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GNSScope and The Split Chip Compression Technique

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Abstract— **The presence of multipath due to obstructions on the signal path coupled with transmitter and channel based perturbations, can significantly degrade the quality of the received satellite navigation signals, resulting in the non-detection of weaker visible satellites, loss of lock on acquired satellites, and increased pseudo-range errors. In this paper, we present a novel technique based on the binary-valued signal compression method, for the detection, identification and compensation of pseudo ranging code discrepancies and signals on the multipath. Following a brief overview of the system, simulation case studies carried out entirely using the in-house developed satellite navigation receiver development, emulation and analysis platform Global Navigation System Scope (GNSScope) will be presented verifying the results.**

I. INTRODUCTION

With the development of the European global navigation system Galileo and the modernization plans for the Global Positioning System (GPS), referred to as GPS III, it is apparent that the civilian navigation signals will be in multiple bands within the next decade offering various applications from roadside assistance to medical services [1], [2]. Therefore, the next generation navigation user terminal will have to be a multi-mode versatile wideband receiver in order to cope with multiple bands and modulation schemes. In such a context, the flexibility offered by Software Defined Radio (SDR) is expected to become the dominant technology in Global Navigation Satellite System (GNSS) receiver development [3], [4].

The Global Navigation System Scope, developed in the Matlab and Simulink platforms, was designed as a complete transmission and reception model for the GPS L1/L2C and GIOVE-A L1/E5 bands. The model can be divided into five major sections, as seen in Fig. 1. Signal transmission covers generation of the GPS L1/L2C and GIOVE-A L1/E5 signals. The downlink path is characterized as a fading channel which caters for atmospheric delays, Doppler and multipath effects. The RF section is a behavioral model of the low-IF GNSS receiver front-end. This is followed by a quadrature ADC and associated DSP chain. The low-IF receiver model, consisting of the acquisition, tracking, and range and range-rate processing blocks, is fully parameterizable and gives control over important variables such as the number of correlators, correlator spacing, PLL/DLL configurations, discriminator functions, transient and lock-in tracking mode behavior, multipath handling and strong signal removal for enhanced weak signal processing; as well as allowing users to enter their own designs using built-in and custom blocks to build their receivers. The Graphical User Interface (GUI) for GNSScope can be seen in Fig. 2

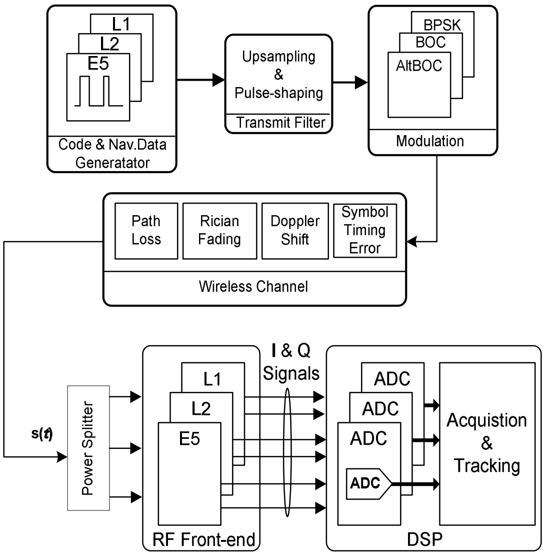
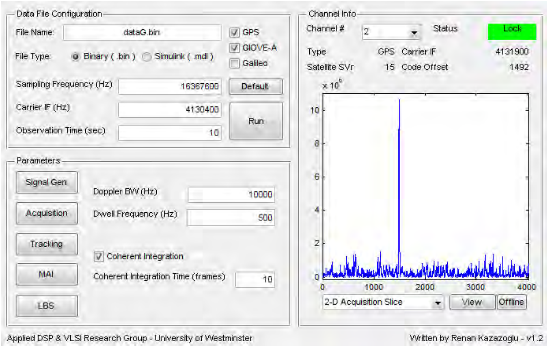


Figure 1. GNSScope Block Diagram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☑ GIOVE-A
☐ Galileo
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Parameters
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Dwell Frequency (Hz) 500
☑ Coherent Integration
Coherent Integration Time (frames) 10

Channel Info
Channel # 2
Status Lock
Type GPS
Carrier IF 4131900
Satellite SVr 15
Code Offset 1492

2-D Acquisition Slice

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Figure 2. GNSScope GUI

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The paper is organized as follows: In Section II we provide a short background on GNSScope and an overview of the binary-valued signal modulation compression method. This will be followed by details of the proposed technique in Section III. Simulation case studies utilizing the proposed method and analyses of the results using GNSScope will be given in Section IV. Concluding remarks and details of further work will be given in Section V.

II. BACKGROUND

A. GNSScope

GNSScope is an end-to-end modeling environment enabling designers to accurately simulate weak signal transmission, signals on the multipath and the receivers' response to environmental dynamics. The capability to fine tune every stage of the signal path beginning from satellite transmission through to the receivers position fix to optimize its response enables hardware and software developers to test and benchmark their own designs before new global navigation systems are fully operational. The ability to simulate controlled weak signal conditions provides a better understanding of the receivers' response in obstructed areas. Adding signals on the multipath gives receiver designers the opportunity to analyze the multipath rejection characteristics of their designs. GNSScope was designed to handle these tasks while giving receiver designers insight into the details of their designs. Having been developed in SDR, it gives receiver designers flexibility and control over every stage of the signal chain.

B. Binary-Valued Signal Modulation Compression

As advances in high-sensitivity GNSS receiver technologies targeting indoor and urban canyon navigation require higher and higher processing speeds for tasks such as multiple access interference mitigation and multipath compensation, the need for improved processing techniques reducing the number of operations for acquisition and tracking is ever increasing [5]. The computational load in these cases can be significantly reduced by the application of the Binary-Valued Signal Modulation Compression for High Speed Cross-Correlation [6] technique. This is accomplished through the summation of the received signal samples rectified by the polarity of the chipping code, resulting in the samples of a single chip of this code. As this technique can be implemented using only simple additions, it greatly reduces the computational complexity while preserving signal range and phase information in the chip waveform. Using this technique, the large number of received signal samples are reduced to a short vector with few samples representing the channel and receiver front-end effects on the chip itself. An example of this, produced using GNSScope, can be seen in Fig. 3 where the compression technique is applied to a generated signal over 100 milliseconds of GPS L1 data containing a multipath component with a 180 degree phase shift with respect to the line of sight signal. The filtering effects along with the multipath signal, are clearly visible.

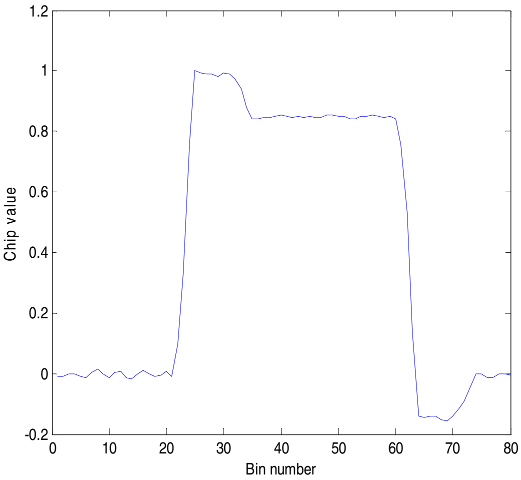

Figure 3. Compressed chip waveform

III. THE SPLIT CHIP COMPRESSION TECHNIQUE

The Split Chip Compression technique is based on the binary-valued signal modulation compression technique, whereby the samples of the received signal are summed after being rectified by the polarity of the chipping code. However, rather than summing all the chips and compressing the waveform into a single chip of the PRN code, losing any information associated with the specific chip polarities, the technique described in this paper splits the chipping code into its positive and negative chips, accumulating them in two separate vectors. This results in increased sensitivity to perturbations on the chipping waveform, as specific perturbations that affect the two polarities of the chipping waveform differently are preserved rather than being integrated, at the cost of a second short vector for the storage of the two separate chips. The two compressed chips represent the effects of the transmitter, channel and receiver front-end on the chipping waveform and can be used in the detection, identification and compensation of distortions such as multipath, unbalanced chipping code duty cycles and filter ringing, which can then be compensated using linearization, curve fitting and parameter extraction techniques.

In order to be able to identify multipath and unbalanced duty cycled effects in the compressed positive and negative chip vector, a simple moving average filter coupled with a thresholding algorithm was also devised. As the thresholding algorithm linearizes the compressed chip waveforms, further work is being carried out to enable the detection of Ionospheric and Tropospheric effects such as dispersion and refraction.

The proposed method has been successfully implemented in MATLAB and integrated into GNSScope. Its uses will be demonstrated in the following section using simulation case studies carried out entirely using GNSScope.

IV. SIMULATION CASE STUDIES

We present simulation case studies and analyses performed entirely using GNSScope in this section. Two case studies are presented. First we present the use of the split chip sum technique in determining the differences in the filtering effects on the positive and negative polarity chips, and how these effects get filtered out during the accumulation process when integrated into a single vector, as in the binary-valued signal modulation compression technique. To this end a simulation file containing a single satellite was generated with 40 megahertz sampling frequency and 5 megahertz center frequency, in order to demonstrate results in high resolution. The signal contains channel and front-end filtering effects that present in typical GNSS receivers. Fig. 4 and Fig. 5 present the compressed positive and negative chips respectively, over an integration period of 200 milliseconds.

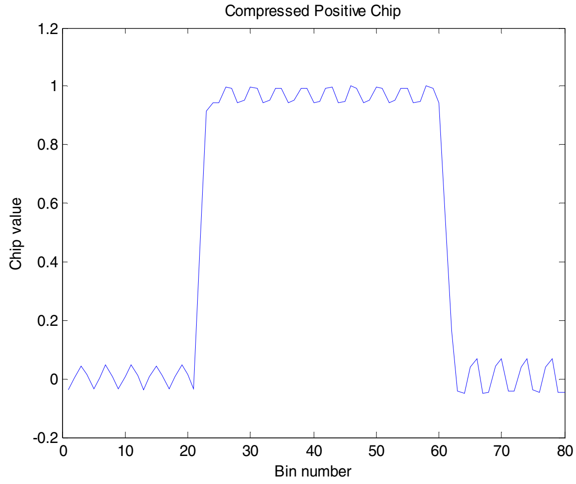

Figure 4. Compressed Positive Polarity Chip

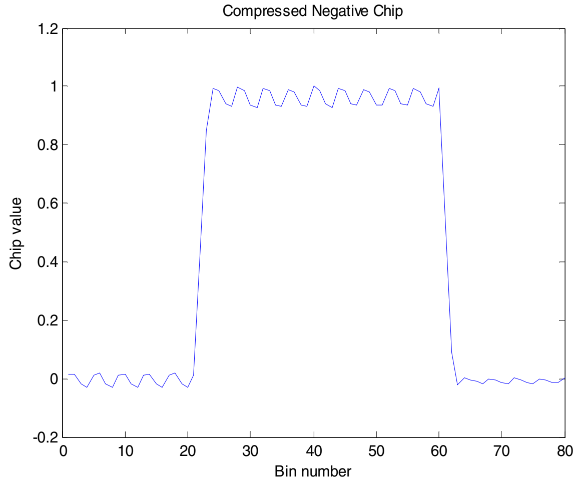

Figure 5. Compressed Negative Polarity Chip

When compared to the binary-valued signal modulation compression technique results given in Fig. 6, it can be seen that part of the filtering effects on the chip waveforms have been integrated out and are non-existent. It is apparent from the compressed positive and negative polarity chip waveforms that the leading and trailing edges of these waveforms have also been affected differently, with larger oscillations on the positive chip waveform compared to the negative chip waveform.

The second simulation case study presents the results for an unbalanced duty cycle error condition on the chipping sequence, where the transmitted widths of the positive polarity chips are not equal to those of the negative polarity chips. Fig. 7 and Fig. 8 present the compressed positive and negative chips respectively, computed over an integration period of 100 milliseconds. It can be seen that the split chip compression method is capable of identifying both chip waveforms without any distortions, revealing the 10% duty cycle imbalance and chip specific perturbations while simplifying computations in subsequent stages.

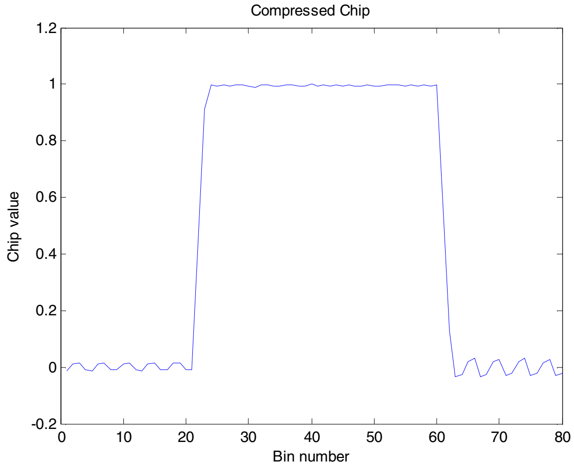

Figure 6. Binary-Valued Signal Modulation Compressed Chip

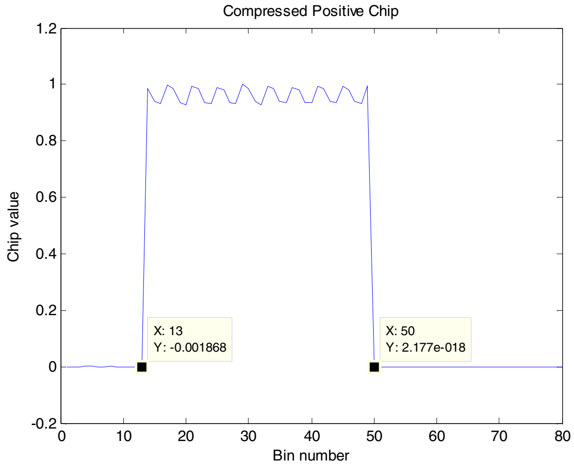

Figure 7. Compressed Positive Polarity Chip

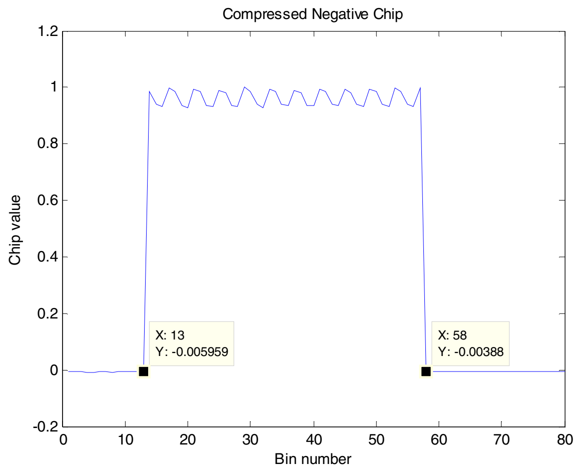

Figure 8. Compressed Negative Polarity Chip

Having knowledge of the duty cycle imbalance, the locally generated PRN code can be modified to compensate for this effect, increasing the SNR of the in-phase and quadrature correlator channel outputs. This results in improved receiver performance in the presence of noise and multipath errors. Fig. 9 presents the compressed chip resulting from the binary-valued signal modulation compression method using the same input file. In the presence of channel based distortions and multipath, the transition region may not be readily detectable, resulting in reduced performance under these conditions.

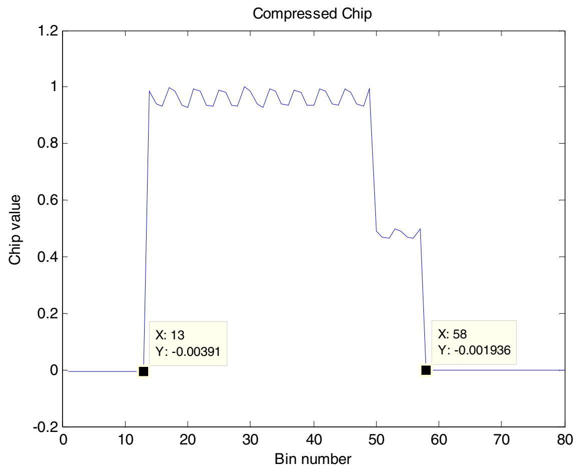

Figure 9. Binary-Valued Signal Modulation Compressed Chip

V. CONCLUSIONS

In this paper we have provided a brief overview of the capabilities of GNSScope and the split chip compression technique. Simulation case studies have been used to demonstrate the techniques' effectiveness under certain threat conditions, and the results have been compared to those of the binary-valued signal compression technique. The method can be used in low complexity high performance GNSS receivers targeting high-sensitivity positioning applications such as indoor or urban canyon navigation.

VI. ACKNOWLEDGEMENTS

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REFERENCES

[1] "Galileo Open Service Signal In Space Interface Control Document", European Space Agency, European GNSS Supervisory Authority, 2008.

[2] "Global Positioning System Standard Positioning Service Interface Control Document", GPS Joint Program Office, 2000.

[3] J. Tsui, "Fundamentals of Global Positioning System Receivers: A Software Approach", Wiley-Interscience Publications, USA, 2005.

[4] K. Borre, D.M. Akos, N. Bertelsen, P. Rinder and S.H. Jensen, "A Software-Defined GPS and Galileo Receiver: A Single Frequency Approach", Birkhauser, Berlin, Germany, 2007.

[5] L.R. Weill, "Lightening the Data Processing Load - Signal Compression in GNSS Receivers", InsideGNSS, p. 37-45, Fall 2007.

[6] B. Fisher and L.R. Weill, "Binary Valued Signal Modulation Compression for High Speed Cross-Correlation", United States Patent, Patent No. US 7,403,559 B1, July 22, 2008.