Relative Moving Baseline Software (RMBS)

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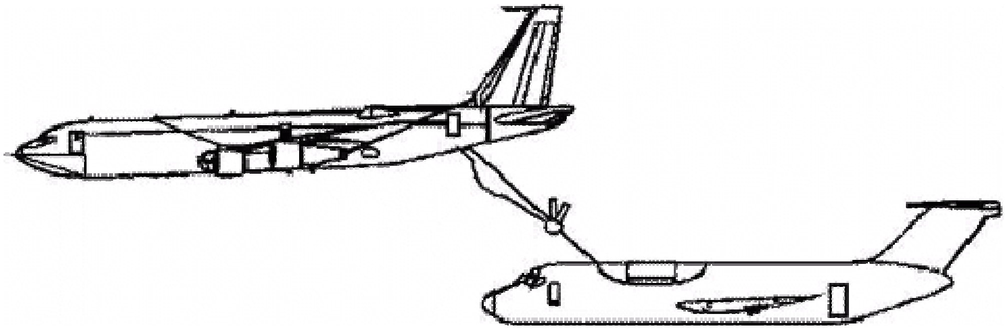
Introduction

To traditionally obtain sub-metre or sub-decimetre accuracy, a differential configuration using a fixed known base station was required in GPS processing. By combining carrier phase GPS receivers such as the NavSymm XR5M, accuracies of several centimetres can be achieved in both real-time and post-processing.



Such a method requires that the base station be fixed at the same location during a mission. For most applications, this is practical. However, a few applications require very high relative accuracies between two moving objects. Examples of such applications include: Offshore seismic, positioning of moving objects such as cranes on ships and precise air to air positioning. For some of these applications, the distance between the fixed base station, and remote units can be very lengthy.

This long baseline length can pose two difficulties. First, as the baseline length increases, it takes longer to resolve the carrier phase ambiguities that are required for precise carrier phase positioning. This results in a degradation in position accuracy. Second, for real-time applications, radio transmission over long baselines can be expensive, unreliable, or even impossible.

Presented here are software technologies that allow accurate relative positioning between two moving platforms. It is called the Relative Moving Baseline Software (RMBS). RMBS comes in two flavors. For post-processing, an upgrade is available to the existing GrafNav GPS post-processing package. For real-time, a graphical guidance package is available for laptop, notebook, and pen based computers. The figure below shows the real-time RMBS running on the Husky FC-486 computer.

How does it work?

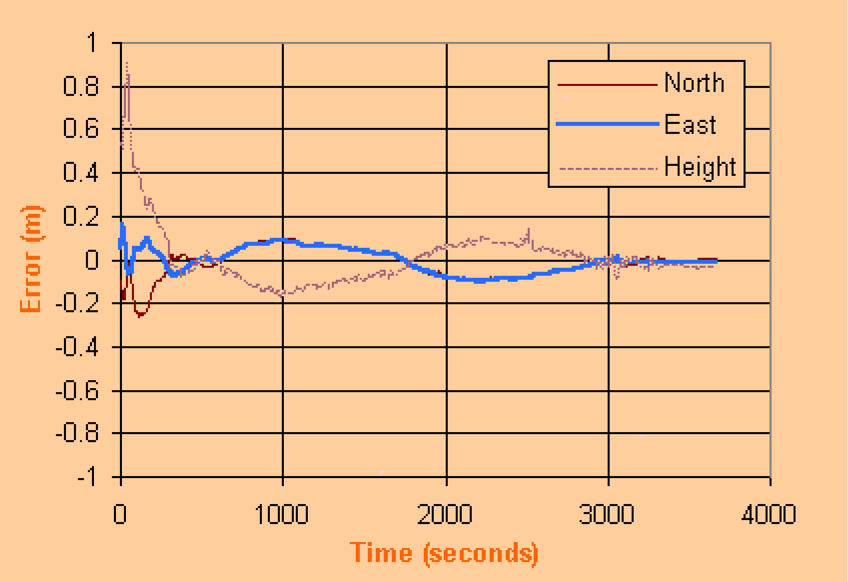
The relative moving base software package can be implemented in real-time and post-processing. Typical real-time applications involve precise navigation. An example would be navigating a sea vessel on a certain pre-defined line. Typical post-processing applications would involve determining the precise relative dynamics after the fact. Such an application would be determining the location of moving objects within a floating barge. The real-time system will be described here as its use is more common, and all of the components of the post-processing system are contained in the real-time system.

The RMBS uses real-time kinematic (RTK) techniques. By combining the pseudorange, carrier phase and doppler measurements from both base and remote, centimetre level results are obtained in real-time. Since the raw data is required, it must be transmitted from the base to the remote where it is used for further processing. The NavSymm XR5M receiver will transmit the base station data directly to the radio so that a computer is not required at the base. Since the real-time baselines are generally short, spread spectrum 900 MHz radio technology can be used for this transmission along with the conventional UHF, VHF bands.

For the RMBS implementation, the base position is not known and must be recomputed for every epoch. This position will be computed from the GPS satellites using a single point solution; however, the solution will have the effects of Selective Availability (S/A) and will be accurate from 30-100 metres. The relative position between base and remote will remain unaffected and be very accurate. Using the XR5PC, 4 Hz output can be attained.

What happens if carrier lock is lost?

One of the realities of carrier phase positioning is that carrier phase lock must be maintained on four or more satellites to maintain high accuracies. The RMBS system is no different. However, a loss of lock can sometimes occur, and it is important to understand how accuracy will be affected. For the epoch after the loss of lock, the accuracy will degrade to 1 - 5 metres. From this point onward, the accuracy will improve. The rate of improvement will depend on the number/PDOP of satellites, how many satellites lost lock, the amount of multi-path present, and the separation between master and remote. Typically, sub-metre accuracies will be achieved after less than 5 minutes. Accuracies of 5-20 cm will be achieved after 10-20 minutes. The graph below shows an example error plot after a loss of lock.



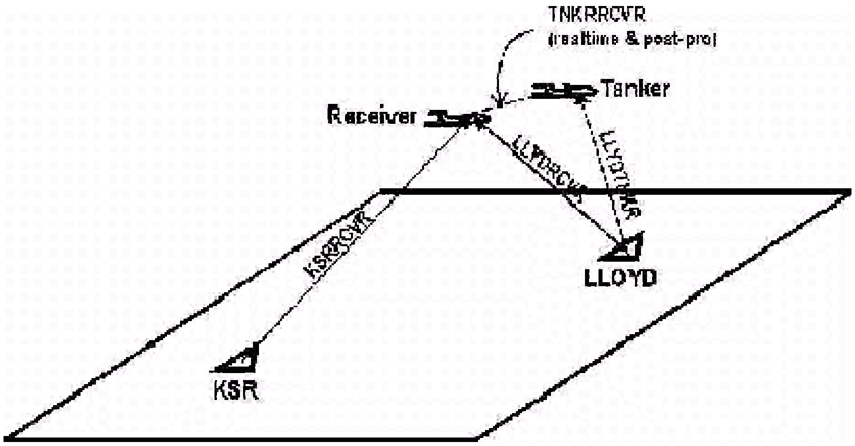
How can accuracies of better than 5cm be obtained?

Using a technique called Kinematic Ambiguity Resolution (KAR), accuracies of a few centimetres can be obtained with both the base and remote in motion. For a single frequency GPS receiver such as the XR5M, this process generally takes from 10 to 30 minutes. During this time, lock must be maintained on 5 or more satellites. This method is generally best suited for open applications such as marine, airborne with wide turns, and ground-based in treeless areas.

What happens if radio lock is lost?

With the current RMBS implementation, short radio losses will not affect the accuracy. There will be a short outage of precise position information, but lock will be maintained. For outages longer than 30-60 seconds, a complete loss of lock will be detected. Efforts are currently being made to lengthen this period to a few minutes.

Case Study: Air to Air Refueling Simulation

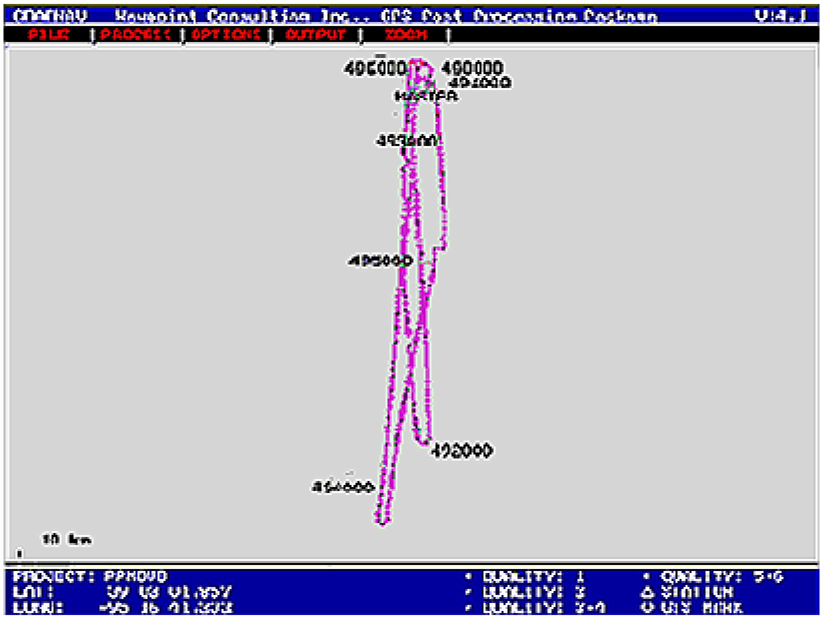


Although this technology can be used for many relative applications, the most difficult task is precise air-to-air refueling. The dynamics of the aircraft environment are very high and aircraft roll can often induce a loss of lock during turns.

An air to air refueling test was conducted in conjunction with three companies: Kohlman Systems Research (Lawrence, Kansas), Waypoint Consulting Inc. (Calgary, Alberta), and NavSymm Positioning (San Jose, California). Kohlman Systems Research was the principal contractor, and the test was conducted in Lawrence, Kansas.

This real-time RMBS system is currently installed on a KC-10A Tanker and a C-141B to be refueled. To simulate the actual tanker and receiver aircraft and test the system before being installed in the large aircraft, two Cessna single engine aircraft were used. This was a complete real-time test implementing FreeWave 900 MHz spread spectrum radio/modems.

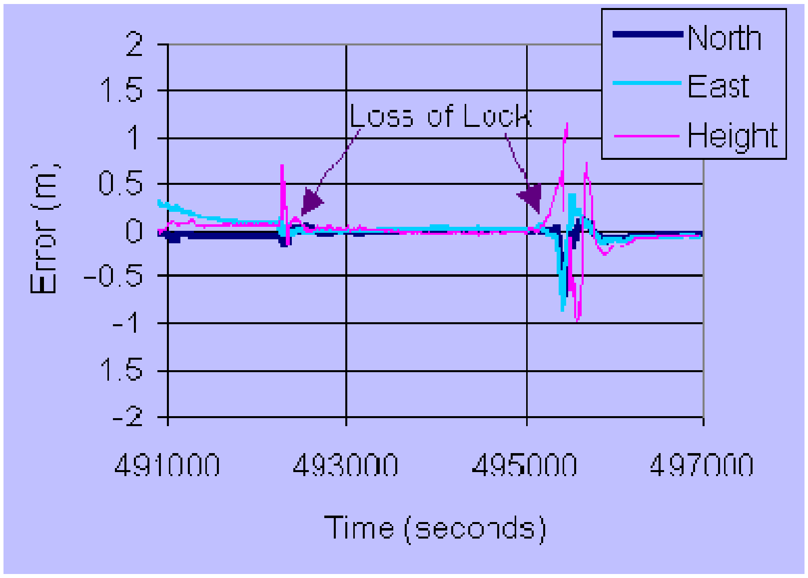
The image above shows the airborne configuration with two ground stations. Only the airborne stations were engaged in real-time testing. NavSymm XR5PCs were used in the air and NavSymm XR5Ms were used on the ground. To assess the relative airborne accuracy computed in real-time, the raw GPS data was collected at the tanker, receiver and the two base stations. By combining all of this data, the relative vector between the aircraft could be reconstructed in post-processing to accuracies of several centimetres, using the ground to aircraft, as well as, the aircraft to aircraft vectors.



The test began with both aircraft engaged in a 15 minute static initialization on the tarmac. After the initialization, both aircraft took off in succession. They flew two 40 km north-south flight lines and then landed. Another 15 minute static initialization was performed. During the flight, the aircraft were as close as 10 metres and as far apart as several kilometres.

For this test, a stationary initialization was performed. However, the receiver aircraft would have realistically approached from a long distance away where no radio contact was possible from the tanker. At some point, perhaps 5 to 20 km away, the radio would gain lock resulting in a kinematic initialization. Therefore during the test, it was important to simulate a loss of lock on all satellites. This would simulate a receiver aircraft approaching the tanker. This loss of lock was simulated by disconnecting the GPS antenna on the receiver during flight.

Results



The graph above shows the agreement between post-processing and real-time over the kinematic portion of the mission. The post-processing vector was carefully processed in forward and reverse directions to minimize errors. The accuracy of the post-processed solution is estimated to be less than 5 cm. Therefore, these differences can be primarily attributed to the real-time solution. For the most part, real-time accuracies were within a less than 10 centimetre range which is very impressive. Even more impressive, is the recovery from the first loss of lock. The solution converged to accuracies of less than 10 cm within a matter of minutes. The second loss of lock that was radio induced converged to less than 10 cm within 13 minutes which is still quite acceptable.

However, for most applications, the occurrence of a loss of lock will be very seldom, and an initial convergence period would be followed by continuous position information with centimetre level accuracies. This model is assuming real-time with no static initialization. With either sufficient static initialization or post-processing, centimetre level accuracies would appear from the beginning of the kinematic portion and onward with carrier lock maintained.

Conclusions

Whether the implementation is real-time or post-processing, relative accuracies for shipborne, airborne, or vehicle-borne applications can be improved with a nearby moving base station and RMBS. The RMBS system has been shown to deliver less than 10 centimetre accuracies very reliably. When combined with the XR5 series receiver and its excellent carrier phase tracking, a robust relative positioning system is evident.