

REAL-TIME SIGNAL PROCESSING INSTRUMENTATION FOR SEARCH AND STUDIES OF PULSARS

THESIS

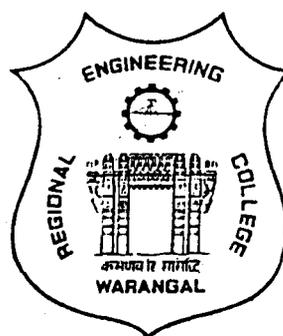
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By

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Dedicated to

my parents

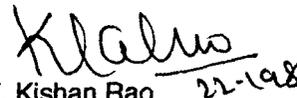
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CERTIFICATE

This is to certify that the thesis titled “ **REAL-TIME SIGNAL PROCESSING INSTRUMENTATION FOR SEARCH AND STUDIES OF PULSARS** “ being submitted by Sri. P.S.Ramkumar for the award of the degree of **DOCTOR OF PHILOSOPHY** to the faculty of Engineering of **KAKATIYA UNIVERSITY, WARANGAL** is a record of Bonafide Research work carried out by him under our supervision and it has not been submitted elsewhere for any degree.



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ABSTRACT

During the past thirty years of Pulsar research, several sensitive observations experiments have been conducted to discover pulsars and study their properties in detail. The current sensitivity limit is about a **milli-Jansky** for Pulsar searches and much better for pulsar studies. To reach this sensitivity, the surveys use low frequency telescopes with large apertures, large R.F. bandwidth and the observed time sequence is folded with the pulsar period for several thousands of periods. It is also required to **remove** the effects of dispersion, Faraday rotation and Doppler acceleration and integrate the power in time and frequency for maximizing the sensitivity. The data rate of the digitized samples at the output of these receivers runs into several tens of **Mbytes** per second, and the offline-processing jobs demand high through-put (several **giga-**operations-per second), making it extremely difficult to store the raw data of large bandwidths and do the processing later with presently available computers. In practice, a hybrid solution is sought using dedicated, real-time processing instruments to perform specific real-time processing tasks so as to reduce the data rate and size and thus the offline processing load. So far, such instruments have been limited in their flexibility to **handle** different types of pulsar observations and cater to small **bandwidths**(typically a few MHz). The first part of the work presented in this thesis (chapters 2, 3 and 4) describes in detail the design and development of a 'real-time signal processor' to be used in pulsar search and different types of pulsar studies. The instrument is designed primarily for use with the Ooty Radio Telescope and the GMRT radio telescope and perform the above mentioned operations over dual, orthogonal-polarization data samples of 512 frequency channels covering a maximum bandwidth of **32MHz**. The digital design exploits the advantages in using look-up-tables, reprogramable logic circuits and DSP chips to provide full programability and a modular architecture so that the bandwidth can be scaled from 1MHz to **32MHz** and interfaced to work with any other telescope. The optimizations used in the signal processing algorithms and the associated software development are discussed.

During the real-time processing, it is desirable to know the amount of Faraday rotation due to the ionosphere with reasonable accuracy. For real-time estimation and correction of Faraday rotation, a possibility of using pulsars themselves as probes of the ionosphere is investigated. Suitable signal processing methods for measuring the rotation measure (RM) of pulsars with a single polarization telescope are developed. The second part of the work presented in this thesis (chapter 5) discusses these methods and the results of observational tests.

This thesis is concluded with a discussion of the current status and future scope of this work. Even though the signal processing system is designed primarily for pulsar work, parts of this machine will be suited for several other signal processing applications. Some of such applications are highlighted towards the end of the chapter.

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APPENDIX A : Photographic copies of the various hardware modules of the system

APPENDIX B : Copy of published paper

REFERENCES

ABBREVIATIONS

| | | | |
|---------------|--|-------------|--|
| μ_0 | Permeability of Free Space (1.3566×10^{-6} H/m) | IDT | Integrated Device Technology |
| ϵ_0 | Permittivity of Free Space (8.8544×10^{-12} F/m) | IF Amp | Intermediate Frequency Amplifier |
| m | Rest Mass of Electron (9.109×10^{-31} kg) | IIR | Infinite Impulse Response |
| e | Charge of an electron (1.602×10^{-19} C) | Imag. | Imaginary part |
| A/D | Analog to Digital | ISA | Industry Standard Architecture |
| AC | Array Combiner | ISM | Inter-Stellar Medium |
| ACF | Auto correlation Function | ISSP | Input Selector for Search Pre-processor |
| ASIC | Application Specific Integrated Circuits | JY | Jansky |
| BFSL | Bit Field Selection Logic | k bytes | Kilo bytes |
| BiCMOS | Bi-Complimentary Metal Oxide Semiconductor | K_b | Boltzman Constant (1.380×10^{-23} J/degree) |
| BPF | Band Pass Filter | LNA | Low Noise Amplifier |
| CAD | Computer Aided Design | LO | Local Oscillator |
| CMOS | Complimentary Metal Oxide Semiconductor | LPF | Low Pass Filter |
| DAG | Data Address Generation | LSB | Least Significant Bit |
| DAS | Data Acquisition System | Mbaud | Million bits per second |
| DCS | Data Collection System | MHz | Mega Hertz |
| DM | Dispersion Measure (cm^{-3} parsec) | MIMD | Multiple - Instruction – Multiple - Data |
| DMA | Data Memory Address bus | MOPS | Million Operations per Second |
| DMD | Data Memory Data bus | MSB | Most Significant Bit |
| DPRAM | Dual Port Random Access Memory | MUX | Multiplexer |
| DSP | Digital Signal Processing | NLS | Non-linear Least Square |
| DSP-PPS | DSP - Parallel Processing System | O/p | Output |
| ECL | Emitter Coupled Logic | ORT | Ooty Radio Telescope |
| EDN | Electronic Design News | PA | Phased Array |
| EMI | Electro Magnetic interference | PC-AT | Personal Computer – Advanced Technology |
| EPLD | Erasable Programmable Logic Device | PCB | Printed Circuit Board |
| EPROM | Erasable Programmable Read Only Memory | PLD | Programmable Logic Device |
| FCT | Fast CMOS Technology | PM | Program Memory |
| FFT | Fast Fourier Transform | PMA | Program Memory Address bus |
| FIFO | First In First Out | PMD | Program Memory Data bus |
| FTP | File Transfer Protocal | PPI | Programmable Peripheral Interface |
| FIR | Finite Impulse Response | PPR | Portable Pulsar Receiver |
| FLEX | Flexible Logic Element Matrix | PROM | Programmable Read Only Memory |
| FPGA | Field Programmable Gate Array | RAMs | Random Access Memories |
| GAC | Giant metre wave radio telescope Array Combiner | RF | Radio Frequency |
| GB | Giga Bytes | RM | Rotation Measure (radians m^{-2}) |
| Gflops | Giga floating point operations per second | RMS | Root Mean Square |
| GMRT | Giant Metre wave Radio Telescope | SCSI | Small Computer System Interface |
| GPS | Global Positioning System | SNR | Signal to Noise Ratio |
| HA | Hour Angle | SP | Search Pre-processor |
| HCT | High Speed CMOS Technology | SRAM | Static Random Access Memory |
| I/O | Input I Output | SSB | Singe Side Band |
| I/p | Input | TCP/IP | Transmission Control Protocol / Internet Protocol |
| IA | Incoherent Array | TTL | Transistor – Transistor Logic |
| IC | Integrated Circuit | USB | Upper Side Band |

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