NAVIGATION SYSTEMS PANEL (NSP)

WORKING GROUP 1 MEETING

Canberra, 10th to 19th November 2003

Agenda Item 3): Future GBAS
b) Category II/III

Status of GBAS Development Activity in Japan

WORKING PAPER

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SUMMARY

Electronic Navigation Research Institute (ENRI) has been developing a prototype of CAT-II/III Ground-Based Augumentation System (GBAS) for Global Navigation Satellite System (GNSS). This paper introduces current ENRI development activity of GBAS in Japan.

1. Background

Electronic Navigation Research Institute (ENRI) in Japan has been developing and evaluating Ground Based Augmentation System (GBAS) includes VHF Data Broadcast (VDB) system. ENRI has made up the pre-prototype model for testing system concept and carried out flight trials for GBAS total system. This paper introduces the current status and directions of our developing activity concerning accuracy, availability and integrity of GBAS.

2. Information and Discussion

2.1 Accuracy and Availability

ENRI carried out flight trials for GBAS total system and already reported the GBAS positioning acuracy and availability at San Antonio GNSSP Working Group meeting. Its results showed all vertical NSE (μ+2σ) were within 0.8 meters at the final approach region, but the cumulative distribution of CAT-II/III VPL from 0 to 5.3 meters was about 97 %. We also carried out more 35 approach trials in November 2002 and total number of approach reached 123 trials. Final result was the vertical NSE (μ+2σ) was about 0.8 meters and the cumulative distribution of CAT-II/III VPL from 0 to 5.3 meters was about 96 %. In this flight experiment, we compared 2 types of aircraft receiver, one was the same type of grand reference receivers and other was deferent type. The result showed the error of deferent types was 20 % more than the error of same type. (refer to Appendix 1) Furthermore, it was observed that the σ_{pr_gnd} of reference stations had seasonal variations shown in Fig-1. The data in winter was larger than other seasons. It might be caused by changes of ground refraction conditions around reference GPS antennas. The 5-degree step average of these data was within the B4 designator and the deference of these data was less than

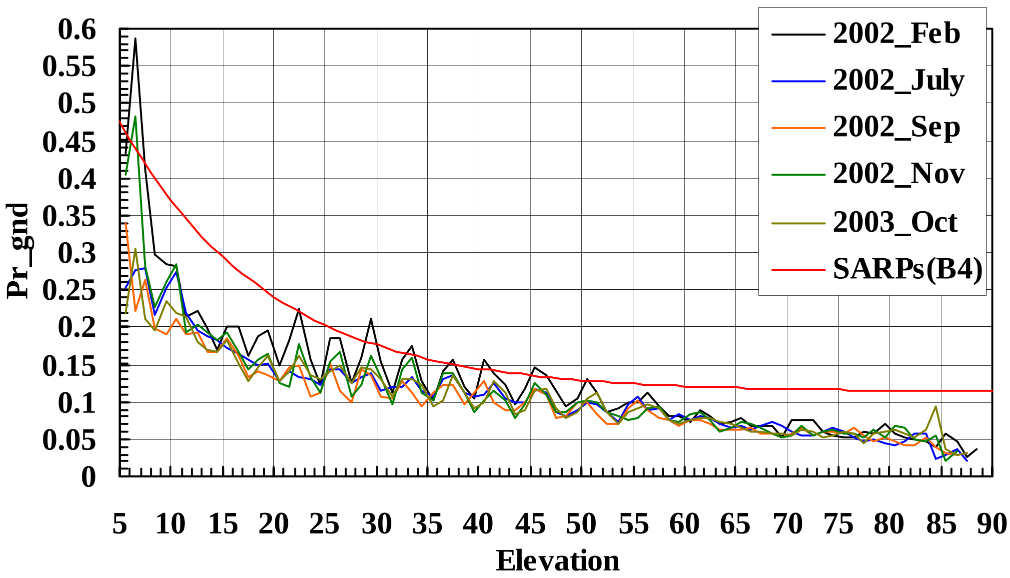

Fig.-1 seasonal variations of σ_{pr_gnd} (1 degree step) of reference stations at Sendai airport

1-degree step data.

ENRI is going to survey the compatibility of deferent receiver types and the impact of the σ_{pr_gnd} seasonal variations on the accuracy and availability of GBAS, and to carry out to flight checks on GBAS to improve its performance.

2.2 Integrity

(a) SQM receiver development

ENRI and Furuno Electric Co., Ltd. have been jointly developing a new SQM GPS/SBAS receiver with real-time correlation-curve monitoring capability. This is the first prototype of the GPS/SBAS receiver with SQM in Japan. This receiver has 16 channels including 3 SBAS dedicated channels for L1 C/A signal tracking and 2 SQM channels. It can output SQM data and the raw GPS/SBAS observation data such as accumulated carrier phase, pseudorange, carrier-to-noise ratio, Doppler-shift frequency, and time-tag. Each SQM channel has 127 correlation points for In-phase and Quadrature (I/Q) signals distributed evenly at 0.025575 chip step. The width of the correlation monitoring range is about 3.2 chips. It can be allocated at any part of 1023-chip width by user selection.
(refer to Appendix 2)

We're going to develop and evaluate the SQM function of this receiver using an arbitrary signal generator and vector generator in order to generate Evil Waveforms of ICAO thread models. We will also collect more GPS/SBAS data at more sites to distinguish Evil Waveforms from multipath signals and research to increase the reliability of the reference receivers. The correlater allocation design will be modified so that it meets user requirements and ICAO recommendations. Next version will be covered full 16 tracking channels at more than 2 Hz update rate.

(b) Ionospheric and tropospheric effect

It was observed at several time by GPS Earth Observation Network (GEONET) and analyzed by researcher of Kyoto-Nagoya university group that the phenomena of vertical ionospheric delay gradient over 10 mm/km appeared in last year at the whole area in Japan.(refer to Fig.-2) They were caused by the equatorial anomaly of the ionosphere. The maximum value was about 20 mm/km. GEONET is a Japan nationwide GPS observation network for crustal deformation monitoring, with about more than 1,000 observation sites. Its stations are settled in average spacing of 25km and it is established by Geographical Survey Institute of Japan.

The slant range ionospheric delay gradient over 85 mm/km caused by plasma babble phenomena was also observed at southern area in Japan by ionospheric researchers of Kyoto-Nagoya university and Communications Research Laboratory (CRL) group. The plasma babble scintillated violently and the variations of ionospheric delay was rapid and severe. Sometime it prevent to receive GPS signals.

There are reports that the positioning drift were more than 100 mm between 50 km distance point caused by passing Bomb Cyclone was observed in 1995. (refer to Journal of the Geodetic Society of Japan, volume 41, pp 379-408 and volume 42, pp 183-204) The rain spot was very local, the tropospheric delay gradient was estimated to be bigger than several mm/km. GBAS CAT-I SARPs does not include such a term.

ENRI GBAS research group started to survey the impact on GBAS of these ionospheric and tropospheric phenomena with ENRI SBAS research group and the researchers of others research fields.

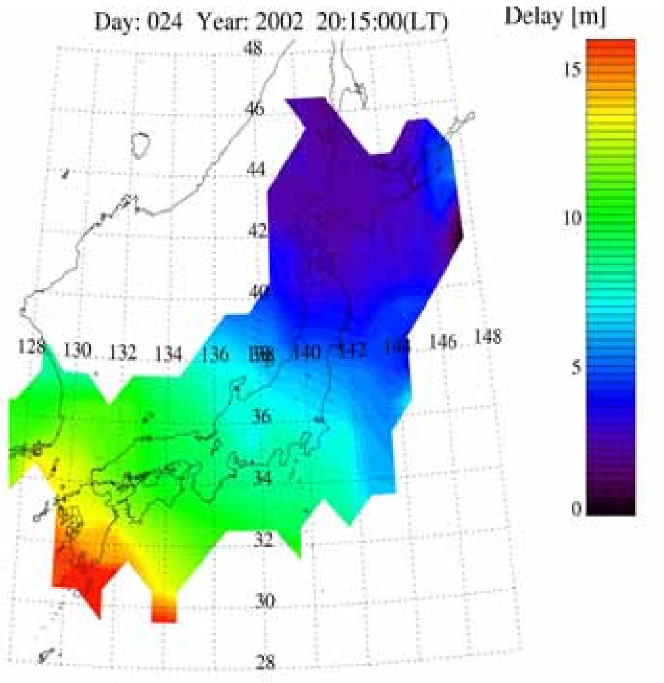

Fig.-2 Ionospheric storm observed by GEONET on January 24, 2002. (prepared by DR. Saito of Kyoto University)

(c) Position and Pseudorange Error distribution model

The researchers of Separation and Airspace Safety Panel (SASP) of ICAO adapt double-double exponential (DDE) distribution models for en-route lateral positioning error to discuss collision risk probability of 10^{-7}~10^{-10} without monitor system. DDE is expressed by equation-(1) and is composite of 2 types of double exponential (DE) distribution expressed by equation-(2). The first term of DDE means the distribution model of central area and it is sometime expressed by Gaussian distribution. The last term of DDE mean the distribution model of tail area and it dominate the probability of collision risk.

$$DDE(y) = (1-\alpha)\exp(-|y|/\lambda_{core}) / (2\lambda_{core}) + \alpha \exp(-|y|/\lambda_{tail}) / (2\lambda_{tail}) \qquad \text{eq.-(1)}$$

$$DE(y,\lambda) = \exp(-|y|/\lambda) / (2\lambda) \qquad \text{eq.-(2)}$$

The researchers of Obstacle Clearance Panel (OCP) of ICAO adapt Gaussian distribution models with monitor system for approach region to discuss collision risk. ILS and MLS have course deviation monitors and the monitors limit the collision risk exceeding boundary. Therefore, the position error distribution is not important to discuss the system collision risk. If it is possible to monitor the course deviation of GBAS, the ordinary concept neglecting the tail of the error distributions will be adapted. If it is impossible to monitor, the discussion of the distributions of GBAS positioning error has meaning to estimate the collision risk. It is necessary to bound the GBAS collision risk for operation.

ENRI has a plan to measure the GBAS positioning error using deference types of receiver and to analyze the cause of the long tail positioning error in field for a few years.

4. Conclusion

This paper introduces current status and directions of GBAS development activity in Japan. The threat on GBAS by Nature, e.g. ionosphere and troposphere activity, is complex and reduces the GBAS integrity. CAT-II/III GBAS might have a monitor to detect thease threats. However, It is beleaved that there are not enough data to develop CAT-II/III GBAS SARPs and Gidance Matirials.

Each state have to provide the necessary data to develop CAT-II/III GBAS SARPs and Gidance Matirials included local issues and WG has to share these data to discuss them.

5. Action

The meeting is invited to consider the ways of understanding the various factor on GBAS to prevent from satisfying the CAT-II/III requirement, and supports the activities of knowing impedimental factors of GBAS operations in future.