Characterizing the Dependence of Satellite-based Augmentation Systems upon the Spatial Distribution of GPS Measurements
L. Sparks, A. Komjathy, A. J. Mannucci, and X. Pi
Jet Propulsion Laboratory, California Institute of Technology

Satellite-based augmentation systems (SBAS) such as the United States’ Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay Service (EGNOS), and the Japanese Global Navigation Satellite System (MSAS) are designed to improve the accuracy and ensure the integrity of user position estimates determined from Global Positioning System (GPS) measurements. In the absence of selective availability, the ionosphere is the largest source of positioning error for single-frequency users of the GPS signals. A critical objective of any SBAS system is to estimate ionospheric delays accurately and to bound the errors in these estimates reliably. Irregularities in the ionosphere that go undetected can result in significant user delay error. Thus, the accuracy of a given delay estimate can depend sharply on the spatial distribution of GPS measurements from which the delay estimate is derived. This paper presents a method for characterizing in terms of a scalar metric the degree to which a given spatial region is sampled uniformly by a given set of GPS measurements. The metric is used to assess the danger posed to WAAS delay estimate accuracy by undersampled ionospheric irregularities.

In WAAS, an ionospheric delay error and its confidence bound at a user location are derived from vertical ionospheric delay estimates, modeled at a set of regularly-spaced intervals in latitude and longitude, i.e., at ionospheric grid points (IGPs). The vertical delay estimate at each IGP is calculated from a planar fit of neighboring slant delay measurements, projected to vertical using the standard thin shell model. The points where the measurement raypaths cross the ionospheric shell height are known as ionospheric pierce points (IPPs). When the spread of IPPs surrounding a given IGP is highly skewed, a region near or to one side of the IGP may be undersampled, allowing a significant ionospheric disturbance to remain undetected. Since each user must be protected from the effects of poor sampling, any sampling metric that tends to confuse “better” and “worse” IPP distributions will cause the “better” distributions to be treated too conservatively, i.e., a higher error bound will be broadcast than is actually warranted. Our IPP spread metric is designed to meet the following requirements: (1) it should be sensitive to the angular distribution of the IPPs about the IGP; (2) the contribution of a single IPP to the metric defined at a given IGP should decrease with separation distance; (3) the metric should improve monotonically as the number of IPPs increases; and (4) parameterization of the metric should permit control of its sensitivity to the variation of a single IPP location. The metric varies in magnitude between 0 and 1, where 0 represents a “good” IPP spread and 1 a “poor” IPP spread. Proper choice of the free metric parameters depends upon the range in the number of points to be included in each fit and the range in the size of fit radii centered at each IGP. We show how metric parameters may be adjusted to produce error confidence bounds that are safe but not overly conservative.