The Future Development of Maritime DGNSS
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Background

The removal of Selective Availability (SA) from GPS at the beginning of May 2000 has prompted a review of the future role of Differential Global Navigation Satellite Systems (DGNSS) from maritime radiobeacons. Consideration of the future development of the service was already underway in Radio Technical Commission for Maritime Services (RTCM) Special Committee 104 and the Radionavigation Committee of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), but the early discontinuation of SA has given these discussions added impetus. This paper draws on the IALA work and will be developed into a policy paper as the plans become more settled. It incorporates ideas put forward by the United States Coast Guard (USCG) and other IALA Member administrations, as well as members of RTCM SC104, but should not be taken as approved policy of any of these bodies.

Baseline Statements

The cessation of SA has two primary effects:

1. The accuracy of the Global Positioning System (GPS) is improved for marine, terrestrial, aviation, and timing applications for individual, commercial, and government applications – in whatever country they are utilized. Expected accuracies are GPS with SA: 60-100 m (95%); GPS without SA: 15-25 m (95%); DGNSS: 1-10 m (95%). IMO Resolution A815(19) specifies an accuracy requirement of 10 m (95%) for navigation in restricted waters.

2. Unaugmented, as well as augmented, GNSS signals can now be used as a calibration source to improve the accuracy and performance of integrated non-satellite backup systems, such as Inertial Navigation Systems, Loran-C/Chayka etc. Integrated systems have the capability to ensure safe, reliable, and independent operations can continue whenever GNSS is lost because of man-made interference (intentional or unintentional), natural interference, system failure or government actions.

It is possible for GPS to give erroneous information for periods of up to a few hours without warning. The integrity warning requirement in IMO Resolution A860 (20) is defined as "the ability to provide users with warnings within a specified time (10 sec) when the system should not be used for navigation". The cessation of SA does not affect this integrity issue. Only receivers provided with RAIM (Receiver Autonomous Integrity Monitoring) will automatically detect a problem. RAIM uses an over-determined position solution and there may not always be enough satellites available to detect a problem or identify the faulty satellite.

GPS satellites that are experiencing a malfunction, are normally set unhealthy autonomously by the satellite or externally by the operating ground station to prevent their use for navigation purposes. DGNSS automatically ceases to provide corrections for a satellite that is set unhealthy, although in certain cases this can be manually overridden by the DGNSS operator. The DGNSS also detects anomalies in 'healthy' satellites and prevents their use in the navigation solution by flagging that satellite in the correction message. This takes place as soon as bad data is detected (within approximately 10 seconds). DGNSS receivers normally do not use uncorrected or unhealthy satellites, therefore integrity checking is inherent in all differential navigational solutions. Integrity warnings for the differential service itself will normally be sent within 10 seconds of a fault being detected (time to detect is also approximately 10 seconds).

Need for a Policy Review

Some users and manufacturers have questioned the continuing requirement for DGNSS following the removal of SA. Much of the investment by service providers in DGNSS systems has already taken place, but given that there are countries which have not yet started to implement systems and that there is a small, but significant cost involved in running existing systems, it is appropriate to review the need for DGNSS.

Analysis

The continuing need for DGNSS is very much application dependent. Although GPS without SA provides an accuracy of approximately 15-25 m (95%), there remains an IMO requirement for 10 m accuracy in the harbour entrance and approach phase of navigation, that can only currently be met by DGNSS. Leisure craft were well-served by the 60-100 m (95%) accuracy of raw GPS; the removal of SA has improved that accuracy even further, although not to the extent afforded by DGNSS. Aside from accuracy, the other main benefit of DGNSS is the enhanced integrity of the navigation solution. Commercial vessels negotiating restricted channels could easily justify DGNSS on grounds of integrity monitoring alone. Specialised positioning applications such as dredging and hydrographic survey and in particular buoy positioning by the lighthouse authorities themselves will continue to benefit from the improved accuracy and integrity afforded by DGNSS, whereas much of the fishing industry probably needs no improvement on GPS without SA. The emerging reliance on automatic positioning systems using ECDIS, automatic pilots and AIS will impose greater requirements on positioning accuracy and integrity, but these are not yet clearly defined.

It is important to note that the maximum error for GPS without SA is not known at present. A revised GPS signal specification is in the process of being developed by the United States.

It is anticipated that DGNSS will remain a core navigation service for maritime safety and efficiency for the next 10-15 years.

Future Development of DGNSS

The remaining error sources (clock, ephemeris, ionospheric and tropospheric) vary much more slowly than SA did. Consequently the rate at which corrections must be received is now much lower. Depending on the characteristics of the DGNSS user receiver this could result in a marked improvement in the effective availability of the service in areas of marginal coverage, because loss of signal for periods of several minutes will have little or no effect on accuracy. Integrity may now be the primary factor determining required DGNSS update rate.

The IALA Radionavigation Committee identified four possible routes for development:

1. Reduction of the data rate, providing better range because the energy would be concentrated in a narrower bandwidth.
2. Reduction of the frequency of correction messages allowing the increased provision of other standard messages (Type 3, 7 & 16). This could be combined with a change from Type 9 to Type 1 messages to shorten the time taken to obtain a full set of corrections.
3. Addition of messages containing phase corrections giving sub-metre accuracy.
4. Addition of messages containing meteorological or hydrographic data.

Another concept that could be considered is the broadcasting of ionospheric corrections derived from a wide-area model, rather than the values obtained at the broadcast site alone. This could lead to an integrated network of stations rather than stand alone broadcast sites, but it does introduce much greater reliance on communication links.
Such developments need to be considered in the context of changes to the message format under discussion in RTCM SC104. The current version of the format, V 2.2, is the one in use by most authorities. SC104 V 2.3 is likely to be published in the first quarter of 2001 and contains a change in the treatment of GLONASS ephemeris to eliminate an anomaly, a message to cope with antenna phase centre variations, Loran data communications, new versions of the phase correction messages (Types 18, 19, 20 & 21) for Real Time Kinematic (RTK) applications and a number of other clarifications.
Future version 3.0 is at an early stage and is likely to include improved datalink integrity using Cyclic Redundancy Checks and a more efficient message structure, allowing better exploitation of RTK messages. This will not be compatible with existing receivers. It could be introduced gradually by interleaving with the present format or embedding the old message structure in the new one, but neither of these options would deliver the full benefit of the new format. It is more likely that the new format will be introduced on different frequencies in particular application areas, requiring centimetre accuracy, meeting the requirements of A.860 for specialised applications such as docking.
The provision of additional frequencies for these stations might not present much of a problem in the Americas, Africa or Asia, where channel spacing can be reduced from 1 kHz to 500 Hz, but in Europe, where spacing is already 500 Hz and the band is fully utilised, it would be necessary to plan such a change in conjunction with the withdrawal of the remaining direction-finding beacons.

Receiver Developments

An IEC Working Group is nearing completion of the test specification for beacon DGNSS receivers (IEC draft Recommendation 61108-4). This group includes members of the IALA Radionavigation Committee and RTCM SC104, so that its work reflects developments in those groups. The main change to existing receiver designs is in the method of automatic station selection, which will be on the basis of proximity as well as signal strength. This is to avoid the selection of distant stations, whose skywave signal may fade in and out. This change requires an almanac approach and the DGNSS receiver must be provided with its location from the GNSS receiver. The removal of SA will almost certainly affect the future development of receivers, as the volume market has probably disappeared and new receivers are only likely to be developed for the more specialised, professional users.

Conclusions

1. The integrity requirement for navigation applications has not changed.

2. The accuracy advantage afforded by DGNSS (1-10 m) remains essential for meeting the IMO requirement for navigation in restricted waters.

3. The accuracy advantage of DGNSS remains significant for specialised positioning applications.

4. The discontinuation of SA removes the attraction of DGNSS for some groups of users, in particular some fishermen and leisure craft.

5. The relaxed requirement for data latency may improve the effective availability of the service in marginal areas and offers the potential to reuse part of the datalink capacity. This opens up many opportunities to improve the service by increasing coverage or by providing additional information.

6. The introduction of phase corrections could allow the service to meet the most stringent accuracy requirements in IMO Resolution A.860(20).