

Operational Field Trials of GPS Equipped Sonobuoys

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Biography

Mr Peter Brown

Mr Peter Brown is the Managing Director of NAVSYS Limited, an Edinburgh, Scotland based company specialising in developing GPS technology. He has been involved in the hardware design and implementation of custom GPS products since 1990.

Prior to NAVSYS Mr Brown was District Technical Manager with the oilfield electronics company Schlumberger. Mr Brown holds a BSc in Electrical Engineering from Imperial College, University of London and is a Member of the Institute of Electrical Engineers.

Mr Trevor Kirby-Smith

Mr Trevor Kirby-Smith is currently employed in the Maritime Systems Department of Defense Research Agency, Farnborough, UK. He is currently working in the field of Air-Sea Warfare, particularly the application of GPS to sonobuoys.

Mr Kirby Smith has spent many years in defence research covering novel helicopter transmission, aircraft/runway interface problems and applied research on parachute systems.

Mr Kirby-Smith holds a Bachelor of Engineering Degree from Liverpool University and is a Chartered Engineer and Member of the Institute of Mechanical Engineers.

Abstract

This paper describes a trial involving the NAVSYS TIDGET™ low-cost GPS sensor in fully-functioning sonobuoys in an operational environment.

Sonobuoys are disposable air-launched buoys that are used in Anti-Submarine Warfare (ASW). Current techniques for localising the buoys once deployed are relatively inaccurate, time-consuming and involve aircraft manoeuvres in the vicinity of the buoy.

Differential-GPS has been proposed as an alternative to the present localising techniques, however the sonobuoy environment leads to problems with a conventional GPS implementation.

- Sonobuoys are disposable, and are therefore extremely cost sensitive.
- Sonobuoys are stored for extended periods (many years), but must be operational immediately when deployed.
- Large thermal transients occur on deployment from the aircraft into the sea.
- The GPS antenna is subject to a high degree of masking due to its low elevation above the sea surface, aggravated by high sea-states and/or high winds.
- Sonobuoys are battery powered and have limited available spare power for a GPS receiver.
- Sonobuoys broadcast 1 Watt of RF power adjacent to the GPS antenna.

This paper describes the GPS technology used for this application and its implementation in a fully-functional sonobuoy, and presents the results from a trials sortie flown in October 1995 using an RAF Nimrod Maritime Patrol aircraft and 9 sonobuoys in the water at the NATO AUTEK ASW range in the Bahamas. The results presented include a comparison between the TIDGET positional accuracies and the range instrumentation, and a summary of objectives met.

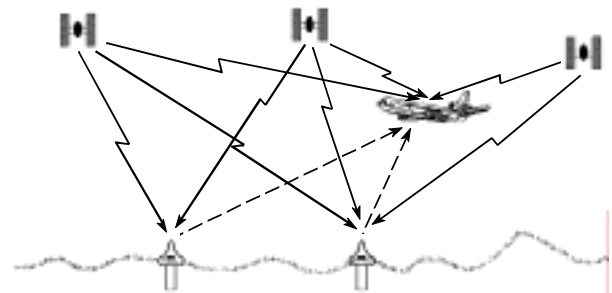


Figure 1 Deployed field of GPS sonobuoys

Introduction

The use of acoustic location sonobuoys deployed by aircraft is a standard means of locating hostile submarines. These sonobuoys are typically launched from Anti-Submarine Warfare aircraft, with the acoustic data from deployed hydrophones being relayed to the aircraft by a VHF RF link. Signal processing of the acoustic data is carried out in the aircraft to compute a vector to the target from the buoy hydrophone(s). Obviously, to use this data to provide a target position, the location of the buoy must be known in the aircraft.

Present buoy localisation schemes involve a variety of Radio Direction finding schemes to home on the RF transmission of the sonobuoy (either using an array of antennas on the aircraft, or by flying a known trajectory in the aircraft, or simply "on-topping" the buoys by flying into the broadcast antenna null above the buoy). These methods require the ASW aircraft to manoeuvre to obtain a sonobuoy position, and also in most cases require the use of some form of directional antenna. These methods also mean the aircraft cannot stand-off at any distance from the buoy pattern without degrading localisation accuracy.

GPS was proposed as a possible solution to the shortcomings of the existing sonobuoy localisation techniques, and a series of trials were carried out by NAVSYS Limited and DRA Farnborough in 1992 and 1993, culminating in a contract award to ULTRA Electronics (the UK's major sonobuoy manufacturer), with NAVSYS Limited as the GPS subcontractor, to develop and trial a series of prototype GPS equipped sonobuoys.

The scope of the trial was modified mid-contract with the involvement of the RAF Air Warfare Centre, to include a full operational trial to be flown with an RAF Nimrod ASW Aircraft at the NATO AUTEK ASW range in the Bahamas. The trial sortie was flown in October 1995, and provided the first real data on the usability of GPS in sonobuoys in a realistic environment (sea state 3-4), both from the point-of-view of the GPS performance itself, and also from the end-user's point of view, using the real-time reported buoy positions within the tactical systems. The trials report showed that TIDGET equipped sonobuoys could successfully achieve rapid (sub one-minute) Time to First Fix in field conditions and with no prior initialisation, and that the position accuracies were consistent with the system design goals.

This paper covers the following areas:

- Description of the TIDGET GPS sensor compared to conventional GPS sensors.
- Description of the implementation of the TIDGET sensor in the ULTRA Difar sonobuoys.
- Description of the actual trial at the AUTEK range
- Analysis of results and performance against objectives
- Conclusions

Description of the sonobuoy environment

The operational environment for GPS in sonobuoys is far more arduous than that experienced by most GPS receivers. The sonobuoy itself consists of a float-bag assembly and upper unit that supports a lower unit acoustic sensor lower in the water. The float bag does not stick up very far above the surface of the water and is subject to wave-wash and wind tilt. A GPS antenna placed in the float bag will see high mask angles due to wave action (dependant on sea-state) and will occasionally be totally submerged.

To further add to the problems, in most operation situations, the buoys are deployed with no opportunity for initialisation of the GPS sensor. Since the last GPS almanac will in this case date from time of manufacture (up to 5 years ago), this relates to what most GPS manufacturers refer to as a Frozen Start (Ref 1). For many tactical situations, a rapid location of the sonobuoy once deployed is very important, and the delay time before the GPS system in the buoy starts provide position information is crucial. Many manufacturers do not even specify a Frozen Start Time-To-First-Fix, since it is not relevant to the majority of GPS applications, and those that do assume unobscured satellite signals during the acquisition phase. For one of the manufacturers that do specify a Frozen Start, a 90% probable TTFF is quoted as 15 minutes, which is probably fairly typical (Ref 2).

Conventional GPS engines

A block diagram of a typical, modern OEM GPS engine is shown in figure 2. The analogue portion of the receiver consists of a GPS antenna, low-noise amplifier and downconversion front-end stage. The downconversion is driven by a precision Local Oscillator, usually a Temperature Compensated Crystal Oscillator (TCXO). After the analogue front-end, the signal is digitally sampled and the resultant digital data stream (which contains the spread-spectrum data of all GPS satellites in view at the antenna) is passed to the correlators for the spread-spectrum processing. Different manufacturers implement different numbers of parallel correlators in their engines. In general, faster signal acquisition can be expected with a receiver with more correlators. The output of the correlation process is converted in the main CPU into pseudo-range data using Ephemeris tables broadcast as part of the satellite message, and the combination of pseudo-ranges from 4 satellites calculates a 3-dimensional navigation solution.

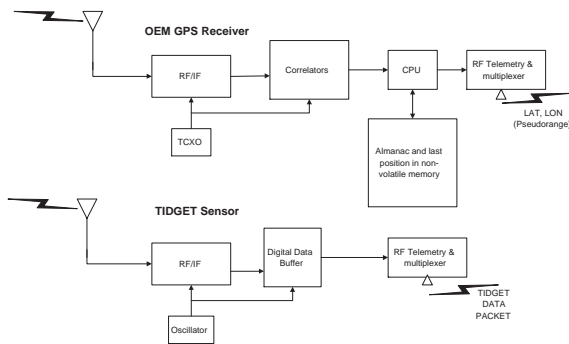


Figure 2 TIDGET and OEM receiver block diagrams

To acquire and track an individual satellite the main CPU must program the correlator with the unique satellite Pseudo-Random Noise (PRN) number, and composite Doppler (a function of satellite angular velocity with respect to the receiver location, the receiver velocity and acceleration (if any), and the local oscillator bias of the receiver) of the satellite signal.

The determination of the PRN number of the visible satellites and the estimation of the composite Doppler is a relatively straightforward task for a conventional receiver in normal use (i.e. a Warm Start or Cold Start, where the receiver has been navigating within the past few days and therefore has a current Almanac table of the satellite constellation, and has an approximate estimate of current position (within 100km)). In this case the receiver will normally use the latest navigation solution and a recent almanac table (both usually held in non-volatile memory from the last time powered-on) to look-up the PRN number and estimated Doppler frequency of all the satellites that are above the horizon. This dramatically accelerates the search and acquisition process necessary before the receiver can start to navigate.

In the Frozen Start condition that pertains to deployment in uninitialised sonobuoys (obsolete almanac, and incorrect or no current position estimate), this preselection of visible satellites is not possible, so the receiver has to carry out a random Open-Sky search until enough satellites are tracked to compute a navigation solution. This process is adversely affected by Local Oscillator ageing (i.e. time in storage) and potentially by large temperature transients as the sensor warms up/cooling down to sea-temperature from the sensor storage temperature (internal or external aircraft stores). Obscuration of a satellite during this Open-Sky search (wave-wash, antenna tilt etc) will also adversely affect this process.

The TIDGET sensor

The TIDGET sensor architecture is shown in figure 2. The TIDGET uses a distributed architecture, with only basic data acquisition in the remote sensor, and all signal processing in a remote processing workstation. The TIDGET was conceived from the beginning for tracking applications (i.e. no need for an on-board navigation

solution) and aims to be the cheapest possible GPS sensor due to the elimination of all signal processing functions from the sensor itself. This approach also has the benefit of extremely low power and size, and near-instantaneous signal acquisition under all conditions. TIDGET is aimed at predominantly commercial (rather than military) applications, and is presently used in emergency location systems for automobiles and for weather balloon tracking.

The TIDGET processing train does not differ significantly from that of a conventional receiver, the difference is in **where** that processing is carried out.

In the TIDGET, a conventional GPS front-end chip is used (with a non-precision oscillator), to acquire and downconvert the GPS spread-spectrum signal to baseband. This signal is then digitised, but instead of being directly passed to a correlator, the signal is streamed into a Digital Data Buffer memory. Typically 60mSecs of data at 2Mbits/second is acquired.

During this data acquisition phase, the DDB has been passing housekeeping information (frame synch, packet count etc) via the comms link at whatever bit-rate the telemetry can support (7500 bits per second in the case of these trials, with a position broadcast every 20 seconds). Once the GPS snapshot acquisition to memory is completed, the DDB starts to output the buffered raw GPS data stream. It is important to realise that this data stream contains the uncorrelated spread-spectrum data from **all** satellites in view at the antenna.

To implement the TIDGET sensor in the chosen DIFAR sonobuoy, a modification to the existing buoy analogue telemetry was made by the buoy manufacturer Ultra Electronics, which permitted transparent transmission of this low-rate digital data along with the existing sonobuoy acoustic data. Since the TIDGET data transmitted consists of uncorrelated spread-spectrum data, the telemetry is exceptionally immune to random data errors, and as such there is no need for any error-correction or parity type information.

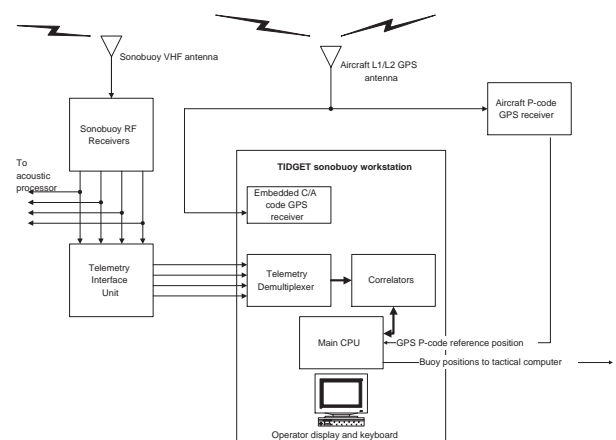


Figure 3 Aircraft GPS-related Equipment

A Telemetry Interface Unit (TIU) connected to the sonobuoy RF receivers in the aircraft strips out the

TIDGET data streams from up to four channels and passes them to the TIDGET workstation for processing (figure 3).

The function of the TIDGET workstation is to carry out the processes normally carried out in the correlator and CPU of a conventional receiver- namely signal correlation to extract the satellite pseudo-ranges, and computation of the navigation solution. However, the TIDGET approach completely bypasses the initial acquisition problems that plague the conventional receiver in the Frozen Start mode. The current satellite Almanac and Ephemeris tables are received by a conventional GPS receiver in the TIDGET workstation, and are therefore already available to the processor. Similarly, a good estimate of the initial position of the sonobuoy is also available. This information effectively means that the TIDGET processor has only to cope with a Warm Start scenario even under worst-case conditions, and can therefore provide a guaranteed fast TTFF in the sonobuoy environment.

Since the TIDGET workstation has access to the reference C/A code GPS receiver, the system can also use a differential GPS technique to compute an enhanced accuracy GPS fix (see later).

Implementation of TIDGET in sonobuoys

Under a DRA study contract, Ultra Electronics, the largest UK sonobuoy manufacturer, modified a series of conventional analogue DIFAR sonobuoys to incorporate NAVSYS TIDGET GPS sensors into them.

The telemetry of the buoys (modulated VHF at between 136 and 173.5 MHz) was modified to accommodate a transparent TIDGET data telemetry at 7500 bits/seconds, while supporting the current analogue telemetry.

The TIDGET sensor itself, is mounted on the rear-side of a GPS patch antenna. The entire assembly was mounted in a screened enclosure and is approximately 70 x 80 x 10 mm in size. Signal connections were made using screened twisted pairs into the rest of the buoy electronics.

The whole TIDGET assembly was mounted within the inflated float-bag of the buoy (rectangle in centre of fig 3), with the antenna surface approximately 30mm above the surface of the sea when deployed.

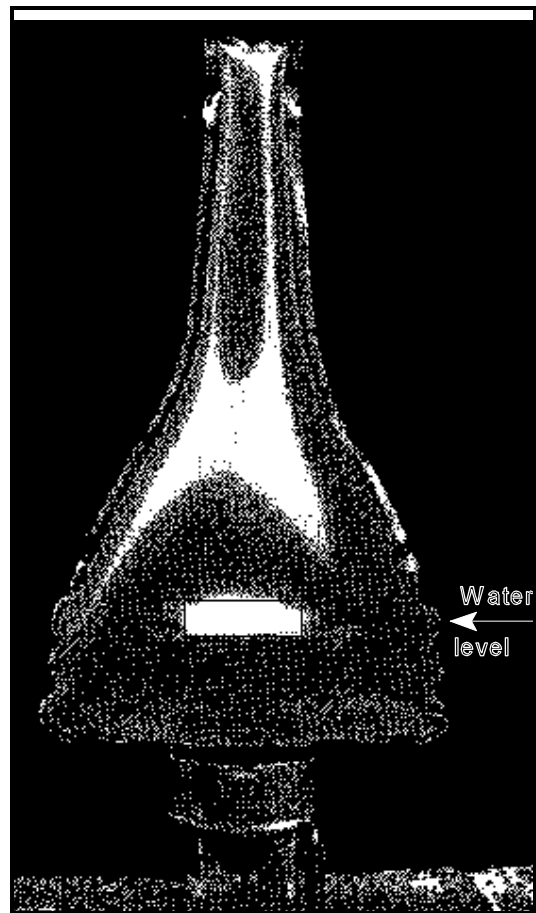


Figure 4 Sonobuoy float bag showing GPS sensor position

The single biggest problem encountered in this integration was cross-coupling between the buoy RF (the buoy broadcasts in excess of 1 Watt RF power) and the GPS front-end (GPS signals are received at -160dBWatt). Harmonics of certain sonobuoy broadcast channels fall directly in-band of either the GPS L1 frequency (1575.42MHz) or the image of the first stage downconversion of the RF front-end chip used (1224.65MHz). This problem is likely to be common to any GPS implementation in this high RFI environment, and resulted in the loss of 8 of the 100 available sonobuoy broadcast channels.

To minimise the power draw of the TIDGET unit, a power management feature was used, enabling the powering down of the GPS RF front end of the TIDGET between snapshots. In this way, the RF front end was powered for approximately 100mSec every 20 seconds, achieving a substantial power saving over a conventional GPS approach.

This series of prototype GPS sonobuoys were designed to be equivalent to fully-functioning buoys, with the one exception that they were not cleared for air-launch and would have to be pre-inflated and deployed by hand.

Workstation implementation in aircraft

The workstation as flown was a suitcase-sized IBM-PC based unit capable of supporting data simultaneously from up to four sonobuoys. The embedded 12-channel reference GPS receiver was connected, via a splitter, to the aircraft main GPS L1/L2 antenna. GPS signal processing is carried out using an embedded Digital Signal Processing card.

The workstation provides an output data stream in RS232 form in the NATO Link 11 protocol to report the real-time positions of the sonobuoys to the aircraft tactical computer. The system is designed to work with no operator intervention, the display and keyboard being used for status and debug purposes during the trial sortie. For the range trial, all the in-aircraft equipment was installed as a Special Trials Fit, with the TIU in a rack in the rear of the aircraft and the TIDGET GPS Workstation secured in a custom frame on the galley table.

After some successful preliminary sea trials in the UK, an opportunity occurred to fly at the AUTEK range, and a decision was made to accelerate the programme and aim for a full operational trial of the system in the Autumn of 1995.

Objectives of the range trial

The objectives of the range trials were as follows:

- To demonstrate the reliability of the sonobuoy GPS telemetry
- To demonstrate that the addition of GPS had not degraded the acoustic performance of the buoys
- To provide a real-time display of the buoy GPS positions on the tactical computer
- To demonstrate the GPS positioning accuracy
- To analyse the tactical effectiveness of the system

To achieve this, the RAF Air Warfare Centre (AWC) organised a trials sortie using an RAF Nimrod Maritime Patrol Aircraft at the NATO ASW range AUTEK in the Bahamas. The sortie was flown out of the US Naval Aviation base at Jacksonville in October 1995.

The AUTEK range is to the East of Andros Island (south of Nassau) in an area called the Tongue of the Ocean.

The main advantage of carrying out the trial at the AUTEK range was the availability at the range of a Sonobuoy Tracking System, a shore-based radiolocation system capable of triangulating using the RF broadcasts of unmodified sonobuoys from several shore based antenna sites, to provide an accurate (25 yards, 60% probable) set of truth positions for the deployed GPS sonobuoys.

To ensure the fullest possible data set from this trial a GPS Ground Monitor was set up at a surveyed point on ANDROS Island. C/A code GPS observables were recorded during the duration of the mission to permit a

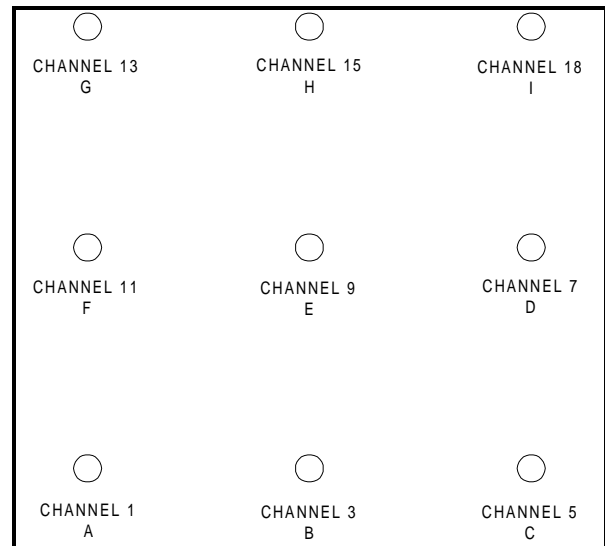


Figure 5 Sonobuoy deployment pattern

full differential GPS buoy position to be computed post-mission.

The trial commenced with the deployment of a field of 18 sonobuoys being deployed by hand using range boats. The 18 sonobuoys comprised 9 GPS-modified buoys and 9 unmodified buoys. The buoys were laid in a square grid at 2 nautical-mile separation (figure 4) with colocated GPS and standard buoys at each location. Each buoy was configured with a different VHF broadcast frequency (channel). Initial deployment position was determined in the range boats using hand-held P-code GPS receivers. Unfortunately, a deployment error meant that two of the buoys (positions E & F) were deployed at the same broadcast frequency. There was insufficient time to lay new buoys, so the mission proceeded regardless. The aircraft arrived on range as the buoy deployment was completed, and tracking of the buoys commenced.

Since the TIDGET workstation flown during the mission was only capable of tracking 4 buoys at any one time, some limited swapping of relevant buoys into the system was carried out over this period by changing TIU RF Input connectors.

After some initial Workstation parameter optimisation, the system performed well, and tracked 4 buoys continuously while providing real-time sonobuoy position updates to the tactical computer.

Mid-mission a hardware problem (believed to be related to the aircraft 400Hz power supply), caused a system crash of the TIDGET workstation. The system eventually recovered after being powered off for some time.

Other gaps in the data set occurred due to channel swapping (with 9 buoys in the water and a 4 channel system this was inevitable).

The real-time results were computed as standalone (i.e.

non-differential) GPS positions, but post-mission processing using the ground-based reference GPS data permitted computation of enhanced accuracy differential GPS positions.

Total on-station time for the mission was 5 hours. During the mission the Nimrod carried out processing of both the modified GPS buoys and the non-modified buoys, while flying a normal mission profile with simulated attacks on target.

Details of results

Telemetry

Of the deployed buoys, the two buoys inadvertently set to the same broadcast channel (E & F) interfered with each other's telemetry, making this data largely unusable (some data points were recovered when the Nimrod was much closer to one or other of these two interfering buoys). One buoy was not tracked at all (operator error), and one experienced RFI on the channel and eventually ceased to broadcast.

For the 5 non-problem buoys, the telemetry reliability demonstrated a reliability of better than 82% (better than 90% for 4 of the buoys) of TIDGET data packets received without error .

Satellite visibility

Predicted satellite visibility plots computed using the NAVSYS GPSSIM mission planning software for the time window of the trials are shown in figure 6. This figure assumes an antenna mask angle of 10 degrees. The prediction shows a minimum of 6 satellites above 10 degrees elevation during the whole trials period, with 8 satellites visible for much of the time.

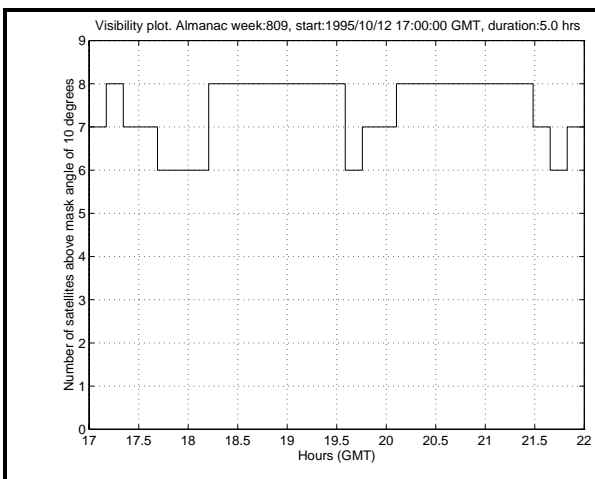


Figure 6 Theoretical Satellite visibility with time (10 degree mask angle)

Figure 7 shows the total number of TIDGET tracked satellites for one of the buoys against time for this period. Most of the time at least 6 satellites were tracked, and a good proportion of the time 8 were tracked. With the

exception of the drop out at 850 seconds (which appears to correspond to a corrupted packet that got through the initial error checking in the Workstation), at all times there were the minimum of 3 satellites in view to enable computation of an altitude-aided navigation solution

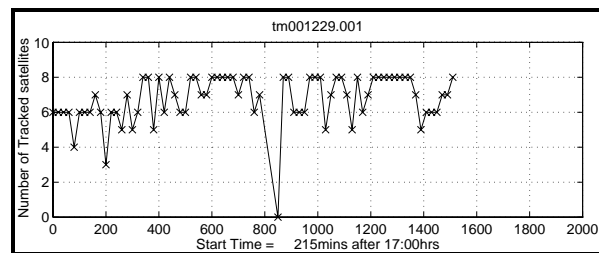


Figure 7 Buoy B Satellite visibility against time

Time-to-First-Fix

A main aim of the TIDGET development was to achieve near-instantaneous GPS signal acquisition, and computation of the buoy positions.

The system as trialled repeatedly demonstrated Time-to-First-Fix of less than 1 minute for buoys appearing to the system for the first time (the buoys had been deployed and were already broadcasting by the time the aircraft arrived on-range). Some problems occurred with the trials software when telemetry errors occurred, but this has now been fixed in a later software revision.

Navigation Solution Reliability

Table 1 shows the reliability of the TIDGET navigation solutions. The TIDGET Workstation software has several levels of validity of the computed navigation solution. In some cases, the processing did not track enough satellites (3 minimum) to compute a 2-dimensional navigation solution, in other cases the Figure of Merit from the navigation solution failed the validity check. Table 1 shows the percentage of navigation solutions that the system did recognise as valid.

For the buoys that were in a "normal" environment (i.e. either were not being jammed or subject to interference), better than 90% of snapshots processed computed a valid result.

Buoy ID	Number of nav solutions attempted	Number of valid navigation solutions	% valid
A	152 (High RFI)	129	85%
B	415	407	98%
C	267	263	98%
D	430	392	91%
E	17 (interfering channels)	2	12%
F	17 (interfering channels)	16	94%
G	Not tracked		
H	148	144	97%
I	258	258	100%

Table 1 Navigation reliability

Navigation solution accuracy

Overview

Figure 8 is an overall plot of the post-processed data set using Differential Corrections generated by the static GPS reference workstation sited on Andros Island.

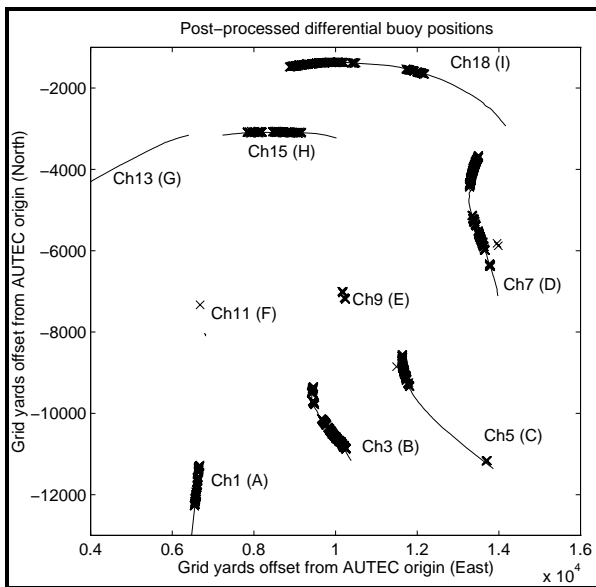


Figure 8 Buoy positions over trial period

With the exception of two outliers on Buoy D, and one outlier on Buoy C, the data matches the Range data well. Due to the mutual interference between Buoys E & F (both set to RF channel 11), the range Sonobuoy Tracking System was only able to derive a position for Buoy F for a short period of time, and not at all for buoy E. Buoy A was not tracked by the STS for long periods of

time, and eventually failed.

The drift of the buoys with time demonstrated two distinct motions. The most Southerly and Easterly buoys drifted in a North-NorthWesterly direction, while the 3 most Northerly buoys drifted from East to West.

In the absence of position updates on all buoys, the tactical system will normally assume a homogeneous drift of the whole buoy pattern-it is obvious that in this case this could have led to some substantial errors in estimated buoy position.

Description of Analysis

The system specification for the AUTEC range Sonobuoy Tracking System (25 yards 68% probable) is very similar to the TIDGET sonobuoy system accuracy (20 meters 1dRMS). As a result there was always likely to be some difficulty in demonstrating absolute accuracy of the TIDGET system during this trial. In the event, the Sonobuoy Tracking System proved to have some problems of its own (later confirmed by independent tests by AUTEC), although these may have been exacerbated by the trial being carried out right at the sea-state limit (greater than 4 feet wave height) of the STS system.

In addition to some clear indications of STS position error (see figure 10), there appeared to be a bias in position as well. No definite explanation has been reached for this, but due to the nature of the GPS navigation process it is unlikely to be due to the GPS. In any case it is within the spec of the STS system.

Buoy		Mean N error (m)	Mean E error (m)	1-d RMS (m)
A	(high RF interference)	21	16	22
B		-14	8	13
C		-18	1	16
C	(one outlier removed)	-18	1	12
D		-27	-2	56
D	(two outliers removed)	-24	-4	23
E	No STS data			
F	No STS data			
H		-18	3	15
I		-18	13	10

Table 2 GPS position comparison with range data

Table 2 shows a summary of the GPS position data as compared to the range STS data, both in Northing and Easting, and also as a 1-dRMS figure (computed after removal of the mean bias term).

The TIDGET position computed by the Workstation is an unfiltered navigation computation computed individually on each discrete snapshot. Further improvement of the TIDGET position accuracy should be achievable by filtering the position data.

Detailed plots of results

Figure 9 shows an enlarged XY plot for the buoy in position B. The smooth line shows the data from the range STS system, the crosses show time-matched STS positions to the TIDGET positions.

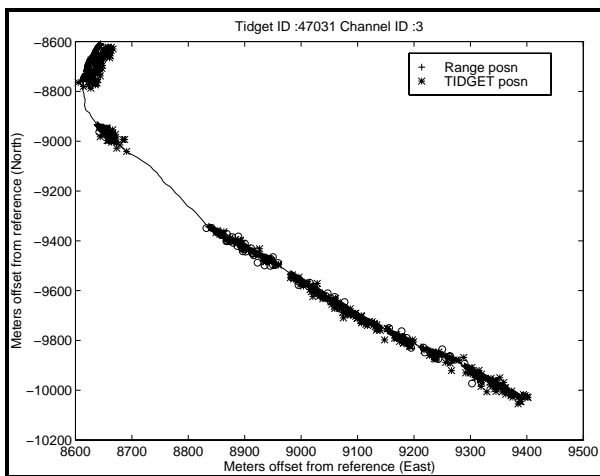


Figure 9 Buoy B XY Plot

The TIDGET position points have been flagged as good quality (asterisk) or poor quality (circle) based on the magnitude of the workstation-computed RMS error figure.

Figure 10 is a zoomed plot showing some suspicious STS position movement, with the STS position stepping out and back in as straight line motion. This was later confirmed by the range as being an STS system error.

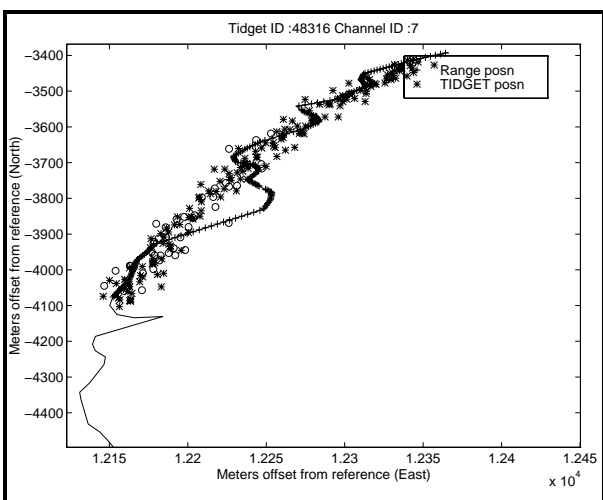


Figure 10 Buoy D XY plot (zoom)

P-code differential GPS

One of the aims of the system was to permit fully autonomous operation while providing buoy positions to better than SPS accuracy. Operational requirements mean this would have to be achieved without the use of differential GPS corrections from an external source.

The proposed means of achieving an in-aircraft differential-GPS solutions was to use the aircraft P-code receiver to provide an instantaneous PPS position fix, which would be combined with the TIDGET workstation C/A code reference receiver pseudo-range output to create pseudo-range corrections for use in a differential navigation solution.

This approach is not expected to provide pseudo-range corrections as accurate as those generated with a conventional static site due to a combination of the P-code PPS position accuracy and aircraft motion dynamics (the aircraft receiver P-code position computation is not time synchronous with the C/A code computation, and hence must be interpolated. However the TIDGET sensor itself has pseudo-range measurement noise in the order of 5-10 meters in any case, so the effect of the expected errors in the P-code differential corrections on the resultant TIDGET position solution is unlikely to be large.

Due to the relatively short lead-time to prepare for the AUTECH trial, the integration of the P-code into the system could not be accomplished. However, as part of the post-mission analysis the recorded P-code positions from the aircraft receiver were played back, along with the recorded TIDGET data set to recompute the buoy positions to confirm the validity of this approach.

The analysis confirmed the validity of the technique (no significant change in the 1-dRMS figures), although the experiment did identify an apparent bias (less than 10 meters) in the positions. This may be simply due to a slight mislocation of the static reference site on Andros Island. A static trial of the system under more controlled conditions should help to isolate this effect.

Conclusions

The trial was a definite success, meeting all the major objectives. The GPS positioning was demonstrated to work in relatively high sea-states, and to meet the near-instantaneous TTF requirement.

It is believed that this is both the first demonstration of fully-functioning GPS sonobuoys, and the first system to demonstrate its performance in other than ideal sea-state conditions.

The analysis of the tactical improvements achievable to a Maritime Patrol Aircraft using GPS located buoys is subject to a separate study by the RAF Air Warfare Centre.

The future

Further development of the TIDGET sensor has reduced both its size and power consumption from the units demonstrated here. Commercial TIDGET units are presently in use in vehicle tracking systems and radiosonde (weather-balloon) systems.

The TIDGET workstation software has been upgraded using the experience gained during this trial, and is presently commercially available in a stand-alone 4-channel, IBM-PC implementation. A VME format 2-card cardset with 8-channel functionality is likely to be available in the near future, with enhanced ruggedisation.

Acknowledgements

The authors would like to thank all those who contributed to the success of the development programme and the field trials.

These include the trials support staff of DRA Farnborough, staff at Ultra Electronics who integrated the TIDGET into the sonobuoys and developed the buoy telemetry, the RAF Air Warfare Centre for their provision of the trials slot at AUTEK and trials coordination, the Nimrod Software Team at RAF Kinloss for their support during the integration to the tactical system, the crew of the RAF Nimrod, and the support team at AUTEK.

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