PROCESSING ASPECTS OF THE SOFTWARE PARIS INTERFEROMETRIC RECEIVER

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1. INTRODUCTION

The use of signals of opportunity, such as those continuously transmitted by the Global Navigation Satellite Systems (GNSS), is a low-cost strategy towards remote sensing purposes. In particular, the analysis of these type of signals reflected off the Earth surface for the retrieval of geophysical parameters is known as GNSS-R. During the last years, many GNSS-R applications have been successfully tested [1], including sea surface characterization, soil moisture sensing, sea ice detection and dry snow layering. In addition, by following the original purpose of the GNSS-R concept presented in 1993 [2], several ocean altimetric experiments have been carried on (e.g. [3]). Moreover, as it was pointed out on this first publication, one of the main advantages of this technique is the possibility of performing mesoscale altimetric measurements by employing the multiple reflection points available over the Earth surface as a result of the extensive GNSS constellation. This point is specially relevant, given that the increase of temporal and spacial resolution that could be then obtained would represent a key feature of the GNSS-R technique to complement RADAR Altimeters. However, to achieve the desirable precision in a spaceborne scenario with several and simultaneous observation areas requires a beamformer strategy to get enough signal power. This is even more significant when considering the interferometric approach of direct cross-correlation between direct and reflected signals, where no encripted codes are needed and higher-bandwitdh GNSS signals can be employed. Recently, this type of approach was first proved in an aircraft GNSS-R experiment using high-gain antennas [4]. The next step then, is to prove a beamformer-capable architecture under the same conditions.

2. ACQUISITION CONCEPT AND RECEIVER FRONT-END

In this context, a GNSS-R instrument has been proposed by ICE (CSIC/IEEC): the Software PARIS Interferometric Receiver (SPIR). The basic idea is to collect GNSS signals at a very high data-rate with several antennas to later properly combine them in post-processing. The resultant signals will be then cross-correlated (both direct/models against reflected signals) to finally obtain GNSS-R waveforms. This approach will provide us a final product which is equivalent of having several high-gain antenna pointing towards a set of desired targets (typically different GNSS satellites and their corresponding surface reflections). Fig. 1 provides a basic scheme of the acquisition concept for a single target.

The SPIR front-end mainly consists of 16 L-band antennas and their corresponding filters and baseband converters, which are grouped in 8 by 8 elements to form an up-looking antenna array (to collect direct GNSS signals) and a down-looking one (to collect GNSS reflections). The acquired signals are 1-bit sampled at 80 Msamples/sec, quantized and recorded at a rate of 320 MBytes/s.

3. SOFTWARE-BASED BACK-END

The SPIR back-end is implemented as a Software Defined Radio, which can be run in a standard computer, and represents the focus of this paper. In a first step, a delay compensation is applied to each antenna element's data stream in order to align the collected signals to perform the beam synthesis (with some additional calibration corrections). The resultant composite signal from the down-looking array is then complex cross correlated against either its equivalent from the up-looking array (interferometric approach), or its synthetic replica (standard or clean-replica approach). Finally, the result

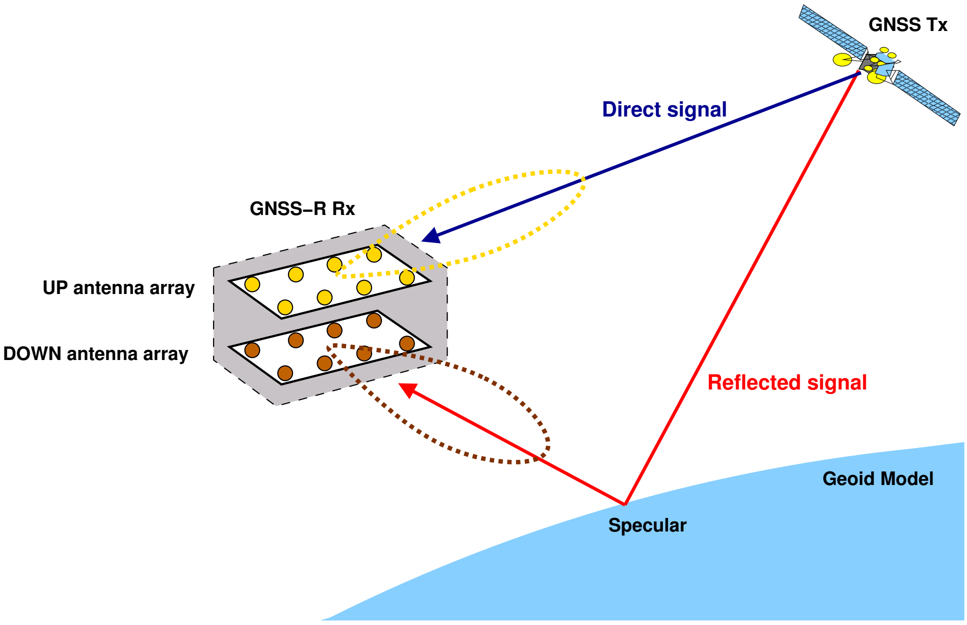

Figure 1. Scheme of the signal acquisition concept used by SPIR for a single GNSS reflection. Two antenna arrays collect GNSS signals: up-looking for the direct line-of-sight path and down-looking for its corresponding surface reflection. With a proper combination of each antenna element (small circles), the antenna array behaves as a narrow-beam antenna pointing towards the desired target (antenna beams represented with dashed lines).

from the cross-correlation is further integrated to obtain the basic observables, the waveforms, from whose analysis we can retrieve geophysical parameters from the reflecting surface. The navigation information needed during this process is obtained in parallel by means of GNSS-SDR [5], an open source GNSS software defined receiver developed at CTTC. A basic diagram of the SPIR back-end is illustrated in Fig. 2.

As a software-based receiver and compared with previous GNSS-R instruments, SPIR has to process a relatively large amount of data. In order to booster the required computational time, a multi-thread approach has been developed with two optional architectures based either on CPU's or GPU's. On the other hand, such flexibility will allow us to explore additional GNSS-R processing strategies or even receiver architectures such as [6] or [7].

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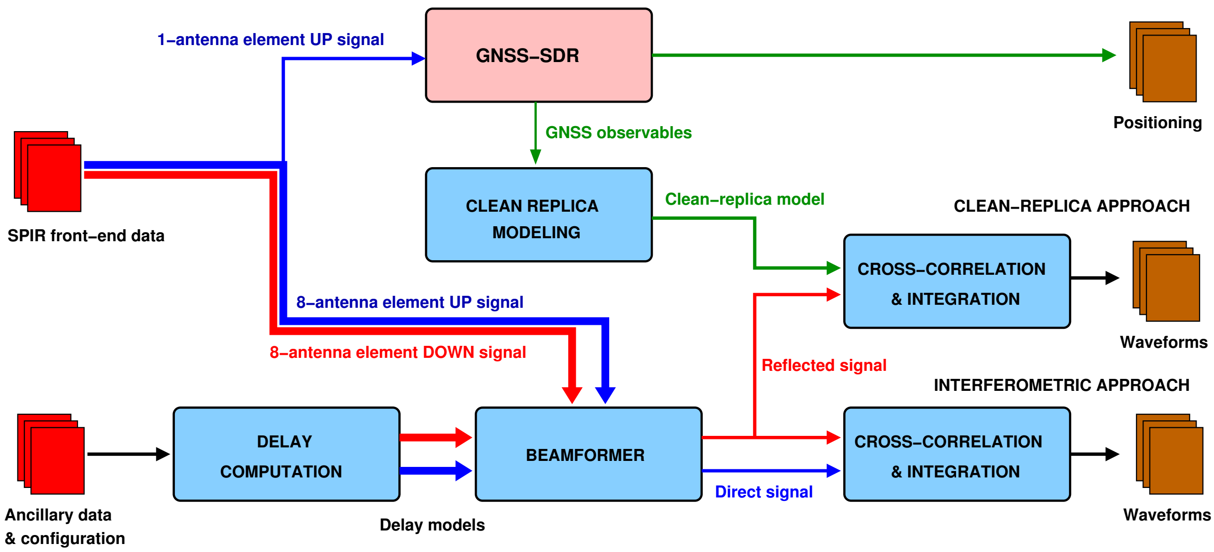

Figure 2. Basic diagram of the SPIR back-end.

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