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The U. S. Army Corps of Engineers has been developing a GPS carrier phase based positioning system for hydrographic surveying and dredging since 1988. This system provides real-time three dimensional positions with horizontal and vertical accuracies better than one decimeter over ranges up to 20 kilometers from a single reference station without static initialization. The project has passed from concept development through feasibility studies, system analysis, resolution of carrier ambiguities on-the-fly (OTF), to final system integration which is nearing completion. The real-time testing of the system began in March of 1993. This testing was performed under varying operating conditions to evaluate the limits of OTF ambiguity resolution for precisely positioning moving platforms. This paper will summarize the results of those tests. Early real-time tests performed have shown 1-3 centimeters in all three dimensions. The final design of the real-time system and its integration to hydrographic survey platforms will also be discussed.

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Results of Real-Time Testing of GPS Carrier Phase Ambiguity Resolution On-The-Fly

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BIOGRAPHIES

Ms. Sally L. Frodge researches and develops applications of GPS and DGPS for implementation within the U.S. Army Corps of Engineers (USACE). Currently she is GPS projects coordinator at the Topographic Engineering Center (TEC) and has been the Principal Investigator for the real-time on-the-fly (OTF) decimeter system development.

Mr. Shannon is an Civil Engineer at TEC who develops hydrographic applications, policy and procedure for USACE. He has been instrumental in the interface of the OTF system to hydrographic applications and headed the recent testing.

Dr. Benjamin W. Remondi has worked with the National Geodetic Survey (NGS) of the NOAA since 1982 specializing in the use of GPS signals for position determination. In 1973, he left NASA and joined NOAA in support of the GOES and TIROS weather satellite programs. Dr. Remondi has been fundamental to the development of the OTF technology as well as other advances within the field.

Dr. Lapucha is a Senior Geodesist at John E. Chance, Inc. (JECA). He holds a M.S. and Ph.D. in Survey Engineering from the Warsaw Technical University, Poland. He also obtained an M.S. in Surveying Engineering in 1990 from the University of Calgary, Canada. He is specialized in GPS navigation and GPS/INS integration.

Mr. Richard Barker is currently Manager of the Special Projects Group of JECA. He has been with JECA for 15 years in the area of design and integration of navigation and positioning systems. He is a graduate of the California State Polytechnic University, Pomona, California. Mr. Barker obtained his B.S. in Engineering in 1974.

ABSTRACT

The U. S. Army Corps of Engineers has been developing a GPS carrier phase based positioning system for hydrographic surveying and dredging since 1988. This system provides real-time three dimensional positions with horizontal and vertical accuracies better than one decimeter over ranges up to 20 kilometers from a single reference station without static initialization. The project has passed from concept development through feasibility studies, system analysis, resolution of carrier ambiguities on-the-fly (OTF), to final system integration which is nearing completion. The real-time testing of the system began in March of 1993. This testing was performed under varying operating conditions to evaluate the limits of OTF ambiguity resolution for precisely positioning moving platforms. This paper will summarize the results of those tests. Early real-time tests performed have shown 1-3 centimeters in all three dimensions. The final design of the real-time system and its integration to hydrographic survey platforms will also be discussed.

BACKGROUND

The development of the On-The-Fly (OTF) prototype system was initiated by the U.S. Army Topographic Engineering Center (TEC) in 1988 and funded by the Dredging Research Program. It has progressed to near completion and the first public demonstrations of the OTF system will be held in October of 1993. Final systems integration, testing and evaluation of the OTF system capable of real-time automated operation began in March 1993 and will be completed by the end of September.

The project progressed in three primary phases. The first phase completed the background research and testing necessary to determine the feasibility of concept (Goad 1989; Wells and Kleusberg, 1989; DeLoach and Remondi, 1991). The research done during this period indicated that the project could meet its stated objectives. It was clearly understood that an efficient and robust approach to resolving double difference integer ambiguities on-the-fly was required. This was considered the primary obstacle and meeting this challenge was the focus of phase two. The early period of phase two focused on the critical questions that needed to be addressed before a working prototype system could be designed and built (Enge and Pflieger, 1990; Geier, Loomis and Kleusberg, 1990; Leick and Liu, 1991; DeLoach and Remondi, 1992). As mentioned, the pivotal element for the success of the system was a practical solution to resolving integer ambiguities *on-the-fly*. Several of the researchers that were working in this area were contacted by TEC (DeLoach, Frodge, and Remondi, 1993), and in early 1990, Dr. Benjamin Remondi of the National Oceanic and Atmospheric Administration / National Geodetic Survey (NOAA/NGS) officially joined the research team. Extensive field tests were run during this phase and their analyses and results have been presented in previously published papers (DeLoach and Remondi, 1991; Remondi 1991; Remondi 1992a; Remondi 1992b; Burgess and Frodge, 1992; DeLoach, Frodge, and Remondi, 1993).

Another primary goal accomplished in phase two was the evaluation and selection of the equipment (DeLoach, Frodge, and Remondi, 1993). The decision was made to build the real-time prototype on a Disk Operating System (DOS) platform using Intel chip based 386/486 Personal Computers (PCs). After extensive data analysis, the GPS receiver type selected was the Trimble 4000 SSE, which is capable of providing full wavelength L2 carrier phase data in the presence of Anti-Spoofing (AS). The data for the project during the research portion of phase two was collected using Geodesist P Trimble SST receivers, which have L2 squaring capabilities under AS and full wavelength capability when AS is not on. Both L2 squared and full wavelength L2 were studied. The processing of full wavelength data showed a tremendous (possibly 8 fold) advantage. An additional advantage of the Trimble 4000 SSE receivers is the low noise C/A code measurements (roughly 0.25 meter), which has proven to be important to the success of the real-time version of the OTF software.

Field testing in phase two was extensive. These experiments and their results are well documented in several other papers (DeLoach and Remondi, 1991; Remondi 1992a; Remondi 1992b, Burgess and Frodge 1992; DeLoach, Frodge and Remondi, 1993).

All test results were post-processed. Several key questions were answered via the analysis of these data sets that indicated the project could successfully meet its stated objectives. The ground work had been laid for phase three to begin. Development of reliable statistical acceptance criteria was a major advancement towards the goal of a real-time system so that the OTF software could determine if the correct solution had been obtained (Remondi 1992a; Remondi 1992b; DeLoach, Frodge and Remondi, 1993).

It was found that: most of the data collected for baselines under 20 km were successfully initialized using the OTF software; kinematic GPS delivered accurate positioning and two independent systems yielded positioning agreement to 0.5 decimeter; over 90% of the data could be recovered in processing (at that time); the comparison of GPS and OTF GPS indicated that GPS was a reliable system and that the OTF GPS was on its way to becoming an operational reality; the OTF software was operable up to 20 km and particularly robust under 10 km; the initialization time for the OTF software could be brought down to less than two minutes constraining the ellipsoidal height of the vessel's remote antenna; the OTF software could resolve the correct integers (post-processed); the mean ellipsoidal height of the vessel's GPS antenna phase center could be calibrated to a few centimeters even in rough seas, nearly reducing the OTF initialization problem to a horizontal initialization problem; and, that real operational conditions could be handled (DeLoach and Remondi, 1991; Remondi 1992a; Remondi 1992b; Burgess and Frodge 1992; DeLoach, Frodge and Remondi, 1993). In addition to the technical findings, the comparison positioning systems selected (Geodimeter™, precise photogrammetric methods, and the Krupps-Atlas Polarfix™) inspired user confidence for the OTF system within the potential users within the U.S. Army Corps of Engineers.

The goal of phase three was to have a working prototype available for demonstration by October, 1993. A contract was signed with John E. Chance Associates (JECA) to achieve an operational, real-time prototype system from the current post-processing research and development capability. A week long meeting was held between representatives of TEC, JECA and with Dr. Remondi to determine the design of the prototype system (See Figure 1).

A working version of OTF post-processing software had been developed during phase two and was being used to analyze the data. The third generation of this software was completed by October 1992 and the modification of this version eventually became the real-time OTF software prototype. The movement of the post-processing versions onto a real-time platform and interfacing the hardware components into a working prototype was a significant challenge.

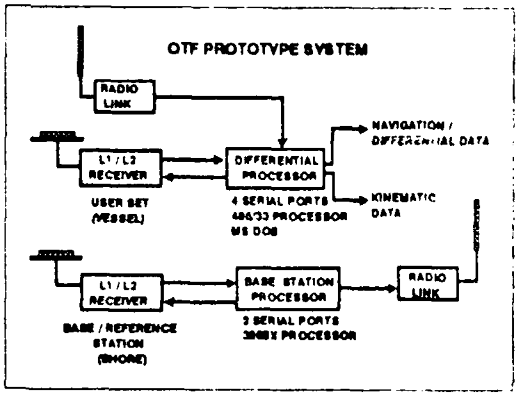

Figure 1. Block Diagram of the OTF Prototype System

Static baseline testing of the initial prototype system began in March of 1993 at the JECA facility in Lafayette, Louisiana. Several iterations of this system were accomplished and have been tested and improved since the spring. Phase three is basically completed and the final prototype system will be officially demonstrated in October, 1993. Although the prototype has been developed and built utilizing 486 computers and Trimble SSE receivers, it is hoped that in the near future other platforms and receiver types will be interfaced to use the OTF software.

DESCRIPTION OF THE OTF SYSTEM

The real-time OTF prototype delivers high precision kinematic positioning accurate to less than 5 cm at the antenna phase center, while simultaneously providing a separate output for meter level DGPS for navigation purposes. The system performs on-the-fly carrier phase ambiguity resolution. The *'OTF mode'* high precision positioning is available from the system once those integer ambiguities are resolved. To remain in this OTF mode requires both reference station data and a maintenance of lock on at least four satellites. If that number drops to below four, the ambiguities will again be resolved after the system reacquires lock on a sufficient number of satellites. Note that the system is still capable of meter level navigation even if loss of lock occurs and will provide this function for a limited time even without data from the reference station. L1/L2 carrier phase and C/A code ranges are used for ambiguity resolution; L2 codeless code ranges and P code ranges may also be used, of course. After ambiguities are resolved, either L1 carrier ranges or the ionospherically free combination of L1 and L2 carrier ranges can be used for kinematic positioning. The system has been designed not to rely on the continuity of L2 carrier phase. Currently, once ambiguities are resolved, the real-time system uses only the L1 carrier ranges for positioning. The meter level Differential Global Positioning System (DGPS) process uses primarily C/A code and L1 carrier ranges.

The current prototype has been developed on the premise that all required raw GPS observations, i.e. the GPS time tag, L1/L2 carrier phase, and L1 code, are transmitted from the reference station and the actual computations necessary for kinematic OTF and code DGPS take place at the remote/user station. The kinematic OTF process requires time-matched reference and remote station data. In the code differential process, extrapolated reference station differential corrections are applied to the current remote station observations, as is done in standard DGPS systems. The difference is, however, that these corrections with their rates are generated at the remote site from the raw data that was received from the reference station data.

The system can be interfaced with any other system requiring this level of accuracy in positioning using an interface string (See Appendix 1). The system works out to 20 km in real-time and is reliable and easy to use.

COMPONENTS OF THE OTF SYSTEM

The OTF system uses off-the-shelf equipment and customized software. Minimum operator attention is required and quality control procedures are built-in so that the high performance and reliability of the system is maintained. The system consists of setups at the reference and remote stations and a data link as shown schematically in Figure 1. Dual frequency

(L1/L2) GPS receivers are required at both the reference and remote stations. Shipping the raw data from the reference station allows a single 386 SX PC to carry out the reference station functions. These functions include setting the GPS receiver to output the required data, translating that data to the desired format and transferring the formatted data to the data link for transmission. Additionally, the reference station package is capable of recording data if the operator requests it. In the final prototype system, the hardware and computing power required by the original design was decreased: not only did the cost to build this system decrease but also this reflects an efficiency in the design and software coding.

The system requires a data link capable of a minimum of 4800 baud. The system has been tested using 9600 Baud Dataradio UHF sets (460 MHz) that can operate at line-of-sight distances up to 25 km, depending upon antenna height and power used. Tests have also been run using 1 watt spread spectrum units. Both Arlan 130s and Trimble TRIMTALK units have been used successfully with the real-time system. These spread spectrum sets have the advantage of not requiring a Federal Communication Commission (FCC) license, but provide a more limited range of 10 km (line-of-sight). VHF sets are on order and testing the performance of different radio systems will occur throughout the next year.

The remote/user station uses one 486 DX/33 PC. There the reference and remote station data are combined to accurately determine the remote station position. The remote station software, in its typical mode of operation, provides navigation and OTF kinematic output at a 1 Hz rate. OTF ambiguity resolution computational time is usually about 1 second, after an OTF initialization interval of typically 30 seconds.

TESTING THE SYSTEM

Four primary goals were targeted for the testing of the real-time OTF system: to determine how quickly the correct integer ambiguity for each satellite can be established; to determine the accuracy of the real-time 3D position measurement; to verify the repeatability of the real-time position even after reinitializing the satellite integers; and, to verify that the system can determine when it is unable to output the correct kinematic position.

To meet these objectives, the testing was broken into stages that progressed from static baseline tests to land mobile tests and, finally, to tests in an operational environment aboard a survey vessel. In the static tests, the position determined in real-time OTF mode was compared to the known antenna position. In the mobile tests, a survey truck was driven to existing control points where the real-time position was compared to known surveyed position. The truck would revisit the points repeatedly with the system, while operators put the system through various tests, e.g. instructing the system to recompute the satellite integers.

The real-time system was configured the same way for all of the tests, whether static, mobile or in the operational marine environment. The setup for the OTF software was: initialization time set to a count of 30 one second epochs; cylindrical search volume of 1.5 m horizontal and 2.0 m vertical; L1/L2 noise set to 50 mm. The receiver was set to track L1 C/A code and L2 P code -- although only one of these is used in the OTF initialization at this time. At both the reference and remote sites, survey grade GPS antennas with ground planes were used. Testing in L2 cross correlation mode was also done with no obvious difference in accuracy results, notwithstanding the lower signal to noise values.

Experience has determined that the setup values listed above allow for robust ambiguity resolution out to 20 km over the full variation of GPS visibility. During optimal GPS visibility conditions, initialization can be achieved in just one second (i.e. two epochs) at short range. Actually, this is equivalent to an instantaneous initialization, however the system is currently configured to require at least two epochs. Using the above values, the system ran successfully with little or no operator intervention.

STATIC BASELINE TESTS

Static testing of the real-time version of the OTF software started in April of 1993 at JECA. Most of the static tests were performed at the JECA facility over a 140 m baseline where the real-time system was running continuously with the 3D real-time position output compared with the known location of the antenna. The antenna positions were previously established using static GPS survey methods. The point on the main JECA office was used as survey control for both the static and mobile tests. The reference station was comprised of a dedicated GPS receiver, laptop and radio link and was setup in a closet and left running unattended.

The results from the static test shown in Table I are typical of what was seen from many other tests run over the same baseline. The statistics shown are calculated using a typical 24 hour period with the system running through the full GPS constellation over that time. These statistics changed little from day to day using the OTF parameters previously described.

MEASURED	STANDARD DEVIATION	MAXIMUM VARIANCE
LATITUDE	0.004 m	0.020 m
LONGITUDE	0.003 m	0.010 m
VERTICAL	0.010 m	0.050 m

Table 1 Summary of static test results.

Typically, positions were obtained 98% of the time (23.5 hrs/day). The remaining 2% of the time integers could not be established due to poor satellite constellations containing several low elevation satellites or not enough satellites.

REAL-TIME TESTING: MOBILE TESTS

The setup for the mobile tests was similar to that used for the static tests but with the user equipment installed in a survey truck or on board a survey vessel. Several truck tests, both short and long range, were conducted at the JECA facility. One set of truck tests was conducted at TEC, but due to the complete success of these tests, a previously scheduled additional set of tests was cancelled. The remainder of the mobile tests were conducted at the USACE Norfolk District aboard the S.V. *Adams*. Future tests and demonstrations of the OTF real-time system are scheduled. Those results will be incorporated into a similar paper and reported at the 20th Conference of the International Federation of Surveyors (FIG) to be held in 1994 in Melbourne, Australia. An additional test was run to compare meter level DGPS versus the real-time system.

The truck tests at JECA were conducted over both short and long ranges from the reference station to the mobile remote. A short range survey test course was established at a local athletic field parking lot, approximately 2.5 km from the JECA office in Lafayette, Louisiana. A single long range test point was set at 19.5 km from the main office. The points of the test course were established using static GPS. For these tests, the GPS antenna was mounted on a range pole which was mounted on the truck with a removable bracket to allow rapid occupation of survey points. The computer, GPS receiver and radio equipment were run using a 12 volt battery.

The tests were conducted by driving away from the JECA facility and, while en route, turning the real-time OTF system on, driving to the known survey points, occupying them, and then driving off to the next point. To occupy a point, the antenna would be swung into place and leveled up using a bubble level. At each mark, real time measurements were noted. Points were occupied as briefly as possible, typically less than one minute. Measurement data were also logged and post-processed to compare with the collected real-time data. The post-processed results were equivalent to the real-time results of the truck test. Driving speeds varied from 8 - 40 kilometers per hour (5 to 25 miles per hour). Both the short and long range tests produced similar results for accuracy and repeatability. Horizontal positions checked within 1-2 cm and the vertical positions were within 1-3 cm.

It should be noted that integers have been successfully established in real time out to 21 km but these tests were not designed to verify the accuracy of the position, since the control did not reach that far. The OTF software calculates the residuals that indicate if a good or bad position fix was obtained. These statistics correctly indicated good versus bad positions where control was available for verification. Although it cannot be verified with control, these statistics indicated that a good position fix was obtained at the 21 km distance.

The truck tests run at TEC were similar to those already described. The reference station was set up on the roof of the main TEC building. The test course of multiple control points was established using static GPS. The remote/user equipment was installed in a truck with an antenna rack on the roof. The testing occurred over a two day period with the survey points being occupied repeatedly and with reacquisition of the integers done between and during occupations. The range of the test was limited to less than 1 km because local obstructions and foliage limited the range of the data link. This data set was also post-processed and the results were the same.

REAL-TIME TESTING: OPERATIONAL ENVIRONMENT

Two series of tests have been conducted in an operational environment aboard a survey vessel. For both tests, the OTF reference station was installed atop the USACE Norfolk District office building and the remote/user equipment was installed on the Survey Vessel (S.V.) *Adams*. These two tests compared the real-time vertical positions obtained over time using the OTF system with tide gage readings to determine vertical accuracy relative to tidal movement of the vessel. Other goals were to determine the operational range of the radio link and the ability to acquire integers at the range limit (i.e. 20 km) and to check the OTF interface to the navigation system.

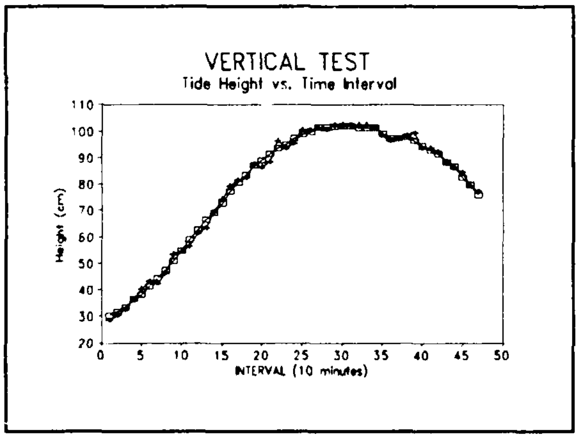

Figure 2 Vertical test results.
NOS Tide Gage (□); GPS a (+).

The first test that was performed was the radio range and integer initialization test. The radios that were used for this test were JECA's UHF 460 MHz two watt units running at 9600 baud (modem internal to radio). The antenna on the monitor station was a broadband yagi pointing down the waterway towards the *Adams*. On the *Adams* was an omnidirectional antenna forward of the main mast. The maximum range obtained was 18.6 km. The maximum range is defined as the usable distance at which the radio link lost data for more than 5 seconds. There was no problem initializing integers at 18.6 km.

The most important test was the vertical accuracy check. The *Adams* was tied to the dock for a full tidal swing of 8 hours. OTF positional data were logged on disk and also recorded with the tide gage data, measuring to a point on the *Adams*. Readings were also made on a level rod (Philadelphia). The distance between the Adams and the reference station was 290 m. The results are shown in Table 2.

The OTF interface to the navigation system test was performed at the same time as the radio link range test. The OTF system interfaced to the navigation system with no problems. There was some data on the two output strings which were not in the correct order but that did not prevent correct operation of the navigation system. This was corrected for the second trip.

The second boat test again took place at Norfolk, Virginia, in late August. The OTF reference station was installed in a TEC survey truck which was then driven to one of the Chesapeake Bay Bridge Tunnel islands. A survey point had been established on that island earlier using static GPS. The user equipment was again installed on the S.V. *Adams*. The purpose of the testing was the same as the first test: check long term vertical accuracy relative to tidal movement of the vessel, determine the operational range of the radio links and, finally, check the OTF interface to the navigation system. The distance between the *Adams* and the reference station was 1900 m.

COMPARED	STANDARD DEVIATION (290 m)	STANDARD DEVIATION (1900 m)
GPS vs LEVEL	1.9 cm (0.061 ft)	1.5 cm (0.049 ft)
GPS vs GAGE	1.4 cm (0.045 ft)	1.6 cm (0.051 ft)
LEVEL vs GAGE	1.3 cm (0.042 ft)	0.9 cm (0.029 ft)

Table 2 Results from the vertical comparison tests.

Again, the first test that was performed was the radio range test. The radios that were used for this test were spread spectrum (920 MHz 1 watt). The antennas on the monitor and user sets were omnidirectional. The maximum range obtained was 8.1 km. There was no problem initializing integers at 8.1 km.

For the vertical accuracy check the *Adams* was anchored about 2 km from the monitor station, near a different tunnel island. Again a full tidal swing was monitored. OTF position data was logged on disk and also recorded with the tide gage data, measuring to a point on the *Adams* from a platform on the island.

The comparison between the two sets was better than the first test, perhaps because of fewer problems with passing boat wake as compared to the dock test.

DISCUSSION OF THE RESULTS OF TESTS: PROBLEMS FACED DEVELOPING THE SYSTEM

The design specifications for the development of the prototype dictated that only off-the-shelf equipment be used. This imposed some limitations on the design. Advances in GPS receiver technology certainly contributed to the success of this project. A considerable problem faced by this project was being able to do the integer search quickly enough to be able to use off-the-shelf PC class hardware. Currently the 486/33 laptops are adequate. Another problem faced by this project (and DGPS in general) is the current radio link equipment that is available and which can be licensed. Both the capability and licensing restrictions limit the extent to which this system can be tested and used. Currently, about 300 bytes per epoch are necessary to ship the L1/L2 data from the reference to the remote/user set. About 20 km is the current maximum range at which the system can operate, due to radio limitations. Because of the radio link restrictions, testing was limited to about 20 km. The real limit of the system has not been established. Dr. Remondi has stated that under good conditions, it should be possible to initialize the system out to 40 km with the current configurations. As mentioned, testing in the area of data links will continue throughout the next year.

In order to have a good starting point for the integer search, low noise L1 C/A code ranges (e.g. 0.25 m) are highly desirable to do the basic differential position computation; receivers that are able to provide this are becoming more common and, in fact, this has possibly become the de facto standard for OTF initialization. If a receiver can deliver low noise L2 code (when AS is on) and L1 carrier plus L2 squared carrier, then the system could operate with that receiver although considerable interface changes would be required and further testing would be necessary to verify performance. With this project, interfacing to the GPS receiver and getting it to provide the raw data needed to do the computations, in a way that was transparent to the user, took considerable time.

PERFORMANCE CAPABILITY, SUMMARY OF RESULTS

The experience we have with the OTF system over the last few months has convinced us that we can obtain centimeter level accuracy in real-time with current GPS receiver and computer hardware using the software developed for this project. In fact, in the testing that was done on the *Adams*, the problem was not in getting the OTF system to operate but to understand how to make the navigation system perform as we needed it to. The OTF system simply ran for hours with no operator intervention at all. If the residuals became too large (i.e. after the integers are fixed) the software would force reinitialization of integers. The tests have shown that real-time tide corrections using OTF are possible; this is very important for the dredging industry. Although this system is referred to as a 'prototype' and will be further developed, it has far exceeded the original design specifications and can be used today as a reliable working system for applications that require real-time centimeter horizontal positioning, for example, breakwater surveys. It is also a valuable engineering tool for those operations for which post-processed data will suffice. In reality, we have demonstrated that real time OTF is as easy to provide as DGPS within the current range limitations.

The OTF system is dependent on the GPS constellation for optimal operation, since low elevation satellites (less than 13°) reduce the ability to resolve integers, particularly for the longer baselines. Antenna location and the quality of the antenna type, will affect the quality of the results. The presence of multipath will increase the positional uncertainties, particularly in the vertical component.

DISCLAIMER

ACKNOWLEDGEMENTS

We would like to express our appreciation to those individuals who are and have been devoting a tremendous amount of energy in the development, testing, analyzing and designing of this new technology.

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APPENDIX 1

INTERFACE STRING
OTF OUTPUT DATA FORMAT / KINEMATIC & DIFFERENTIAL

General Information:
This output string format was developed for this project. It is a NMEA-like string, so that manufacturers can easily interface to it. An example string is:
$RTGGK,HHMMSS.SS,MMDDYY,DDMM.MMMMMM,N,DDDMM.MMMMMM,W,Q,UU,DD.D,EHT.XXX,M*HH<CRLF>

Where the fields are comma delineated and represent:

$RTGGK	**$RT** is in place of the **$GP** NMEA designator for GPS
GGK is NMEA-like for lat, lon, and kinematic	
HHMMSS.SS	UTC TIME of POSITION FIX (e.g. 102933.00)
MMDDYY	UTC DATE of FIX in month, day, year format (e.g. 052493)
DDMM.MMMMMM	Latitude of FIX in degrees and decimal minutes to 6 places (e.g. 3013.123456)
N	Latitude N or S (e.g. 3013.123456,N)
DDDMM.MMMMMM	Longitude of FIX in degrees and decimal minutes to 6 places (e.g. 09203.123456)
W	Longitude E or W (e.g. 09203.123456,W)
Q	GPS *Q*UALITY INDICATOR 0 : FIX not available or invalid (not used) 1 : Non-differential GPS FIX (not used) 2 : Differential FIX 3 : Kinematic FIX (e.g. 3)
UU	Number of SATELLITES IN SOLUTION (e.g. 07)
DD.D	DILUTION OF PRECISION (DOP) of FIX (e.g. 01.3)
EHT.XXX,M	ANTENNA ELLIPSOIDAL HEIGHT *(not MSL)* in meters (**M**)
***HH**	CHECKSUM (e.g. *FB)
<CRLF>	CARRIAGE RETURN-LINE FEED CHARACTERS

The length will change depending on the ellipsoid height value. The maximum length of a NMEA string is 80 characters. Differences from NMEA GGA format:

1. Ellipsoidal height not antenna altitude (msl/geoid)
2. Geoidal separation not output
3. No age of correction or differential station number
4. Date of fix output