CSSR: a 2For1 Compressive Sensing Software Receiver with Combined Correlation For GPS-CA and Galileo-OS Signals

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This is a 2for1 receiver because it acquires both GPS and Galileo signals at less than 50% of the complexity and processing time required by a Matched Filter acquisition process. This achieved by, for the first time, using a new implementation of the Compressive Sensing technique (CS) to process the two signals at the same time. Note that CS allows recovery of the full signal band, but with using below-Nyquist rate sampling, because the signal of interest occupies a smaller bandwidth [1].

New in this proposed CSSR implementation are: 1) matrices are implemented to have the knowledge of the two GPS and Galileo signals while preserving the code and frequency information in a compression format, which leads to decreasing the size of code search processing requires and thus less memory storage requirement; 2) the acquisition process is transferred from the time/frequency domain to the CS domain with known signal sparsity, which can be recovered by linear measurement from fewer samples; and 3) to help acquiring low sensitivity signals, the processing of increasing the dwell time from 4ms to 8ms or 20ms will cost the same as processing 4ms dwell. The above modifications we introduced to the CSSR implementation has resulted in almost 60% reduction in computational resources and processing time.

There are two matrices used in the CSSR framework. The first matrix is denoted the “sensing matrix” such as the Hadamard or Discrete Fourier Transform (DFT) matrix. The second matrix is called the “measurement matrix”, which includes a bank of correlators in compression format, achieved by multiplying the sensing matrix with a bank of correlators that is called a dictionary matrix. This multiplication will transfer the search dimension (number of samples) to the CS dimension (number of columns vectors in the sensing matrix). Also, the bank of correlators is designed to contain only the shifted PRN-code phases of the GPS+Galileo multiplied by the same carrier frequency forming a “bank of codes”. Thus, the number of columns vectors in our CSSR are equal to “satellites number x codes shifts”, while in a Matched Filter method, for example, the number of columns vectors are equal to “satellites number x codes shifts x Doppler frequencies shifts”; resulting in huge matrix dimension reduction. Note that these matrices are generated and stored in memory at the beginning of the process without needing to be regenerated again for each acquisition process.

The following four steps describes the process to overcome the complexity of this CSSR implementation:

1. The subcarrier frequency is first eliminated from the Galileo signal before mixing it with a filtered GPS signal to form a BPSK signal (GGBPSK).

2. GGBPSK signal is then passed through "m" Doppler channels simultaneously to generate non-Doppler shift vectors. These "m" Doppler channels contain a range of all possible Doppler shifts. Channels with the best match to the frequency of the received signals (carrier frequency with Doppler shift) will be selected for our CSSR framework later. The number "m" will control the acquisition complexity as it determines the number of columns vectors in the sensing matrix that are used to reduce the problem from "n" dimension, the number of samples, to "m" dimension, and where "m" is much less than "n". Note that, increasing the "m" number will enhance the probability of detection by increasing the row numbers of the sensing matrix as well as increasing the frequency resolution to "20Hz", which is equivalent to the fine frequency. Note that these Doppler channels are also generated once and stored in the memory as a matrix.

3. These non-Doppler shift vectors will now be transferred to the CS domain. This is achieved by coding/sensing these vectors with a known orthogonal transform, "the sensing matrix". Actually, this process is accomplished by taking the inner product between these matrices to create an "m" by "m" matrix containing compressed form of the necessary information so to be simply acquired in the CS domain by linear measurements.

4. Acquiring GPS+Galileo signals, is then accomplished by calculating the dictionary element, using a 2-dimensional orthogonal matching pursuit algorithm [2]. This algorithm determines the matching between the outputs from the sensing step (3) with the measurement matrix through multiplying them and taking the union of the columns matching matrix, that is the outputs from this multiplication. Once the matching achieved, then the dictionary element can be easily calculated by locating the peak in the matching matrix, which represent the acquired satellite number, code phase delay and Doppler frequency shift.

Several experiments were carried out to evaluate the performance of our CSSR with various signal conditions. We have captured signals of actual wireless communication channel using Signalion HaLo-430 platform to run with our simulation environment. The results show that CSSR performance is as good as that of a Matched Filter implementation performance but with:

1. CSSR achieving saving of 60% in computational complexity and processing time; thus saving much valuable battery energy and resources of a Smartphone implementation for example.

2. CSSR is achieving High frequency resolution acquisition of about 10Hz in high C/N and around 40Hz in low C/N. This is much less than that of a Matched Filter frequency resolution that can be up to 160-250Hz. This means that CSSR needs no post processing to calculate fine frequency.

In conclusion, unlike other SW receivers, our CSSR implementation achieves significant saving as well as achieving higher frequency resolution acquisition. We therefore believe that CSSR is a good candidate for multi-GNSS software receiver onboard Smartphones.

References:

[1] Y. C. Eldar and G. Kutyniok, Compressed sensing: theory and applications, Cambridge University Press, 2012.

[2] A. Albu-Rghaif and I. A. Lami, “Novel Dictionary Decomposition to Acquire GPS Signals Using Compressed Sensing,” in International Conference on Network Computing and Applications (ICNCA), 2014 IEEE International Conference on, 2014.

Description of new and innovative aspects of the presentation:

A novel implementation for using Compressive Sensing technique to acquire both GPS-CA and Galileo-OS signals in a single process.