Real-time Acquisition and Processing of Data from the GMRT Pulsar Back-ends

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Objectives

- 'Software subsection' of pulsar data acquisition system
- Online processing facilities:
  - Checking data integrity: Marker, GPS bit check
  - Monitoring data quality: psr_mon, channel monitoring
  - Real time post processing: GPS time stamping, Time and frequency integrations, bit packing, de dispersion, gating.
Plan

- Pulsar - Overview
- Basic processing techniques
  - Marker check
  - GPS time stamping
  - Time/Frequency integrations
- Bit Packing
- De dispersion/gating
- psr_mon
- Others – supporting programs, data format at different points in pulsar data
Pulsars – an overview

- Highly magnetised, rapidly-rotating neutron stars
- “True north” and “magnetic north” are misaligned.
- Period – ranges from few seconds to milli­seconds
Pulsar observations @ GMRT

- Incoherent array mode
- Coherent array mode
- Polarimeter
- Spectral resolution – 16MHz BW divided into 256 channels
- Time resolution requirements
  - High data rates
    - 0.5 ms sampling will give: \( \frac{256}{(0.5 \times 10^{-3})} = 512K \) channels, with each channel 2 bytes = 1Mb and full polar mode = 4Mb
Basic data flow – software sequence

- Inter process communication
- Modes: For all - ia, pa, polarimeter same software can be used
- Format of the output data
Markers and marker check

- Marker - Periodic patterns embedded in data
- To check data integrity
- To know the start of the time sample
- Marker scheme for IA/PA
- Marker scheme for polarimeter
GPS Time stamping of data

- Pulsars – most stable of known natural clocks
- Pulsar Timing studies
- GPS – provides accurate clocks
- GPS information in GMRT pulsar data
- Getting more accurate time stamps
Post Time and frequency integrations

- What is this?
- Need?
- Time integrations increase SNR
- Time resolution is decreased
- Frequency resolution is reduced – dispersion effects may increase
Profile with no time and frequency integrations

Profile with 2 time integrations (post integrations)

Profile with 4 time integrations (post integrations)
Bit Packing

- Concept
- One biting – 80% of information from original signal is retained
- Pulsar search – One biting, IA mode
- Running mean subtraction
  - Threshold for bit quantization
  - Running mean window
- Data is packed into 16-bit integer
Dispersion

- Dispersion - ?
- Effect: The pulse is detected at the high frequency end before it arrives at low frequency end.
- Dispersion Measure – Column density of free electrons along the line of sight to the pulsar
- Spectral line observations for pulsar signal
De dispersion

- De dispersion – compensation of interstellar dispersion
- Incoherent de dispersion
- Implementation of incoherent de dispersion
- For each frequency channel, the dispersion delay is calculated in terms of integer number of bins
- Data \([N_{\text{ch}} \times (n_{\text{tdelay}}+1)]\) is buffered in circular manner
Incoherent dedispersion algorithm

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Dispersed vs. de dispersed data

Profile of signal with dedispersion and without dedispersion

Dedispersed data

Dispersed data

Chart Record of DEDISPERSED data for

Bin Numbers

Amplitude
Gating

- Pulse has 5-10% duty cycle
- Gating – setting an on-pulse time window, recording the data within the window and rejecting the rest
- Setting a gate – data is folded
- Requirement of two gates
- Phase resolution = sampling time / period
- In each gate fixed number of bins are recorded
Monitoring program – psr_mon

- Different plots:
  - Band shape
  - Time series
  - Profiles
- Advantages – Monitoring data quality, pulse presence, drift in the pulse
- Reading from shared memory/ file
- Input parameter file – psr_online.in
Other programs

- **Read_acqpsr** – recording data directly from shared memory
  - Marker check
  - No gps check – time stamping
- **unpack_recdata** – unpacking bit packed data
  - Also useful for splitting 4K header and Data
- **psr_srv** – communicating with 'online'
  - Interface provided by sockngetcmd, which can act as server, client or simply taking command string from terminal/console
- **acqsimf** – same as acqpsr, reads data from file instead of
Data formats at different points in pulsar data flow
Performance!

- Current software is used for the full speed provided by the hardware.
  - For IA mode - 0.128ms (sampling rate)
  - For PA mode - 0.256 ms -- Total intensity
  - For Polarimeter - 64 microseconds -- Total intensity
- Analysis using acqsimf program was carried out, it shows data up to 1 integration (same as raw data) can be handled with the existing shared memory size
Conclusion and future scope

- Software is being used for the routine observations
- The modules are tested and working well
- This is the first module for the pulsar DAS software subsection and can be advanced!

- Future scope:
  - GPS time stamping for polarimeter
  - Online recording of folded data
  - Increasing number of gates in gating
  - Different real time techniques

- Road ahead…!
Thank You!