AN EXPERIMENTATION AND VERIFICATION NETWORK TO ANALYZE SMALL SCALE IONOSPHERIC DISTURBANCES

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Introduction

Trans-ionospheric radio signals of global navigation satellite systems (GNSS) like GPS, GLONASS, and GALILEO may suffer from rapid and intensive fluctuations of their amplitude and phase caused by small-scale irregularities of the ionospheric plasma. Such disturbances occur frequently during the evening hours in the equatorial region due to plasma flow inversion causing "plasma bubbles" or during geomagnetic storms in the polar region. This phenomenon, which is called radio scintillation, can strongly disturb or even disrupt GNSS signal transmission.
DLR investigates the effect of small scale ionospheric irregularities on Global Navigation Satellite System (GNSS) positioning using the Experimentation and Verification Network (EVNet).

Figure 1: Global coverage of operational and envisaged EVNet stations.

Station setup

EVNet is a global network of GNSS receivers for scintillation measurements from high latitudes down to equatorial region and capable to continuously measure GPS, GLONASS, Galileo, Beidou signals at very high sampling rates (20 to 100 Hz).
The station's configuration, data recording and processing is completely automated and can be controlled remotely. For further processing (real time, post processing) EVNet provides interfaces for GNSS data access for C++ and Python.

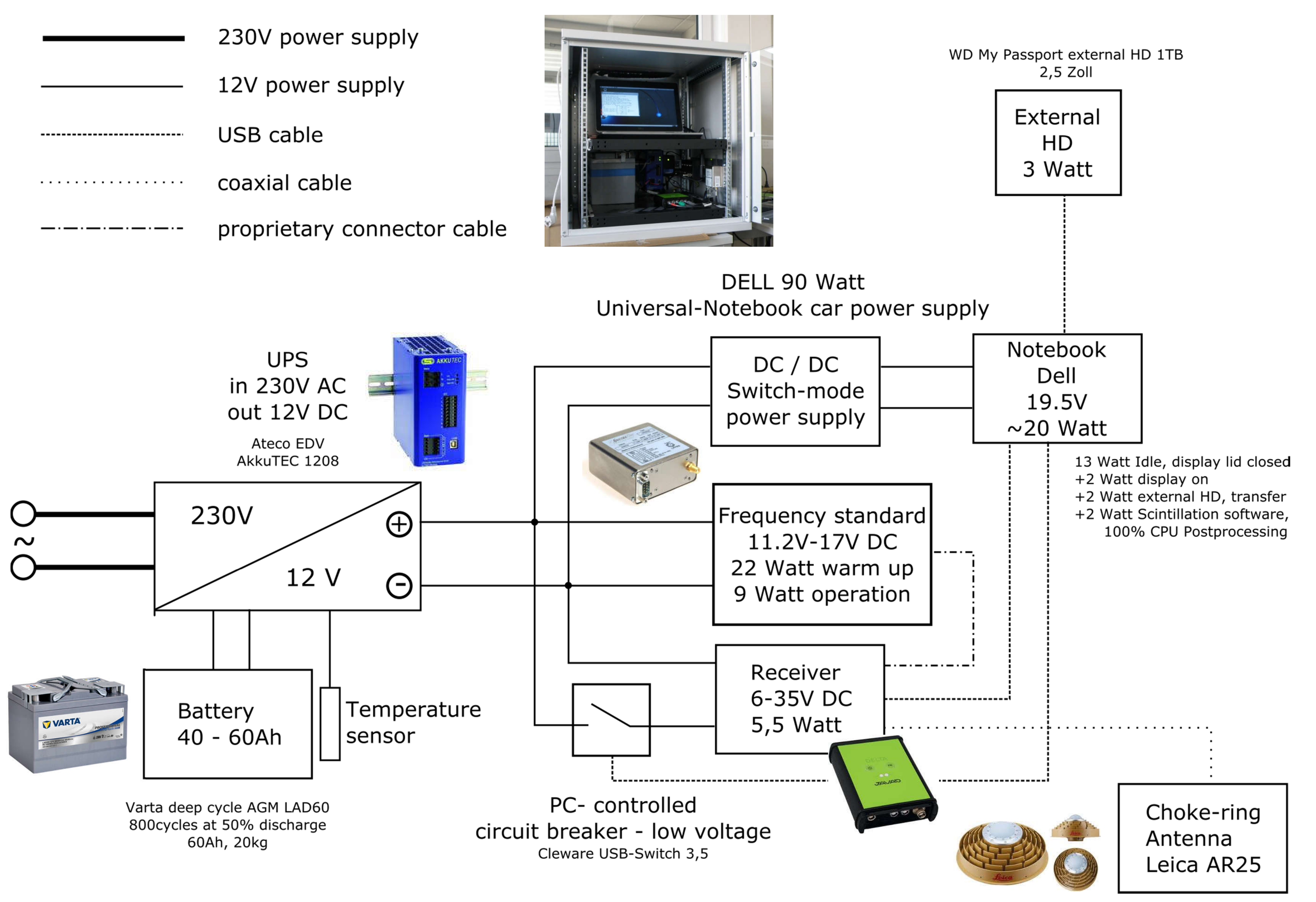

Figure 2: EVNet station design as deployed in Bahir Dar, Ethiopia.

Related research

Hlubek et al., 2014 have shown statistics of scintillation events for equatorial Africa using different GNSS signals. As a general trend it was observed, that the magnitude of scintillations is smallest for the L1/E1 signals and largest for L5/E5a. Statistics for the scintillation occurrence during the course of one year revealed a double peak structure with the largest magnitude of scintillations during equinox. The peak is more pronounced during spring equinox, which coincides with a higher solar activity and higher Kp-index. Statistics for the average scintillation occurrence for the course of a day have shown the expected result with the strongest scintillation occurrence after sunset. A more detailed look revealed two interesting results. First, the overall strength of scintillations is largest for Galileo. Second, the signal affected over the longest period is GLONASS L2.

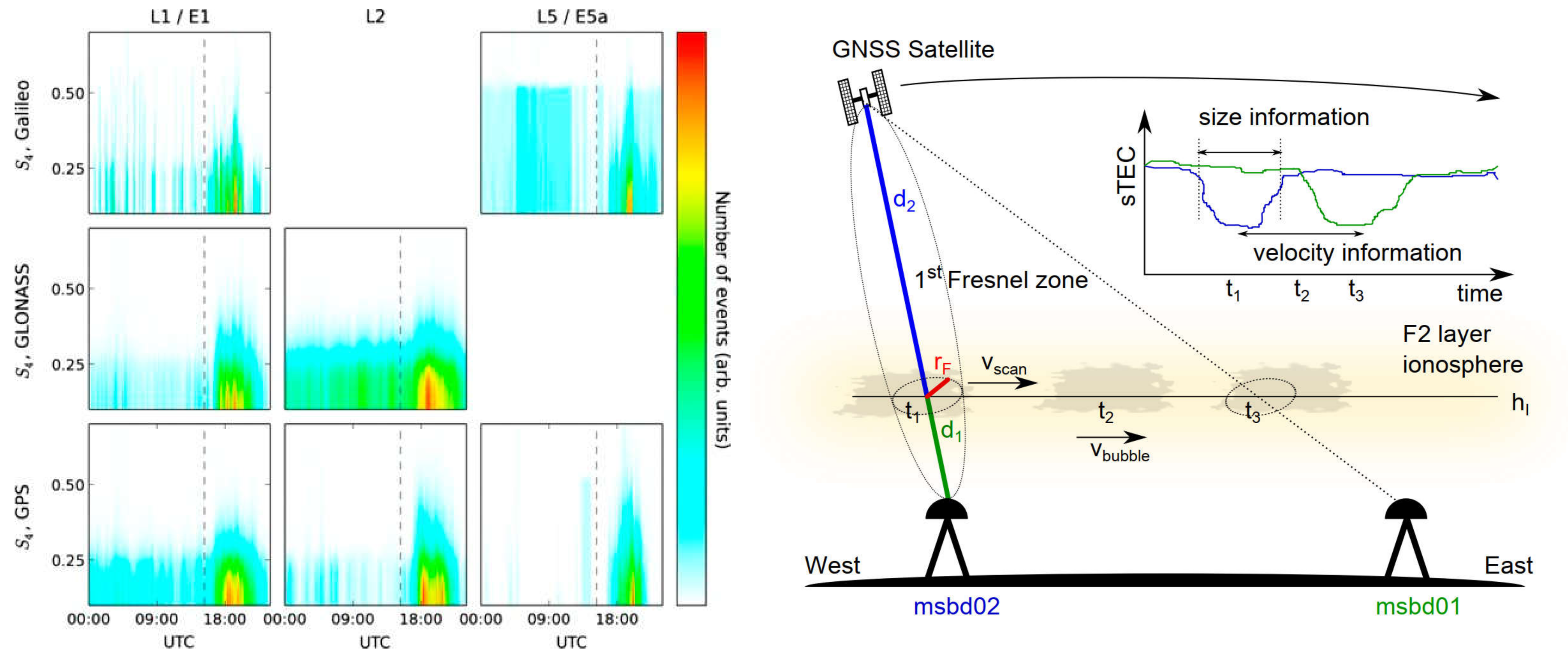

Figure 3: GNSS related statistics of amplitude scintillation events (left) and methodology for the characterisation of EPBs by using co-located GNSS receivers in Bahir Dar, Ethiopia (right).

In Kriegel et al., 2015 characteristics of equatorial plasma irregularities were analysed by processing simultaneously collected 50 Hz GNSS data in Bahir Dar. Both stations are located close to each other and are aligned in east–west, direction which allows to estimate the zonal drift velocity and spatial dimension of equatorial ionospheric plasma irregularities.
Therefore, the lag times of moving electron density irregularities and scintillation patterns are derived by applying cross-correlation analysis to high-rate measurements of the slant total electron content (STEC) and to the associated signal power, respectively. Finally, the drift velocity is derived from the estimated lag time, taking into account the geometric constellation of both receiving antennas and the observed GPS satellites.

Space Weather activities

EVNet data are additionally used for the operational real time monitoring of small scale irregularities (quantified as S4 for amplitude and Sigma Phi for phase scintillation) within the Ionosphere Monitoring and Prediction Center (IMPC), ESA SSA and PECASUS. Low rate GNSS data (1Hz) are integrated into the near real time TEC processing by using the Networked Transport of RTCM via Internet Protocol (Ntrip).

Outlook: receiver independent storage of ionospheric phenomena

The EVNet station at UFC in Fortaleza, Brazil is additionally equipped with an intermediate frequency (IF) sample recorder which dumps the L1 and L5 raw signals from the GNSS antenna before they are processed by the GNSS receiver itself. The ability to replay recorded ionospheric scenarios on different receiver types or on different receiver configurations on the same receiver enables to analyse GNSS receiver characteristics to improve its robustness under scintillation conditions.

References

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