PROJECT REPORT

On

DETECTION AND ANALYSIS OF BURST SIGNAL FROM LASER DOPPLER VELOCIMETER USING LAB VIEW.

PROJECT WORK CARRIED OUT AT

EXPERIMENTAL AERODYNAMICS DIVISION, NATIONAL AEROSPACE LABORATORIES, BANGALORE.

A project report submitted to Bharathidasan University in partial fulfillment of the requirements for the award of degree of

BACHELOR OF ENGINEERING
IN
ELECTRONICS AND COMMUNICATION

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This is to certify that the project work titled **"DETECTION AND ANALYSIS OF BURST SIGNAL FROM LASER DOPPLER VELOCIMETER USING LAB VIEW"** is a bonafide record of the work done by

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Carried out at **NATIONAL AEROSPACE LABORATORIES**, Bangalore in partial fulfillment of the requirement for the award of Degree of Bachelor of Engineering in Electronics and Communication of Bharathidasan University, Thiruchirapalli.

Internal Guide **External Guide**

Internal Examiner **External Examiner**

Date :
Place :

CERTIFICATE

This is to certify that the Project report entitled :

"Detection and Analysis of Burst Signal from Laser Doppler Velocimeter using Lab View"

submitted by

Manoj Kumar.A **Ganesh Ram.R**
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in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF ENGINEERING
in
ELECTRONICS AND COMMUNICATION,

Bharathidasan University

is a bonafide record of the work carried out at

NATIONAL AEROSPACE LABORATORIES, Bangalore

from 2 January 2003 to 20 March 2003

under my supervision and guidance.

Signature of the Guide

Date :

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We wish our sincere thanks to our project guide Mr. J. Palanivel, HOD, Department of Electronics and Communication Engineering, A A M Engg. College for his encouragement and support.

DECLARATION

We hereby declare that the entire work embodied in this dissertation has been carried out by us and no part of it has been submitted for any degree or diploma of any institution previously.

Signature of Students

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ABBREVATIONS USED

LDV	-	Laser Doppler Velocimeter.
Df	-	Doppler Frequency.
PM	-	Photo Multiplier.
DCA	-	Double Clipped Auto-Correlation.
FFT	-	Fast Fourier Transform.
SNR	-	Signal to Noise Ratio.
Th.	-	Threshold.
VI	-	Virtual Instrumentation.

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   by *(Aleksander Zavaljevski, Goran Zivanovic)*

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4. Statistical Theory of Communication by *W.Y.Lee*
5. Lab View Manual by National Instruments.

AIM:

To Detect and Analyze the Burst Signal from Laser Doppler Velocimeter using the Frequency Domain Methods.

OBJECTIVES:

Simulation of Burst Signal generation and analysis in Virtual Instrumentation Software – Lab View.

Analysis of burst signal using

- Fast Fourier transform
- Double clipped autocorrelation

Validation of signal processing by plotting various graphs.

IMPORTANCE OF OUR PROJECT:

Laser Doppler Velocimeter is being applied in many fields especially in Experimental Aerodynamics. The processing of signals (i.e. Burst Signals) from it gains greater importance as it results in

- Measurement of flow velocity in unknown direction.
- More accurate result than other existing methods.
- Measurement of true velocity component.
- Accurate measurements in unsteady and turbulent flows.

INTRODUCTION:

LASER DOPPLER VELOCIMETER

Laser Doppler velocimetry is a measuring method which allows the absolute Determination of the velocity distribution in flowing media. The functional principle is Based on the optical Doppler Effect (Christian Doppler 1803-1852), which effects a Frequency shift DF of electro magnetic waves, which are reflected on moving objects With the velocity $\mathbf{V}_{object}$, compared to the frequency of the pristine light wave.

This frequency shift is proportional to the velocity of the object:

$$\mathbf{V_{object}} \sim \mathbf{D\ f}\ .$$

Therefore, by comparing the frequency of the original and the reflected light beam, it is possible to determine the velocity of a flowing medium. It also senses true velocity component, and measures that component in a sequence of near instantaneous samples.

The following can be stated as the reasons for choosing laser in LDV

1) Well-collimated, which means the beam will not diverge or change in size much;

2) Highly coherent, meaning its electromagnetic wave fronts are all in phase; and

3) Nearly monochromatic, which means that the radiation is composed of a very narrow range of wavelengths.

Thus, it is ideal for making measurements of Doppler shift

PRINCIPLE :

Laser Doppler Velocimetry is based on the frequency shift of the light scattered by any particle, optical heterogeneity or moving surface (Doppler effect), illuminated by a beam of monochromatic and coherent light : the frequency shift induced by Doppler effect is proportional to the velocity of the particle.

The expression relating velocity and Doppler shift is given by

$$\mathbf{V = (\Delta f * \lambda) / 2 \sin \beta}$$

V - velocity of flow

Δf - Doppler shift in frequency

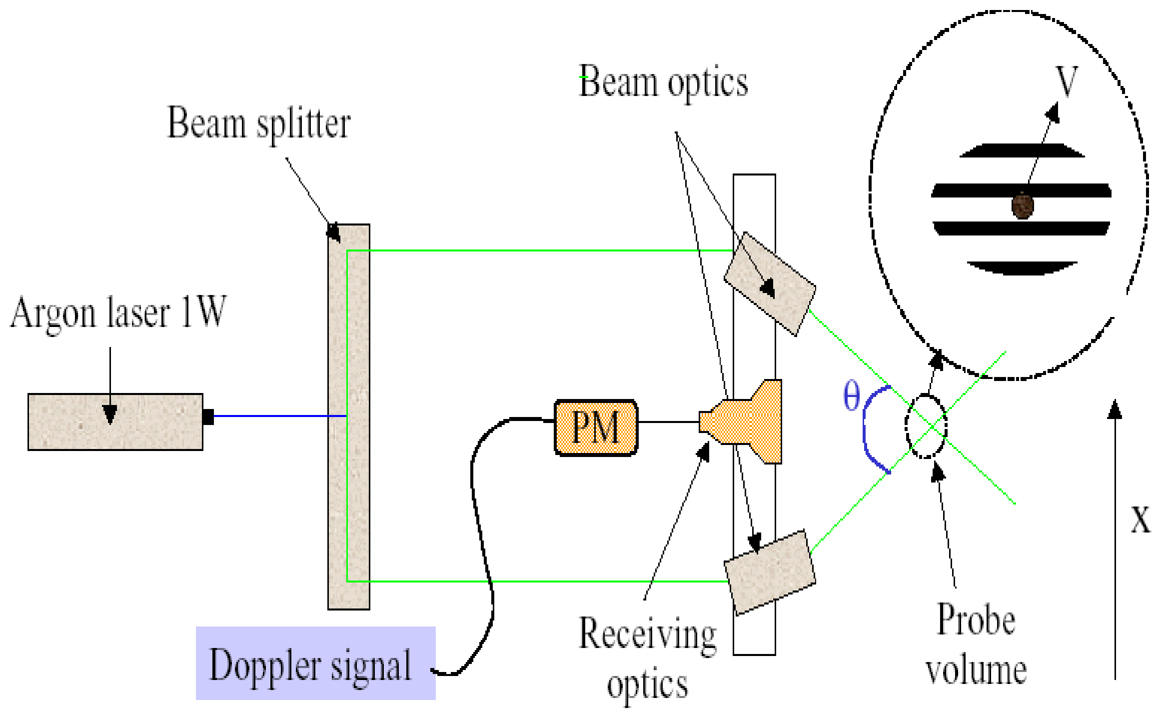
λ - wavelength of the laser beam used.

β - angle between the two interfering lasers.

ADVANTAGES OF LDV

- It is a non-intrusive technique.
- Physical principle is depending directly from a direct measurement of speed and not from a parameter which can be connected to speed i.e. no flow calibration required.
- Phenomenon to be measured is not disturbed by measurement
- Very high measurement dynamics.
- As sensor is not within the medium to be investigated, measurements can be realized in harsh environment.
- Precise measurement of velocity components.

EXPERIMENTAL SETUP:



WORKING:

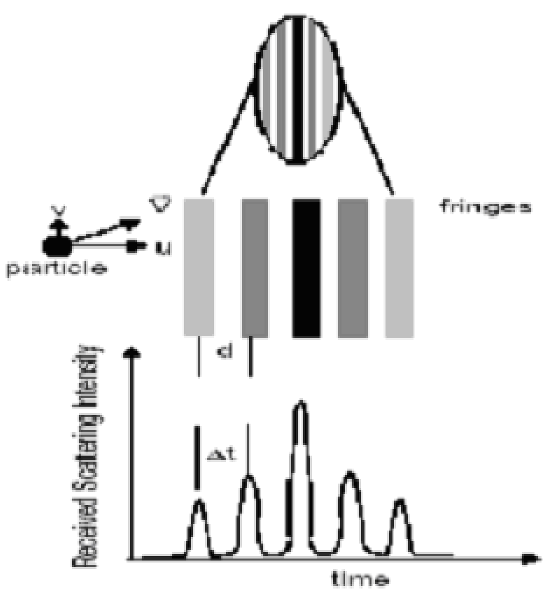
The above figure shows a One-component dual-beam system. It is One component because it measures one specific velocity component (X in the diagram) and Dual beam as it uses two laser beams of equal intensity.

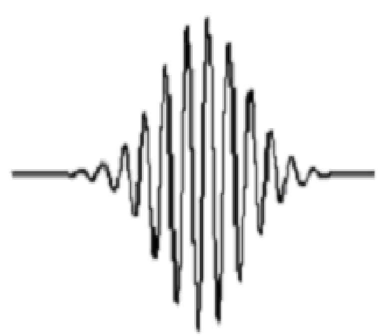
The beams are generated from a single laser using a half silvered mirror (the 'beam splitter'). They are then focused using a lens (called the sending lens). The lens also changes the direction of the beams causing them to cross at the point where they are focused. The region where the beams intersect is where the velocity measurement is made. It is called the measurement volume or probe volume.

The interference of the light beams in the measurement volume creates a set of equally spaced fringes (light and dark bands) that are parallel to the bisector of the beams. A measurement is made when a tiny particle being carried by the flow passes through these fringes. As it does so the amount of light received by the particle fluctuates with the fringes. The amount of light scattered (i.e. reflected) by the particle therefore also fluctuates. The frequency of this fluctuation is proportional to the velocity of the particle normal to the fringes.

To detect this frequency, the light scattered by the particle is collected by a second lens (the receiving lens) and focused onto a photo detector which converts the fluctuations in light intensity into fluctuations in a voltage signal which is then processed to get the velocity of flow.

GENERATION OF THE FRINGES [JET LDV]





Doppler Signal

Since laser light is monochromatic (i.e. of one frequency and wavelength) and coherent (all adjacent and successive waves are in phase) all the peaks line up. In the measurement volume the two sets of light waves cross. Where the interfering light waves are in phase (peak aligned with peak) they add up creating a bright fringe.

Where the light waves are out of phase (peak aligned with trough) they cancel creating a dark fringe. As can be seen in Figure , the bright and dark fringes form in lines parallel to the bisector of the beams and the corresponding output Doppler signal.

SEEDING:

As mentioned above tiny particles must be present in the flow for a measurement to be made. These are referred to as seed particles, or just seeding . It is important that these particles be small enough (diameter in micron range)[ld France] to accurately follow all the movements of the flow. That way, when we measure the velocity of the particles, we are also measuring the velocity of the flow. Materials used for particles include latex (as in latex paint) or oil, water droplets.

As the particles form only a minuscule fraction of the volume of the fluid. They therefore have no significant effect upon the flow.

THE PROBLEM OF DIRECTIONAL AMBIGUITY - FREQUENCY SHIFTING :

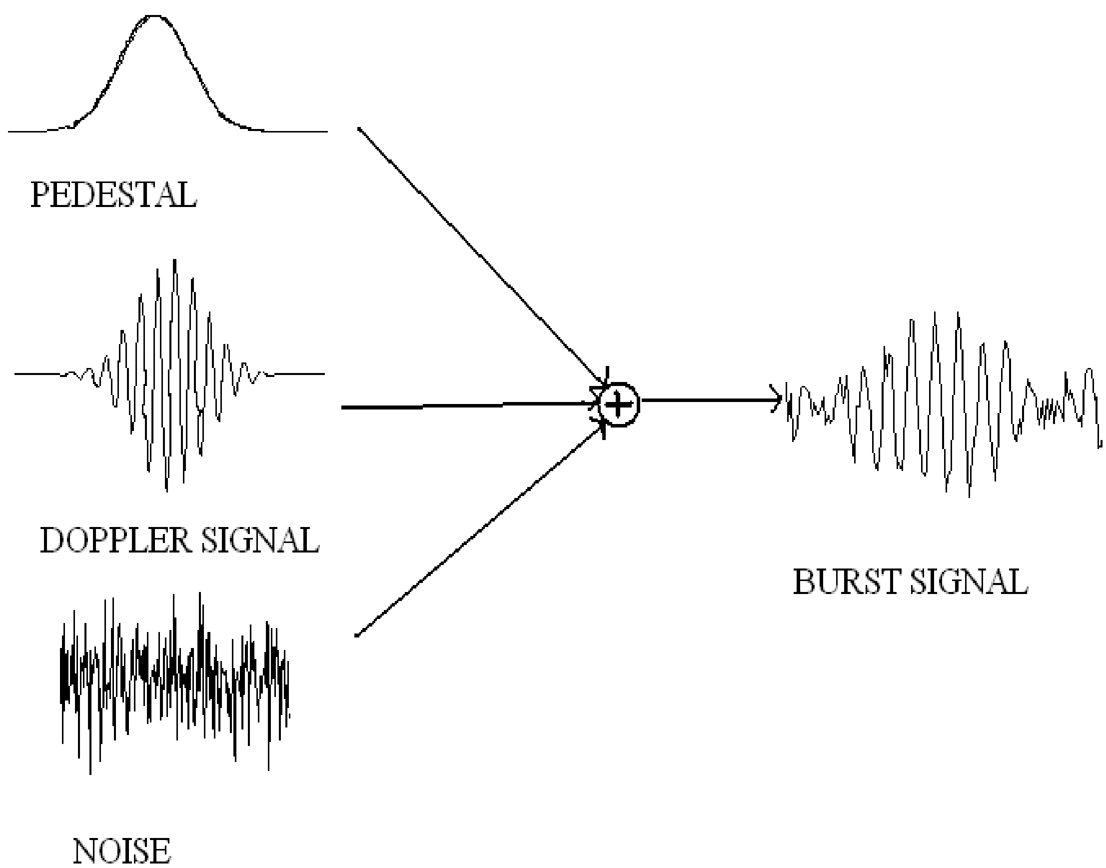
As we have described it so far, an LDV system effectively measures the frequency at which a particle crosses a series of equally spaced fringes. This technique has two serious limitations - a stationary particle produces no signal and, more seriously, two particles moving with the same speed but in opposite directions will give rise to indistinguishable signals.

Both problems may be solved by slightly shifting the frequency of one of the laser beams. This causes the fringes in the measurement to volume to move at a constant speed in the directions depending on the direction of the frequency shift. Stationary particles exposed to these moving fringes now produce signals of constant frequency (this frequency turns out to be the same as the frequency shift). Particles moving with the fringes produce signals of lower frequency than this and particles moving against the fringes produce signals of higher frequency, the frequency difference still being determined by the LDA equation. The directional ambiguity is thus removed.

The most common device used to produce the frequency shift is called a Bragg cell. The Bragg cell contains a transparent medium (either liquid or solid) through which the laser beam passes. The medium is excited by passing ultrasonic sound waves through it. These sound waves (which are also density waves and therefore waves of refractive index) diffract the laser beam. Since they are moving they also shift its frequency, by an amount equal to the frequency of the sound wave.

NATURE OF THE SIGNAL:

COMPONENTS:



from the above diagram it can be seen that the output signal from the photo detector is not exactly the Doppler signal which we require for processing but it contains noise components of electrical and background noises.

PROPERTIES:

The following properties prove a challenge in processing the Doppler signals,

- The seed particles which pass through the fringe pattern are random so the Doppler signal that is generated is also random (Gaussian distributed).
- In a general way, if the particles concentration within the measuring volume is increasing, Doppler modulation will be more and more reduced, and, for a too high concentration, completely annihilated. Hence it is influenced by particle density and also by size.
- The other important limitation which forces us to move towards faster signal processing is that it consists only fewer number of cycles (say <30).

- The electrical and external noises present in it deform the actual waveform due to which we require more sophisticated processing methods.
- And addition to these properties the widely varying

  Transit time for each burst

  Amplitude range

  Signal to noise ratio

  Frequency range

really prove a challenge for the signal processing

So ultimately we have to focus on a way to Detect and Process the Burst Signals in order to get the Velocity of flow through Frequency.

VARIOUS SIGNAL PROCESSING TECHNIQUES:

In time critical measurements of flow using a laser Doppler velocimeter, performance of the processing technique involved in one of the most important factors.

The conventional electronic processing systems used were as follows:

- Spectrum analyzer
- Frequency tracker
- Period counter
- Photon autocorrelation
- Transient recorders and computer processing
- Frequency domain real time processor

Spectrum analyzers can directly be linked to the photo detector and provide a direct frequency analysis of the signals. For low frequencies, a real time analysis of the signals may be done using a standard real time spectrum analyzer.

Swept filter spectrum analyzer may also be used but statistical results only will be provided.

The frequency tracker is a local oscillator that continuously “tracks” the frequency of the signal. A voltage analogue of the local oscillator frequency provides a real time output of the velocity. Although frequency trackers are still in use in some laboratories, they have rapidly been superseded by period counters. Their main limitations were the need of a high rate of seeding and low drop out of signals and their limited ability to follow high turbulence levels.

The period counter is very simple in practice: a fast clock the period of each signal corresponding to the passage of individual particles within the probe volume.

The photon correlator gives the autocorrelation of the arrival of photons. The most probable time of collection of a photon corresponding to the moment of a particle is passing at the peak of a bright fringe, the most probable interval between photons is related to the distance between bright fringes by the velocity of the particles.

Transient recorders have been used for both low and high frequencies. The direct Doppler signal is digitized and processed by a computer in order to extract the Doppler frequency. Depending upon the software used, large noise rejection could be made and relatively noisy signals may be processed. The drawback of this procedure was that only data rate was achieved.

Spectrum analysis is interesting for low frequency signals and for first analysis at higher frequency ones.

Frequency trackers were best used in low turbulence flows(or small fluctuations)and when many scattering centers were present.

Period counter needs a sophisticated logic to reject noise and “wrong signal”. It can be used in the same situations as the frequency trackers but it has the advantage of being suitable for very low numbers of scattering centers and large velocity fluctuations.

.

The drawbacks in the above said signal processing methods drives us to the frequency domain real time processing. It consists of the following two methods :

- Double clipped Auto-Correlation.
- Fast Fourier Transform.

They are capable of dealing with lower signal to noise ratios. In our project we use this frequency domain method for detecting and analyzing the signal from LDV.

FREQUENCY DOMAIN METHODS:

Theoretically, FFT and Autocorrelation are inverse transform pairs and therefore should yield the same results. However each technique displays its results differently. The results of the Fourier analysis are displayed as spectrum plots providing amplitude and frequency information of the signal. On the other hand Auto-correlation results are displayed as coherency plots, where the amplitudes of Correlation coefficients are directly related to the coherency of the signals of interest.

At this moment the main objective of our project can be narrowed down to the following:

- Detection and Validation of the burst signal out of the noised burst.
- Processing of the burst signal using the above mentioned frequency domain real time processing techniques (FFT & DCA) to get the velocity through frequency.

The important parameters that must be considered for signal processing are

Signal to Noise ratio

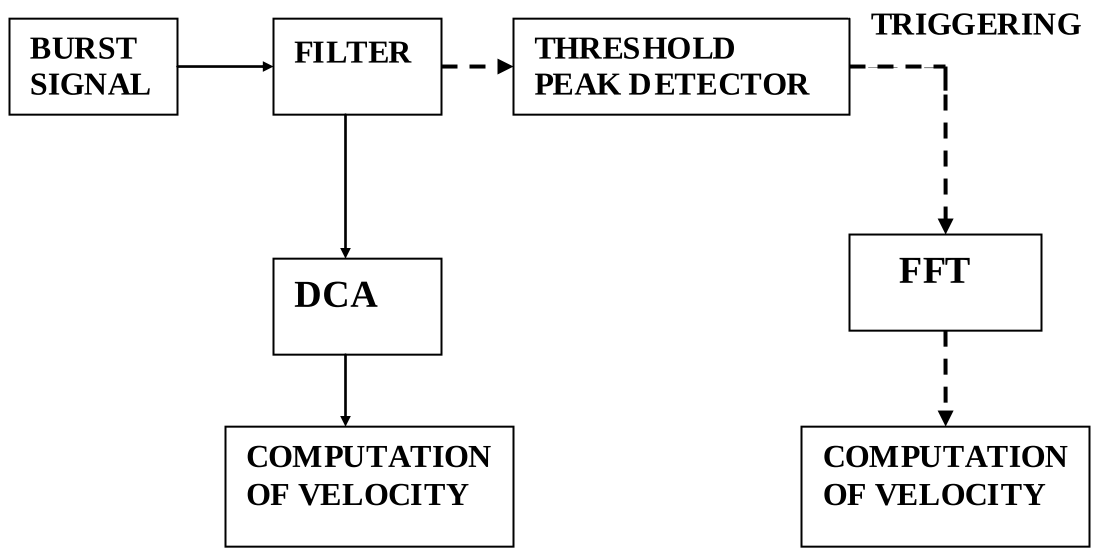
Sampling information

Threshold value levels

Filter parameters.

Further steps to be followed for signal processing using frequency domain real time technique can be well explained with the help of the following block diagram:

BLOCK DIAGRAM:



GENRAL OUTLINE:

At this juncture the important task ahead of us is to ensure that we are processing the valid burst to get the desired results. So we go for different burst validation techniques.

From the block diagram it can be well established that we follow two methods of signal processing (DCA & FFT).

The burst signals that are generated are filtered first to get rid of various electrical and background noises. But this filtering does not ensure that we are going to process the valid burst signal and not a noise that closely resembles the burst. So we are going for a burst validation technique called PEAK DETECTION. In peak detection we differentiate the Noise and valid burst signal by computing and comparing the peak amplitudes of the signal. Upon detecting the valid signal the peak detector triggers the FFT block to immediately process that and if a noise signal is detected there is no triggering to the FFT block. This is how the peak detection guarantees that we process the valid burst.

It can also be seen that the peak detection is used only for computation of velocity through FFT because the use of double-clipped Auto-correlation itself takes care of detection of valid burst signal and the calculation of frequency from the Correlogram. This eliminated the need for the separate procedure to detect and confirm that a given signal is a valid burst signal from Laser Doppler Velocimeter and not Noise.

This method can be used for large span of frequencies and also very easy to implement.

In the methods of Fast Fourier Transform we plot the spectrum of the signal from which we find the frequency of the signal by measuring the value of the highest component in the spectrum.

The Double clipped Auto-Correlation (DCA) refers to the degree of correspondence between a code and a phase shifted replica of itself.

This DCA gives some valuable results upon plotting the Correlogram, out of which we get the information about the validity of the burst and its frequency.

The frequency computed using by any of the methods mentioned above can be used in velocity calculation by following the expression:

$$\mathbf{V = (\Delta f * \lambda) / 2 \sin\beta}$$

The important thing is that utmost care must be taken to make sure that we are processing a valid burst otherwise it may cause havoc.

Now the objective of our project can be broadly classified into the following two modules:

- Detection and Validation of the Burst.
- Computation of frequency from which the velocity can be calculated

.

THEORETICAL EXPLANATIONS :

BURST DECTECTION AND VALIDATION TECHNIQUES:

THRESHOLD PEAK DETECTOR TECHNIQUE :

This is the technique which we use for burst detection and validation is the Threshold Peak Detection.

The objective of this peak Detection must be

- Elimination of Noise signal based on threshold voltage.
- Identification of the valid burst by comparing the peak values of the signal.
- Faster and Rugged Validation.

We start the peak detection by fixing a optimum threshold value say milli volt range to eliminate noise. The burst signal input to the peak detector is first compared with a threshold. The signals that are above the threshold are allowed to pass to the next stage. The threshold value is fixed so that it is always less than the burst signal amplitude. By the way the noise signals whose amplitude is less than the threshold is stopped from passing through the next stage, but there is more bad news this threshold validation does not fulfill our requirement of complete elimination of noise. This due to the fact that some of the noise amplitudes may exceed the threshold and got to the next stage. It is here the comparison of successive peak amplitudes of the signal comes into the picture.

Here we exploit the nature of the burst signal that the rise in the peak amplitudes of the successive peaks in a valid burst signal is regular and periodical till we reach the falling edge of the signal. As we cannot expect noise to have such a property we can well use this for the elimination of noise above the threshold level. So what we do here is that we compare the peak ratio of the successive peaks of the signal that passes out of the first stage and if this peak ratio is with in the optimum level and if its variation is regular and periodical we allow that to pass to the next stage of signal processing else we block the signal as noise. Upon finding the valid burst the peak detector triggers the FFT block to process the signal.

This algorithm is more powerful and efficient to eliminate all type of noises which satisfies our most desired need of detection of a valid burst that can be used for the processing.

CORRELOGRAM TECHNIQUE :

This is the technique which we follow for burst validation if we use Double Clipped Auto-Correlation for Signal Processing. In the case of the Double Clipped Auto-Correlation we plot a Correlogram which has peaks only if the shift between the two correlated sequences is Zero. Such a property of correlogram helps it to answer the following questions :

Are the data random?

Is the observed time series noise or sinusoidal?

Is the observed time series autoregressive?

Is the observation related to an adjacent observation?

We use the answers to these above mention questions to detect and validate the burst. We do this first by plotting the correlogram and by looking for the symmetry of the plot about the highest peak corresponding to the Zero shift between the sequences as a whole. We can conclude that the plotted correlogram is right. Our task doesn't end here, we continue to look for the peak values of the successive peaks and compute the peak ratios.

For a valid burst signal this peak ratio will be well with in a fixed threshold value and for a noise signal the peak ratios will surely exceed the fixed threshold. Thus depending upon the comparison results of the peak ratio result with the threshold we can differentiate noise and valid burst. This clearly shows that the correlation coefficients are directly related to the coherency of the signals of interest. That is why this correlogram technique has the following distinct advantages over the peak detection technique:

- Does not need any external triggering .
- Faster validation and validation of signals.
- Well suited for the analysis of Low SNR signals.

As we have completed one of the prime objectives of our project (Burst Validation) successfully, we can step forward towards the processing of the valid burst signals.

SIGNAL PROCESSING:

For the processing of signals from LDV we go for Frequency Domain Real Time Processing. The distinct advantages of this method of processing over the other existing methods dragged to opt for this. Here there are two processing techniques:

- Fast Fourier Transform
- Double Clipped Auto-Correlation

Basically the above two methods are inverse transform pairs and therefore should yield the same results. However the difference is in the way in which they display the results. The results of the Fourier analysis are displayed as spectrum plots providing amplitude and frequency information of the signal. Whereas the Auto-correlation results are displayed as coherency plots, where the amplitudes of Correlation coefficients are directly related to the coherency of the signals of interest.

FAST FOURIER TRANSFORM TECHNIQUE:

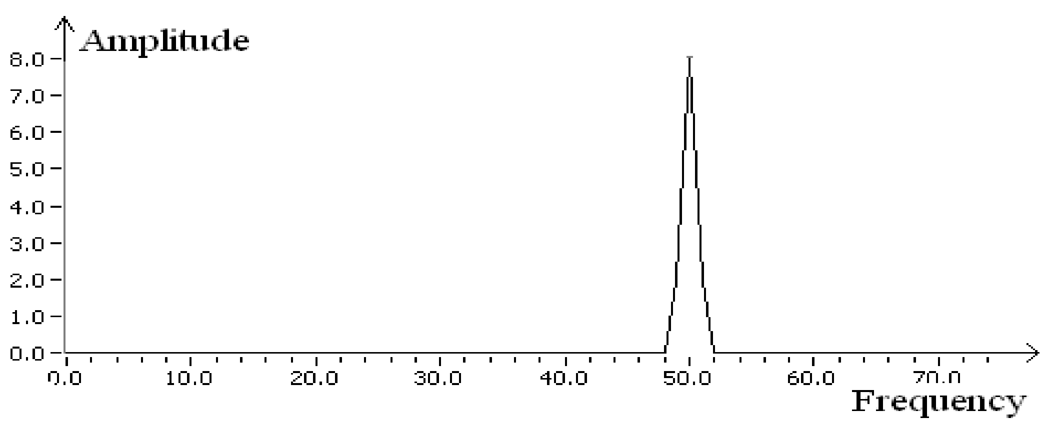
The process of obtaining the spectrum of the given signal using a mathematical tool is known as frequency or spectrum analysis. This frequency analysis involves the resolution the signal in to its frequency (sinusoidal) components. This resolution must be in the form that we must get the original waveform upon summing these sinusoidal components back.

One such powerful and efficient mathematical tool for spectrum analysis if the Fourier Transform. The Fourier Transform for discrete time signal is given by:

$$X(K) = \sum_{n=0}^{N-1} x(n) * \exp(-j*2*pi*n*k/N) \; ; \quad k=0\ldots\ldots N-1$$

As the above process involves more number of multiplications and additions to make it faster we go for Fast Fourier Transform. Using FFT we can plot the power spectrum of the signal. Power spectrum is the one which gives the information about the range of frequencies over which the power of the signal is fed. In the power spectrum the peak power corresponds to the frequency of the signal which is input to it. This property of power spectrum can be used for detecting the frequency of the burst signal.

The following example shows the power spectrum of a sinusoidal signal of frequency **50 Hz** .



From the above power spectrum it can be seen that there is a peak at 50 Hz which corresponds to the transformed frequency.

AUTO-CORRELATION:

Autocorrelation refers to the degree of correspondence between a code and a phase shifted replica of itself. Autocorrelation plots show the number of agreements minus disagreements for the overall length of the two codes being compared for every shift in the field of interest. Such a plot can be generated easily with a pair of code generators or a computer simulation.

The plot of code correlations for the linear maximal sequences is two valued, with a peak only at the zero shift point. This is an invaluable property because it allows to discriminate between signals on a yes-no basis.

The autocorrelation of the sampled data depends on code type ,code length ,bit rate and even the bit by bit structure of the particular code being used. Autocorrelation in general is defined as below:

$$\mathbf{S(k) = \sum_{n=0}^{N-1} A(n) \;\; XNOR \;\; B(n + k)\ ; \;\; k = 0\ldots\ldots N\text{-}1.}$$

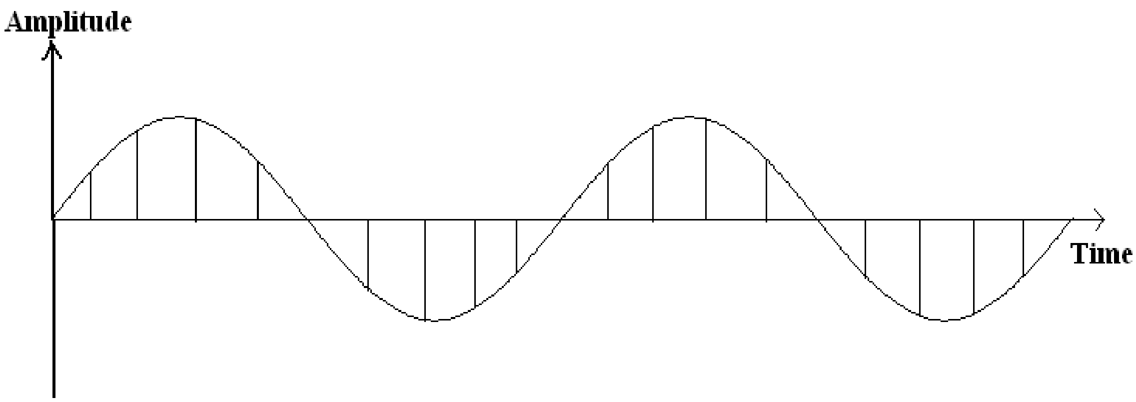
where

A(n) is the code

B(n) is the phase shifted replica of A(n)

k is the number of shifts from 0 to N-1

Let us consider the following example to show how autocorrelation can be used for signal processing. The following depict the signal to be processed using auto correlation.

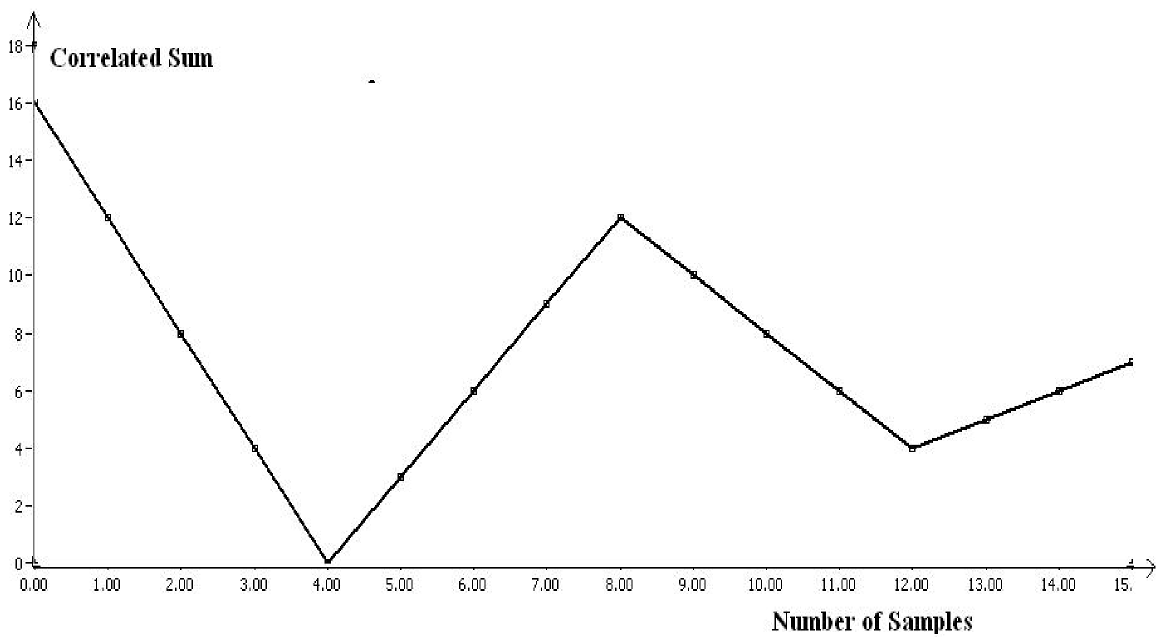


The samples shown in the above diagram is compared with a threshold value (say 0). The sample values above the threshold are assigned as “1” else “0”. The corresponding sequence is **1111000011110000**. this sequence is auto correlated with its zero padded sequence **111100001111000000000000** as follows:

Number of shifts	Shifted Sequence	Correlated Sum
Original Sequence	**1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0**	
0	**1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0**	**16**
1	**0 1 1 1 1 0 0 0 0 1 1 1 1 0 0 0**	**12**
2	**0 0 1 1 1 1 0 0 0 0 1 1 1 1 0 0**	**8**
3	**0 0 0 1 1 1 1 0 0 0 0 1 1 1 1 0**	**4**
4	**0 0 0 0 1 1 1 1 0 0 0 0 1 1 1 1**	**0**
5	**0 0 0 0 0 1 1 1 1 0 0 0 0 1 1 1**	**3**
6	**0 0 0 0 0 0 1 1 1 1 0 0 0 0 1 1**	**6**
7	**0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 1**	**9**
8	**0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0**	**12**
9	**0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0**	**10**
10	**0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0**	**8**
11	**0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0**	**6**
12	**0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1**	**4**
13	**0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1**	**5**
14	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1**	**6**
15	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**	7
16	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**	**8**

From the above table it can be seen that maximum correlated sums corresponds to the 0,8,16 shifts of the sequence. By the property of auto correlation it can be understood that at these maximum sum points there is zero shift between the correlated sequences.

The auto correlogram for the above table is as follows.



Hence the period between the two peaks can be interpreted as the time period of the signal which in turn gives the frequency of the signal. This is how auto correlation is used to compute the frequency of the given signal.

PRACTICAL IMPLEMENTATION:

INTRODUCTION TO LABVIEW:

Lab view a Software developed by National Instruments is used for Virtual Instrumentation. It can run on any windows platform. It is a graphical programming language that uses icons instead of lines of text to create applications. In contrast to text-based programming languages, where instructions determine program execution, LabVIEW uses dataflow programming, where the flow of data determines execution.

In Lab VIEW, we build a user interface by using a set of tools and objects. The user interface is known as the front panel. We then add code using graphical representations of functions to control the front panel objects. The block diagram contains this code. In some ways, the block diagram resembles a flowchart.

LabVIEW programs are called Virtual Instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters. Every VI uses functions that manipulate input from the user interface or other sources and display that information or move it to other files or other computers.

A VI contains the following three components:

• Front panel — Serves as the user interface.

• Block diagram — Contains the graphical source code that defines the functionality of the VI.

• Icon and connector pane — Identifies the VI so that you can use the VI in another VI. A VI within another VI is called a Sub VI. A Sub VI corresponds to a subroutine in text-based programming languages.

FRONT PANEL :

We build the front panel with controls and indicators, which are the interactive input and output terminals of the VI, respectively. Controls are knobs, push buttons, dials, and other input devices. Indicators are graphs, LEDs, and other displays. Controls simulate instrument input devices and supply data to the block diagram of the VI. Indicators simulate instrument output devices and display data the block diagram acquires or generates.

BLOCK DIAGRAM :

After building the front panel, we add code using graphical representations of functions to control the front panel objects. The block diagram contains this graphical source code. Wires are used to connect various components of block diagram.

The block diagram consists of the following three components:

- Terminals
- Nodes
- Structures

TERMINALS:

Front panel components appear as terminals in the block diagram. These terminals are entry and exit ports that exchange information between the front panel and block diagram. Data we enter into the front panel controls enter the block diagram through the control terminals.

NODES :

Nodes are objects on the block diagram that have inputs and/or outputs and perform operations when a VI runs. They are analogous to statements, operators, functions, and subroutines in text-based programming languages.

STRUCTURES :

Structures are graphical representations of the loops and case statements of text-based programming languages.

IMPLEMENTATION IN LABVIEW:

After the exhaustive theoretical approach for burst detection and signal processing. Now let us turn our pages to the implementation of it in Lab View.

This implementation can be broadly classified into the following:

- Generation of burst signal from LDV
- Burst detection and validation
- Computation of frequency through FFT
- Computation of frequency through double clipped autocorrelation.
- Computation of velocity through frequency.

The various block diagrams involved in our project and their explanation are as follows:

GENERATION OF BURST SIGNAL FROM LDV:

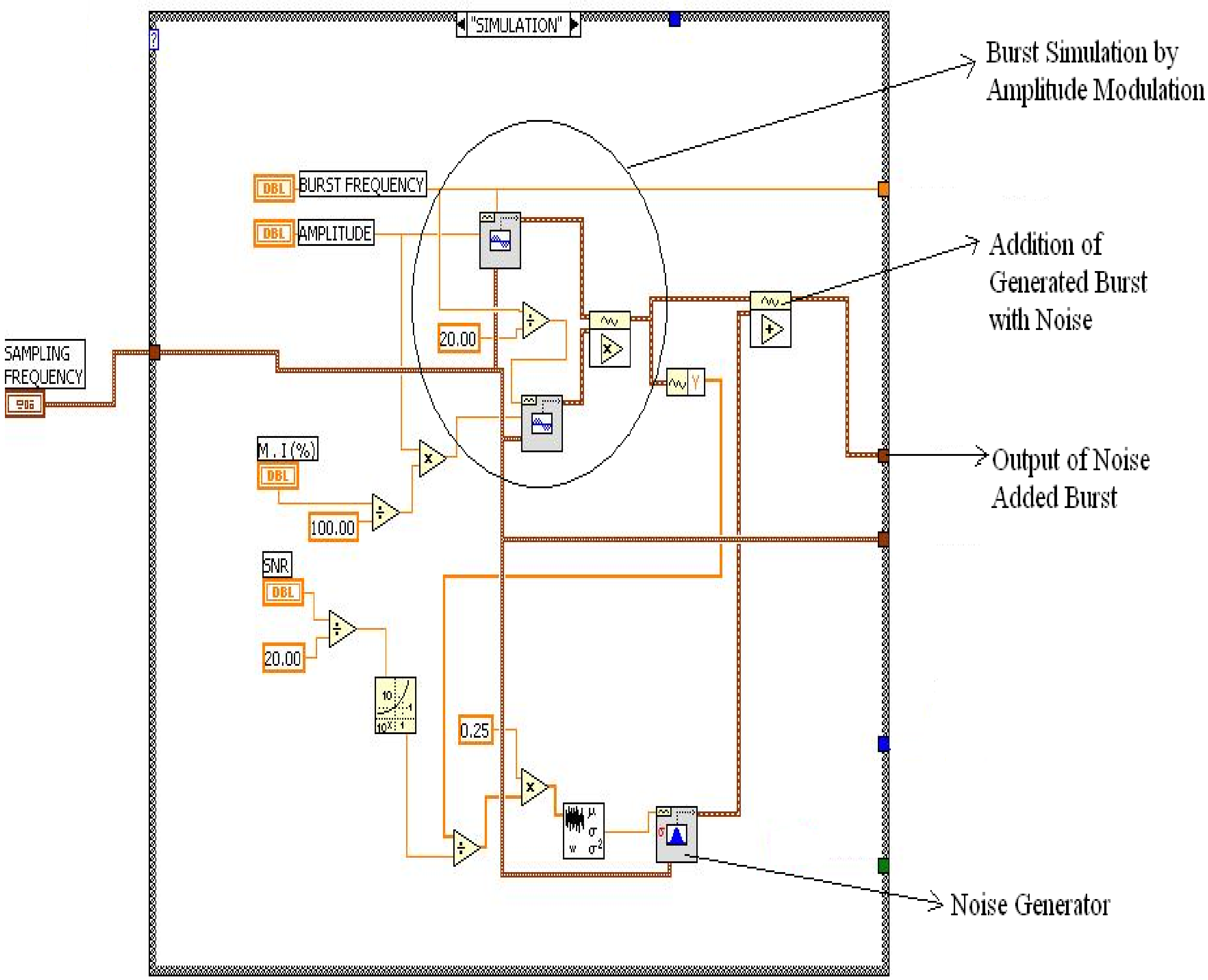
In order to process the burst signal from LDV first it becomes necessary to generate the signal. This generation can be effected by the following methods:

- Simulation of burst signals.
- Generation of burst signal by reading samples from a file.
- Direct real time acquiring of burst signals.

SIMULATION OF BURST SIGNALS :

The burst signal output from LDV almost resembles an amplitude modulated signal. So the basic idea behind simulation is the generation of an amplitude modulated signal. The block diagram for this simulation is as shown below

Modules For Simulation of Burst Signal From LDV



From the block diagram it can be seen that amplitude modulation is performed by using a multiplier which multiplies the sine waves generated by two sine wave generators.

As we have already seen the signals from LDV constitutes various electrical and background noises. In order to bring this situation exactly in our simulation we are adding a random noise generated by a noise generator. The characteristics of the noise output from the noise generator are controlled by the SNR value which we specify. Thus we get the burst signal to which the noise of desired Decibel is added.

The simulated noise added burst then passes to the next stage of processing through the output terminal.

BLOCKS IN THE SIMULATION

SIGNAL GENERATOR:

Using a signal generator we generate a sine waveform. Let us represent the sine waveform by the sequence ‘Y’. Then the VI generates the pattern according to the following formula:

Y[i] = amp * sin (phase [i]) , for i = 0, 1, 2, ..., n-1,

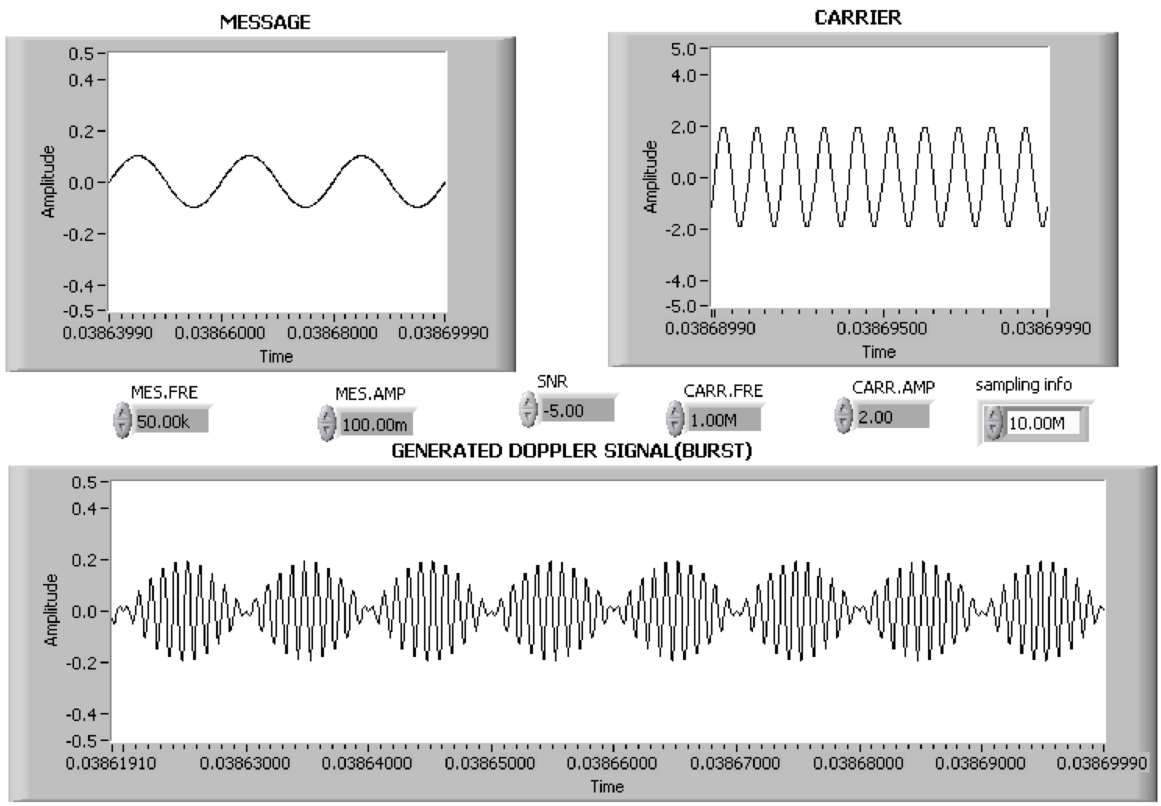
INPUT PARAMETERS:

- Frequency
- amplitude
- Sampling Information

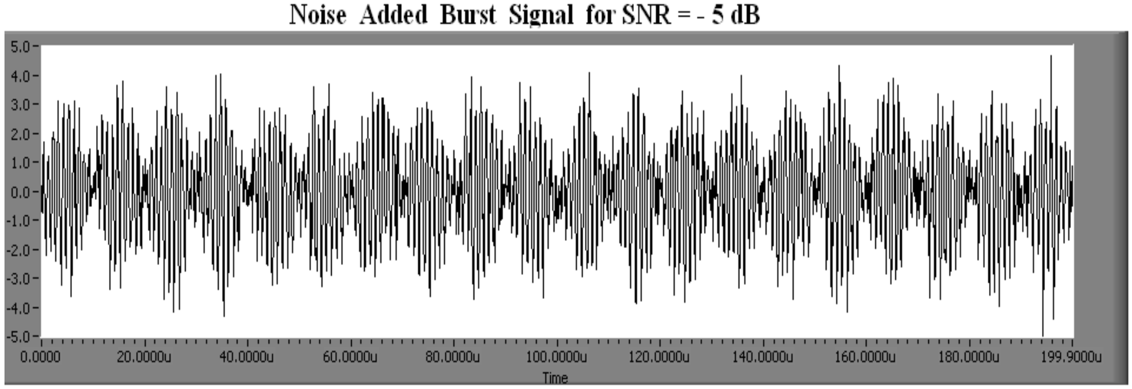
The output of the signal generator is a sine wave of the specified input frequency and amplitude.

SAMPLES OF SIMULATION:

The following diagram show the instances of simulated amplitude modulated Burst of frequency 1 MHz and the noise added Burst for SNR of -5 dB.



Noise Added Burst Signal for SNR = - 5 dB



GENERATION OF BURST SIGNAL BY READING SAMPLES FROM A FILE:

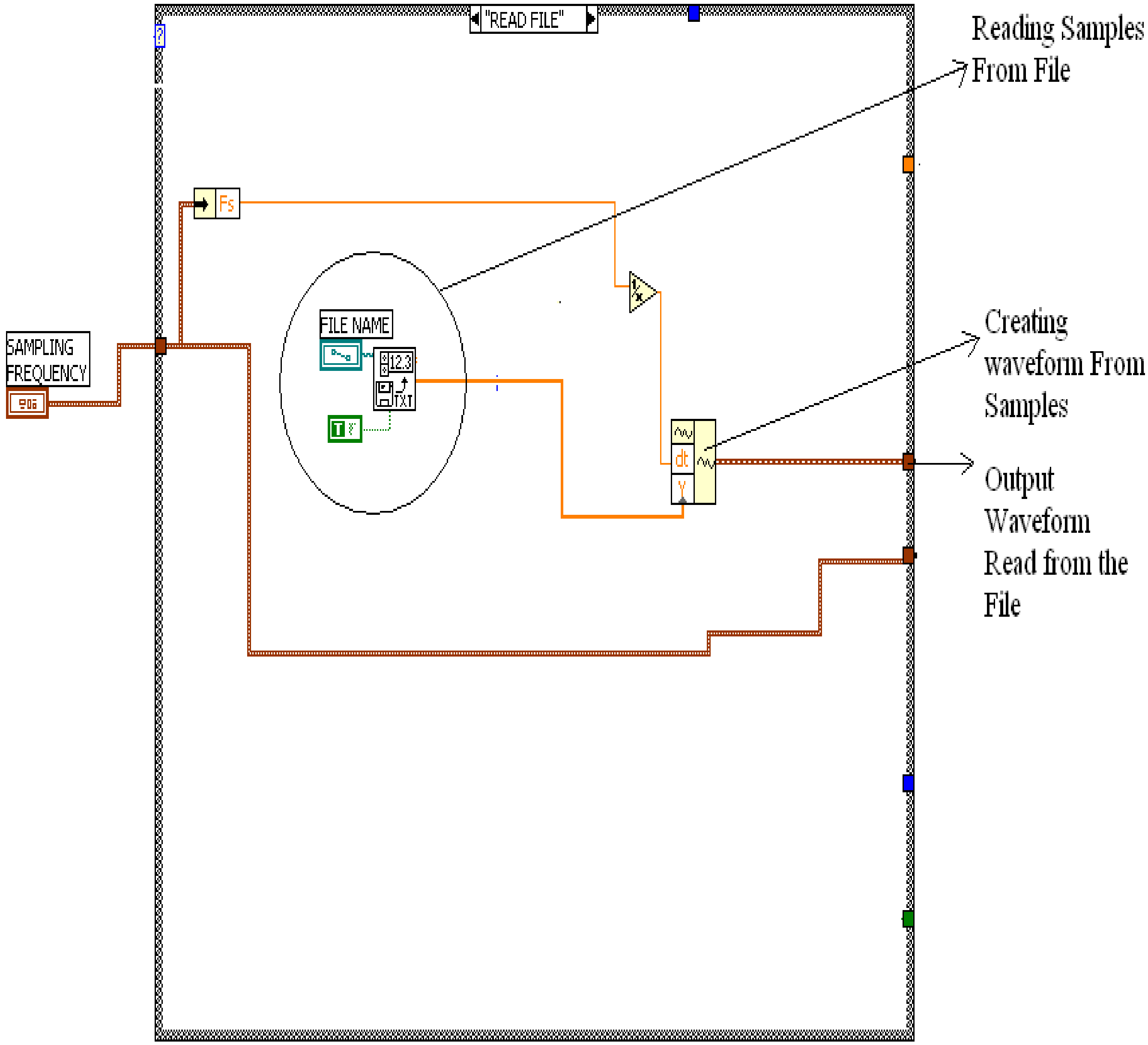
The other way of generating burst signal apart from simulation is by reading the stored samples of previously generated burst. This is done by selecting a particular number of samples from the stored set of samples.

Examples of the Samples Stored:

0.000	0.000
0.074	0.796
0.239	1.400
0.358	1.511
0.295	1.001
0.000	0.000
-0.441	-1.133
-0.830	-1.937
-0.946	-2.038
-0.656	-1.322
0.000	0.000

the above 20 samples represents a part of 1 MHz signal.

Modules for Generation of Burst Signal from Stored Samples



The above block depicts the modules used in Lab view used for reading stored samples from a file and generating a burst

LIBRARY FUNCTIONS IN THE MODULE

READ FROM SPREAD SHEET FILE:.

Reads a specified number of lines or rows from a numeric text file beginning at a specified character offset and converts the data to a 2D, single-precision array of numbers.

Input parameters:

FILE NAME : Specifies the file from which the samples are to be selected and the number of samples to be selected.

The output of this block is the number of samples that we have specified.

BUILD WAVEFORM:

Builds a waveform based on the components we enter i.e. it plots the waveform corresponding to the samples selected.

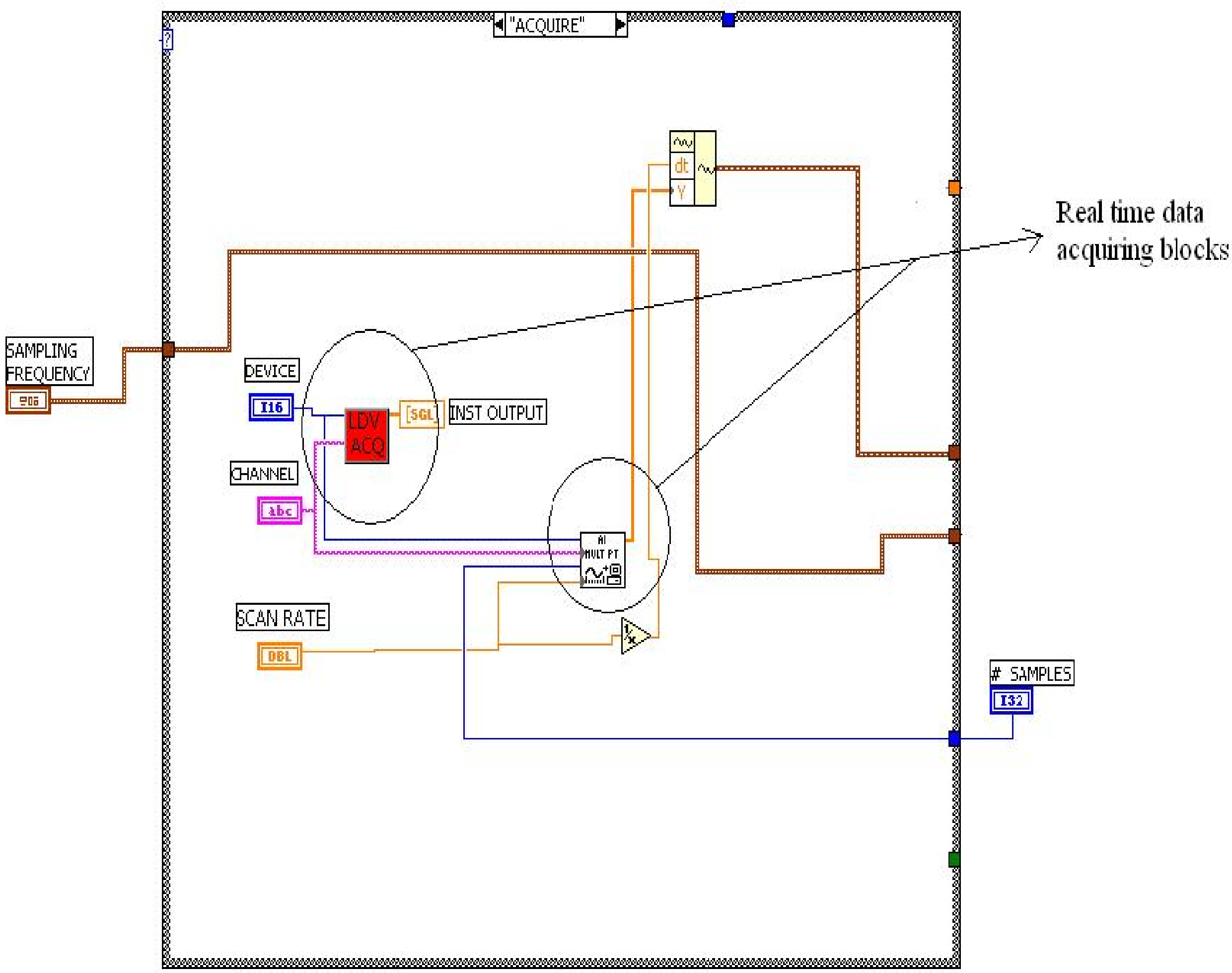
INPUT PARAMETER:

N – Dimensional array : This N – Dimensional array is the array of samples which we input to the build waveform block to generate the burst signal corresponding to the samples. Thus the output of this block is the generated burst.

DIRECT REAL TIME ACQUIRING OF BURST SIGNALS:

The above mentioned methods of signal generation is not real time. It is also possible to acquire the burst signal in real time by interfacing the system to the Photo Detector output of LDV. This is made possible by the following module of our program:

Modules for Real Time Acquiring of Burst Signals from LDV



LIBRARY FUNCTIONS IN THE MODULE

ANALOG INPUT ACQUIRE WAVEFORM :

This block acquires a specified number of samples at a specified sample rate from a single input channel and returns the acquired data.

The samples thus acquired are then passed to the next stage to build the burst signal from it.

INPUT PARAMETERS:

- Device
- Channel
- Sample rate
- Number of samples

BURST DETECTION AND VALIDATION:

In the modules that follows we perform the most important and essential part of our project i.e. the burst detection.This burst detection and validation is done by using an algorithm called **Threshold Peak Detection.** The objectives of peak detection which we have mentioned in the theory are met by the following algorithm:

ALGORITHM:

Step 1 : Sample the Burst from the previous stage.

Step 2 : Store the samples in an array.

Step 3 : Fix a Threshold Value(Th).

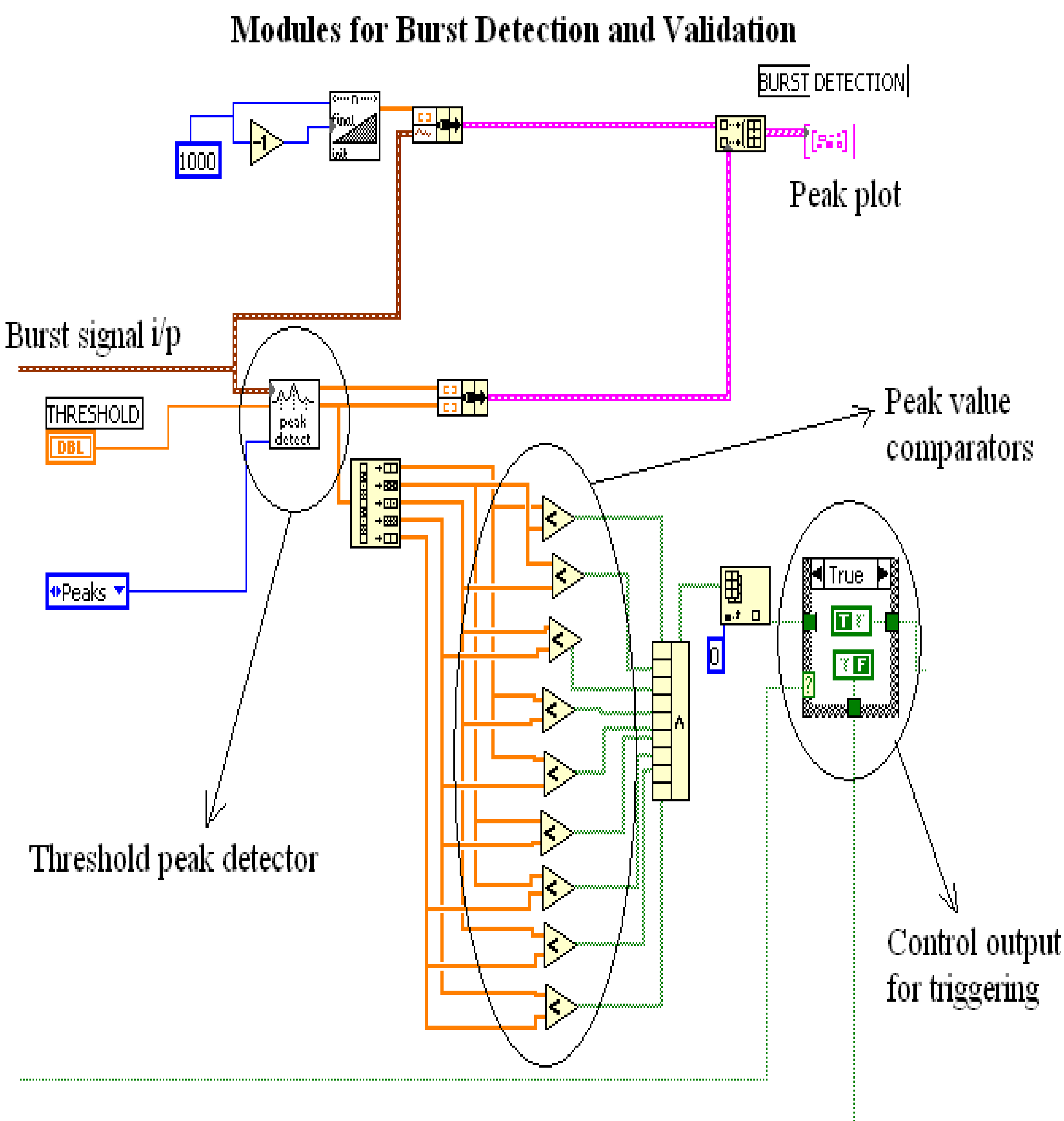
Step 4 : Compare the samples with Th to discard Noise.

(samples > Th).

Step 5 : Compare the successive Peak Amplitudes to identify rising peaks so as to validate the burst.

Step 6 : Trigger the FFT block if a Burst is Valid.

The above algorithm is implemented through the following modules :



FUNCTIONS IN THE BLOCK DIAGRAM:

THRESHOLD PEAK DETECTOR:

It is through this peak detector we discard noise based on threshold which we fix. The data input can be passed to the VI as a single array or as consecutive blocks of data. Sample values which are lower than the threshold are passed to the next stage and that are less than the threshold are not allowed to pass out of this. Thus the noise signal of amplitude less than the specified threshold are eliminated. It also gives the peak amplitudes of the Samples exceeding the threshold.

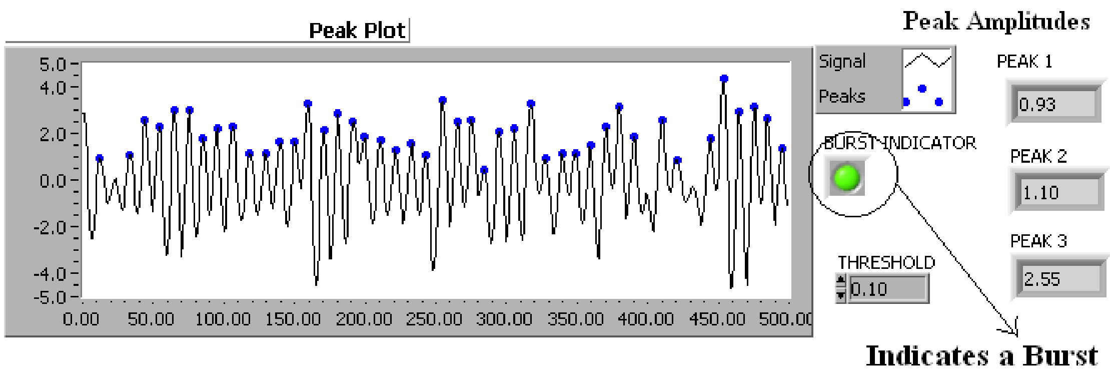
INPUT PARAMETERS:

- Threshold value.
- Samples of the signal

COMPARATOR BLOCKS:

The above said peak detection fails to discard noise if the noise amplitude happens to be greater than the threshold. To overcome this problem we go for the comparison the peak amplitudes of the successive peaks which is made possible by this comparator blocks. It mainly constitutes comparators which compares the input peak amplitudes to validate the burst. Upon detecting the valid burst it activates the triggering unit to trigger the FFT. It also passes out the valid burst signal to the next stage of processing.

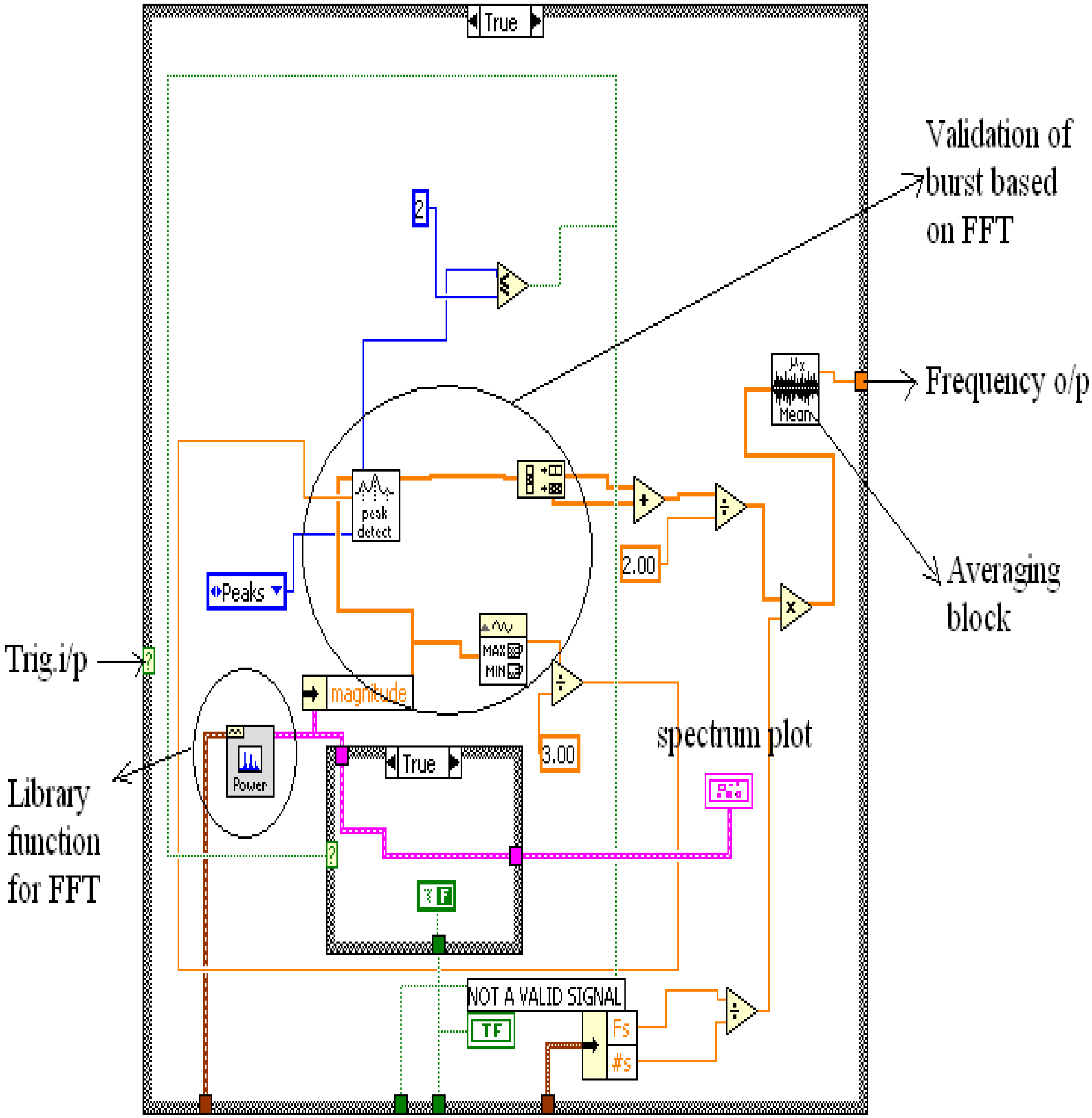
PEAK PLOT OUTPUT:



COMPUTATION OF FREQUENCY THROUGH FFT:

Completing the process of burst detection and validation we step towards the other objective of our project i.e. Signal Processing. As we have already seen upon detecting a valid burst the peak detector module triggers the FFT block to process the burst signal. The design of FFT block looks as follows:

Modules for Signal Processing using FFT



BLOCK DIAGRAM EXPLANATION:

The above design is based on the following algorithm:

Step 1 : Input the burst signal on triggering.

Step 2 : Restrict the signals using window functions.

Step 3 : Convert windowed signals to samples.

Step 4 : Follow FFT or DFT routines to compute the Power Spectrum.

Step 5 : Display the frequency.

FFT POWER SPECTRUM:

Computes the averaged auto power spectrum of the input signal. Each time waveform corresponds to a single FFT block and has to be passed individually to this block. It computes the FFT power spectrum based on FFT and DFT routines. This computed power spectrum gives the range of frequencies over which the power of the system is distributed. In the case of power spectrum of the burst signal it can be seen that the maximum power will be distributed over the frequency of the burst signal from which the frequency of the signal can be known.

INPUT PARAMETERS:

- Time signal
- Window control input

BURST VALIDATION THROUGH FFT:

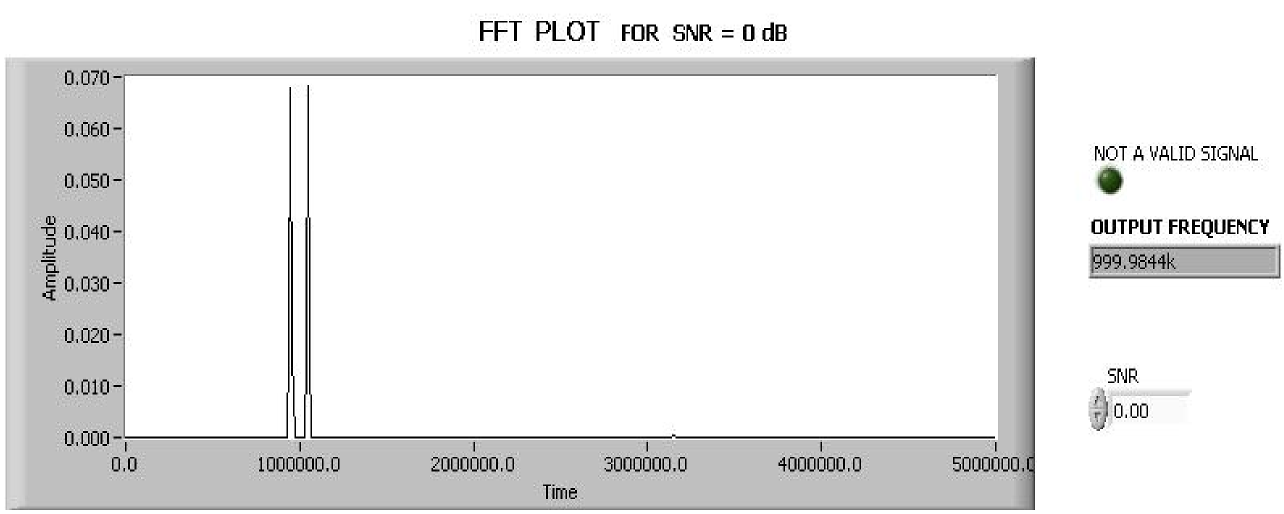
The other important function that is performed by the above module is the burst validation through FFT plot. Such a burst validation through FFT plot helps us to check thoroughly that we have processed only a valid burst.

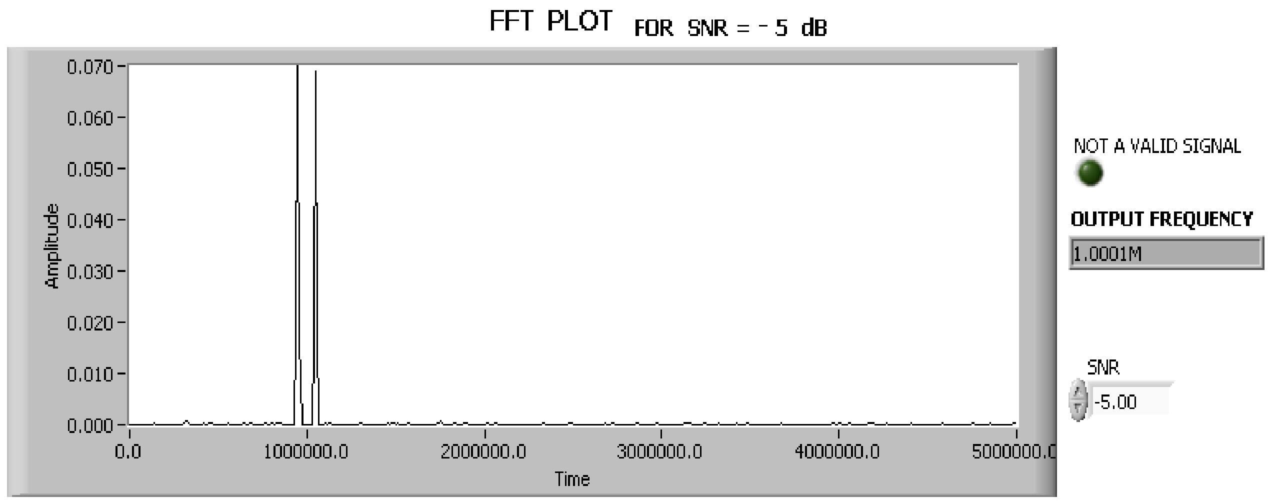
This is done by counting the number of peaks above the fixed threshold. For a valid burst as it is suppressed carrier amplitude modulated signal the number of FFT peaks must be equal to two each corresponding to one side band. We use this condition to discriminate the noised burst. Such a burst validation is achieved by using a threshold peak detector.

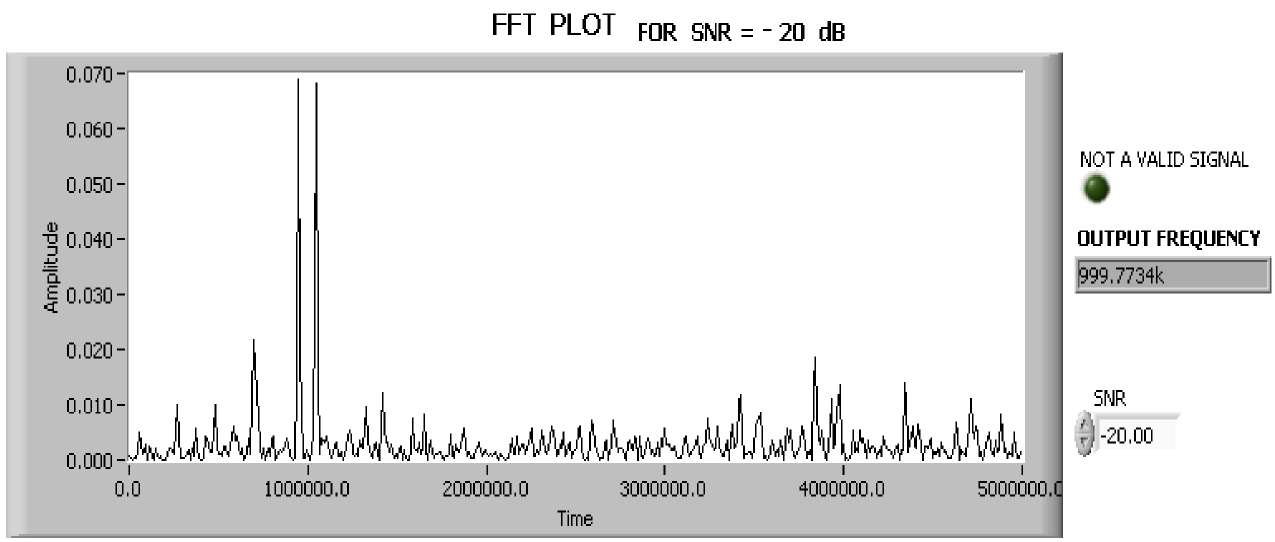
AVERAGING BLOCK:

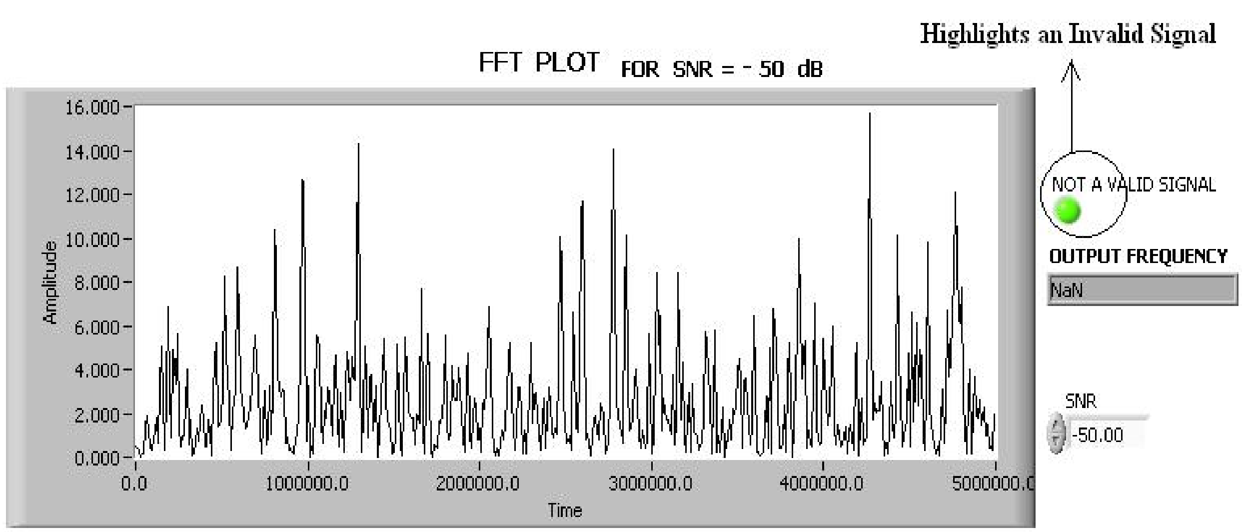
The mean of the frequency corresponding to the peaks is calculated using this averaging block. The output of this block gives the desired frequency of the signal.

OUTPUT FFT SAMPLES FOR DIFFERENT SNR VALUES:




FFT PLOT FOR SNR = - 5 dB
Amplitude
Time
NOT A VALID SIGNAL
OUTPUT FREQUENCY
1.0001M
SNR
-5.00


FFT PLOT FOR SNR = - 20 dB
Amplitude
Time
NOT A VALID SIGNAL
OUTPUT FREQUENCY
999.7734k
SNR
-20.00


Highlights an Invalid Signal
FFT PLOT FOR SNR = - 50 dB
Amplitude
Time
NOT A VALID SIGNAL
OUTPUT FREQUENCY
NaN
SNR
-50.00

It can be seen from the above output displays we get a valid FFT plot and hence output frequency for the SNR values up to -20 dB. When the SNR is about -50 dB the FFT plot contains more number of peaks above the threshold which means that it is not a valid burst signal. This non validity of the signal is indicated as seen above through FFT plot validation.

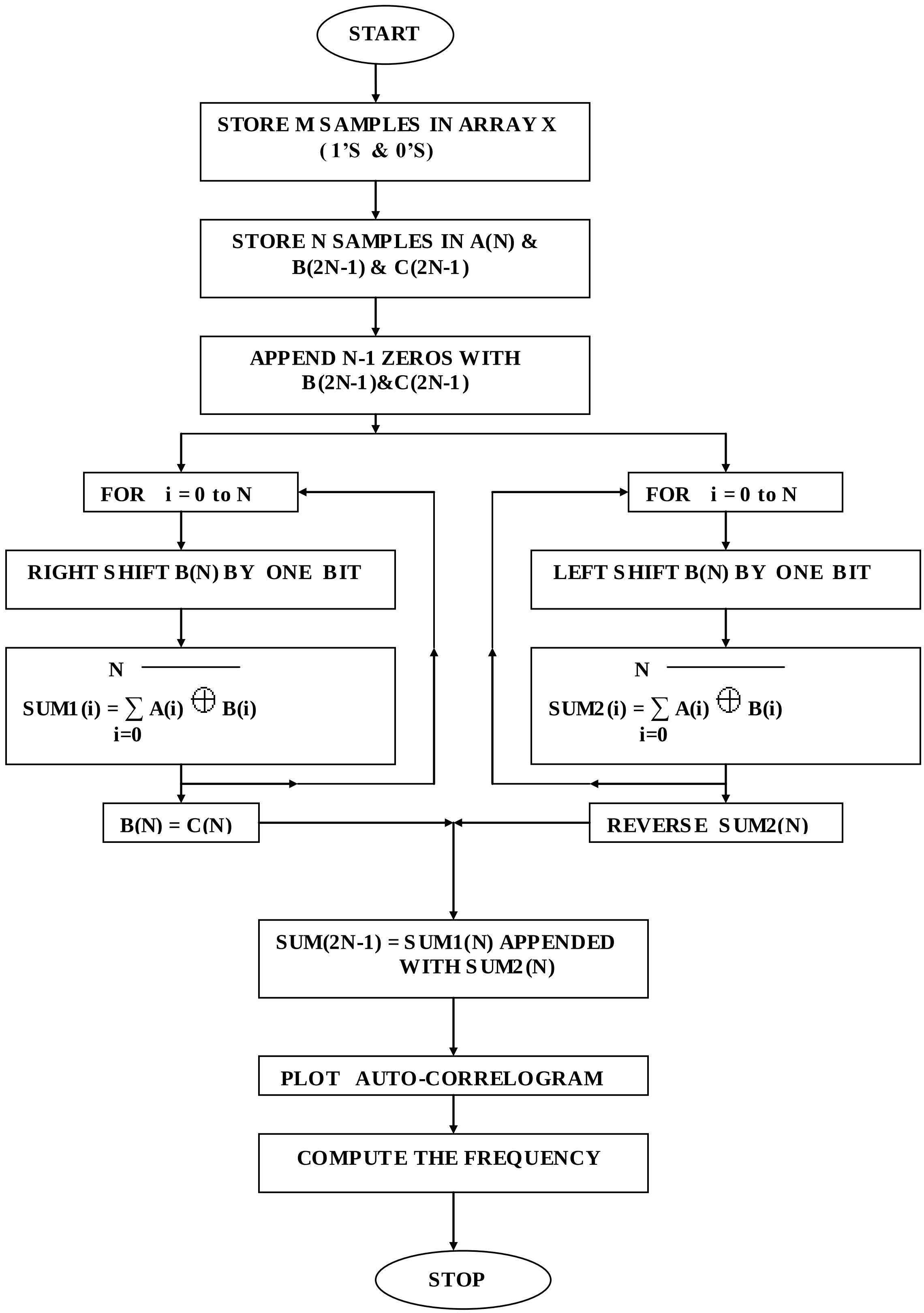
COMPUTATIOIN OF FREQUENCY USING DOUBLE CLIPPED AUTO-CORRELATION:

As we have already seen in the theoretical part we can use auto-correlation effectively for the computation of frequency. Here in our implementation we shift the sequence both in right and left directions to find the correlated sum. The auto correlogram corresponding to such a process will be symmetrical about X-axis. The implementation objectives for this DCA are:

OBJECTIVES:

- To convert the sample values in to 1's and 0's based on a threshold value.
- To find Auto-Correlated Sum by XNORing the original and shifted data.
- To plot the Auto-Correlogram and identify the valid burst.
- To compute the frequency from the correlogram and hence find the Velocity.

FLOW CHART:


START
STORE M SAMPLES IN ARRAY X (1'S & 0'S)
STORE N SAMPLES IN A(N) & B(2N-1) & C(2N-1)
APPEND N-1 ZEROS WITH B(2N-1)&C(2N-1)
FOR i = 0 to N
RIGHT SHIFT B(N) BY ONE BIT
SUM1 (i) = ∑ A(i) ⊕ B(i) N i=0
B(N) = C(N)
FOR i = 0 to N
LEFT SHIFT B(N) BY ONE BIT
SUM2 (i) = ∑ A(i) ⊕ B(i) N i=0
REVERSE SUM2(N)
SUM(2N-1) = SUM1(N) APPENDED WITH SUM2(N)
PLOT AUTO-CORRELOGRAM
COMPUTE THE FREQUENCY
STOP

IMPLEMENTATION ALGORITHM:

Step 1 : Store the sample values in an array x(n).

Step 2 : Fix a Threshold value (Th).

Step 3 : Fix the number of samples to be considered (N).

Step 4 : Initialize array A(n) and B(i) ; (n=N-1 & i = 2n)

Step 5 : Compare the N sample values with Th.

A(n) = { 1 ; sample > Th.

0 ; sample < =Th. }

Step 6 : Assign B(i) as follows

B(i)= { A(n) ;for i= 0 to N-1

0 ; for i= N t0 2N-1 } (zero padding)

Step 7 : Ensure that A(n)&B(i) contains only 1's & 0's.

Step 8 : Find the sum of A(n) **XNOR** B(i) and store in an array.

Step 9 : Rotate the array B(i) right by one bit (right shift)

Step 10 : Repeat till i=N-1.

Step 11 : Take the initial A(n) and B(i) arrays

Step 12 : Repeat the steps **8,9,10** and **11**by rotating B(i) left by one Bit(left shift)

Step 13 : Plot the Auto-correlogram.

Step 14 : Find the peak ratio and compare with the optimum value to discard noise

Step 15 : Find the peak Locations if it is a valid Burst signal.

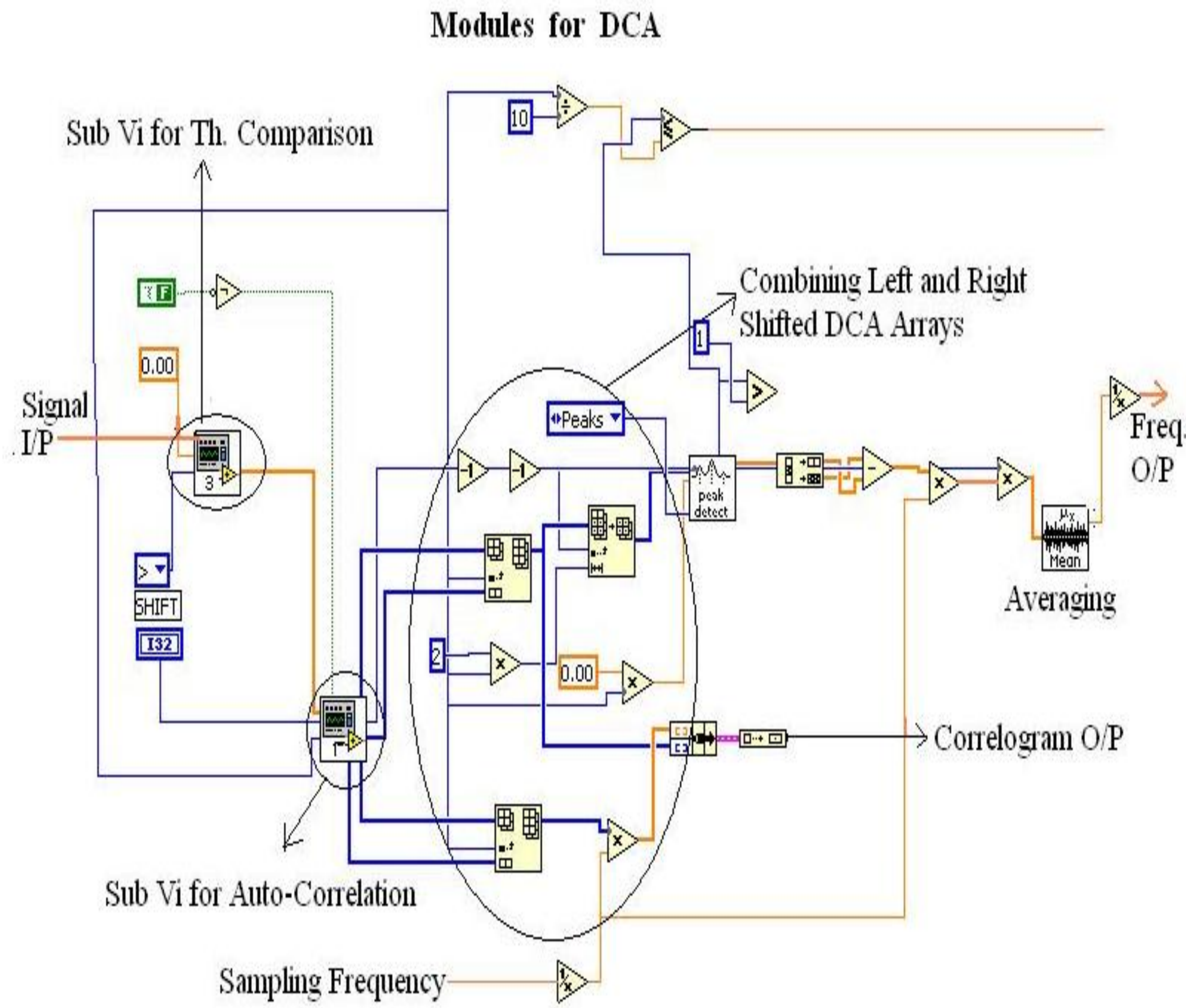
Step 16 : Find the difference between the successive peak locations which will be constant.

Step 17 : Calculate the corresponding time value of the difference which based on the sampling frequency.

Step 18 : Compute frequency and Display the result.

Step 19 : End the program.

LAB VIEW IMPLEMENTATION OF THE ABOVE ALGORITHM:

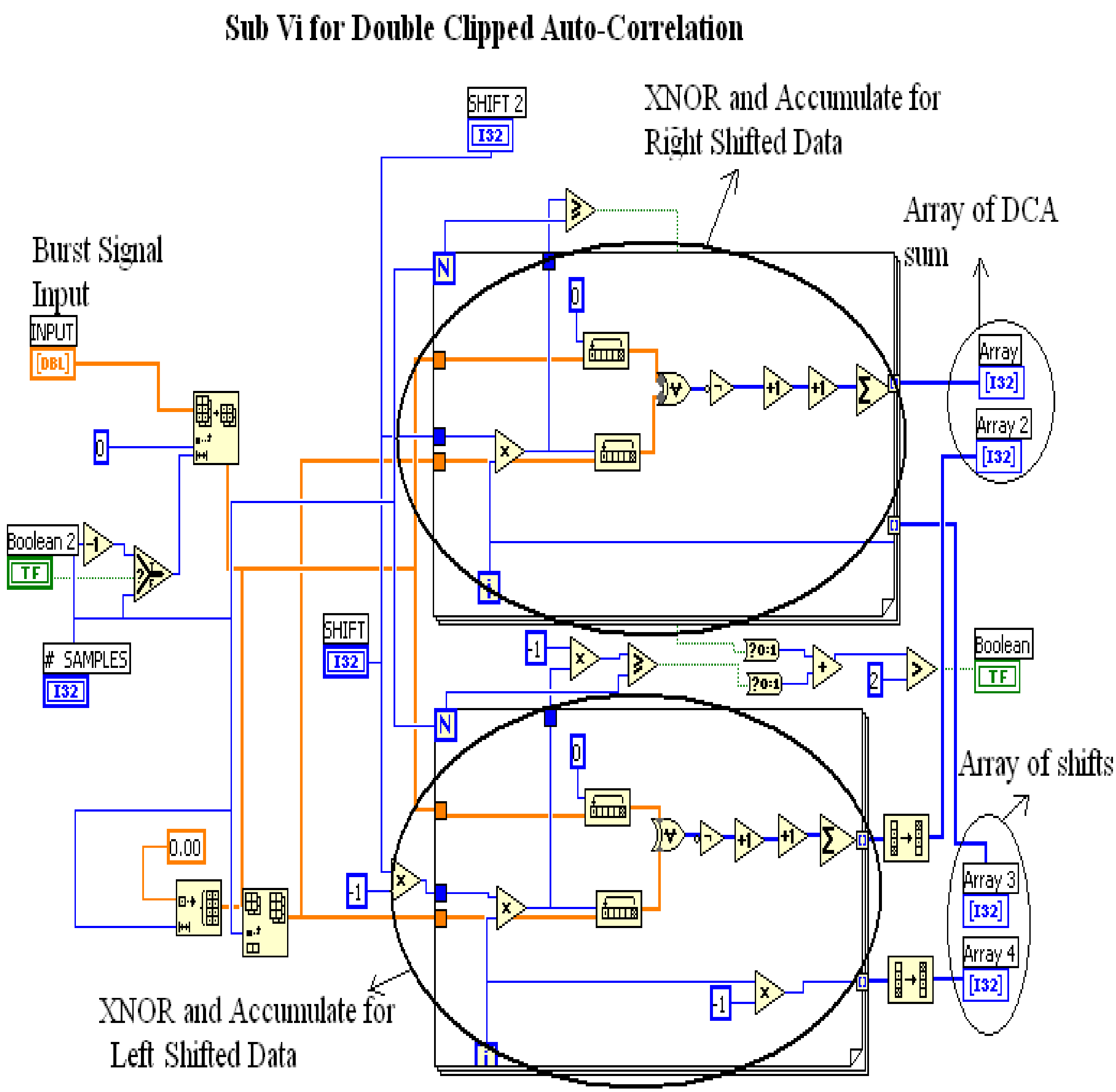


Using the above block diagram the input samples are individually compared with the threshold and assigned 1 or 0 according to its value. Then it is Auto-correlated to find the frequency by following the above algorithm. This is achieved by the following Sub Vis:

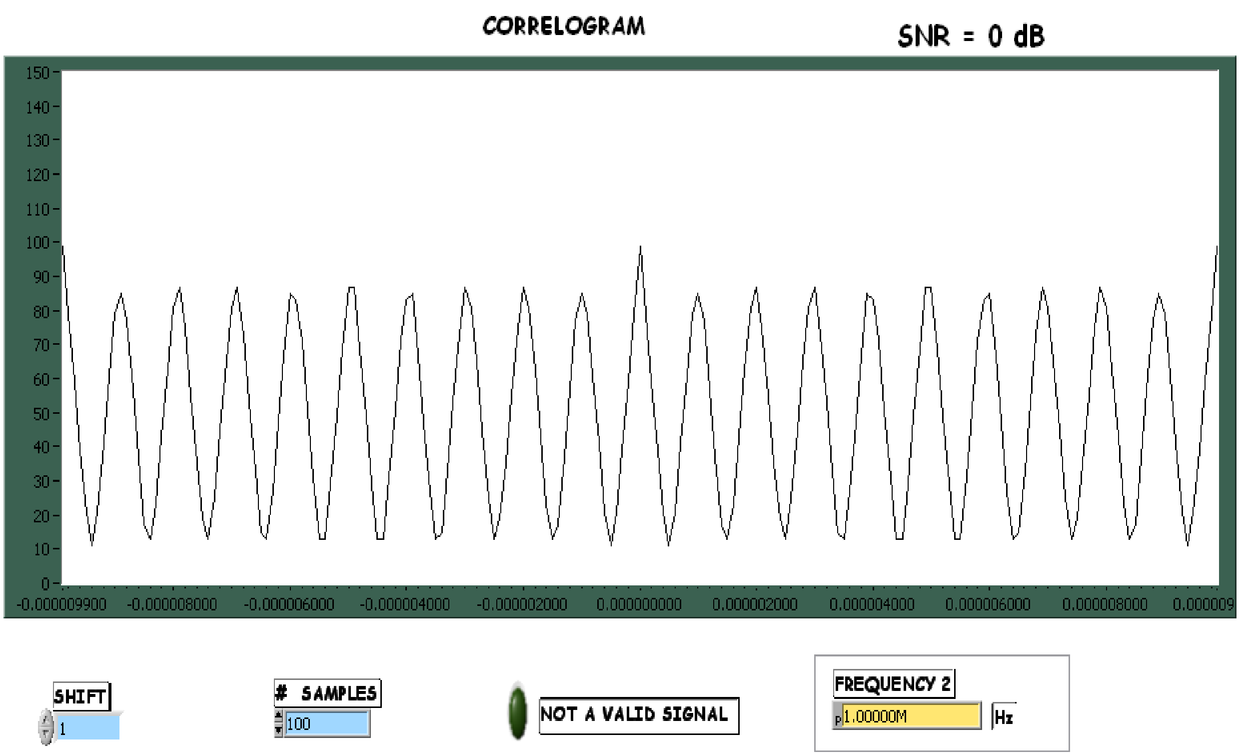
SUB VI FOR THRESHOLD COMPARISON:

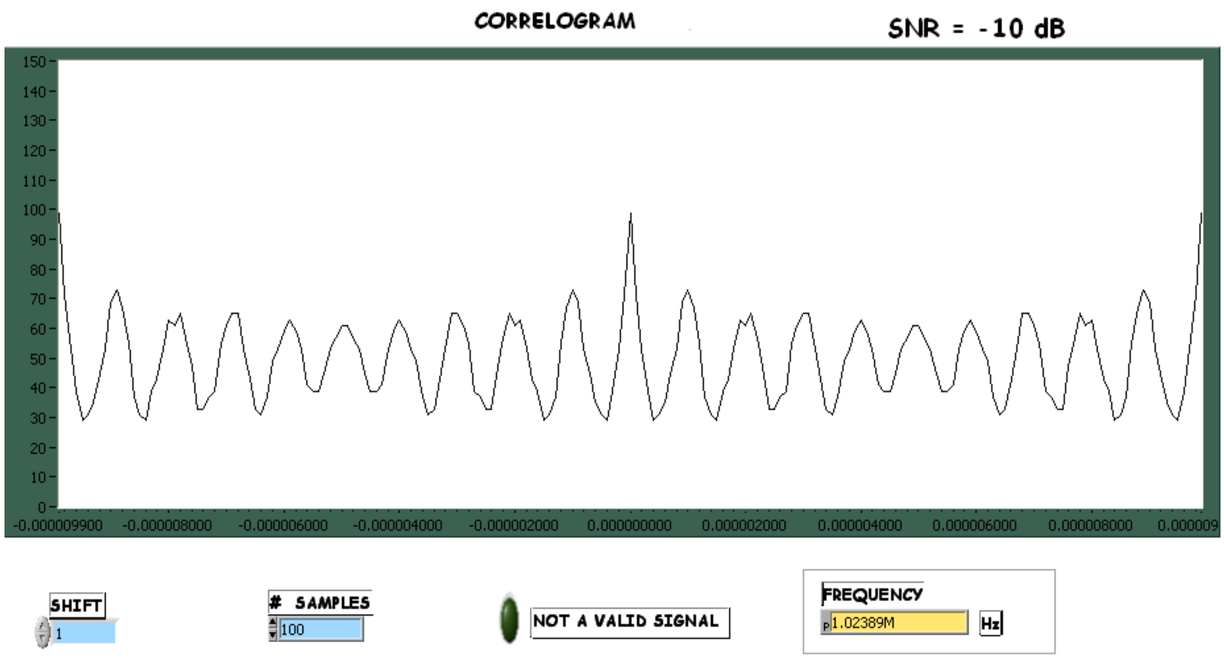
Here the input samples are converted into 1's and 0's and stored in an array.

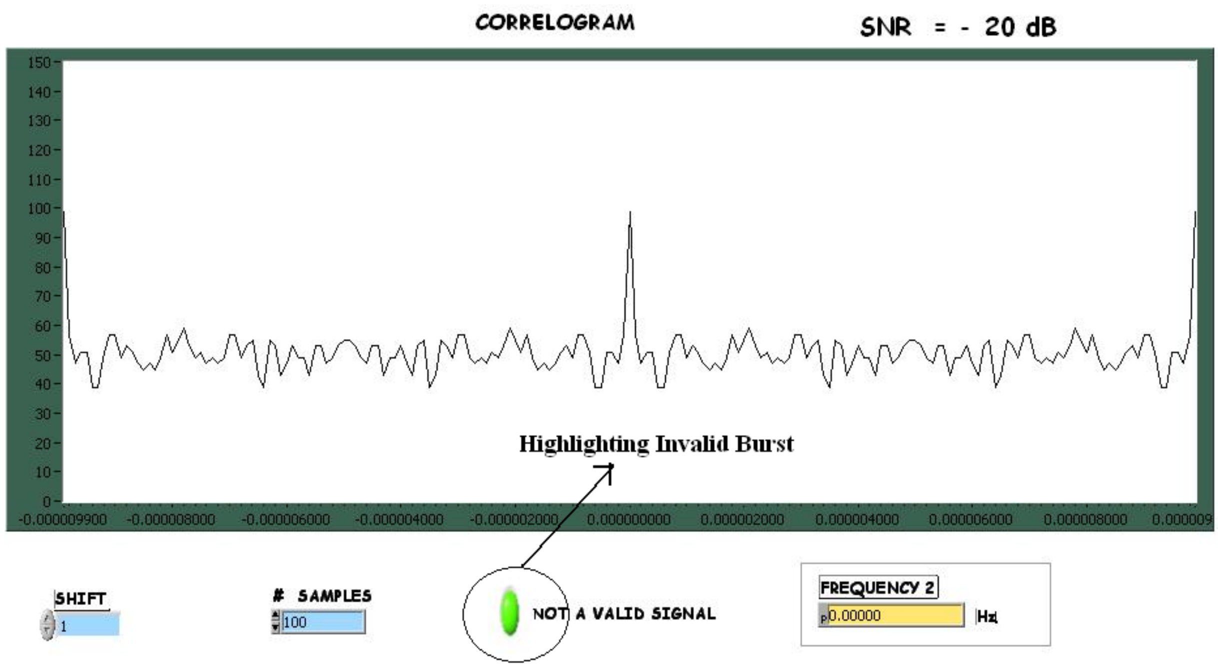
SUB VI FOR AUTO-CORRELATION:



Using this Sub Vi we get the information stored in the array to limited number of samples and then auto-correlate both left and right sequences. After which we plot the auto-correlogram. The auto-correlogram for different SNR values are as follows:







From the above correlogram plots it is clear that they can be well used for detecting invalid burst using the peak ratios. One such example is shown for the SNR of -20 dB.

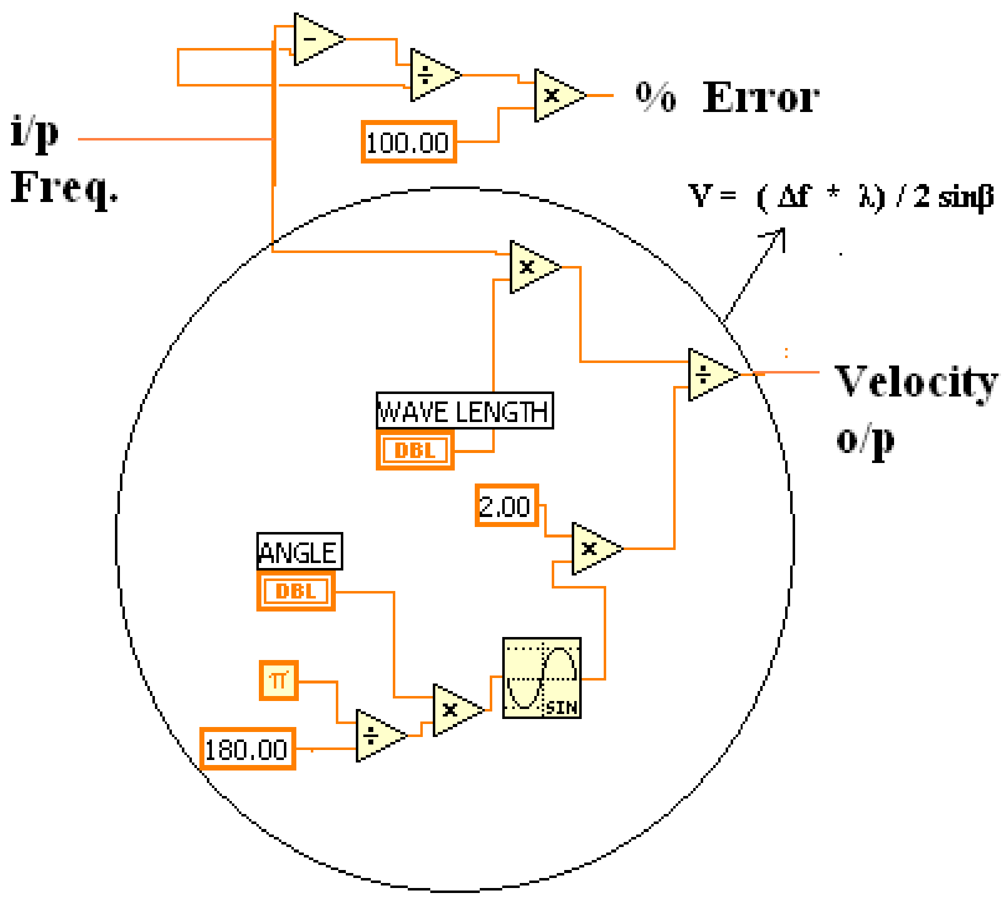
COMPUTATION OF VELOCITY THROUGH FREQUENCY:

After completing the two main objectives of our project we proceed towards the computation of Velocity. As we have already the velocity can be computed through frequency as follows:

$$V = (\Delta f * \lambda) / 2 \sin \beta$$

The implementation of the above formula in lab view is as shown below:

Module for Computation of Velocity Through Frequency



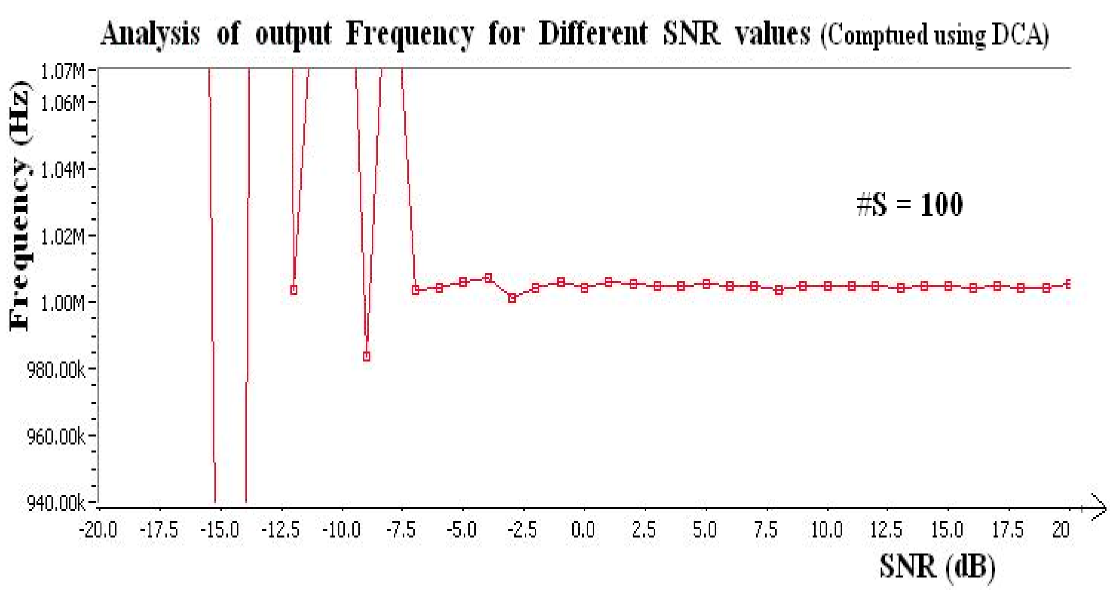
The inputs to the above block diagram are:

- The frequency **(Δf)** of the signal.
- The Wavelength of the laser used (**λ).**
- The angle of interference between the two lasers (**β).**

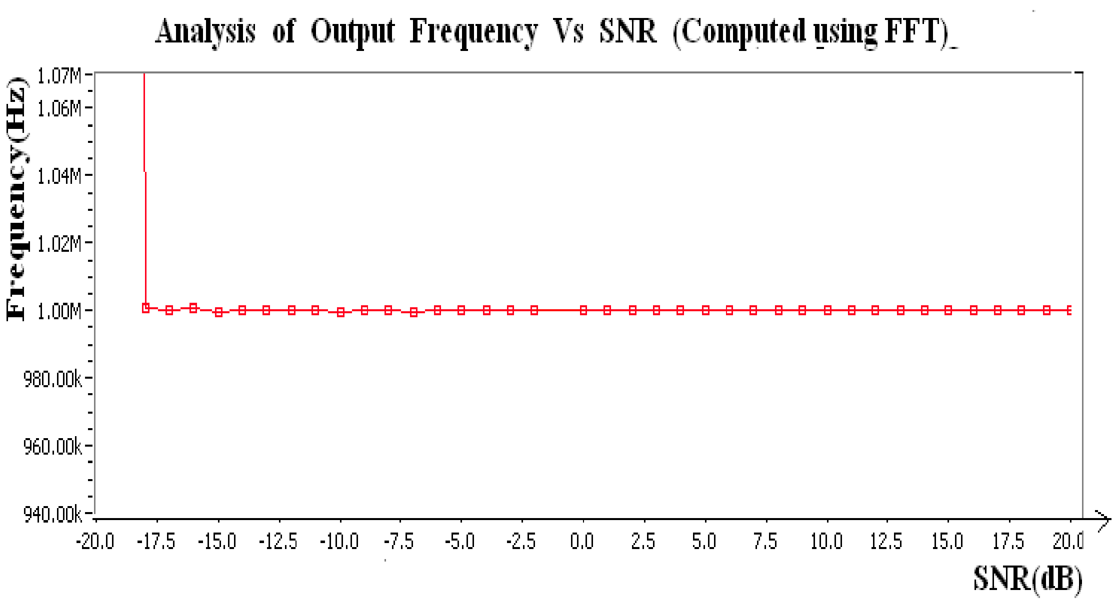
The frequency input is obtained from the previous stages of the program whereas the wavelength and the angle of interference is given by the user.

VALIDATION OF OUTPUT FREQUENCY COMPUTED USING DCA & FFT:

This validation is done by finding the output frequency for different SNRs. A graph is plotted between the output frequency and SNR as shown in the figure where the frequency of the input signal is 1 MHz.



The above graph depicts the various output frequency computed using DCA for 100 samples. From the above graph it can be inferred that till the SNR of – 7dB the output is exactly equal to the input frequency and when the SNR value is above -7dB and below -12dB the output frequency is with in the tolerable range and
above that the output frequency cannot be considered.

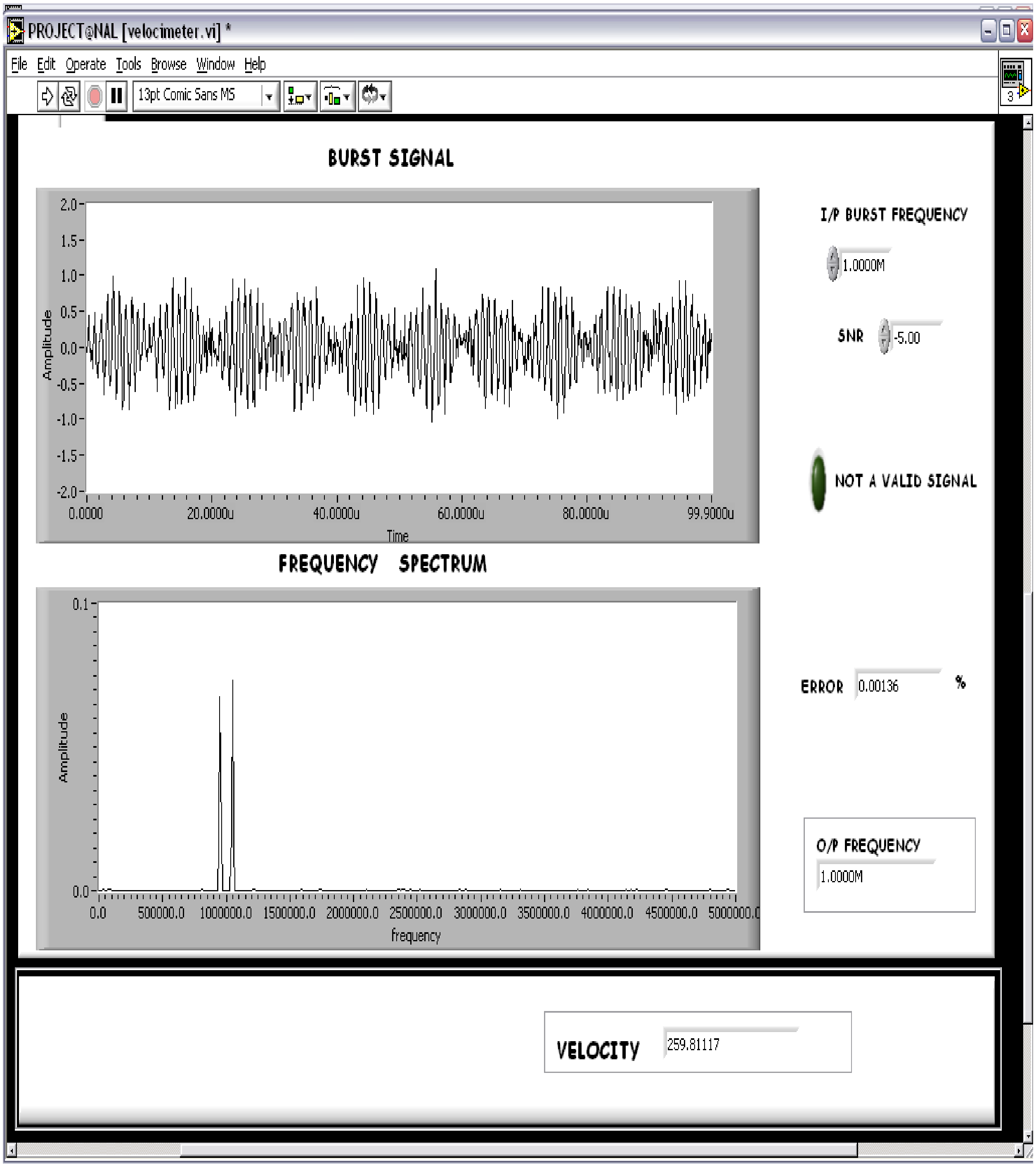


The above graph depicts the output frequency variations with SNR computed using FFT. As against the DCA technique it can be seen that the output frequency is well with in the tolerable range till the SNR of -18 dB above which the value cannot be computed.

RESULTS AND CONCLUSION:

The result of our project can be visualized through the Front Panel Display as follows.

COMPUTATION OF FREQUENCY USING FFT TECHNIQUE:



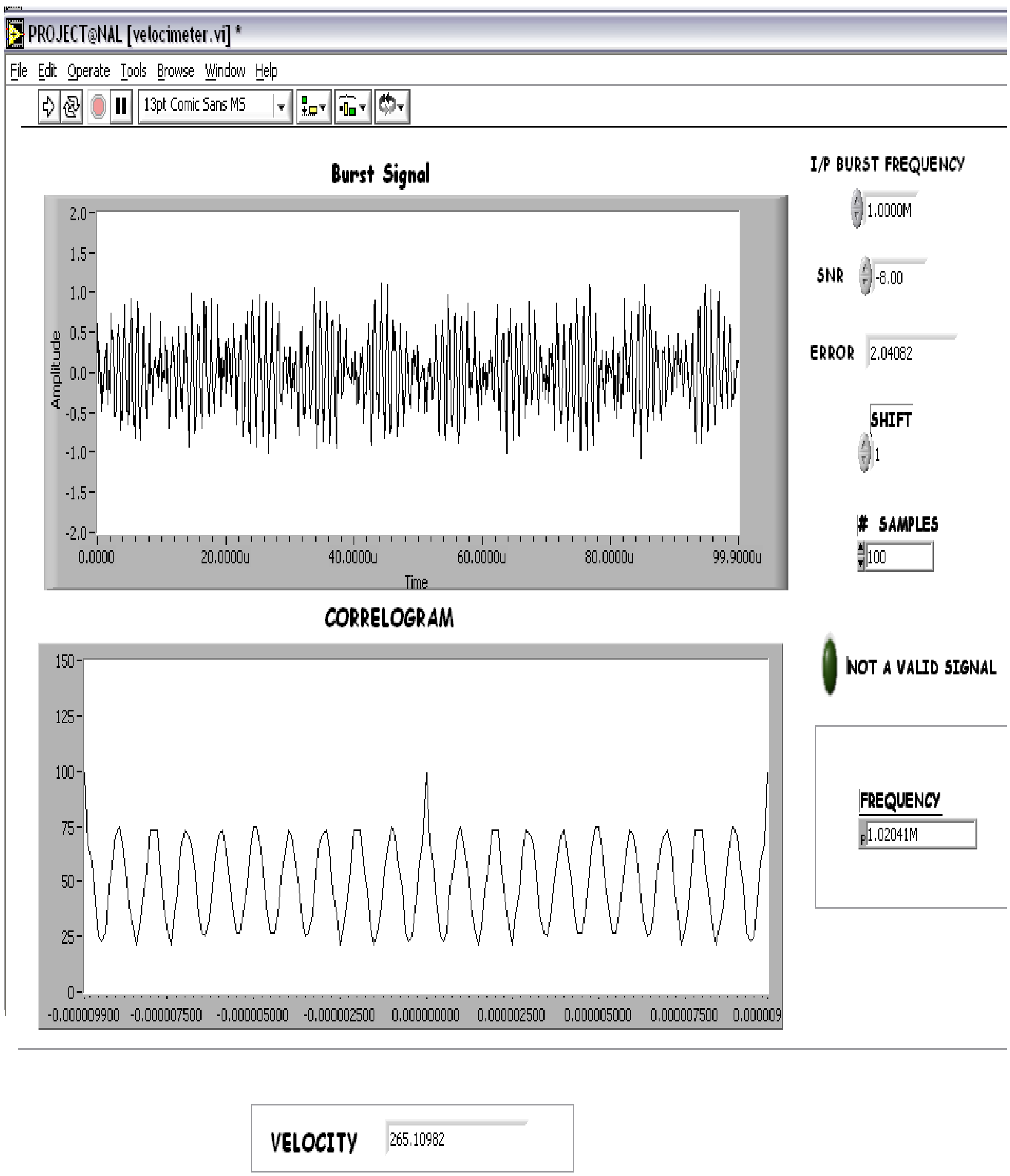
The output screen displayed above is the Front Panel of our project that corresponds the computation of frequency through FFT technique. It displays the generated burst signal the frequency spectrum, output frequency and corresponding velocity. The result consists of the following information:

- Input Frequency = 1 MHz
- SNR = -5 dB
- Output Frequency = 1.0000136 MHz
- % Error = 0.00136 %
- Velocity = 259.81117 m/s

The above velocity is computed for $\boldsymbol{\lambda} = 450$ µm and $\boldsymbol{\beta} = 60$ deg.

COMPUTATION OF FREQUENCY THROUGH DCA :

The following Front Panel output corresponds to the Frequency computation using DCA.



It delivers the following information:

- Input Frequency = 1 MHz
- SNR = -8 dB
- Shift = 1
- Number of samples = 100
- Output Frequency = 1.02041 MHz
- % Error = 2.04082 %
- Velocity = 265.10982 m/s

The above velocity is computed for $\boldsymbol{\lambda} = 450\ \mu m$ and $\boldsymbol{\beta} = 60$ deg.

CONCLUSIONS:

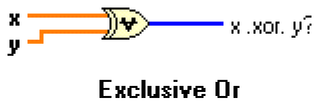
The Frequency Domain Real Time Signal Processing (DCA & FFT) is the most efficient of other existing signal processing method. From the validation graph for the different outputs obtained we can conclude that among the two techniques that can be used for signal processing, the results computed using FFT technique is more accurate and acceptable. This is due to the fact that the output frequency computed using FFT is acceptable over the wide range of SNRs relative to DCA technique. The other important limitation on the DCA technique is affected by number of samples we consider for the processing.

But only for this reason we should not crown this FFT technique because when it comes to time taken for processing DCA leads the race. So the further modification can be effected in such a way that DCA technique also gives accurate results which will advantage to its advantage of quick processing time.

FUTURE DEVELOPMENTS :

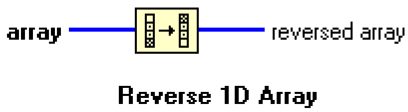
- Implementation using Digital Signal Processors.
- Implementation in FPGA system.

EXCLUSIVE OR:



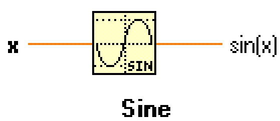
Computes the logical exclusive OR of the inputs.

REVERSE 1D ARRAY:



Reverse the order of the input 1D array.

SINE BLOCK:



Computes sine x; x in radians.

INDICATOR:

Used for displaying the output.

WAVEFORM CHART:

Used for displaying waveforms.