless tactical radios that distributes digital data between many mobile users. In addition, EPLRS has a position reporting capability allowing mobile users to determine their position based on time difference of arrival measurements from multiple reference radio units.

EPLRS has the potential to be used in Unmanned Aerial Vehicles as a navigation system backup to GPS. This report details a number of EPLRS position tests conducted at DSTO Edinburgh and the outcome of these tests with a view to UAV usage.

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PO Box 1500
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Telephone: (08) 8259 5555
Fax: (08) 8259 6567

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Enhanced Position Location Reporting System (EPLRS) Positioning Capability

EXECUTIVE SUMMARY

The Enhanced Position Location Reporting System (EPLRS) is a network of wireless tactical radios that distributes digital data between many mobile users. EPLRS also has a position reporting capability allowing mobile users to determine their position based on time difference of arrival measurements from multiple reference radio units.

A series of EPLRS position tests were conducted in and around the DSTO Edinburgh site. Using up to 5 EPLRS reference units with good reference station geometry resulted in an average bias of 32 ± 27 m. With poor reference station geometry, the average bias increased to 60 ± 61 m, although this was based on a very small data set. Due most likely to building obscuration and multipath, there were a number of inconsistencies in the positioning results.

The EPLRS position reporting capability has the potential to be used as a backup to GPS, in such platforms as Unmanned Aerial Vehicles (UAVs). An EPLRS Micro-Light unit has been used in a UAV for extending tactical communication range and could be utilised for position determination also.

Integrating the EPLRS position solution into the avionics of the UAV will allow switching between GPS and EPLRS for the source of position data depending on the environment and system requirements. This option could allow navigation of the UAV in a GPS-denied environment or whilst deploying GPS denial payloads.

Contents

Acronyms

DSTO	Defence Science and Technology Organisation
ENM	EPLRS Network Manager
EPLRS	Enhanced Position Location Reporting System
GPS	Global Positioning System
ICD	Interface Control Document
IP	Internet Protocol
JVMF	Joint Variable Message Format
PLGR	Portable Lightweight GPS Receiver
RS	Radio Set (EPLRS)
UAV	Unmanned Aerial Vehicle

1. Introduction

The Enhanced Position Location Reporting System (EPLRS) is a network of wireless tactical radios that distributes digital data between many mobile users. In addition, EPLRS has a position reporting capability allowing mobile users to determine their position based on time difference of arrival measurements from multiple reference Radio Set (RS) units.

The Australian Army has around 50 EPLRS radios that it uses as a tactical radio network in small and medium-sized field trials but without utilising its positioning capability.

The EPLRS positioning capability has the potential to be used as a navigation system backup to GPS, in such platforms as Unmanned Aerial Vehicles (UAVs). An EPLRS Micro-Light unit has already been used in an Aerosonde Unmanned Aerial Vehicle (UAV) for extending tactical communication range. Integrating the EPLRS position solution into the avionics of the UAV will allow switching between GPS and EPLRS for the source of position data depending on the environment and system requirements. This option could allow the UAV to be navigated in a GPS denied environment or whilst deploying GPS denial payloads.

2. EPLRS

2.1 Introduction

The Enhanced Position Location Reporting System (EPLRS) is a network of wireless tactical radios that distributes digital data from many mobile users to many other mobile users. The EPLRS network consists of many EPLRS radio sets (RSs) and one or more EPLRS Network Manager (ENM) host computers.

The RS uses a wide-band direct sequence spread spectrum waveform, Time Division Multiple Access (TDMA), frequency hopping, and embedded error correction encoding. These attributes are programmable allowing the planner to configure the network to provide optimal anti-jam performance and data rate according to the environment.

In addition, EPLRS has a position reporting capability allowing an RS user to determine their own location.

The RS is available in two forms: a high power vehicle mounted unit and a lower power Micro-Light unit. Both forms contain a baro-altimeter. They are shown in Figure 1.

An EPLRS Micro-Light unit has been used in an Aerosonde Unmanned Aerial Vehicle (UAV) for extending tactical communication range. Figure 2 shows the Micro-Light installed in the UAV.

Figure 1: Vehicle Mounted and Micro-Light EPLRS

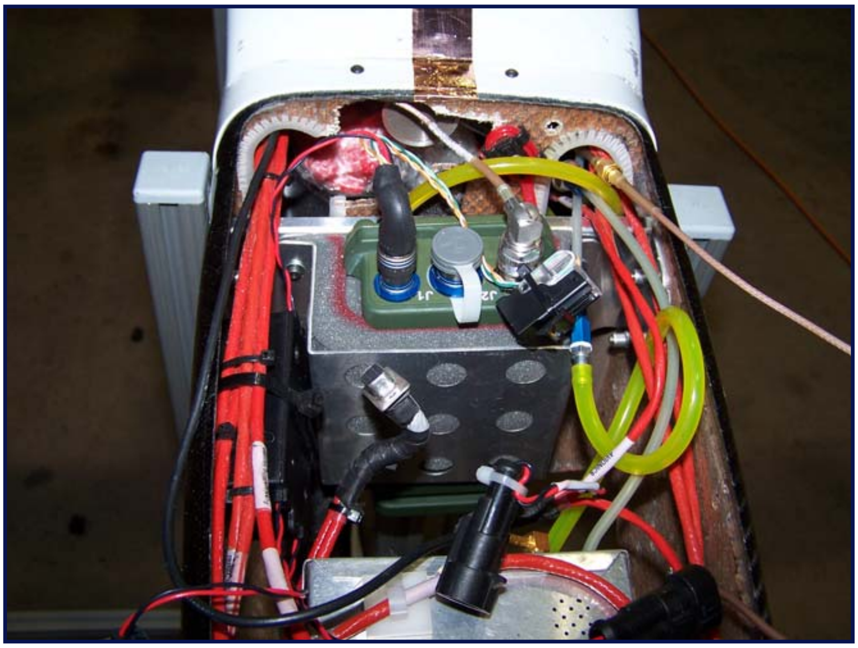

Figure 2: EPLRS Micro-Light installed in UAV

2.2 Position Location

The EPLRS position location service utilises multiple reference RS units. A reference unit RS is an RS that the network planner has designated to have the ability to be given, either manually (via the ENM) or electronically (via a Portable Lightweight GPS Receiver (PLGR)), its current position data.

Non-reference RS units use the position data provided by reference RS units to determine the position of themselves and other RS units.

The positional accuracy of EPLRS improves as more numbers of accurately located reference RSs are used. In addition, the geometry of the reference RS units is an important factor. The limiting geometric factor in determining the position of an RS is the vertex angles formed by lines drawn from the supporting reference units to the RS to be located. It is suggested in Ref 1 that vertex angles should be greater than 30 degrees where possible.

2.3 Position Data

The position data is delivered from an EPLRS RS over an ethernet link as multicast packets with the IP address and port number configurable via the ENM.

It is distributed in Joint Services Variable Message Format (JVMF) using K05.01 and K05.19 message types. The following Interface Control Documents (ICD) can be used to decode the header and content of the VMF messages:

MIL-STD-2045-47001	for the header format
MIL-STD-6017	for K05.01 and K05.19 message format (controlled document)

The position information available includes the following parameters:

- Latitude, longitude, altitude
- Speed, course
- Location Quality indicator

The definition of the Location Quality indicator as given in the ICD is brief and vague but is related to the deviation in range as reported by the RS unit.

2.4 Gumstix

Although not required in the tests to evaluate the EPLRS position capability, the mini Linux-based computer, Gumstix, is one option available for use in a UAV to read and process the EPLRS position data.

The Gumstix, shown in Figure 3, is small and has small/low power requirements and contains a 400 MHz Intel PXA255 processor, 64 MB of RAM, and 16 MB of flash memory. Expansion boards allow the addition of serial and ethernet ports, as well as flash card slots.

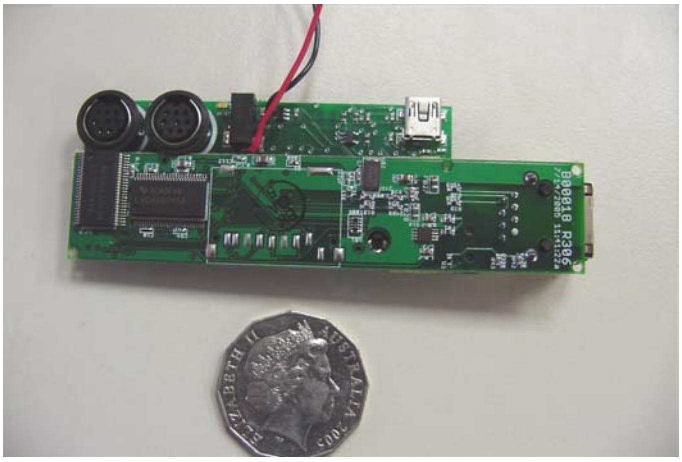

Figure 3: Gumstix Module

By adding the ethernet port expansion board and directly connecting it to the EPLRS micro-light ethernet port, the Gumstix is capable of:

a) reading and processing the EPLRS multicast position message, and

b) forming a network connection to a PC that is connected to another EPLRS receiver. This requires some EPLRS network management.

When used in an airborne platform, such as a UAV, air-to-ground data communications over the EPLRS network is possible. The Aerosonde UAV currently transmits its GPS position to the ground via a separate radio link. By incorporating the EPLRS micro-light and Gumstix into the UAV, the EPLRS position can be compared with the GPS position without any changes to the UAV avionics hardware or software (Figure 4).

As part of the position tests making up this report, a Gumstix was connected to an EPLRS unit to confirm data communications over the EPLRS network to another PC.

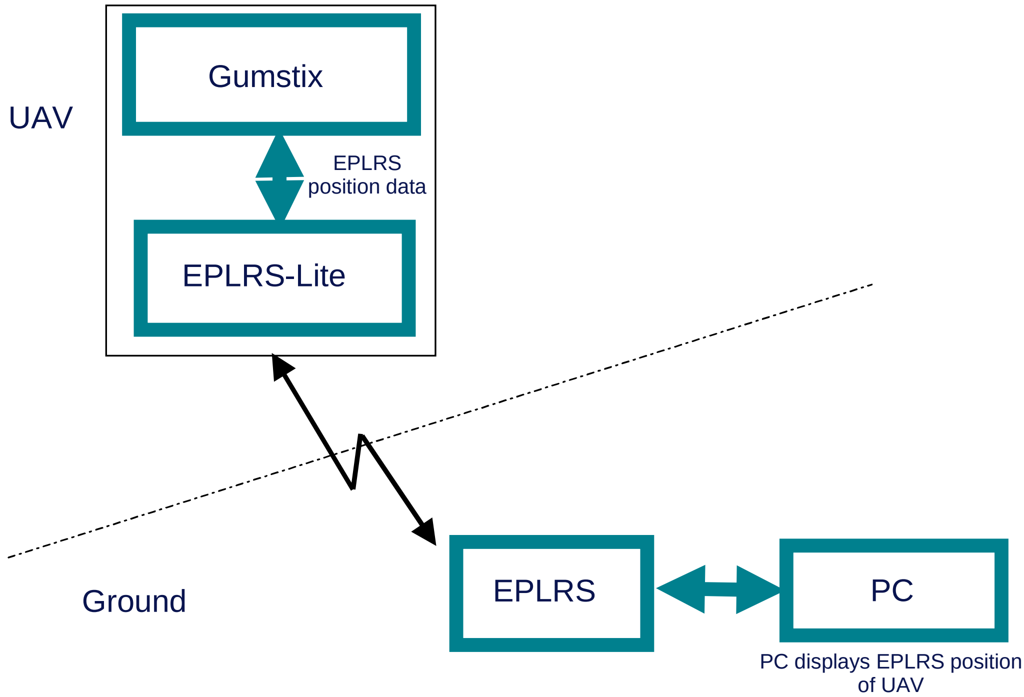

Figure 4: Proposed Air-to-Ground Communications over EPLRS for EPLRS Position

3. EPLRS Position Tests and Results

3.1 Tests

A series of EPLRS position tests were performed in and around DSTO Edinburgh during August and September of 2006.

Five EPLRS radio units were sited at known locations around the DSTO area. One of these was the network manager (ENM) and the other four were Micro-Light units. Figure 5 shows the layout of the static reference units at sites S1-S5.

A non-reference EPLRS unit, along with a Y-code capable GPS receiver (PLGR) were mounted in a van allowing dynamic and static tests to be performed. Both EPLRS and GPS position were logged.

A number of tests were performed with the van containing the non-reference EPLRS sited at V1 with different combinations of reference units employed. Other tests included the van sited at V2, V3, and a hillside location about 4 km from the reference units.

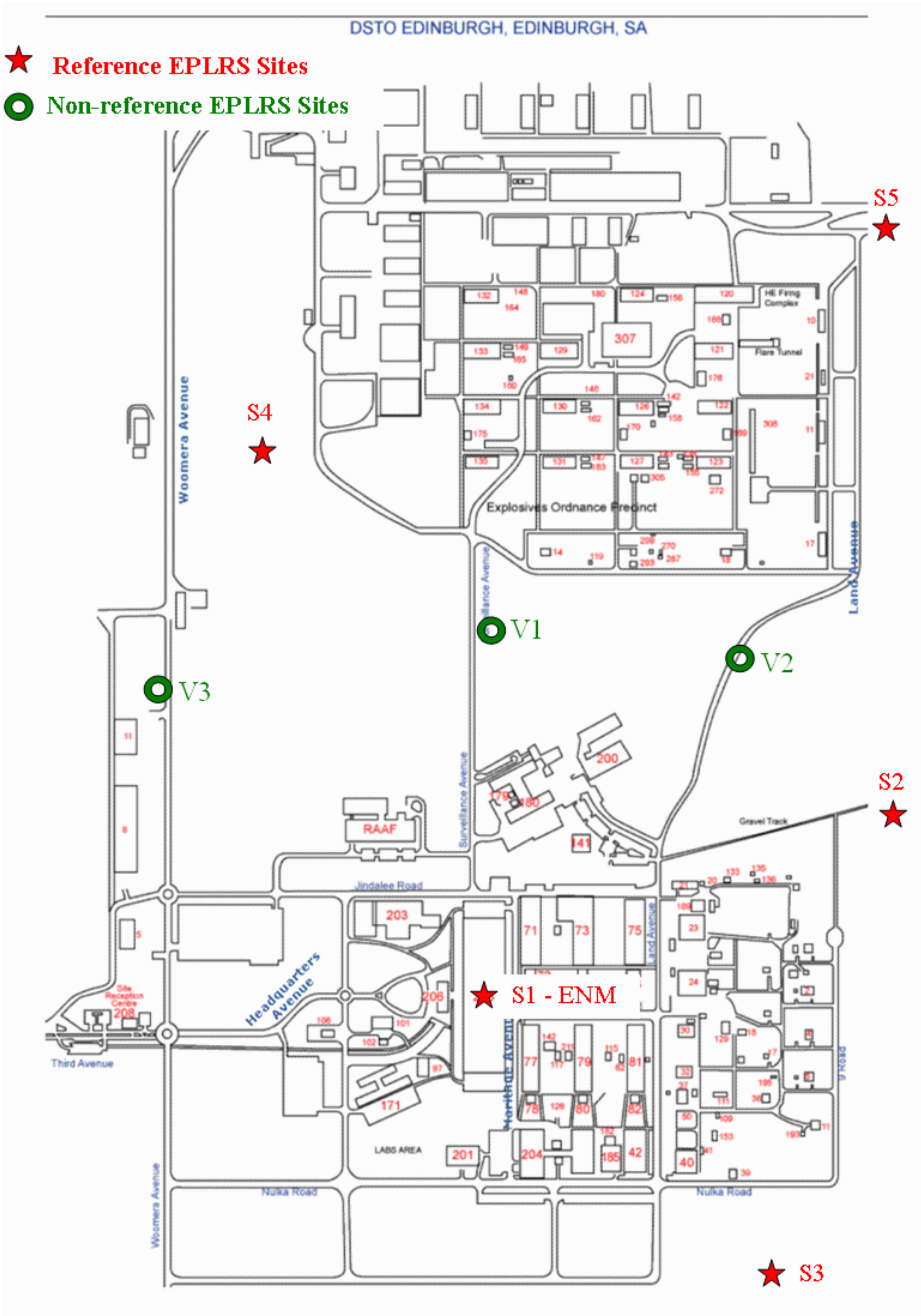

Figure 5: EPLRS Reference Unit sites (S1-5) and Mobile Unit sites (V1-3)

3.2 Results

We define the *average bias* (ρ) as the average distance between the estimated EPLRS location and its true location. Let ξ be the east bias with variance σ_ξ^2 and ψ the north bias with variance σ_ψ^2 so that

$$\rho = \sqrt{\xi^2 + \psi^2}$$

and

$$\sigma_\rho^2 = \frac{1}{\rho^2}\left(\xi^2\sigma_\xi^2 + \psi^2\sigma_\psi^2\right)$$

from standard statistical theory, for example see Ref 2.

Table 1 shows the results of east, north and average bias measurements for a variety of receiver configurations. Horizontal error graphs are shown in Figure 7 to Figure 15.

Table 1: EPLRS Test Results

Location	Num Ref Units (RSIDs)	East Bias ±Std	North Bias ±Std	Average Bias ±Std	Quality Indicator	Figure
V1	5 (1,2,4,5,6)	-10 ± 63	16 ± 28	19 ±41	Avg	Figure 7
V1	5 (1,2,4,5,6)	4 ± 46	12 ± 24	13 ±27	Avg	Figure 8
V1	4 (1,2,4,6)	41 ± 28	17 ± 17	44 ±27	Avg	Figure 9
V1	4 (1,2,4,5)	0 ± 41	2 ± 28	2 ±28	Avg	-
V1	3 (1,2,4)	37 ± 27	18 ± 19	41 ±26	Avg	Figure 10
V1	3 (1,2,6)	20 ± 16	33 ± 12	39 ±13	Avg	-
V1	3 (1,5,6)	-18 ± 24	22 ± 15	28 ±19	Avg	-
V2	5 (1,2,4,5,6)	28 ± 39	11 ± 32	30 ±38	Avg	Figure 11
V2	4 (1,4,5,6)	-9 ± 34	1 ± 26	9 ±34	Avg	-
V2	3 (1,5,6)	-25 ± 22	16 ± 17	30 ±21	Avg	-
V3	5 (1,2,4,5,6)	-54 ± 22	12 ± 19	55 ±22	Avg	Figure 12
V3	4 (1,4,5,6)	-57 ± 23	2 ± 23	57 ±23	Avg	-
V3	3 (1,5,6)	-34 ± 22	27 ± 20	43 ±21	Avg	-
Hill	5 (1,2,4,5,6)	30 ± 37	23 ± 80	38 ±57	Poor	Figure 13
Hill	4 (1,4,5,6)	14 ± 22	-6 ± 42	15 ±26	Avg	Figure 14
Hill	3 (1,4,5)	71 ± 47	106 ± 98	128 ±86	Avg	Figure 15

Location Quality indicators of 'Avg' relate to a range deviation of between 25 and 50 m, while the 'Poor' indicator relates to a deviation of between 100 and 200 m.

Inconsistencies are apparent in the above table. For example, more reference units did not always result in a more accurate position solution. Factors such as multipath and obstructions due to nearby buildings likely affected the position solutions.

From Table 1, the following average biasses can be concluded:

Non-reference RS inside the ring of reference units: 32 ±27 m

Non-reference RS offset from the ring of reference units: 60 ±61 m (small dataset)

Results for a typical dynamic test are shown in Figure 16. In this test, the van containing the non-reference EPLRS was driven around the DSTO establishment at speeds ranging from 25 kph to 60 kph.

3.3 Gumstix Test

The setup used for the Gumstix test is shown in Figure 6. Here, a GPS receiver is connected to the Gumstix allowing both GPS position and EPLRS position to be sent over the EPLRS network to the PC.

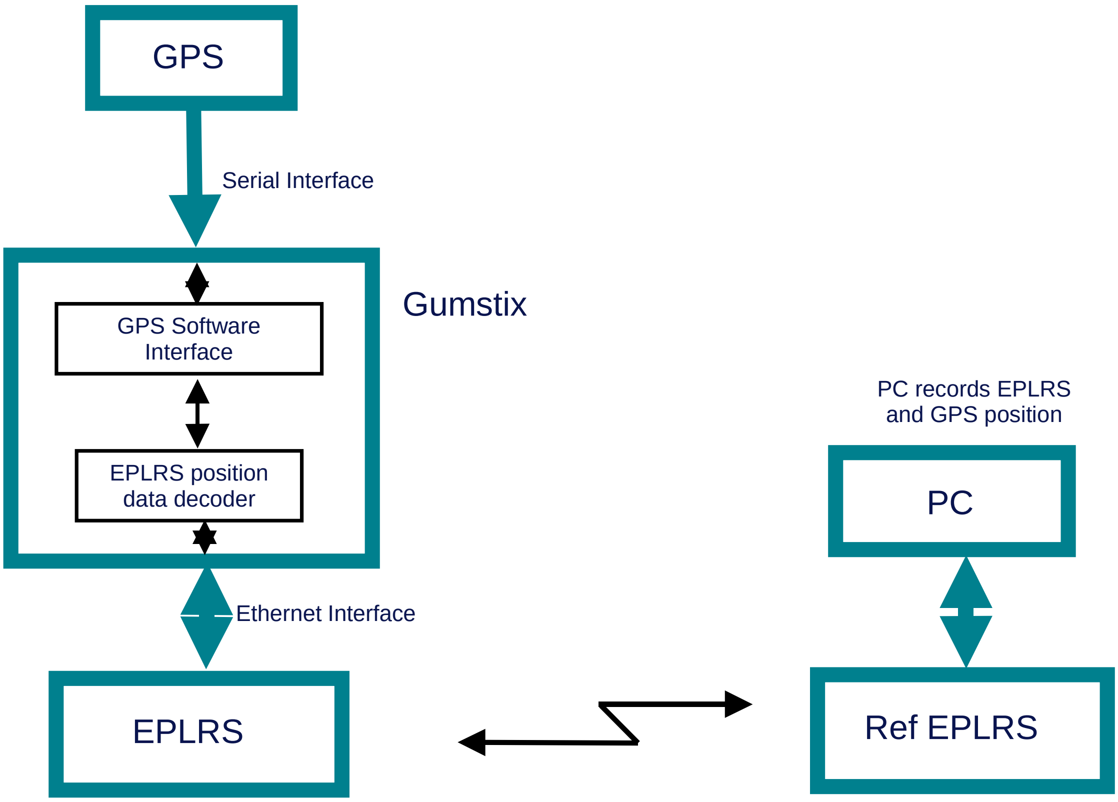

Figure 6: EPLRS and Gumstix Test Setup

The ENM is required to setup a unicast route between two EPLRS units. Once this is configured, and gateways are setup on the Gumstix and PC, the PC is able to connect to the Gumstix over the EPLRS network. The Gumstix then transmits the GPS and EPLRS position data to the PC which displays and records the data for later analysis.

With the GPS, Gumstix, and an EPLRS unit in a van, the stationary PC (connected to an EPLRS reference unit) successfully recorded the GPS and EPLRS positions of the van as it travelled around the DSTO area.

3.4 Results Summary

Where the non-reference was surrounded by reference units, the average bias of the EPLRS position was 32 ±27 m.

Where the non-reference is not centred between the reference units, as would be typically the case in a UAV deployment operation, the average bias increased to 60 ±61 m.

The latter bias was taken from a very small sample set and included one test where the Quality Indicator was significantly poorer.

These results suggest the EPLRS position accuracy should be sufficient to enable coarse navigation of a UAV in the event of GPS becoming unavailable. Flight tests are required to confirm these findings.

3.5 Operational Issues

Managing the EPLRS network to allow one or more EPLRS units to determine their location involves the following ENM tasks:

a) Entering the position coordinates (and estimated accuracy of coordinates) for every stationary EPLRS reference unit

b) Selecting the GPS option for reference units whose position will be updated continuously by a GPS receiver. This dynamic reference capability was not tested as part of the EPLRS tests discussed in this report.

c) Entering the host multicast IP address and port number used for delivering position data for the non-reference EPLRS unit. This information is also required by a computer connected to the non-reference EPLRS unit to record and display the position data

d) In addition, to allow two computers connected to two EPLRS units to communicate over the EPLRS network, a unicast route is required to be set up between the relevant EPLRS units.

4. Summary

The EPLRS position reporting capability has the potential to be utilised as a backup to GPS in situations where GPS is denied and precise positioning is not required.

The small size of the EPLRS Micro-Light unit allows the use of EPLRS on a UAV platform and whilst the position accuracy is less than that obtained using GPS, it could be sufficient for UAV flight navigation purposes. Altitude information is provided by the Micro-Light's built-in baro-altimeter.

The positional accuracy of EPLRS is dependent on the number and configuration of the EPLRS reference units.

EPLRS average position biasses were found to be 32 ±27 m for good reference unit configuration and 60 ±61 m for the small number of poor configuration tests performed.

Some points to note from the results obtained:

1) In general, position accuracy lessened when the non-reference EPLRS unit was moved a large distance from the reference units. This was expected due to the much poorer geometry of the reference unit layout with respect to the non-reference unit resulting in vertex angles of less than 20°.

2) The positional accuracy did not always correlate with the number or configuration of reference units.

3) The results were not always repeatable. That is, different position results were sometimes obtained when using the same configurations of EPLRS units.

4) Some anomalous findings may have been due to the testing environment. The environment contained many buildings and other obstructions likely to have resulted in multipath and signal degradations affecting the resultant position solutions. As an example, the ENM antenna is a permanent installation on the roof of a building with other considerable structures on the roof in the antenna's immediate vicinity.

Further EPLRS position tests are desirable in a more open environment, such as Woomera, to ascertain the magnitude of the effect of multipath and visibility anomalies on the position solution. UAV flight tests will also evaluate the EPLRS position reporting capability and verify its usefulness for navigation in the absence of GPS.

Other potential benefits of EPLRS integration into UAVs include:

a) deployment of GPS denial payloads
b) payload access to the EPLRS communications network
c) UAV-UAV communication via the EPLRS network

5. Acknowledgements

The author would like to thank Stephen Leak of Information Networks Division for the loan of the EPLRS equipment and his work and assistance in managing the network during the tests.

The author also appreciated the assistance given by Dr. Sam Drake of Electronic Warfare and Radar Division to the statistical analysis of the results.

6. References

[1] Planners Manual for EPLRS Networks, TB 11-5825-298-10-3, Department of the Army, Washington, DC. 15 Sept 2003

[2] Spiegel, Murray R. Shaum's Outline of Theory and Problems of Statistics, Second dition. McGraw-Hill, Inc.; New York; 1988

Appendix A: EPLRS Position Plots

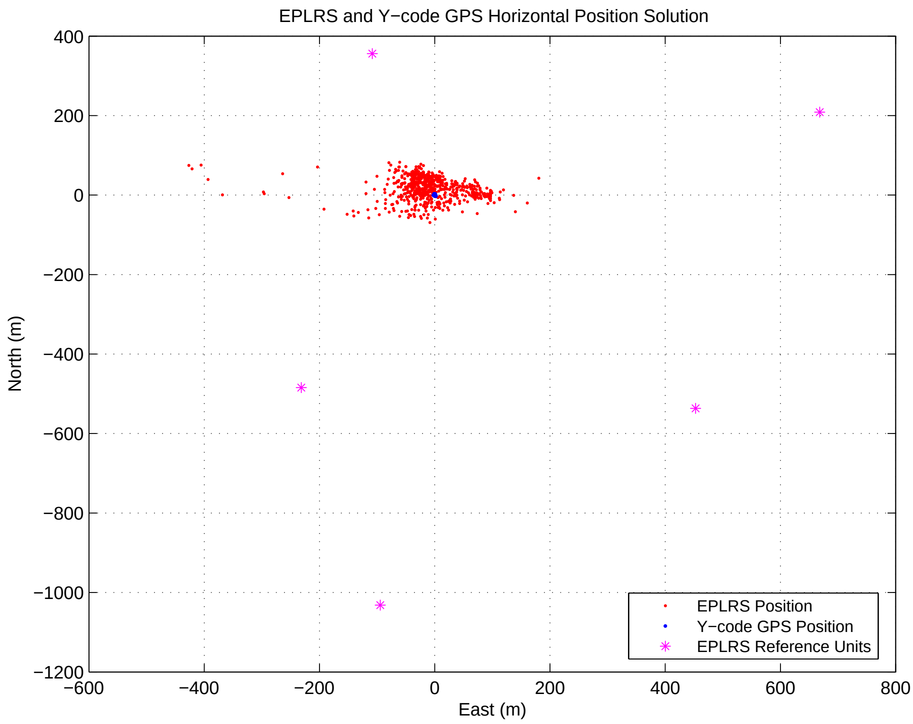

Figure 7: V1 EPLRS Position Error with 5 reference units (1 of 2)

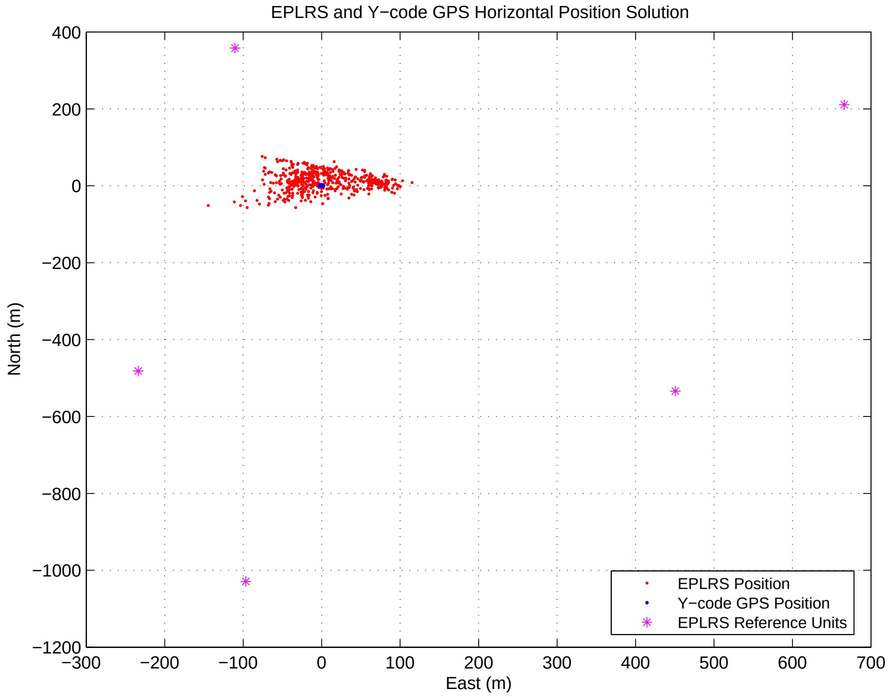

Figure 8: V1 EPLRS Position Error with 5 reference units (2 of 2)

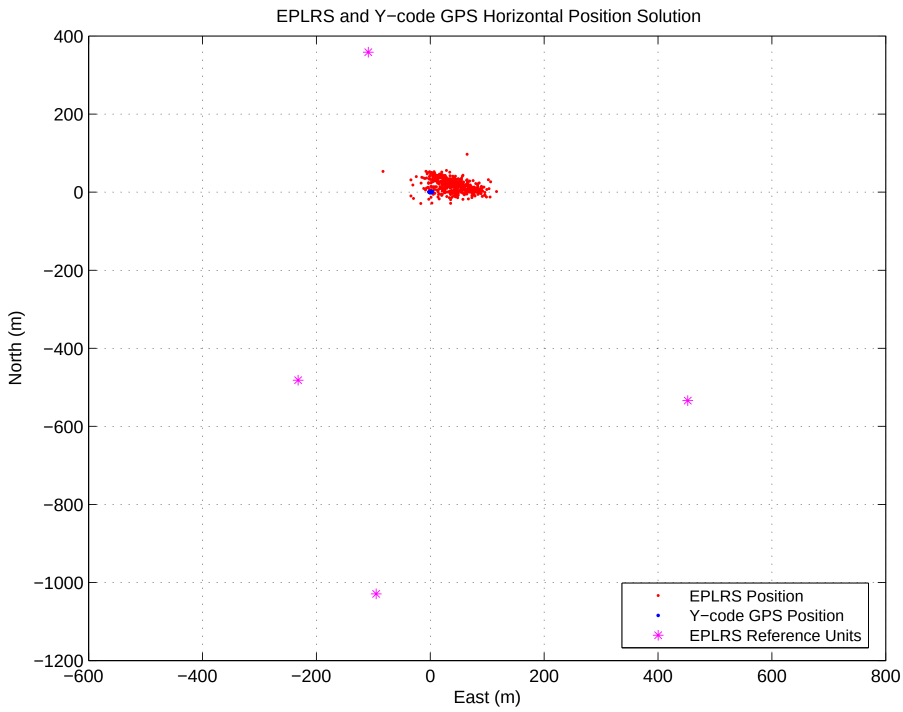

Figure 9: V1 EPLRS Position Error with 4 reference units

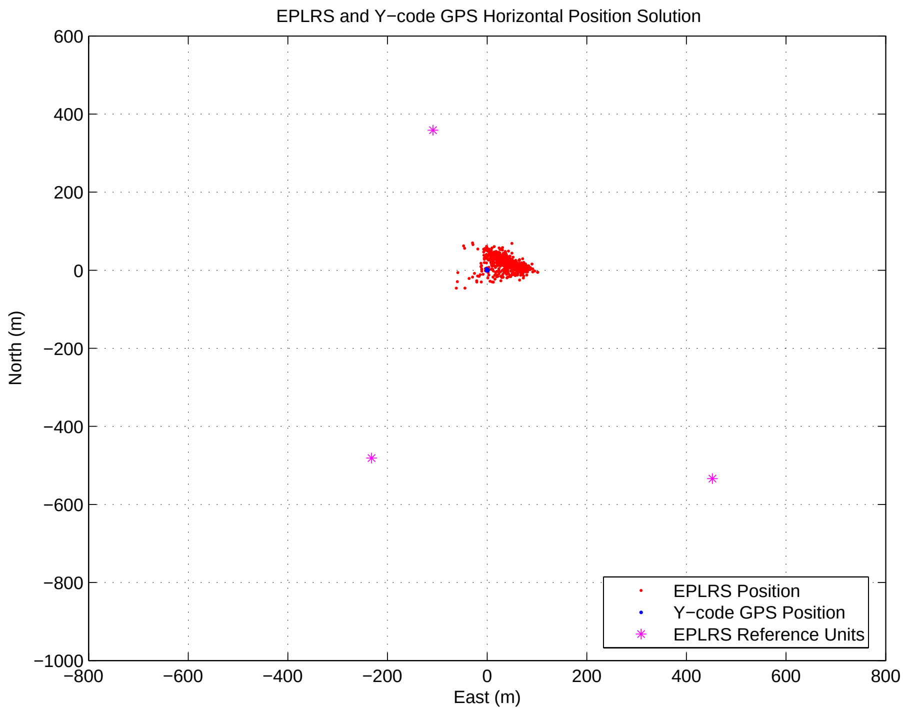

Figure 10: V1 EPLRS Position Error with 3 reference units

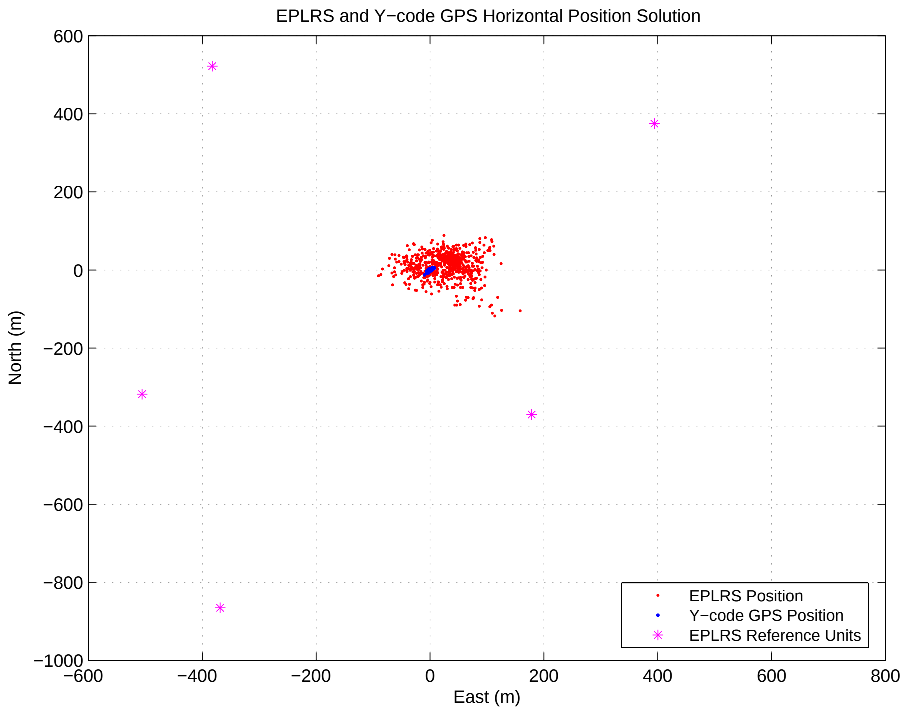

Figure 11: V2 EPLRS Position Error with 5 reference units

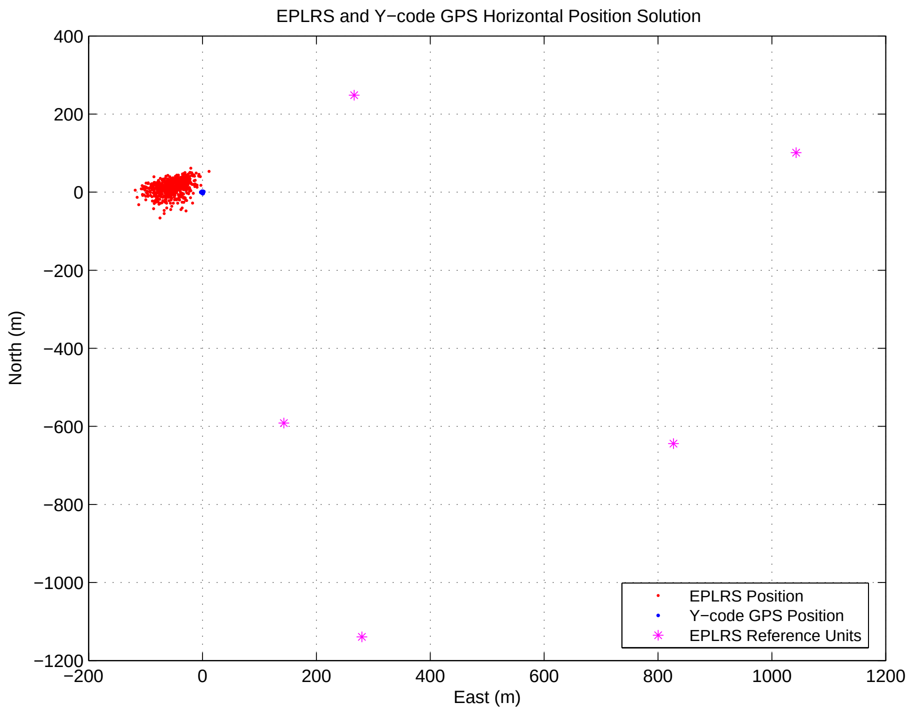

Figure 12: V3 EPLRS Position Error with 5 reference units

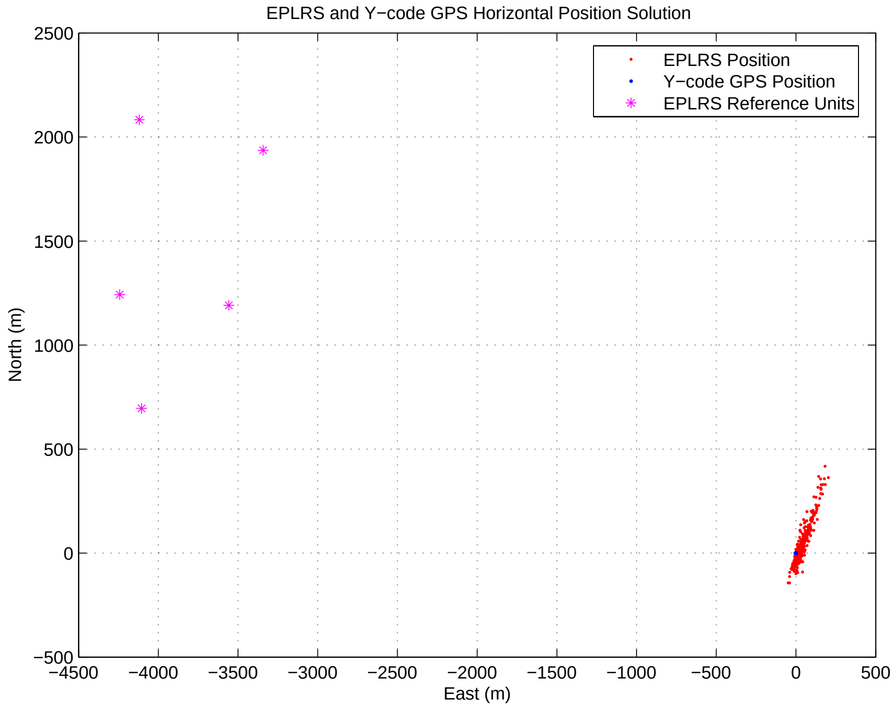

Figure 13: 4 km offset EPLRS Position Error with 5 reference units

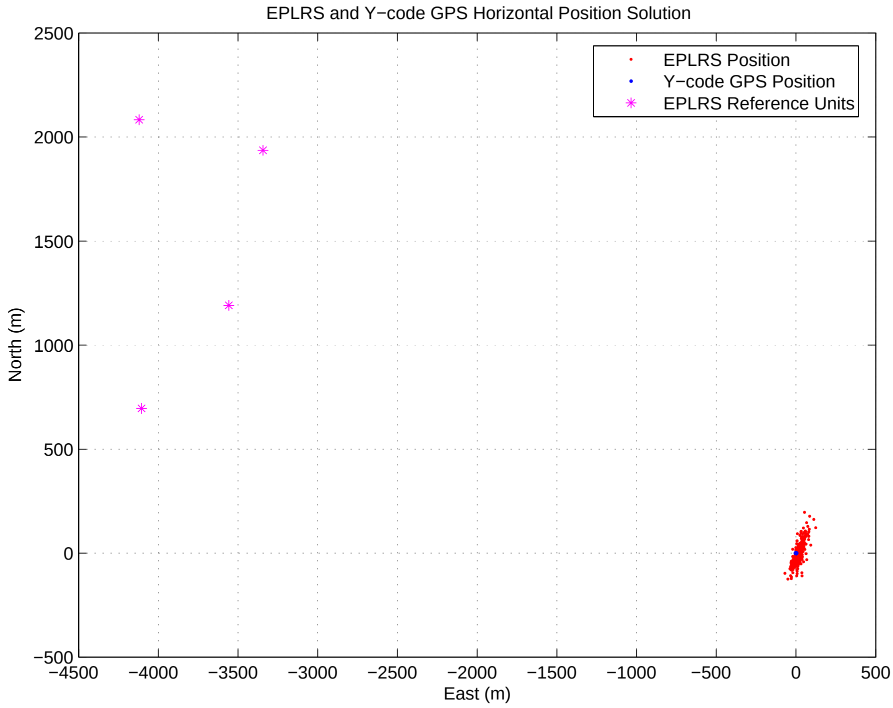

Figure 14: 4 km offset EPLRS Position Error with 4 reference units

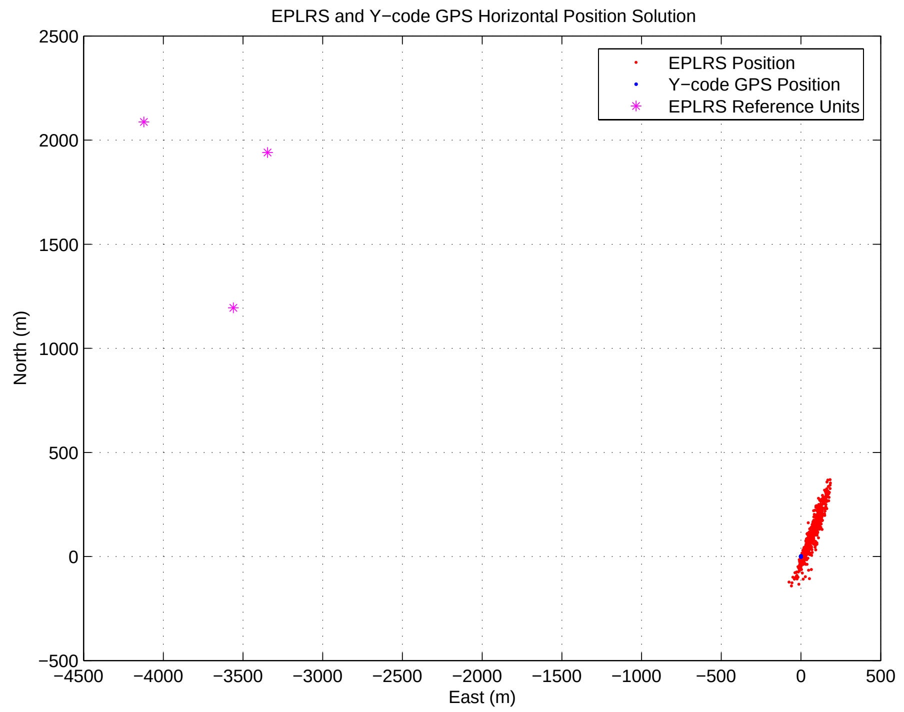

Figure 15: 4 km offset EPLRS Position Error with 3 reference units

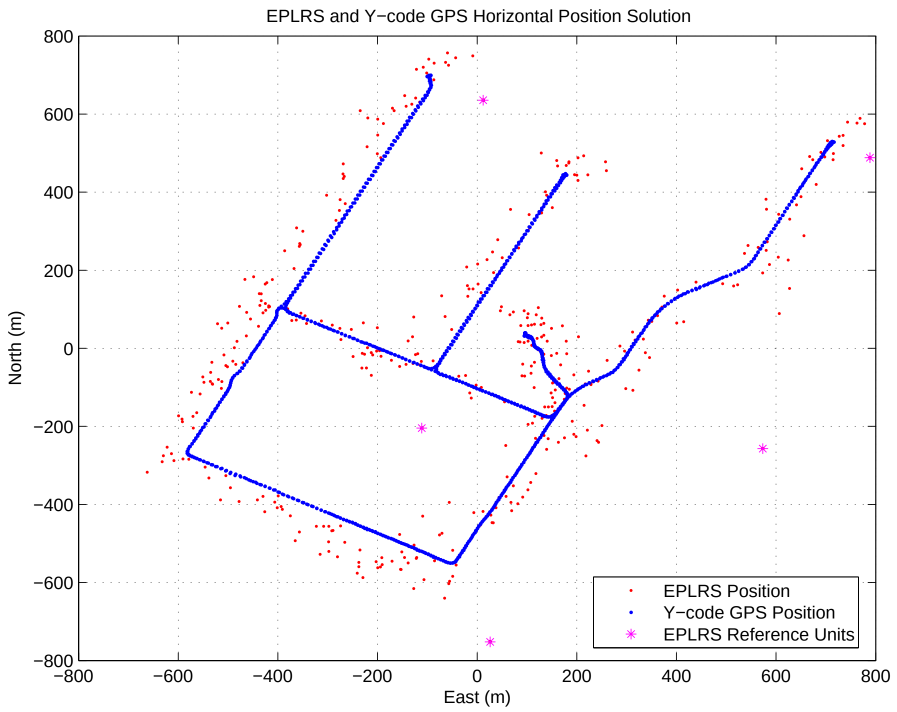

Figure 16:Dynamic Tests with 5 reference RS units

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19. ABSTRACT

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