The software defined radio approach to ionosphere monitoring using GNSS: multiple receivers at the price of one

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Professional and commercial hardware GNSS receivers have been successfully exploited for ionosphere monitoring since years. In particular, Ionospheric Scintillation Monitoring Receivers (ISMRs) are commercial devices specifically designed for monitoring ionospheric events affecting GNSS signals. Nevertheless, recent trends in GNSS receivers implementation also consider Software Defined Radio (SDR) as a valuable technology.

SDR refers to an ensemble of hardware and software technologies that enable re-configurable radio communication architectures. Dedicated hardware components are realized in software, either on programmable platforms (high-performance general purpose processors) or on re-configurable hardware, like FPGA, DSP, microprocessors or ASIP).

With respect to commercial hardware tools, SDR receivers allow to access intermediate and low level signal processing; therefore, they offer to the user a larger subset of observables. This fact yields higher flexibility and re-configurability and, in turn, enables the possibility to design and implement innovative ionosphere monitoring techniques.

The most common architecture of a GNSS SDR receiver can be split in two blocks:

- A GNSS antenna and a Radio Frequency (RF) front-end, which acts as a data grabber; the GNSS signal is received, pre-conditioned, analog-to-digital converted, and finally raw GNSS samples are stored on mass memories for further processing.
- A signal processing stage, which can process the stored data, either in real time or in a post-processing phase. This is the actual stage of the receiver which is SDR implemented.

The implementation by means of the SDR approach adds flexibility to the implementation of the whole monitoring station. In fact, when using commercial GNSS receivers, only the storage of post-processed data is possible, such as ionospheric data and outputs of the correlation stages. By means of the SDR implementation, the two different blocks can operate independently during monitoring operations. Raw signal samples collected on site can be transferred exploiting external memories and then post-processed, either by using different configurations and architectures of the receivers (e.g. loops bandwidth or order), or by implementing techniques and innovative algorithms tailored to ionosphere monitoring.

This feature makes the approach equivalent to a plethora of receivers, the performance of which can be replicated changing the configuration of the software architecture.

Last but not least, even considering the hardware cost for the front-end section, the solution is cost effective, especially when considering the possibility to mimic the behavior of different receiver architectures and the possibility to replay scenarios for significant atmospheric events by means of advanced signal processing algorithms (for example for multipath and interference removal).

The effectiveness of the architecture has been proved in several installations at equatorial regions, and lately by the installation of two data collection systems designed and realized for the purposes of the DemoGRAPE project in two Antarctica research stations: the Brazilian station Estação Antártica Comandante Ferraz (EACF), and the South African Antarctic base SANAE IV.

During the first months of operation, significant events have been observed, and the software processing has been able to provide values for the scintillation indexes S4 and phi60 with the quality of a Septentrio PolaRxS PRO ISMR.

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