GPS TIME STAMP FOR PULSAR RECEIVER

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1. INTRODUCTION :

This report mainly describes the details of GPS signal implementation in the hardware path of Pulsar receiver.

The details will include following :

a) Pulsar data–flow at GMRT.
b) Different methods for implementing the GPS signal in the system.
c) Currently implemented Scheme.
d) GPS signal time equation and associated software logic.
e) Data analysis.
f) How to improve the accuracy of detecting the GPS signal.
g) Future plans.

2. PULSAR DATA–FLOW AT GMRT :

(Ref. FIG. 1).

At any observing band, the analog electronics chain of each antenna produces a signal of 32 MHz bandwidth for each of two orthogonal polarisations. This signal is available as two 16 Mhz base–band outputs (USB and LSB) for each polarisation. There are ,thus , a total of 120 analog signal channels for further processing.

Data from each signal channel is sampled at Nyquist rate to produce 4–bit digitised data samples at rate of 32 Msamples/sec. After this ,the signal travel through delay units for delay compensation . The delay adjusted signal from each channel is then Fourier transformed in real–time (once over 16 microsecs) to provide a continuous stream of 256 complex spectral channels.

In the aperture synthesis mode , the signals are processed through a FX type digital correlator. In the array mode signals are passed to a pulsar receiver.

The first block of the pulsar receiver is the GMRT Array Combiner (GAC), built by the Raman Research Institute , Bangalore. It combines the signals from a maximum of 30 antennae for both incoherent and coherent array operations.

Currently , two pulsar back–ends are attached to the incoherent array output of the GAC:

i) The search processor which preintegrates the data to a desired sampling rate , subtracts long term running mean for each frequency channel and provides 1–bit samples to the data acquisition computer (sub system of GAC rack).

ii) The DSP platform which provides full multi–bit data at fast sampling rates.

In the currently implemented scheme , the GPS signal has been connected to the DSP platform of incoherent array mode of pulsar receiver. To have better understanding of the scheme , below is the block level description of DSP platform.

DSP platform – block schematic for incoherent array mode of pulsar receiver :

(Ref. FIG 2).

8 bit data signal (power) along–with init and clock signals from each of the polarisation from GAC is acting as input to Input interface card (IIC) where it has been converted from ECL

differential levels to TTL single ended output. This is fed to input FIFO memory (4 no. – each of 8k x 8 size) on the Input interface card . The multiprocessor DSP processor system further processes the data according to the parameters defined. The processed DATA (16bits) is finally given to the output FIFO memory of PSC card which later pushed out for acquisition on high speed computers through HSDIO–PCI card.

All sections of the pulsar receiver are controlled by a pulsar master console program with GUI , that runs on a UNIX workstation. The data are acquired on high speed computers using high speed PCI data acquisition cards and transferred to the UNIX workstation for off–line analysis and storage.

3. DIFFERENT APPROACHES OF IMPLEMENTING THE GPS SIGNAL :

This section describes various methods of implementing the GPS signal time stamp as well as describes the advantages and the drawbacks of each method.

One can connect the GPS signal anywhere in the hardware path , provided that it can be interpreted correctly with reasonable degree of accuracy . For this one should check the hardware feasibility as well as signal quality.

Method 1:

(Ref. FIG 3: a):

As shown in this figure, one can detect the occurrence of the GPS signal by using a mono–stable multivibrator and a multiplexer. The instant ,when the GPS signal got detected ,the appropriate marker value will be placed on the 32 bit DSP bus.

The DSP software intelligence will make out this instant by uploading the FFT channel and input memory block in which it got detected.

Here user has to sacrifice any (random) frequency channel for the GPS marker data.

Method 2:

(Ref. FIG 3 : b):

One could go ahead by implementing more generalised scheme for detection of GPS signal as shown in the FIG 3.b.

In this , a simple counter has been put which will measure the GPS clock in terms of basic clock cycle (32 MHz). This counter value gives the time difference between the instant of input data acquisition on IIC FIFO memory and the instant of GPS signal detection. This value can be read by DSP processor by sacrifying a particular frequency channel.

Counter Feasibility :

In the digital back–ends connected to analog part of GMRT , the GPS signal used is minute pulse. Hence to count 60 sec. pulse width with the basic clock of 32 MHz , the total no. of bits (say N bits) used in counter are given as : (N–bit counter)

2 pow N = 60 sec. * 32 MHz

= 1920 * 10 pow 6. (Decimal)

= 2 pow 31 (binary)

So one should have 32 bits counter in the hardware.

Advantages : (for method 1 and 2)

1. GPS detection accuracy will be within ± one clock cycle (~32 ns). GPS itself is accurate to ± 100 ns.

Difficulties in implementation : (for method 1 and 2)

1. This needs extra piece of hardware to be built on Input interface card where GPS signal will be getting acquired.
2. In addition to this, it needs to make changes in current DSP software (written in ADSP 21020 assembly language) for taking care of the GPS signal.
3. User has to sacrifice one frequency channel. Already one frequency channel is being used for marker to check acquired data validity.
4. Needs to calculate pipeline delay from the point where GPS getting in to the point where final data comes out.
5. Needs to make changes in the OFF–LINE analysis software.

Method 3 :

(Ref. FIG 4)

The GPS signal can be implemented by using one of the bit of the input signal data on the Input Interface Card e.g. one can use MSB of input signal from either pol1 or pol2 signal.(user has to take care that input signal should not grow beyond 7 bits value to maintain signal quality).

Advantages :

1. GPS signal detection accuracy will be ± 32 ns.
2. Negligible changes in the hardware.

Drawbacks :

1. Compromise on input signal level from GAC i.e. the signal should stay in 7 bits value only as MSB will carry the GPS signal.
2. Needs to make changes in the DSP software with proper intelligence for detecting GPS as DSP system processes the data for accumulations (Maximum accumulations are 32).
3. Needs to make changes in the OFF–LINE analysis software.

4. CURRENTLY IMPLEMENTED SCHEME :

(Ref. FIG 5)

To have better understanding of this scheme , here is functional description of the blocks from GAC to DSP platform used for incoherent mode of pulsar receiver.

Concept – GMRT Array Combiner adds the input signal from the selected antennae and generates three outputs viz.

a) POWER : 8 bits/POL along–with clock and sync. init signal

b) VOLTAGE : 8 bits real + sign bit.

c) VOLTAGE : 8 bits imaginary + sign bit.

Power signal goes to Incoherent Array mode of DSP based hardware for further processing. DSP processor based Incoherent Array processes the data for following parameters :

i) No. of accumulations. (max. 32 acc. for both pols added , or 64/pol)
ii) No. of FFT channels. (max. no. of FFT channels –256).
iii) Polarisation used (upper/lower/both).
iv) Adjacent channel collapse.
v) Output data format – 0 for 2 byte output.
Output data bits shift from LSB to MSB – in powers of 2 (only for one byte data output format).

In the present scheme , the GPS signal is connected to the MSB of the final output data.

Once the decision of above parameters made by the user , the DSP program can be fired from the control computer (dual2 machine) and data can be acquired on local hard–disk (on dual1 or dual2 machine) or on remote machine through the network.

DATA RATE details :

FFT to GAC : (1/(sampling clock)) * (512 + 4).

i.e. 1/32 (MHz) * 516 .

GAC to IA : no change, same as FFT.

IA to DAS : (1/(sampling clock)) * 516 * No. of accumulations by DSP.

e.g. One time sample data rate = (1/32 (MHz)) * 516 * 32 .
= 516 microsec.

Hence ,one data output sample (16 bits) comes out every 516 microsec.

One data output sample contains 256 FFT channels.

Hence one word time (16 bit o/p data)= 516 /256 = 2.0125 microsec.

So with above considerations , in principle , one should get the GPS signal with the accuracy of ± 1/2 (one word time) i.e. ± 1/2 (2.0125) = 1 microsec.

Since one data word time is not integer multiple of one minute pulse , one can discover the GPS signal accuracy <= 1 microsec by designing the appropriate mathematical model.

In the practical situation , the data is not coming out in a continuous stream but gets driven by PSC card in the bursts by using specific output clock.

At present the driving clock is selected to 3 MHz .

With this GPS signal can be measured with the accuracy of ± (1/output driving clock). i.e. ± 333 ns.

LOGIC :
(Ref. FIG 6 and FIG 7).

GPS signal measurement is based on following two logical views :

1. If the GPS signal falls within the burst ON time i.e. in the burst , the acquired data till then will not be integer multiple of no. of FFT channels , but it will show the GPS transition in the BURST. This should be considered as VALID GPS transition.

2. If the GPS signal falls within the burst OFF time i.e.does not falls in the burst , the acquired data till then will be integer multiple of no. of FFT channels and GPS transition will be spurious.

5.TIME EQUATION :

This detects first valid GPS edge and then keep the track on next valid GPS edges. It includes following three basic equations .

a) gps_time_{first}=(total_words*word_time)+($fract_{initial}$*out_clk);

This equation detects first VALID GPS edge in the data with respect to marker in the data ,based on above LOGIC . The pulsar data acquisition software uses this information to give the time at which data acquisition started.

b) $fract_{next}$=((n*60000000–(sam_t–($fract_{initial}$)*1/out_clk))/sam_t);

This gives useful information about next VALID GPS edge in the data. This information is given to following equation to calculate time.

c) gps_time_{next}=(total_words*word_time)+($fract_{next}$*out_clk);

This equation calculates the time similar manner as of equation a). This equation is an important tool to keep track on VALID GPS edges and its accuracy.

Where ,

$fract_{initial}$ = Fractional part of one output data sample for the first VALID GPS edge detection.
$fract_{next}$ = Fractional part of one output data sample for immediate next VALID GPS edge detection.
gps_time_{first} = Time for the very first VALID GPS edge detection . (In FIG 6 , t4)
gps_time_{next} = Time for next VALID GPS edge detection . (In FIG 7 , T3)
total_words = Total no. of data words till GPS transition.
sam_t = Time for one sample of the data . (All FFT channels). (e.g.516 us)
word_time = One word time i.e. time for one FFT channel data to come out. (e.g.2.0125 us)
out_clk = Output driving clock on PSC card (e.g.3 MHz)

6. SOFTWARE FEATURES :

1. It works for various parameters used for data processing in the DSP hardware like no. of acc.,no. of FFT channels etc.
2. It works in asynchronous mode of final data output from DSP bin and data acquired by high speed machine by detecting the first marker value. As the marker seats in the last FFT channel, can be used to indicate the start of one output data sample.
3. Detects all the VALID GPS edges by using above LOGIC and TIME EQUATION as well as valid marker status for the entire data.
4. Stores GPS width and checks for $t2-t1= 60sec\pm(1/\text{output driven clock})$.
5. All forthcoming GPS signal transitions are cross–checked by TIME equation by detecting very first GPS valid transition.
6. Stores the result in GPS.log file.

7. GPS signal recognition for given data :

1. For 32 accumulations , 256 FFT channels one needs to acquire at least 15 minutes of the data to get VALID GPS transition.
2. For 16 accumulations , 256 FFT channels one needs to acquire at least 7–8 minutes of data for VALID GPS transition.

8. DATA ANALYSIS :

(Ref. FIG. 8)

To ensure the LOGIC , TIME EQUATION and accuracy of the GPS signal detection following parameters are selected for DSP based incoherent array mode.

1. No. of FFT channels : 256.
2. No. of accumulations : 32 .
3. Polarisation : both (upper and lower).
4. Channel collapse : 0.
5. Shift in the output data : 0 bits .(2 byte output).

With this selection a DSP program fired and data is acquired in different data files . The data acquisition time is kept around 15–17 minutes.

The acquired data files then processed through the developed GPS software to detect valid GPS edges and report the time. This information is used to check the accuracy of the detected GPS signal.

This analysis has been shown in FIG. 8. In this plot (FIG. 8) , X–scale is no. of valid GPS edges from different data files and Y–scale is mean error in GPS edge detection . This clearly shows that we can measure the GPS time information with the accuracy of $\pm$ 333 ns.

9.BETTER ACCURACY :

It has been concluded that detected GPS signal accuracy depends on the output driving clock on PSC card. The output driving clock selection is done by DSP processor.

Thus, if we increase the output clock , we will get better accuracy.

If we increase the output clock from 3 MHz to 6 MHz , we should able to detect the GPS time information with the accuracy of ± 170 ns.

But , if we double the clock , the burst OFF time (dead time) will increase. In turn , a burst of data of half time duration (compared to previous clock selection i..e. 3 MHz clock) is available to allow VALID GPS edge transition. Hence ,to detect the VALID GPS edge transition , one has to acquire large length of the data .

10.IN PROGRESS :

1. To add GPS detection and GPS time equation feature in the final pulsar acquisition software. This software is similar to present CORRELATOR acquisition software.
2. To measure the correlator pipeline delay from sampler to final IA output by feeding the GPS modulated signal to samplers.
3. To add GPS time stamp facility to Phased array mode of pulsar receiver.

PULSAR DATA FLOW AT GMRT

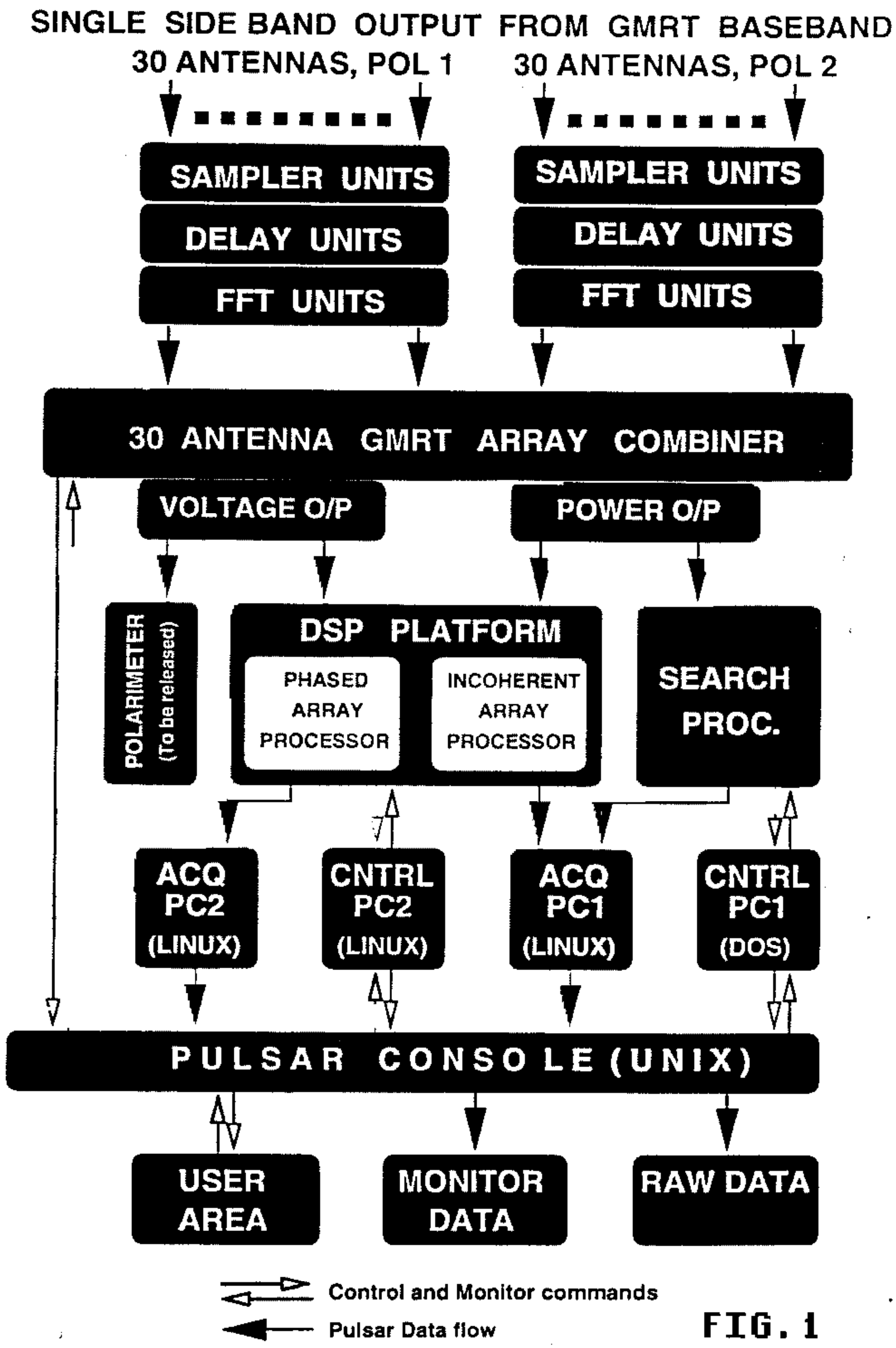


FIG. 1

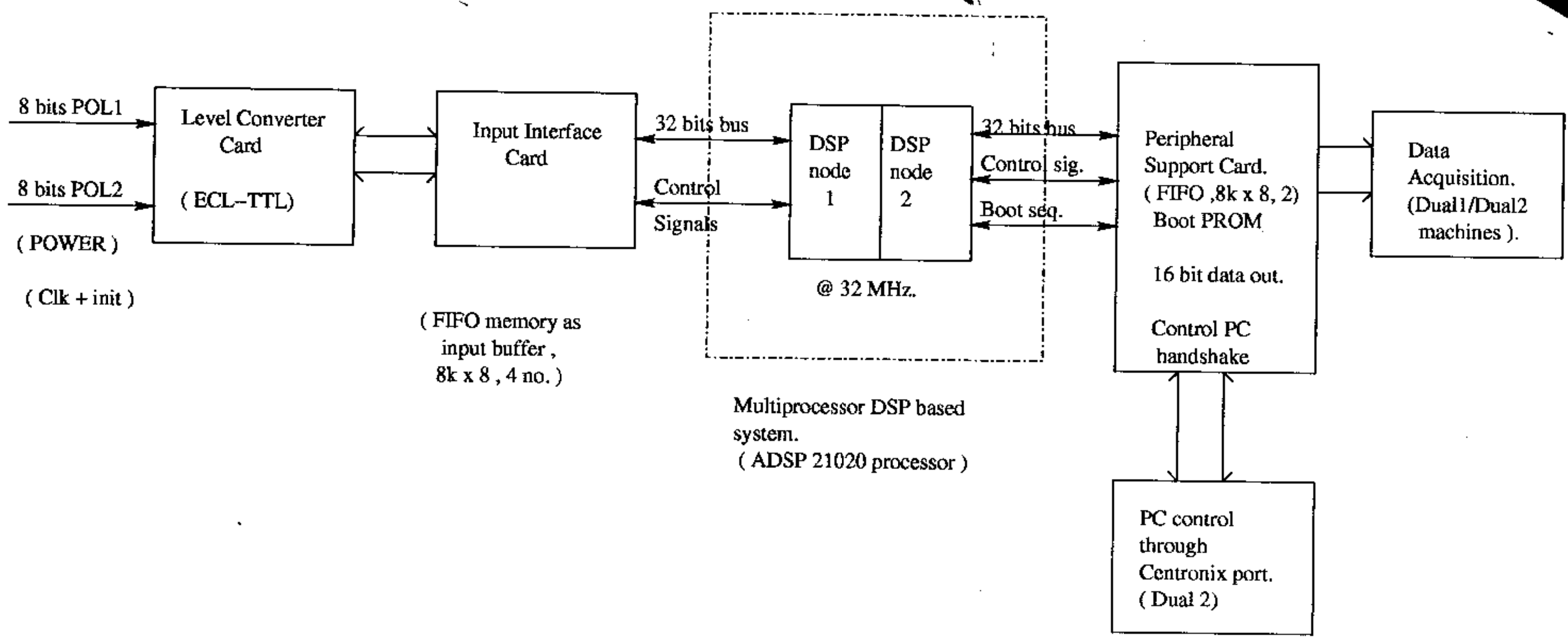


FIG 2 : Incoherent Array mode of PULSAR receiver.

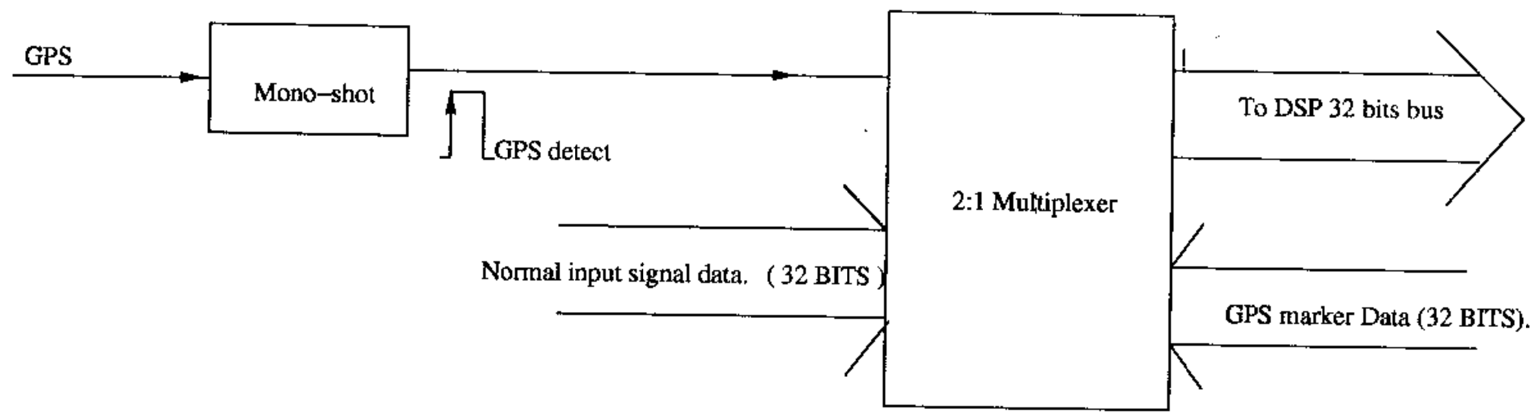


FIG 3 :a)

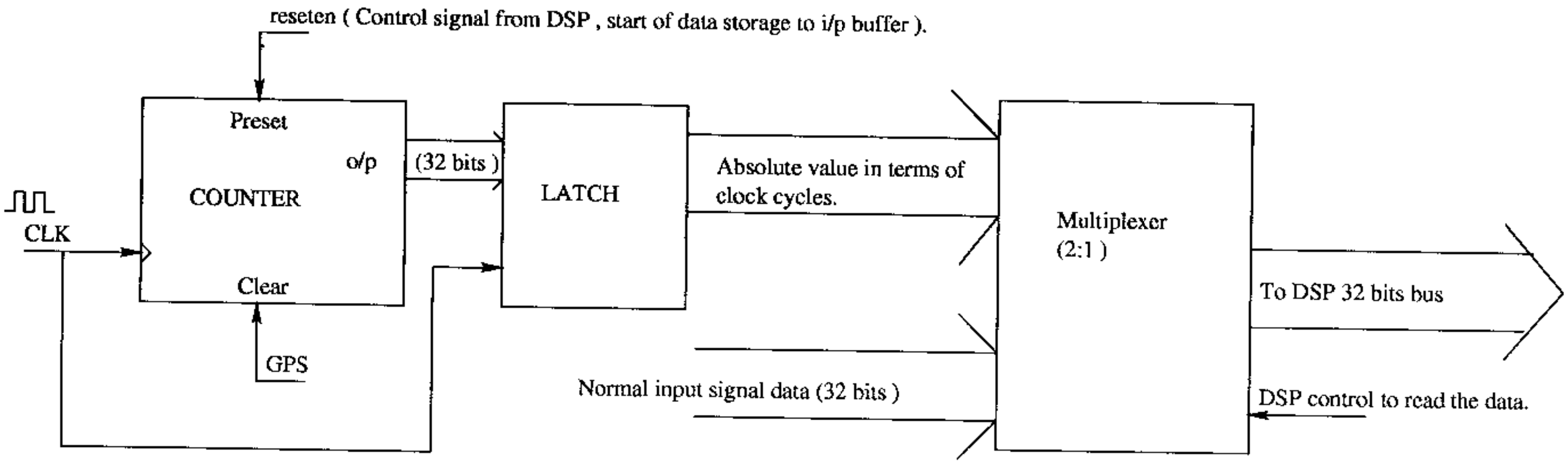
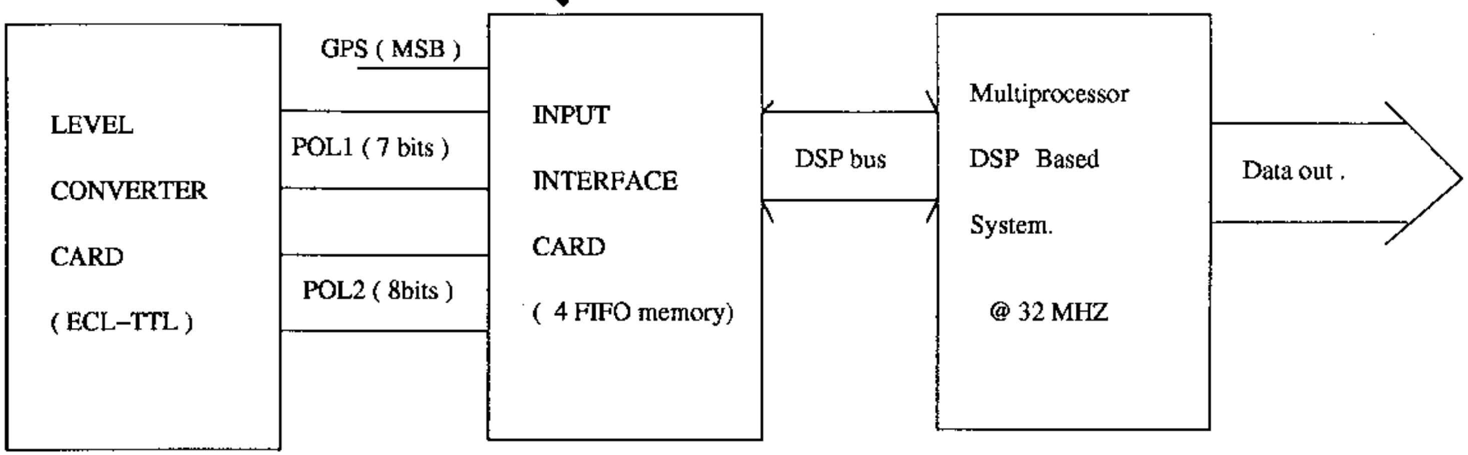


FIG 3: b)

FIG 3 : a) GPS signal insertion and detection using less hardware, but need to sacrifice one frequency channel (random) for GPS marker data.
b) Needs more hardware and GPS counter value can be stored on specific frequency channel.



Maximum 32 no. of accumulations by DSP.

FIG 4 : GPS signal insertion at Input Interface card on MSB of the input signal , thus making a compromise on signal information.

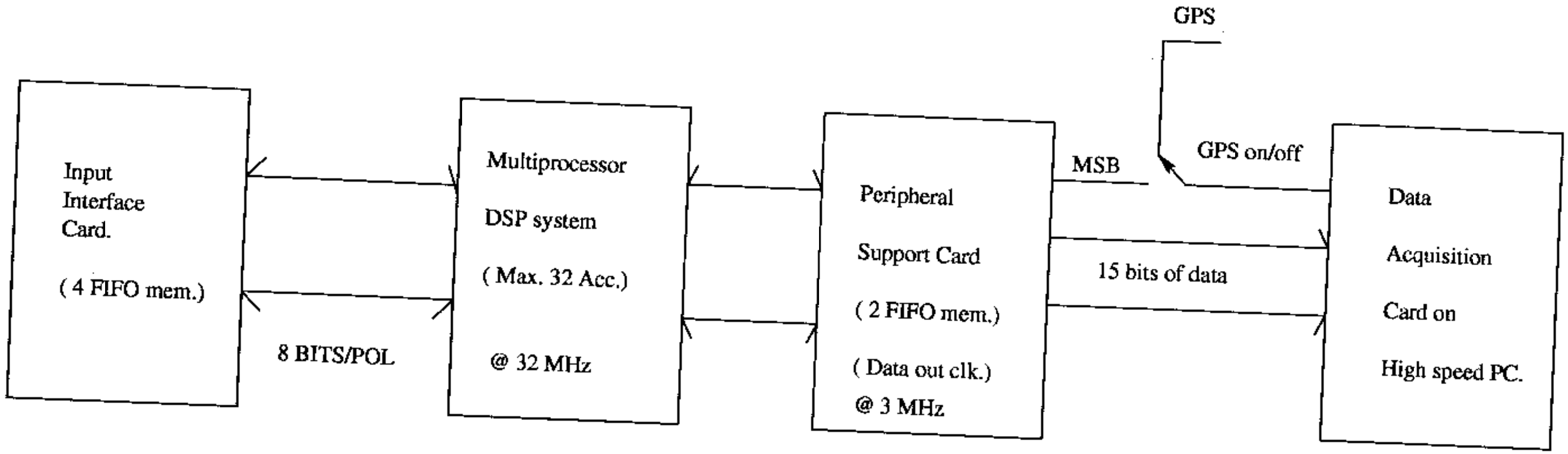
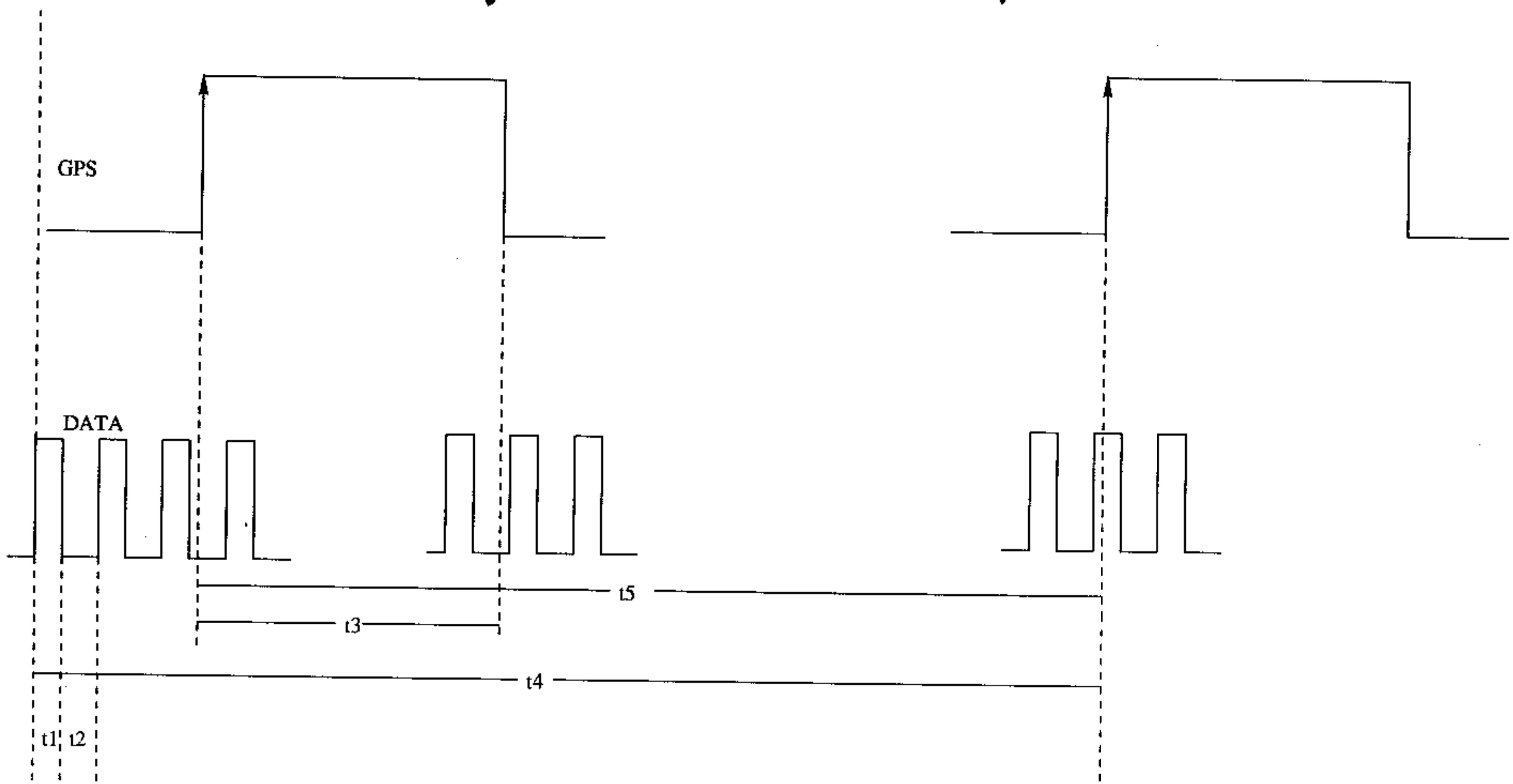
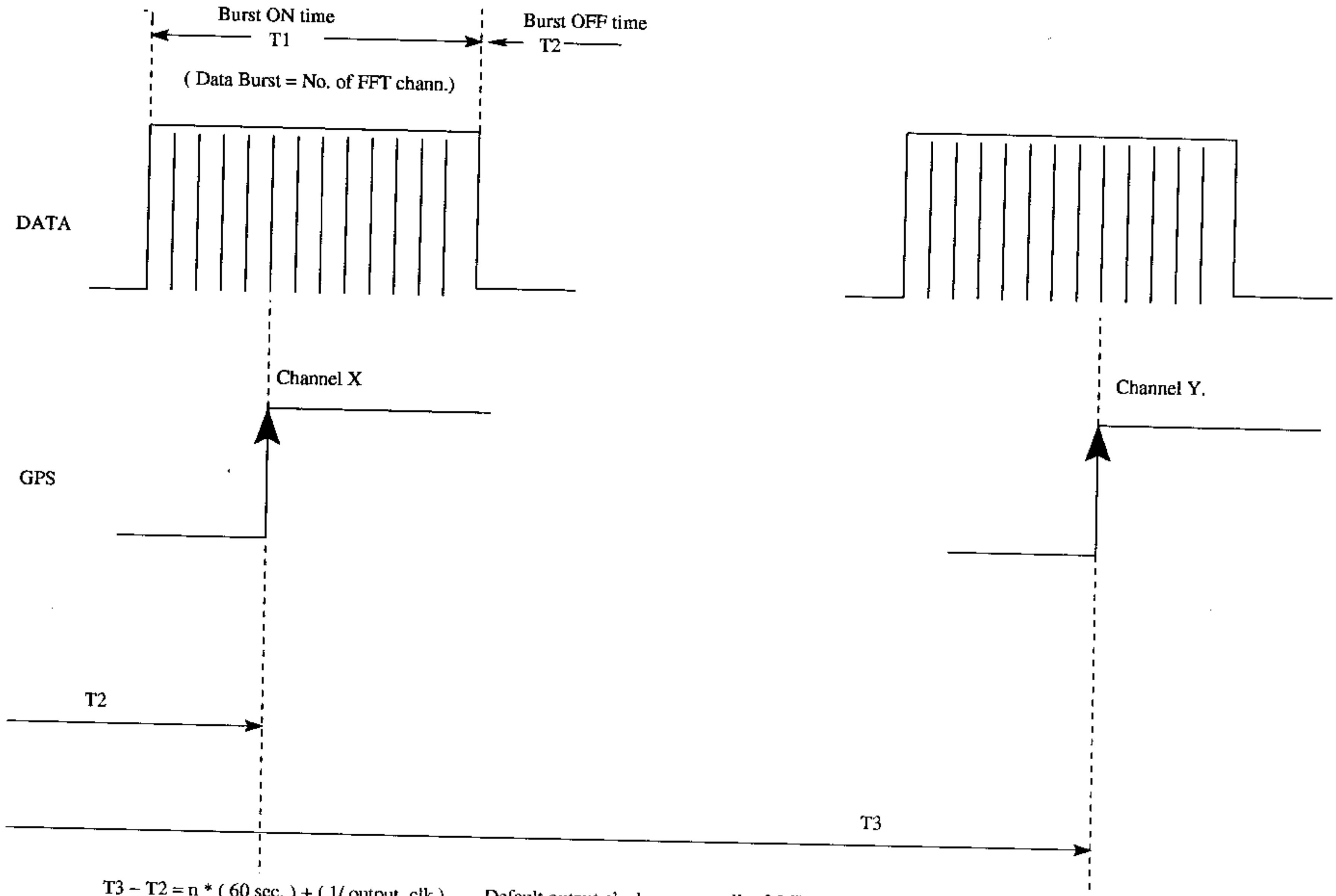


FIG 5 : Currently implemented scheme for GPS insertion and detection.



t1 = Burst ON time .
t2 = Burst OFF time.
t3 = GPS ON time.
t4= The time for valid GPS edge detection.
t5 = GPS pulse width = n * 60 sec. where n= 1 ,2,3 etc. (integer).

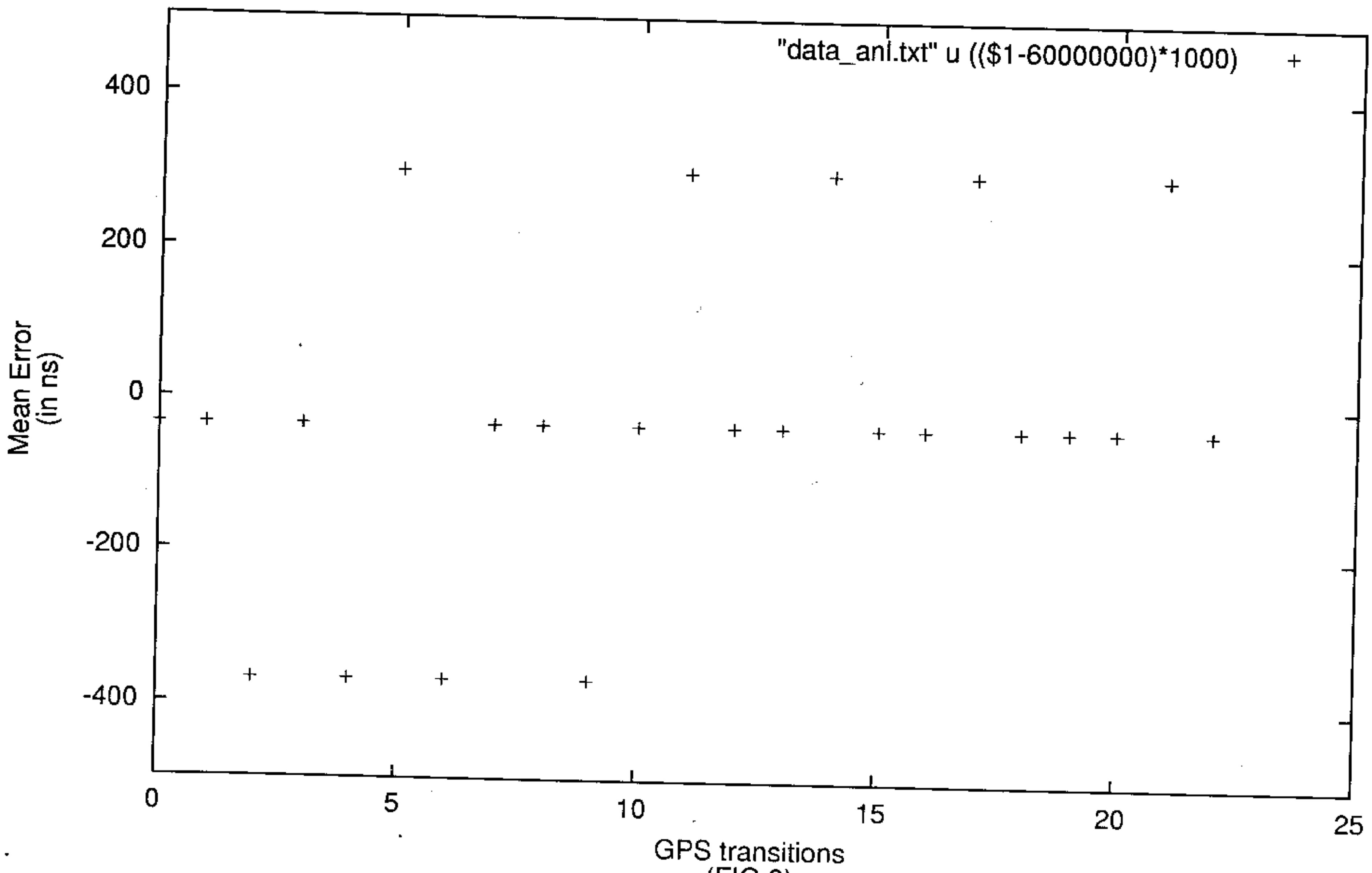
FIG 6 : GPS signal measurement LOGIC.



$T3 - T2 = n * (60\text{ sec.}) \pm (1/\text{output\_clk})$, where n=1,2,3...(integer). Default output clock =output_clk= 3 MHz.

FIG 7 : GPS signal measurement and validity.

DATA ANALYSIS



(FIG.8)