Behavior of Vision correlator in Real Time Scenario

Sudarshan Bharadwaj DS
Department of ECE, Cambridge Institute of Technology,
Bengaluru.
Email: sudarshan12355@gmail.com
Contact no: +91 9632610293

Abstract— This paper provides some of the initial performance results of Vision Correlator. Vision Correlator measures and process the synchronization signals of PRN code. Vision correlator has the capability to remove the effects of erroneous signal on the code and carrier measurements. This characteristic of vision correlator makes it a key factor for signal quality monitoring. This paper also provides the experimental results of the vision correlator under varying power levels and compared with the early performance results. It is observed that, the theoretical concepts as stated by the device designer differ when it comes to real time implementation.

Keywords— PRN, VC, RF, GNSS, SPS, MMT, LOS.

Introduction

NovAtel Inc has been gradually implementing many signal processing techniques to reduce the effects of multipath as much possible over years. Several techniques that have been implemented to reduce the multipath effects are listed below:

- Narrow Correlator.
- Multipath Eliminating Technique.
- Multipath Eliminating Delay Lock Loop.
- Pulse Aperture correlator.

Correlation:

Standard Correlation can be done by correlating the incoming signal with a simulated replica of broadcasted pseudorandom number code (PRN). The incoming signal has to be down converted to baseband before correlation. This conversion is needed because the satellite data will be of Giga Hertz (GHz). This Giga Hertz data has to be down converted to mega Hertz (MHz) for simple analysis purpose and to meet the DSP hardware requirements. The standard correlation is mathematically expressed as follows.

$$Cor_t = \sum_{n=0}^{N} s(n) * Cx(n+t)\ t) \qquad (1.0)$$

The outcome of equation 1 represents the sum of the entire down converted base band samples multiplied by a simulated PRN code which is being operated at a particular delay.
Figure1 represents the standard correlation output which is sampled continuously with a code phase delay between ± 1 chip from zero offset. From the figure 1 a deviation from a perfect straight line is seen which is negligible. These deviations are the small variations due to Radio Frequency (RF) anomalies and multipath effect. Due to the summing of data during correlation process a small amount of fine detail of RF chip transitions are lost.

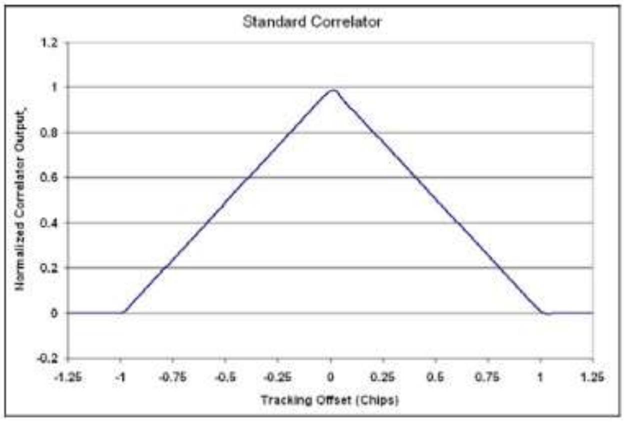

Figure 1: Standard Correlation of GPS PRN1 [1]

Vision Correlator (VC) has a unique hardware to collect the Global Navigation Satellite System (GNSS) signals in the receiver. The basic principle of VC is to measure the RF chip transitions in point detail. The PRN comprises of a unique quality that, it has hundreds and thousands of chip transitions happening every second. The transition of PRN code from 1 to 0 is the replica of 0 to 1 transitions except that they are inverted. Figure2 demonstrates the signal modulation of down converted signal which is the base-band in phase channel during a sequence of PRN code.

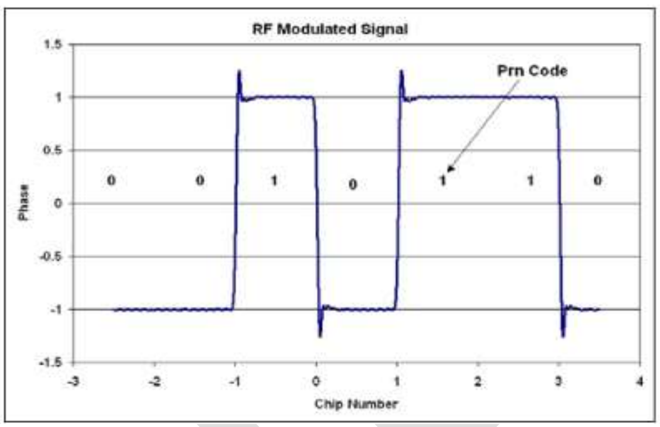

Figure 2: Simulation of Inphase Channel of a receiver in time domain [1]

The vision output is obtained by filtering all the PRN chip transitions over a period of time. This results in the vision output which gives the transitional “shape”. Figure3 represents the bit transition shape which is measured from a particular satellite and GPS receiving equipment.

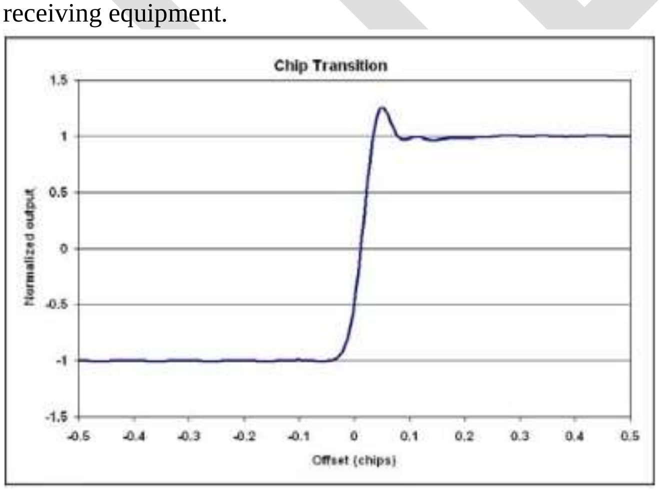

Figure 3: Average chip transition of GPS PRN1 [1]

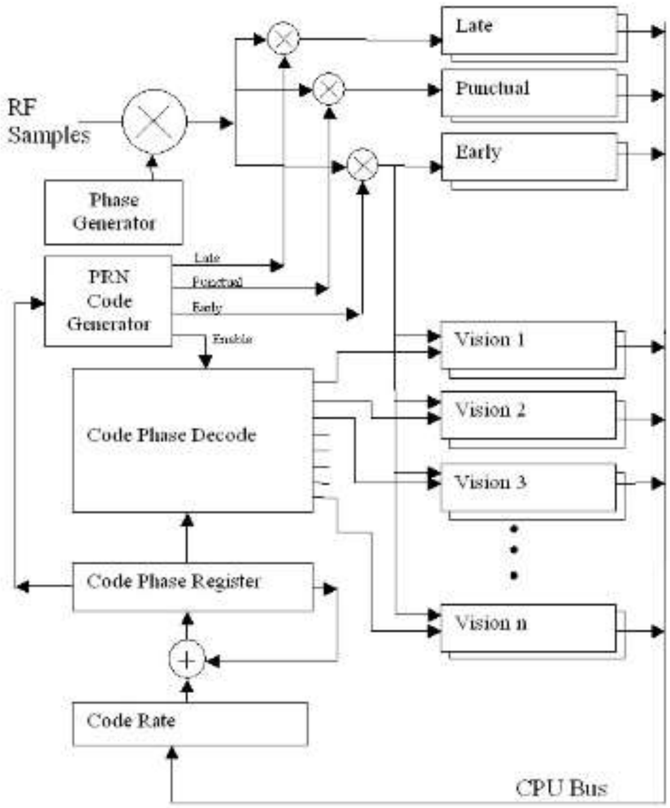

Figure 4: Vision Hardware [1]

Figure 4 gives the hardware circuitry that is necessary to compliment the novel approach towards signal quality and integrity monitoring and also to extract the Vision Data. This advanced hardware setup to extract the vision data superimposes all the chip transitions over a period of time and filters the noise component and gives the average chip transition "shape" over that period of time. These vision samples are then processed through multipath mitigation technique (MMT).

The cross correlation curve for an IRNSS signal is shown in figure 5. The correlation in the figure is between the L5 and S frequency bands for an IRNSS signal. Although the summation process during correlation as stated in equation1 reduces majority of the noise, there are still traces of noise on the PRN code which is seen during the chip transitions from 1 to 0 and 0 to 1. This noise causes a huge spike in the correlation curve which alters the pseudorange of the satellite data resulting in large pseudorange error in the order of several meters. This is a serious threat for navigation and also for the aviation applications.

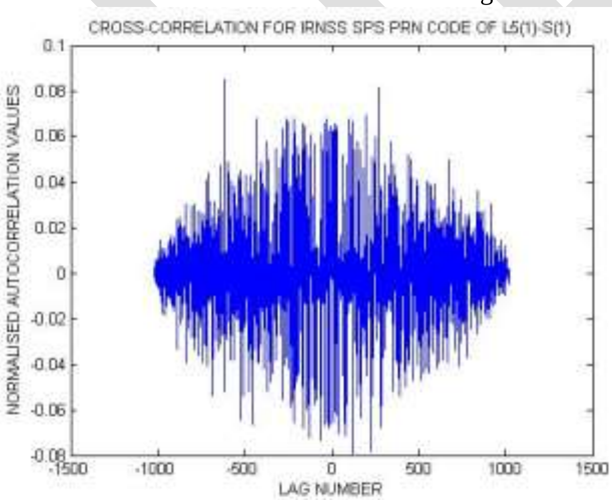

Figure 5: Cross correlation curve for an IRNSS SPS PRN code.

Figure6 illustrates the advantage of Vision Correlator technique over the traditional correlators.

It shows the correlation output with the amplitude of multipath being half of direct path signal and multipath signal delayed by 0.1 chip transitions.

The top curve in figure 6 shows the multipath signal in phase with the direct path signal and the bottom curve shows the multipath signal out of phase of the direct path signal, i.e. phase shifted by 180º in par with the direct path signal.

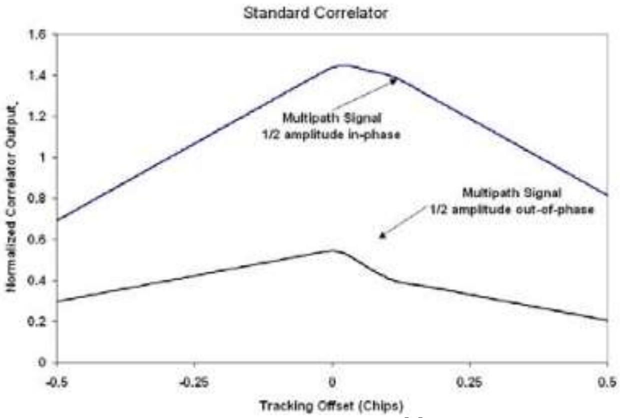

Figure 6: Standard Correlator output [1]

Figure 7 shows the output of Vision Correlator with multipath signal amplitude being half of the direct signal and delayed by 0.1 chips.

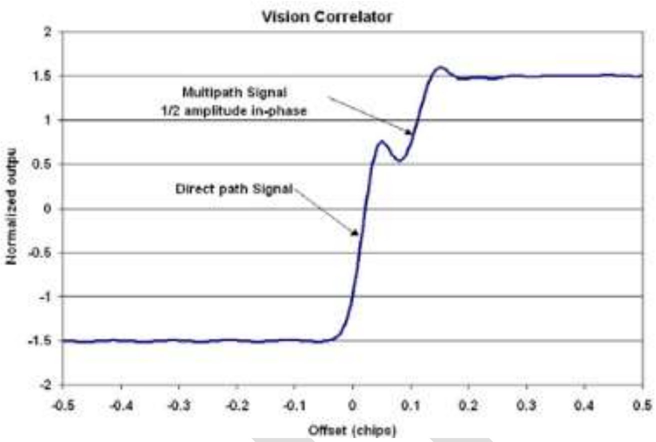

Figure 7: Vision Correlator output with Inphase Multipath [1]

Figure 8 gives the average chip transitions, shape of the Vision correlator when the multipath signal is out of phase from the direct signal.

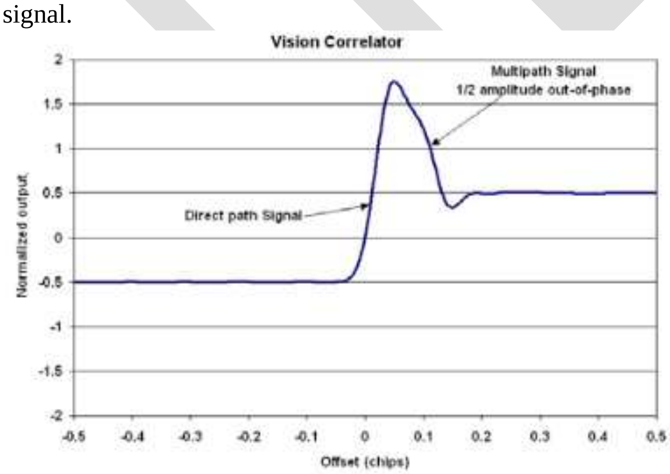

Figure 8: Vision Correlator output with Multipath out-of-phase by 180° [1]

However, the theoretical explanations about the performance and results of vision correlator are quite questionable when implemented practically. The prime purpose of implementing VC is to eliminate the multipath effects on the PRN code. The added advantage of VC

is it can eliminate the close in multipath effects on the PRN code. This helps in improved signal quality monitoring.
The obtained average chip transition of the vision correlator i.e. “shape” appears to be entirely different when experimented. The S-curve of the VC appears between the chip locations -0.1 and +0.1. But as explained earlier, the results are entirely different.
Following figure9 shows the S-curve obtained from the Vision correlator. The multipath signal is Inphase with the direct signal.

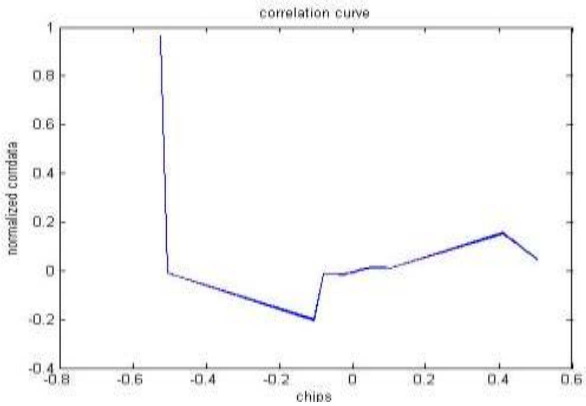

Figure 9: Shape of vision correlator.

Between the chips -0.1 to +0.1 we can see the S-curve obtained from the Vision Correlator as mentioned in Figure7.
The above plot is obtained when the amplitude of the multipath signal being -1db. -1db of attenuation is drawn from the direct signal. This is obtained in the L5 frequency band which has a carrier frequency of 1176.45 MHz The carrier to noise ratio during this stage is 52.4 db which shows to be a clean signal. But we can observe an attenuation of -1db from the received signal. Although this attenuation of multipath signal seems very minimal and negligible, in applications such as aviation this error seems very critical. This causes a large pseudorange error of order of few meters. This is again a serious threat for the airborne users.
Following figure10 gives a comparison between the Vision Correlator output that has been explained with theoretical and the practical plots.
From the figure7 and 9 it is clearly seen that there is a large bias of the signal behavior in real-time when compared to the theory.
Although the required shape has been achieved, the entire signal behavior is changed and appears to be a different one. Conceptually the direct path signal is observed between the locations -0.5 to +0.1 and the multipath signal is obtained between the locations +0.1 to +0.5.
Even when there is no multipath added to the direct signal the output of the vision correlator still remains the same. From these results it is seen that multipath signal can be easily identified and the data between those locations can be discarded. The shape is the cream of the signal which is not affected by multipath.

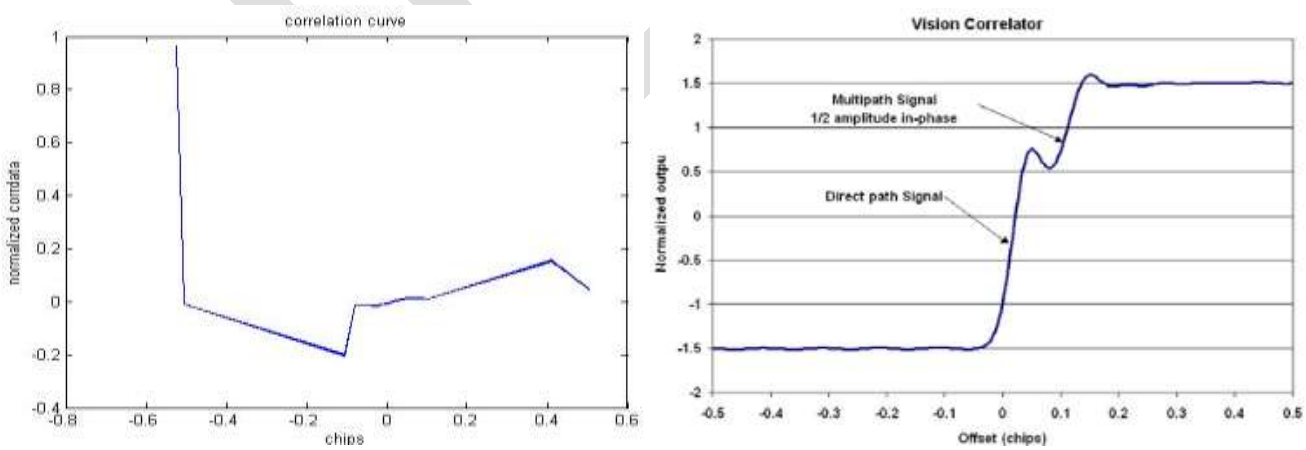

Figure 10: Comparison of VC between theoretical explanation and practical outcome.

In the figure 9, there is only one multipath signal that has affected the Line of sight (LOS).
What happens if there are more than one multipath signals that disturbs the direct signal is still unknown. These analysis and results are just not enough to conclude that the signal between -0.1 and +0.1 is a clean signal and it is not affected by multipath. Since the

amplitude of multipath signal is lesser, the carrier to noise ratio is not deviated much from the routine. What happens if the amplitude of multipath is more than the direct signal and how the S curve is affected because of multipath with higher amplitude has to be known? Also what kind of multipath affect the signal to what extent has to be known before using vision data for aviation application.
The result shown in figure9 is the vision output having single multipath in the LOS. This multipath is ground reflected one, i.e. before it reaches the receiver, the signal is hit to the ground and reflected back along with the direct signal at the receiver. There are several multipath effects such as fixed offset, ground reflection, Doppler offset, vertical plane, reflection pattern, Legendre, polynomial and sinusoidal multipath. Signal behavior under all these multipath scenarios has to be experimented.
Once these different multipath effects are simulated an1d its effects on the signal is studied we can say VC performs the best compared to standard correlator which are in use.

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CONCLUSION:

Vision Correlator provides a significant improvement in detecting and removing multipath signals. It is able to correct for the effects of multipath, where delay from the direct path is as low as 10m.In the test data collected, it showed up to a 50% improvement in reducing the effects of multipath in low elevation angle measurements. It also provides an excellent Signal Quality Monitoring (SQM) capability. Tests showed that the Vision Correlator was able to detect Evil Waveforms caused by unbalanced duty cycle, RF transition ringing and a combination of both. Also, the results show that conceptual explanations differ when it is implemented in real time. The effect of multipath on VC data is lesser when compared to that of existing correlator techniques. Hence Vision Correlator helps to maintain the receiver integrity and can be used for Navigation purpose since it is less prone to multipath and effects due to multipath are easily detected by its correlation curve.

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