Research on Satellite Navigation

Japan’s H-IIA launch vehicle No. 7 blasted off from the Tanegashima Space Center carrying the Multi-functional Transport Satellite No. 1 (MTSAT-1R, nicknamed Himawari No. 6) at 6:25 p.m. (Japan Standard Time) on February 26, 2005, leaving behind a deafening roar and trail of blinding light. The launch vehicle had a normal flight and separated from the MTSAT-1R approximately 40 minutes after blast-off, at around 7:05. The operation to place the satellite in a stationary orbit also proceeded smoothly, and station acquisition was completed 10 days later, on March 8.

Research on the use of satellites at ENRI began 38 years ago, immediately after the establishment of the institute in 1967, with the creation of the Satellite Technology Division. We would like to express our respect for the foresight of those concerned at the time. Later, during a 9-year period from 1983 to 1991, ENRI developed basic technologies such as satellite positioning, ranging techniques, and satellite data communications, etc. through work on the large subject of “Developmental Research on Navigation Technologies” using the Engineering Test Satellite No. 5 (ETS-V). Based on this, ENRI expanded its work to research on satellite navigation augmentation systems (SBAS, GBAS), and research related to the ionosphere, which controls the accuracy and integrity of GPS and other satellite signals, as described in this issue.

In the following pages, recent research will be introduced by a researcher in this field.
The present aeronautical navigation methods are limited in various respects, including their coverage and accuracy. To overcome these limitations, the International Civil Aviation Organization (ICAO) decided to introduce a global navigation satellite system (GNSS) using GPS and other technologies. However, in order to use the existing GPS, it will be necessary to improve its integrity, positioning accuracy, and availability. The satellite-based augmentation system (SBAS) and ground-based augmentation system (GBAS) were conceived to improve these properties.

SBAS is a system which improves positioning accuracy, integrity, and availability by transmitting positioning correction information and integrity information by the wide area differential method (method in which error factors are differentiated in transmissions; effective in large areas) and ranging signals like those with GPS from a geostationary satellite. For this, Japan is creating a multi-purpose satellite augmentation system (MSAS) for transport satellite use.

GBAS is an augmentation method for use in CAT-I, II, and III precision approaches, which require higher accuracy and integrity. Positioning accuracy and integrity are improved by transmitting positioning correction information and integrity information by the local range differential method (method in which error factors are transmitted collectively as pseudorange error; effective in limited geographical areas) from the ground using VHF band radio waves, and is applied in the approach, landing, takeoff, and ground operation phases with all methods. Coverage is on the order of a radius of 20NM to 30NM.

In research on SBAS and GBAS, ENRI is conducting an analysis of error factors such as the effect of factors related to radio wave propagation, including the ionosphere, multipath, etc., and is carrying out research on methods of improving accuracy and creating integrity information, system performance, and other topics.

※CAT- I : Means operation with the decision height (DH) set to touchdown zone elevation + 200ft or more, in cases where the runway visual range (RVR) is 550m or more or ground visibility is 800m or more.
※CAT- II : Means operation with DH set to 100ft to less than 200ft, in cases where RVR is 350m or more.
※CAT- III : Means operation in the precision approach and landing phases with the auto pilot set to the basic mode, in cases where DH has not been decided, or where DH is less than 100ft and RVR is 200m or more.
Research on Effect of Ionospheric Disturbances on SBAS

The ionosphere is a layer of the atmosphere at a altitude from about 100 to several 1000 kilometers, where the atmosphere is separated into electrons and ions (forming a plasma condition). The speed of radio waves in the ionosphere is delayed depending on the ionospheric density. Therefore, users of satellite navigation system must correct for this ionospheric delay for in making position calculations.

In SBAS, the geographical distribution of ionospheric delay is estimated by monitor stations on the ground, and the amount of delay is transmitted to users. However, monitor stations are considered to sometimes miss detecting spatially small changes in the density of the ionosphere (called ionospheric disturbances).

As one such ionospheric disturbance, in the area around Japan, low ionospheric density regions called plasma bubbles form in some cases. Plasma bubbles generally occur generally in low magnetic-latitude areas. In order to conduct research on the effects of this phenomenon on SBAS, ENRI has installed a new receiver at Ishigaki island and collects and analyzes the observation data, in addition to data from GEONET (GPS Earth Observation Network), operated by Japan’s Geographical Survey Institute (GSI).

Research on Dual-Frequency SBAS

Improvement of the performance of the present GPS by addition of a private-sector channel (L5) is planned. Because the conventional SBAS is only a single-frequency system, it is easily affected by ionospheric activity, limiting its integrity and availability for use in the precision approach phase of aircraft landing. However, the influence of the ionosphere can be virtually eliminated by measuring ionospheric delay with 2 frequencies, making it possible to improve accuracy and availability when used in combination with SBAS correction and realize CAT-I precision approach with satisfactory availability. Realization of precision approach by dual-frequency SBAS is strongly desired, as this will greatly improve convenience and profitability for users of aircraft by improving the rate of service, etc. Use of dual-frequency SBAS will also improve robustness against obstructions and interference and thereby enhance safety.

Research topics at ENRI include a method of correction for ionospheric effects using the dual-frequency technique, method of creating integrity information, method of improving the ionospheric correction performance of single-frequency systems, and method of predicting the performance of dual-frequency systems.