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

Smt. C.Nagarathna and Sri. P.N.Sachidananda

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.

CONTENTS

ABBREVIATIONS

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

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