Impact of multi-constellation satellite signal reception on performance of SBAS under adverse ionospheric conditions

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Multi-constellation satellite signal reception capability has provided an important tool for enhancing the performance of satellite based navigation system under conditions of intense ionospheric scintillations as experienced during equinoctial months of high sunspot number years at equatorial locations. The equatorial ionosphere is characterized by sharp latitudinal gradients of ionization for a major part of the day existing till about 22:00LT. Transionospheric satellite links operating near the crests of the Equatorial Ionization Anomaly (EIA) experience unusually large range errors and range error rates through such steep ionization gradients which may be particularly hazardous for reliable operation of high dynamic platforms like an aircraft. It has been observed through studies conducted earlier that the detrimental effects of the sharp latitudinal gradients of ionization occurring in the equatorial region may be limited if sufficient number of satellite links are available at high elevation angles in excess of 60°. As GPS-only constellation was not possible to address this issue, a multi-constellation GNSS receiver capable of tracking GPS, GLONASS, GALILEO and SBAS at L1 (1575.42MHz), L2 (1227.6MHz) and L5 (1176.45MHz) frequencies was operated at the Institute of Radio Physics and Electronics (IRPE), University of Calcutta (22.58°N 88.38°E geographic; magnetic dip: 32°N) since April 2013. It provides at its output elevation, azimuth, time (UTC), carrier-to-noise ratios (CNO) and amplitude scintillation index S_4 at a sampling interval of 1minute. Availability of multi-constellation satellites were studied from Calcutta during March 2014 particularly under adverse ionospheric conditions. Significantly larger number of transionospheric satellite links, 18, were available instantaneously in comparison to 12 normally observed under GPS-only scenario thereby providing scope for application of spatial diversity techniques to improve navigation position solutions during ionospheric scintillations. On March 1, 2014, intense amplitude scintillations (S4>0.6) and associated fluctuations in carrier-to-noise ratios (CNO) were noted on 6 GPS and 8 GLONASS links above an elevation mask of 15° during 13:00-19:00UT. Sky plots corresponding to subionospheric tracks of the satellites affected by amplitude scintillations during that time interval were plotted to understand the changing look angles affected by different levels of amplitude scintillations every hour, namely, mild (0.2<S4<0.4), moderate (0.4<S4<0.6) and intense (S4>0.6) during that time period. Proportion of satellite vehicle (SV) look angles unaffected by intense scintillations every hour during 13:00-19:00UT were analyzed to assess the improvement, if any, and applicability of the principle of spatial diversity for ionospheric scintillation mitigation. The 99 percentile values of elevation range of SVs unaffected by scintillations during 14-15, 15-16 and 16-17UT were found to be 30.45°, 29.38° and 32.62° using multi-constellations compared to 23°, 14.3° and 28.62° when using only GPS. The corresponding range of unaffected azimuth values at 99 percentile level showed improved values of 10°, 26° and 22.38° using GNSS in contrast to 7°, 24.68° and 10.38° when using GPS. This process of estimating scintillation-free SV look angles when using multi-constellation was performed every evening during March 2014 thereby providing system designers with figures to validate the suggestion of the concept of spatial diversity for scintillation mitigation. Variabilities were noted in the scintillation-free look angle ranges at different hours which may be attributed to the temporal behavior of equatorial ionospheric scintillations.