FPGA IMPLEMENTATION OF AVERAGING CORRELATION FOR C/A CODE ACQUISITION OF GPS SIGNAL IN SOFTWARE RECEIVERS

J.V.Sharma[1], S. Chakradhar Naidu[2]
[1]Department of Electronics and Communication Engineering,
CVSR Engineering College, Hyderabad, India
[2]Reasearch Scholar, Department of Electronics and Communication Engineering,
CVSR Engineering College, Hyderabad, India

Abstract

Conventional software receivers perform correlation in frequency domain using FFTs in the acquisition stage of gps receivers. They are required to process the digital sample sequences obtained from RF front end which are usually non radix 2 in number. In order to take advantage of the readily available and faster radix 2 FFT cores in VLSI design tools new methods called averaging correlators are being investigated that convert the samples obtained from rf front end into radix 2 sequences. This paper presents investigation of development and implementation one such averaging correlation method on an FPGs for acquisition of gps signals. The scope of work is confined to developing an algorithm for acquisition of gps satellites by averaging correlation of digitized signal samples obtained from the front end of a gps receiver and adapting circular correlation on the sequences. Xilinx ISE 13.2 is used to develop the code in Verilog and implemented on Xilinx ZYNQXC7Z010 FPGA. Test results are presented along with comparison with other existing methods of acquisition. It is found that averaging correlation gives better performance without loss of c/n.

Key words: GPS signal, Acquisition, **Correlation, convolution, FFT,** circular correlation, **Averaging correlation, , FPGA**

. INTRODUCTION

Global Positioning System (GPS) is the most widespread global navigation satellite system that enables users anywhere in the world to determine their position within a few meters accuracy. The space segment of GPS consists of 24 or more satellites at an altitude of 22000km orbiting in 6 different inclined orbits and transmitting signals continuously towards earth. All the satellites transmit the GPS at the same carrier center frequency of 1575.42 MHz and 1227.6 MHz in the L1 and L2 bands, respectively. However each satellite signal is distinguishable by its unique PRN GOLD code with which its data bits are encoded under CDMA spread spectrum multiple access system. The data bits are modulated by Binary Phase Shift Keying (BPSK) of the carrier. This scheme enables the user receiver RF front end to receive signals from all satellites of adequate signal strength and convert them and into a digital stream of samples at a common IF in its ADC and while in the subsequent Base Band Signal processing stage individual satellite signals separated and processed. The BSP involves acquisition of satellites identified by their PRN codes, tracking them, decoding the data to extract satellite ephemeris and time of transmission etc.

In the next stage of the receiver computation of user position, converting to proper coordinate system are executed.

Fig1.

Acquisition:
As the receiver starts its operation, the received composite signal is screened for all possible PRN sequences. In order to detect the presence of a particular satellite signal, the phase of the respective C/A code sequence and the effective [2]Doppler shift that is associated with this satellite signal must be determined, which can be done by iterative correlation

Correlation: Although the job of correlators can also be accomplished in frequency domain, most of them are traditionally sequential and in time domain. Time domain correlators are easy to implement in time domain, since only addition and multiplication operations are needed. On the other hand, a complete search will cost a significant amount of time.

Convolution:
Circular correlation
FFT: Another choice is to do acquisition and tracking in frequency domain, for example, using the Fast Fourier Transform (FFT) converting the GPS signal into the frequency domain. This Fast Fourier Transform (FFT) algorithm is believed to be computationally efficient.

CIRCULAR CORRELATION
AVERAGING CORRELATION: The averaging method averages the incoming 5,000 samples to become 1,023 averaged samples. If the starting point of the averaging operation is chosen in the right place, the 1,023 new samples may represent the original chips of the C/A code. In other words, one can say that a full C/A code is presented by 5,000 samples and that its chips are represented by either 4 or 5 samples each. Since the C/A code is circular, therefore, the right averaging starting point is one of 5 successive samples. This will generate 5 of the 1,023 averaged-samples code. As a result, detection probability This paper intends to fill this gap by employing Averaging Correlation technique. [3]Averaging Correlation can yield coarse code phase estimates even if not all possible down sampling phases are computed.

II. ACQUISITION

During the acquisition process, the coarse values of carrier frequency and code phase are determined for all visible satellites. The latter parameter indicates the circular shift of the locally generated C/A code with respect to the code screened for in the received signal. If the frequency of the locally generated carrier and the code phase of the local C/A code match with the frequency and code phase of the individual satellite signal, the correlation between the local and the received signal is maximal. The two-dimensional search over code phase and carrier frequency may thus result in a correlation function. The simplification is justified by the fact that this paper focuses on the correlation part of acquisition, and due to the fact that any residual carrier can be incorporated by reducing the signal-to-noise ratio accordingly. Since both the received and the locally generated signal are periodic with the same period, the linear correlation can be substituted by a circular correlation. However, direct frequency domain acquisition and tracking of the C/A code needs 5000 point FFT processing block, which significantly increases the cost of most civil receiver producers. A new technique will be introduced in the next section to do the frequency domain correlation with much cheaper FFT blocks[4], which can be realized in more popular hardware[5].

III.AVERAGING CORRELATOR

Is not affected by replacing the 5,000-point FFT-based method with the averaging method.

The acquisition time is reduced by using this method, because calculating five 1,023-point FFTs and IFFTs requires less time (in software and in hardware) than the 5,000-point FFTs and IFFTs. However, implementing 1,023-point FFT (or IFFT) is not an easy task since it is not a power of two. The signal energy loss on average was acceptable.

However, the computation time or the necessary hardware resources are increased to a certain level that makes it useless, especially when real-time acquisition is required. One possible solution to the problem of size mismatching of the code and the available Xilinx's 1024-point FFT core[6][7].The new approach will show a fast acquisition method that can be implemented much easier than the 5,000-point FFT- based method.

IV.MODIFIED C/A CODE

As stated above, the averaging correlator[3] needs to be applied five times with five successive starting samples. When the five correlation functions for this averaged C/A code are generated, the correlation function that contains the strongest peak keeps the important information necessary for acquisition.

The peak is not based on equilateral triangle, as what it should be in a normal C/A code, but it is good enough to roughly estimate the code phase for acquisition shown in below figure1. One may notice that each point in this correlation function is one out of 1,024 modified chips. Each modified chip is a 1 ms while the original chip width is 1023 ms. To estimate the code phase, one needs to consider this change in chip width and should correct the value of the code phase. the averaging computation requires about 25,000 additions and 5,120 divisions.

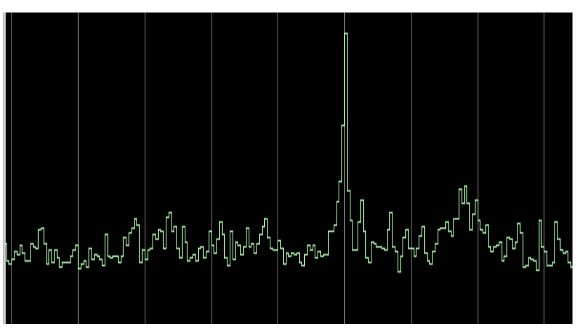

Figure1: Modified-Code FFTCorrelation Function

The implementation of 1,024-point FFT[7] is much simpler than the 5,000-point FFT. This will lead to significant simplification in the hardware implementation. In order to use this method, the effects on signal-to-noise ratio and the other characteristics should be studied. The characteristics of the modified-code averaging correlation method in terms of signal-to-noise ratio (SNR) loss code phase accuracy and carrier phase accuracy.

IV. Implementation of Digital GPS Receiver

The averaging correlator for the implementation of the acquisition process is shown in below diagram.

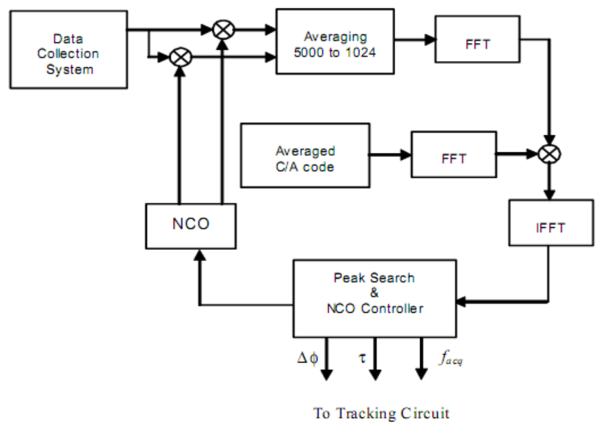

Figure 2: Acquisition using Averaging correlator

First, the samples are multiplied by in-phase component of the carrier signal. The samples are each averaged to 1,024 points. Then they are converted to frequency domain using 1,024-point complex FFT and multiplied by the conjugate of the FFT of the averaged-local-code. A 1024- point complex IFFT is used then to return back to the time domain .A peak searcher inspects the 1,024 outputs of the IFFT[7] and stores the location of the peak and its value. The peak searcher compares the peak value to a threshold to decide if the peak (or a GPS code) is detected. If the searcher does not detect a peak, then the process repeated for different frequency bins. This is repeated until a true peak is found or until all frequency search bins are completed. When the GPS signal is acquired, the frequency is selected and the search is conducted only in the code-phase dimension.

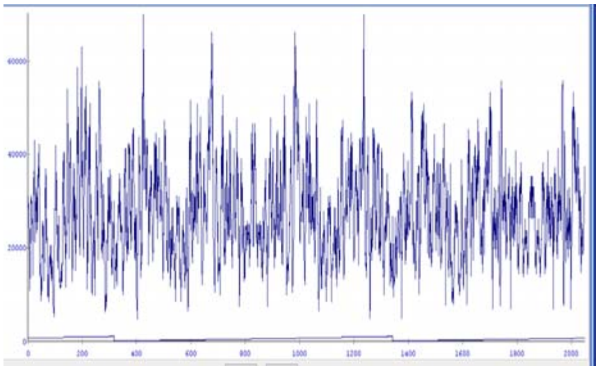

Figure 3:Averaging Correlation Hardware Result.

V. HARDWARE BOARD

The Z-7010 is based on the Xilinx All Programmable System-on-Chip (AP SoC) architecture, which tightly integrates a dual-core ARM Cortex-A9 processor with Xilinx 7-series Field Programmable Gate Array (FPGA) logic. It has 650Mhz dual-core Cortex-A9 processor.

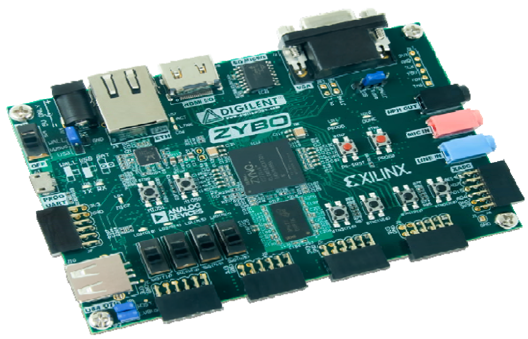

Figure 4: ZYNQ FPGA Board

VI. RESULTS

The figure shows the Averaging correlation of Gps signal of a Satellite no 3 with the carrier frequency of 1.25Mhz.

Figure 5: The Acquisition of Satellite 3 with Carrier frequency of 1.25 MHZ.

The below figure shows the Averaging correlation of a Gps signal for satellite no 3with carrier frequency Shift of 1.25+5Khz.

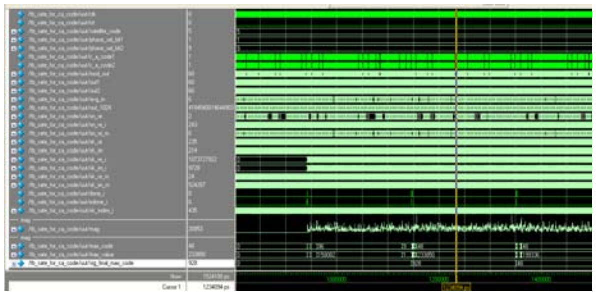

Figure 6: The Acquisition of Satellite 3 with Carrier frequency of 1.25 MHZ +5khz.

VII. CHIPSCOPE RESULTS

The Figure 7 describes the Peak Search for The FFT Based Averaging Correlation of a Gps signal for Satellite no 3.

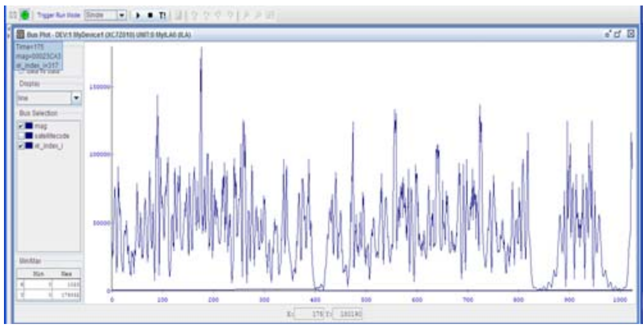

Figure 7:The FFT Based Correlated Peak.

VIII. TEST Analysis Report

The Averaging correlation method, however, shortened the acquisition time significantly using the FFT-based correlation concept. The implementation of this new architecture provided fast acquisition with accurate synchronization without losing much of the signal energy. The implementation was able to process 1-ms of a normal GPS signal in less than 1-ms. Real-time acquisition was achieved when the carrier frequency was determined by a frequency search step. Therefore, the Averaging correlator based architecture is considered a viable solution to the described problems of the slow acquisition with the current GPS receivers. The extension of this work is to Acquisition of GLONASS satellite signal, GALILEO satellite signals. Although there is more research needed to compare this developed averaging correlation method with other acquisition and tracking solutions in both time domain and frequency domain, it must noted that this method will be beneficial to commercial GPS receivers. It can lower the cost of these receivers and at the same time improve the performance, which may make the software frequency domain processing more popular in the civil receivers.

IX. CONCLUSION AND FUTURE RESEARCH

Sl.no		Parameters	Default	1000 chips delay	IF + 5khz	IF + 500khz
1	Test for Default Conditions	Satellite code	3	4	5	6
		Phase selection Bits	{4,8}	{5,9}	{1,9}	{2,10}
		C/A code(Input,Local)	3	4	5	6
		Carrier frequency(Input,Local)	{1.25,1.25}	{1.25, 1.25}	{1.25+5k, 1.25+5k}	{1.25+500k, 1.25+500k}
		Maxcode	982	976	928	976
2	Test for Failure Conditions	Satellite code	3 & 9	4	5	6
		Phase selection Bits	{4,8},{3,10}	{5,9}	{1,9}	{2,10}
		C/A code(Input,Local)	3 & 9	9(delay)	5	6
		Carrier frequency(Input,Local)	{1.25,1.25}	{1.25, 1.25}	{1.25,1.25+5khz}	{1.25,1.25+500khz}
		Max_code	48	48	0	0

VIII.REFERENCES

[1] J.A.Starzyk and Z.Zhu, Averaging Correlation for C/A/code acquisition and tracking in frequency domain.
MWSCS conference, Fairborn, Ohio. Aug 2001

[2]Michael S oudan, Berhard C.Geiger, On the Averaging Correlation for satellite acquisition in software defined radio receivers. 23rd international Technical meeting of the satellite division of the institute of navigation, Portland, OR, Sept 2010

[3]D.Djebouri, Averaging Correlation for fast gps satellite signal acquisition in multipath Rayleigh fading channels. Microwave Journal, Aug 2004 issue

[4]Jing Pang,Direct global positioning system P-Code acquisition field programmable gate array prototyping. P.hD dissertation

[5]Wie Ling Mao, New code delay compensation algorithm for weak gps signal acquisition , ScienceDirect, Elsiever, May 2008

[6]Shaik Fayaz Ahmed, GS Rao,Fast acquisition of gps signal using FFT decomposition. ScienceDirect, Elsiever, May 2016

[7] Helge Glinvad Gron and Group, Allborg University,Acquisition for gps receivers, an investigation for fpga implementation. 2009

[2]Falin Wu and Kefei Zhang,"GPS SIGNAL ACQUISTION AND TRACKING USING SOFTWARE GPS RECEIVER," IEEE Conference on Signal Processing and its Applications, Vol. 2, (2005).

[2] Gunter Heinrichs and Frank Henkel, "A Fully Digital Direct-Sequence Spread-Spectrum Receiver Architecture for GNSS Applications," IEEE Conference on Spread Spectrum Techniques and Applications,_Vol.2, (2000).

[3] Abdulqadir Alaqeeli,Janusz Starzky, Frank van Graas, "REAL-TIME ACQUISTION AND TRACKING FOR GPS RECEIVERS," IEEE Conference on Satellite Navigation,Vol.3, (2003).

[4] Jianfeng Wu ,Yonghui Hu "The Study on GPS Signal Acquisition Algorithm in Time Domain," IEEE Conference on Wireless Communications, Network and Mobile Computing , 12-14 OSct,(2008).

[5] Akos D., "A Software Radio Approach to Global Navigation Satellite System Receiver Design", Ph.D. Dissertation, Ohio University, August 1997.

[6] Xilinx FFT, "High-Performance 1024-Point Complex FFT/IFFT," V2.0,Product Specification, Xilinx Inc., July, 2010.

[7] Xilinx Inc., "Numerically Controlled Oscillator," V.1.0.3, Product Specification, Xilinx Inc., December