Modelling and assessing ionospheric higher order terms for GNSS signals

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BIOGRAPHIES

Dr. Angela Aragon-Angel is a scientific/technical officer at the Joint Research Centre (JRC) of the European Commission (EC), Italy. Her working topics range from ionospheric radio occultation to precise positioning and navigation within the area of GNSS data processing.

Dr. Manuel Hernandez-Pajares is Full Professor and head of the research group IonSAT at Universitat Politècnica de Catalunya (UPC, Barcelona, Spain), and Expert Advisor of the European Space Agency. He is working since 1989 in new scientific and technical applications of GNSS, with special emphasis on precise positioning, ionospheric sounding and Space Weather.

Dr. Pascale Defraigne got her PhD in Physics at the Université Catholique de Louvain (UCL), Belgium, in 1995. She is now head of the Time Laboratory at the Royal Observatory of Belgium. She is actively involved in the time and frequency applications of the GNSS, and chairs the working group on GNSS Time Transfer of the Consultative Committee for Time and Frequency.

Dr. Nicolas Bergeot is a geophysicist of the Royal Observatory of Belgium. He is working on ionospheric monitoring and modelling in the frame of the Solar Terrestrial Center of Excellence (STCE). He is lecturer at the University Catholique de Louvain since 2010.

Roberto Prieto-Cerdeira is GNSS R&D Engineer in the GNSS Evolutions Programme and Strategy Division of the European Space Agency, where he coordinates technology R&D and scientific activities for the evolution of European GNSS Systems. From 2005 to 2014 he was ESA responsible for the activities related to radiowave propagation (ionosphere, multipath) for GNSS.

ABSTRACT

High precision positioning and time transfer are required by a large number of scientific applications: seismic ground deformations, sea level monitoring or land survey applications require sub-centimeter precision in kinematic position; monitoring of stable atomic frequency standards requires an increasing sub –nanosecond precision.
Differential GNSS is presently the best tool to reach such precisions, as it removes the majority of the errors affecting the GNSS signals. However, the associated need for dense GNSS observation networks is not fulfilled for many locations (e.g. Pacific, Africa). An alternative is to use Precise Point Positioning (PPP), but this technique requires correcting signal delays at the highest level of precision, including high order ionospheric effects. It is thus essential to accurately characterize the higher order ionospheric terms (I2+), i.e. I2, I3, I4, geometric bending and differential STEC bending, which is the goal of this paper. For that, we used a network of well-distributed GPS stations, and the Bernese v5.0 software [4].
We have focused our attention in the I2+ terms, studying two approaches:
A) Combining independent and simultaneous measurements of the same transmitter-receiver pair at three (or more) different frequencies, in order to remove the I2 term: it is theoretically possible to cancel out both I1 and I2 similarly as it is done typically in precise dual-frequency GNSS measurements for I1. It is shown that, as expected, due to the proximity of the corresponding frequencies in L-band, the high noise of the combinations makes this approach unpractical to either isolate or remove I2.
B) Modelling the I2+ terms, in function of estimates of electron content, geomagnetic field and electron density values. Their characterization has been done in a realistic and full-control environment, by using the last version of the International Reference Ionosphere model (IRI2012) and International Geomagnetic Reference Model in its 11th version (IGRF11) [16].
Two metrics have been considered to assess the importance of the different higher order ionospheric corrections and their approximations:
a) At the signal level, or range level, directly provided by the corresponding slant delays.
b) At the geodetic domain level, provided by the impact of such values in the different geodetic parameters estimated consistently (i.e. simultaneously) from a global GNSS network.

INTRODUCTION

The first order ionospheric term (I1) is the main contribution of the ionospheric delay to GNSS observations (typically higher than the 99.9% of the total value, [2], [3], [15]).
I1 can be removed when considering the carrier phase or the code ionospheric free combinations of dual frequency measurements (L3/Lc and P3/Pc). However, because of