A REAL-TIME DATA ACQUISITION AND SIGNAL PROCESSING SYSTEM FOR ISRO'S AIRBORNE SYNTHETIC APERTURE RADAR (ASAR)

N.M. Desai
J.G.Vachhani, S.M.Trivedi, B.S.Raman, A.A.Shah, R.B.Gameti, R.Neelakantan and V.R.Gujraty

MSDD/MSDG/RSA, Space Applications Centre (SAC),
Indian Space Research Organisation (ISRO), Ahmedabad-380 053, India.

Commission II, Working Group 1

KEY WORDS: ASAR, DHCU, RTPD, SMC, HDDTR, Azimuth processor, Doppler Centroid, DSP, PSPE, DCE, Autofocus.

ABSTRACT

An On-board Real Time Data Acquisition and Signal Processing (DASP) System has been developed for Indian Space Research Organisation's (ISRO) C-band Airborne Synthetic Aperture Radar (ASAR). One of its constituent, the Data Handling and Control Unit (DHCU) assists the operator in centralised initialisation, configuration, control and monitoring of the complete ASAR system during flights and also carries out data acquisition, recording and certain motion compensation related tasks. The other digital unit, the Real Time Processor and Display (RTPD) system, is utilised for continuous monitoring of ASAR performance during imaging sessions and also performs estimation of some parameters critical for ASAR motion compensation. The RTPD system is configured for generating a true multi-look selectable limited swath ASAR image with moderate resolution or a full swath image with a reduced resolution. It carries out, in real time, azimuth signal compression of the range compressed radar returns, tracking of Doppler Centroid frequency and fine estimation of the along track velocity of the aircraft using autofocus technique. The line-by-line scrolling multi-look ASAR image is displayed on a high resolution display monitor, along with certain important annotation parameters in engineering units for image identification. The system also supports an off-line processing mode, wherein quick look ASAR images can be generated by replaying the raw data, recorded on a High Density Digital Tape recorder. The multi-processor hardware architecture of RTPD is based on Motorola's DSP56001 digital signal processors. This paper describes the design requirements, configuration details, processor algorithm, architecture details and salient performance features of this Real Time Data Acquisition and Signal Processing system for ASAR.

1. INTRODUCTION

In 1989, ISRO approved the development of a C-band Airborne Synthetic Aperture Radar (ASAR). Various technical activities were initiated at Space Applications Centre (SAC), Ahmedabad for this indigenous development. Considering the operational requirements of ISRO's ASAR system, it was decided to have a real-time digital SAR processor for generation of Quick Look Browse products along with the facility to digitise and record ASAR return signals on a High Density Digital Tape Recorder (HDDTR). With these objectives in mind, the design and development of a Real-Time Data Acquisition and Signal Processing (DASP) System for ISRO's ASAR was taken up.

The breadboard model of ASAR was test flown aboard a Beechcraft 300 aircraft with a rigidly mounted antenna and without the real time processor during April/ May 1992. In 1993, the breadboard development of Real Time Processor and Display (RTPD) unit was also completed and the raw data recorded on High Density Digital Tapes during the breadboard test flights was utilised to process and display, in real-time, the first Quick Look ASAR images. The Flight model was completed in late 1995 and after detailed Test and Evaluation, various experimental/ calibration flights with a stabilised antenna aboard a Beechcraft-200 aircraft, were conducted in March/ April, 1997. Similar campaigns are also underway presently in April/ May, 1998.

2. ASAR SYSTEM OVERVIEW

Table-1 gives the major mission parameters and system specifications of ISRO's ASAR. The ASAR is configured in a monostatic mode. The baseband impulse modulates the stable coherent 123.256 MHz IF signal fed to a Surface Acoustic Wave (SAW) Expander for generation of a linear frequency modulated chirp signal. This chirp signal is upconverted to 5.3 GHz, amplified to 2 Kw peak power in the TWTA and fed to a Microstrip antenna. The received signal is amplified by LNA, down converted to IF level, compressed in SAW compressor and conditioned in AGC/MGC amplifier before demodulation in I-Q demodulator. The baseband signal is fed to the DASP system where it is digitised, formatted and stored onto the HDDTR. Fully focussed SAR azimuth processing and estimation of Doppler centroid frequency and aircraft along-track velocity are also carried for generation of quick look images of a portion of the terrain being mapped. The processed image is displayed on a high resolution monitor along with annotation parameters. The calibration subsystem provides necessary stimuli for system calibration and IF replica generation. The overall co-ordination and control of ASAR is performed by a processor based unit. An onboard Stabilisation of Antenna and Motion Compensation (SAMCS) unit senses and compensates for the effects of aircraft spurious linear and angular motion errors on ASAR data. Various aircraft motion and attitude parameters sensed by INS, GPS, RTPD etc. are fed to SAMCS computer for necessary actions, to implement the scheme for antenna stabilisation and motion compensation, in association with DASP.

PARAMETER	SPECIFICATION
(1) MISSION	
Frequency of Operation	5.3 GHz
Aircraft Type	Beechcraft superking B-200
Aircraft Altitude	8 Kms ± 0.4 Kms
Aircraft Velocity	120 m/sec. (Nominal), 102-126 m/sec.
Polarisation	HH, VV
Off Nadir Look Angle Coverage	7 ° - 74 °
Swath Coverage	25 Kms.
Back Scattering Coefficient	-30 dB to +7 dB
Slant Range Resolution	6 meters
Azimuth Resolution	6 meters
(2) ANTENNA	
Antenna Pattern	Cosecant squared
Gain	24.4 dB
Elevation Beamwidth	67 °
Azimuth Beamwidth	2.2 °
(3) TRANSRECEIVER	
IF Frequency	123.256 MHz
Peak RF Power	2 Kw.
Average Power	20 Watts
Transmit Pulsewidth	20 μsec.
PRF	500 Hz (Nominal), 425 Hz-525 Hz
RF Bandwidth	27.5 MHz
Compressed Pulsewidth	40 nsec.
(4) DIGITAL	
Quantization	6 bits I + 6 bits Q
Doppler Bandwidth	184 Hz
Data rate	37 Mbits/sec. (raw data) 150 Kbits/sec. (Quick look data)

Table 1: Major mission parameters and system specifications of ISRO's ASAR.

PARAMETER	SPECIFICATION	
(A) DHCU SPECIFICATIONS		
ADC Quantization	6 bits I + 6 bits Q	
Sampling frequency	30.814 MHz	
Sampling Window Duration	166.1 μsec.	
IF/replica/Calibration Window Duration	20 μsec.	
Recording rate	3.0814 MHz	
No. of Range samples	5120 samples	
Data Format	5888 Samples/frame	
HDDTR Recording details	12 channels, 304 cps, 90 % density	
HDDTR RS-232C Serial Link	300 bauds	
Other RS-232C Serial Links	9600 bauds	
SAMCS RS-422 Serial Link	10 Mbauds	
(B) RTPD SPECIFICATIONS	**Narrow Swath**	**Full Swath**
Slant Range Resolution	6 meters	48 meters
Azimuth Resolution	6 meters	48 meters
Input Data	6 I + 6 Q	6 I + 6 Q
Range Swath Coverage	512 range cells	4096 range cells
No. of Looks	3 or 1 selectable	3 or 1 selectable
DCE Accuracy	± 10 Hz	± 10 Hz
Autofocus Accuracy	± 0.25 m/sec.	± 0.25 m/sec.
DCE/Autofocus update rate	2 Hz	2 Hz
Display format	512 x 512 pixels	512 x 512 pixels

Table 2: Major specifications of DASP system for ASAR.

3. DESIGN REQUIREMENTS

DASP consists of two units viz. Data Handling and Control Unit (DHCU) and Real Time Processor and Display Unit (RTPD). Table 2 gives the major specifications of DASP system for ISRO's ASAR. Figure 3 shows its block schematic.

The major functions performed by DHCU are as follows:

- Digitisation of the received complex radar signals.
- Formatting of digitised data and auxiliary information.
- Continuous On-line Storage of formatted data onto the HDDTR.
- Slaving of PRF to aircraft's along track velocity for equispatial azimuth sampling on ground.
- Fine tuning of the sampling window start time to take care of range variations with aircraft trajectory.
- Computations for Phase compensation of the return data to remove across-track motion errors in the slant-range plane.
- User interface for operator interaction with ASAR system.
- Initialisation and configuration of various ASAR subsystems.
- Individual control and status monitoring of various RF subsystems like Transmitter, Receiver and Calibration units.
- Interface for Data Acquisition from Aircraft Altimeter, INS and GPS through SAMCS.
- Remote control of RTPD and HDDTR.

The RTPD system is required to perform the following functions:

- Reception of input data and its de-formatting.
- Focussed SAR Azimuth signal processing over the selected swath.
- Estimation of unambiguous Doppler centroid from ASAR signal.
- Autofocus computations for aircraft's fine velocity estimation.
- Display of line-by-line scrolling ASAR image.
- Periodic update and display of annotation parameters below ASAR image frame.

4. DATA HANDLING AND CONTROL UNIT

The Data Handling and Control Unit consists of two sub-units called Data Acquisition Unit (DACQ) and Status Monitoring and Control Unit (SMC).

4.1 Data Acquisition Unit

Data Acquisition unit consists of high speed digitizers, buffer storage, phase compensation unit, formatter and the necessary timing and control logic circuits. The digitizer module comprises of the wideband Op-amp based signal conditioners and 8-bit flash analog to digital converters, AD9002, for both the In-phase and Quadrature phase channels. The demodulated radar return signals bandlimited to 13.75 MHz, are digitised at 30.814 MHz rate in each channel and stored in the high speed buffer memories. The PRF is slaved to aircraft velocity and gives rise to proportional variation in the average output data rate. Hence, the buffer memories are read at a rate marginally higher than the average rate corresponding to the expected maximum PRF, thereby resulting in periodic invalid null data frames. All the front end circuits are designed with 8-bit resolution instead of 6-bit to achieve better performance.

The timing generator and control logics provide various timing signals required for synchronised operation of ASAR system. The STALO of 123.256 MHz is used as the reference signal for deriving the required timing signals for transcreceiver like Sampling Clock, start impulse for chirp, Tx Window, Rx Protection Pulse, Expander Gating Pulse, AGC controls etc. and other programmable digital signals like PRF, data acquisition window, IF replica/ Calibration window, record clock etc. To reduce the processing complexity of the ASAR processors, elaborate on-line motion compensation tasks like PRF slaving, window tuning and phase compensation are also performed. The phase compensation of each range return sample is performed on the fly using a Multiplier Accumulator. The phase corrected data are multiplexed in dual port memories with other auxiliary data acquired by SMC Processor. The formatter reads out these data in continuous fashion and feeds it to a ruggedised HDDTR of M/s Enertec Schlumberger make, through line drivers as twelve parallel PCM channels in bit parallel, word serial mode.

4.2 Status Monitoring and Control Unit

A 16-bit processor Intel 8086, along with a co-processor, 8087 operating at 8 MHz clock speed has been configured to perform various ASAR control and command tasks. It supports RS-232C serial links to interface with operator console and for remote control of HDDTR and RTPD. The ASAR operator is provided with a menu driven user command interface for configuring ASAR system, on-line health monitoring and alarm indications. SMC also receives clutter lock (yaw angle) data and health status from RTPD. The ASAR transmitter, receiver and calibration units are controlled and monitored through parallel digital and analog interfaces. The RS-422 serial interface with SAMCS, operating at 10 Mbauds, is used to send commands and clutter lock data and to receive the computed across track displacements, INS and GPS data and SAMCS health status. The various programmable inputs and outputs are exchanged with DACQ unit through parallel I/O ports while the dual port memories are used for multiplexing of auxiliary data with radar video data. SMC also computes phase compensation coefficients for each range return sample, with the help of Coprocessor, utilising the current across track displacement parameters received from SAMCS. SMC is a single user real time multitasking operating system, which follows a prioritised scheduling algorithm. Here a group of processes are assigned a single time slice instead of each task being given a time slice. The various tasks to be performed by SMC have been classified into three categories viz. High, medium and low Priority events, served by three schedulers of different periodicity.

5. REAL TIME PROCESSOR AND DISPLAY UNIT

The RTPD unit generates in real time a true three-look limited swath (2.5 Kms), 6 m. resolution or a full-swath (20 Kms), 48 m. resolution ASAR image and provides a quick look facility for viewing the terrain being mapped on a continuous basis. For ASAR, range compression is performed using SAW devices. The SAMCS system ensures that the antenna always points to the broadside and hence residual Doppler centroid shift can be ignored in processing. PRF slaving to

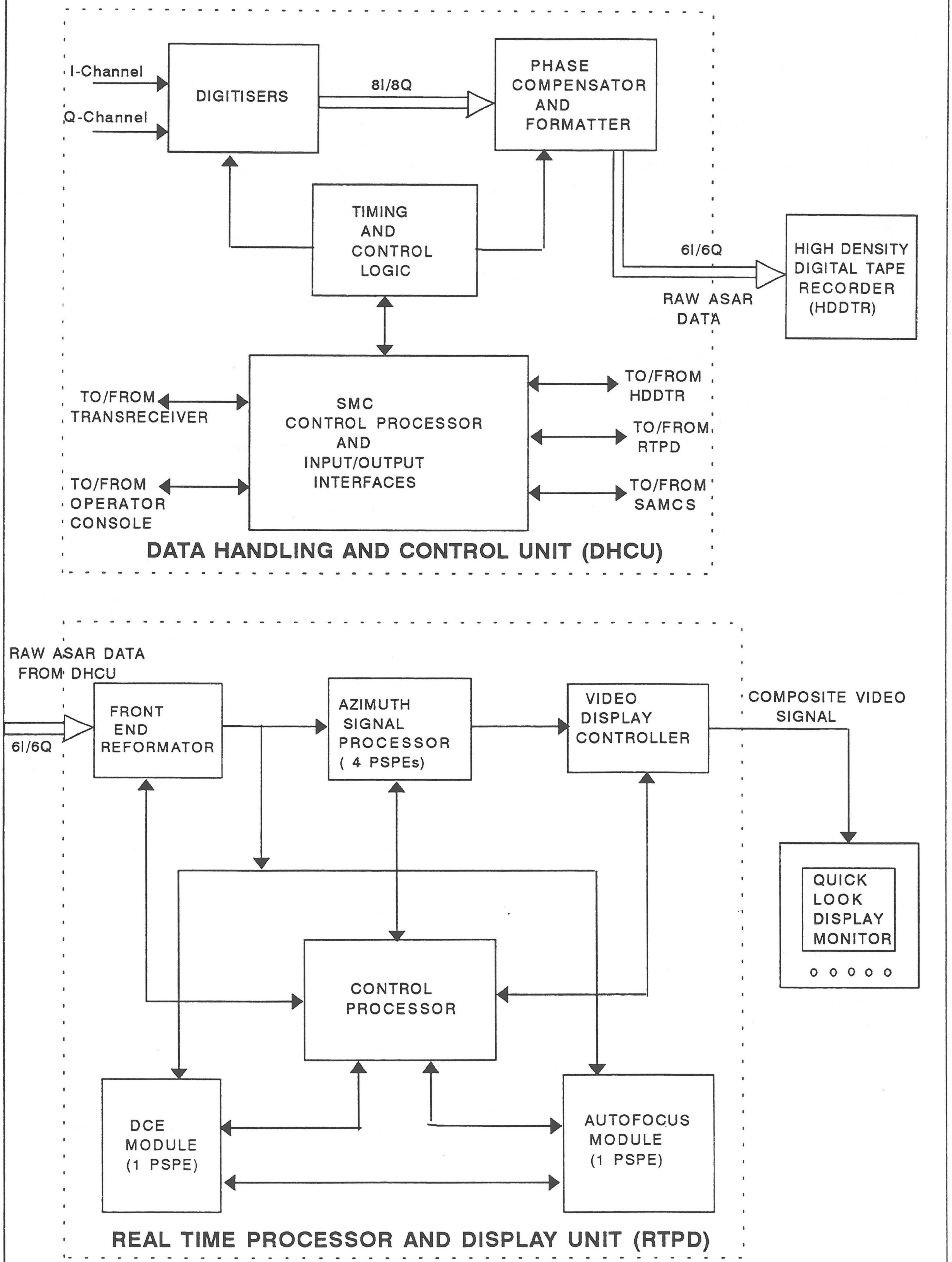

Figure 3: Block Schematic of DASP System for ISRO's ASAR

aircraft velocity results in a constant azimuth sample spacing and hence there is no need of frequent updating of azimuth reference function for a given depth of focus. The range walk and range curvature corrections can be dispensed with for the given C-band frequency of operation, range and resolution. The phase compensation of the received data removes across track motion errors. The azimuth compression (Bennet et. al., 1980), is done using time domain correlation technique in view of shorter matched filter durations. The incoming data at PRF rate, having a bandwidth of 184 Hz, is phase rotated and corner-turned and multi-rate complex prefiltering (Barber, 1985), is performed using 31 tap FIR filters to limit signal bandwidth to 78 Hz. The prefiltered data are separated into three contiguous looks viz. Fore, Mid and Aft, of equal bandwidth (26 Hz) heterodyned around zero Doppler using 31 tap FIR filters. The outputs of these multi-rate look filters then undergo 13 to 52 point complex correlation with azimuth reference during azimuth compression. The azimuth reference coefficients are computed and windowed with generalised Hanning weighting of β=0.7. The compressed outputs from the three look correlators, which appear at different times, are magnitude detected using a linear approximation and registered by giving appropriate integral delays before incoherent summation (SAC/ISRO, 1990a), to reduce speckle. For the full swath processing option, the basic algorithm remains the same. Eight range gates are averaged at input to generate one range sample while Eight azimuth lines are averaged to generate one output image line, thereby reducing the range and azimuth resolutions.

The front end electronics of RTPD unit receives the formatted ASAR data and performs the tasks of synchronisation, invalid frame rejection, auxiliary data separation and selection of range swath for subsequent azimuth processing. The azimuth processor hardware consists of Four identical Programmable Signal Processing Elements (PSPE) based on Motorola's 24-bit fixed point Digital Signal Processor (DSP), DSP56001, interconnected by common data and control path (Dall, et. al., 1992), parallely processing a portion of swath. Each PSPE consists of a DSP56001 operating at 20 MHz, Two 8K x 9-bit FIFOs for input data interface, 64 Kwords high speed static data memories, 16 Kwords of program memory PROM, a serial communication link and host microprocessor interface and consumes about 4 Watts power. The azimuth processor receives the range compressed, full motion-compensated, zero offset complex baseband data and performs the tasks of corner turning, azimuth prefiltering, look extraction filtering for three contiguous looks, matched filter computations, complex azimuth correlation, magnitude detection, look registration and summation to generate the ASAR image pixels. An unique feature of Azimuth Processor architecture is that each constituent PSPE contains exactly identical DSP firmware and performs complete azimuth processing over a portion of swath and can be on-line re-configured by the host control processor. No coupling exists between various PSPEs, thus reducing the hardware complexity and interconnections (Anderson, 1992). The required communication between the DSPs takes place through the common host processor. The hardware configuration of the subprocessors being identical, any module can be assigned to process any portion of the swath.

Doppler Centroid Estimation (DCE) PSPE module computes, with an accuracy of ± 10 Hz, the shift in the centroid of the azimuth spectrum due to random platform motions, using spectral analysis and time-domain correlation techniques (Madsen, 1989). In the frequency domain approach, the average power spectrum of the input raw data is computed using 256 point radix-2 FFT over 64 range gates at the mid-swath position. The peak of the azimuth spectrum is then detected by means of spectrum shifting, energy balancing and linear curve fitting algorithms (SAC/ISRO, 1991a), to estimate Doppler centroid frequency modulo PRF. Alternate time-domain autocorrelation techniques like Correlation Doppler Estimation (CDE) and Sign Doppler Estimation (SDE) have also been implemented. In CDE method, the linear phase shift of the time domain correlation coefficients is utilised to directly measure the magnitude of frequency shift. In SDE approach, the correlation coefficients are estimated on the basis of the signs of the data values, thereby reducing the sensitivity of the estimator to bright targets. The mPRF ambiguity removal algorithm is utilised to estimate the azimuth ambiguity function using image correlation technique. A 64 point Range cross correlation is performed between extreme fore and aft look ($f0$ = ± 78 Hz) images of the same target area to compute the range walk over eight azimuth lines from which modulo PRF number is estimated. This estimate along with Doppler centroid is utilised to compute yaw angle information which is sent to SAMCS for appropriate antenna steering to ensure broadside pointing of the antenna.

Autofocus (Curlander et. al., 1991), is a scheme which derives the optimum reference chirp rate from the azimuth returns to avoid image defocussing effects due to platform errors. The autofocus PSPE module estimates using the multi-look misregistration algorithm (SAC/ISRO, 1990b), and with an accuracy of ± 0.25 m/sec., the aircraft along track velocity information which is used to perform PRF slaving. Azimuth cross correlation is performed between extreme fore and aft look images of the same target area to compute the average misregistration factor over sixteen range gates from which along track velocity is computed. The DCE and Autofocus outputs are updated at a rate of 1.953 Hz.

A Control processor similar to the SMC processor provides overall co-ordination and control of the various constituent subsystems. A dedicated display controller is used to display line-by-line up or down scrolling ASAR image in range-azimuth domain on a high resolution monochrome display monitor in 512x512 pixels format along with certain important annotation parameters in engineering units such as latitude, longitude, track number etc. for image identification. Provisions also exist for lateral inversion and freezing of the image frame and periodic update of the displayed annotation parameters. Various other options like swath selection, azimuth processor gain, single look mode, full swath low resolution mode, DCE algorithm, image scrolling mode etc. are kept programmable through front panel or operator console for functional and operational flexibility. RTPD also supports an off-line processing mode, wherein ASAR images can be generated, by feeding the raw data, recorded on HDDTR or the data from hardware radar return signal simulator. RTPD's Multi-DSP heterogeneous computer configuration yields a sustained processing throughput of about 30 MOPs. The complete software development is carried out in DSP56001 and 8086 Assembly languages. Figure 4 shows the photograph of onboard RTPD unit mounted in one of the ASAR racks.

6. PERFORMANCE EVALUATION

Digitiser dynamic performance was verified by carrying out Signal-to-Noise Ratio measurements on ADCs for full scale sinusoidal inputs. SMC processor hardware and real time operating system performance were verified using 8086 development system and various interface simulators. The simulated azimuth point and distributed target data were fed, at real-time rates, from a PC-based simulator to verify RTPD functions like azimuth compression, DCE and Autofocus and ascertain the consistency and repeatability of the results. Various DSP56001 development tools were extensively utilised to verify PSPE hardware and benchmarking of DSP software modules like FIR filter, complex convolver, radix-2 FFT, magnitude detector etc. Various image quality parameters like azimuth resolution, Integrated Side Lobe Ratio (ISLR) and Peak Sidelobe Ratio (PSLR) were computed for Azimuth Signal processor (SAC/ISRO, 1991b). Table 5 gives the processing and performance parameters of DASP system. The DCE and Autofocus results, being highly scene dependent, were verified by feeding simulated radar returns as well as by replaying ASAR breadboard test flight data.

7. TOWARDS FUTURE

In India, there is a growing user demand for real-time full swath high resolution ASAR images. Efforts have been initiated to develop a full swath RTP and also to improve the processing throughput by utilising signal processor modules based on Analog Devices state-of-the-art floating point, ADSP-21020 and ADSP-21060 SHARC DSPs. The necessary porting of the existing ASAR signal processing software is under progress using ANSI C and ADSP-210XX assembly languages. One big advantage of change-over to these new generation DSP devices is that these devices are likely to be available in space qualified levels in near future and hence these development efforts would directly feed into the activities related to onboard real time processor for ISRO's future spaceborne SAR satellite. A new airborne SAR configuration having fine resolution (3m x 3m) and wide-swath (60 Kms) modes is also under consideration to meet new user demands. The data acquisition and signal processing system for such a SAR would involve about two to three-fold increase in overall complexity and digital hardware compared to the existing design. The new RTP configuration would also be adaptable to the processing needs of satellite SAR data from missions like ERS-1/2, Radarsat and Envisat-1.

8. CONCLUDING REMARKS

DASP system, the main control and co-ordination element of ISRO's ASAR system, has now been in operation for last couple of years. Its utility and performance has been widely acknowledged and appreciated by ASAR operators and users. It has admirably assisted ASAR operator in centralised initialisation, configuration, control and monitoring of SAR system during imaging sessions and well-supported ASAR data acquisition, recording and critical motion compensation related functions. The preview capability offered by RTPD helps in a rapid assessment of the area being mapped and environmental conditions during imaging and for identification of raw data portions for off-line processing using ASAR ground processor, thereby optimising its usage. The quick look ASAR images have also supplemented the off-line ground processor in quite a few user applications. ISRO's ASAR is likely to be made available for operational missions by the end of this year, after a detailed analysis and performance evaluation from the latest flight data and some necessary and prospective enhancements.

9. ACKNOWLEDGEMENTS

The authors would like to thank Dr. George Joseph (Director, SAC), Mr. A.K.S.Gopalan (Associate Director, SAC), Mr. R.C.Garg (Director, ADRIN) and Mr. N.S.Pillai (Group Director, PPG) for their guidance and encouragement to the ASAR project. The authors also wish to acknowledge the contributions of Mr. S.S.Rana (Group Director, MSDG), Dr. S.B.Sharma, Mr. V.H.Bora, Mr. A.M.Jha, Mr. Tapan Misra, Mr. D.B.Dave and all the other staff members of MSDG/SAC/ISRO and other ISRO centres like VSSC, ISAC, IISU and NRSA, which made possible the successful development of ISRO's ASAR system.

10. REFERENCES

[1] Anderson A. J., 1992. Selection criteria in the development of a multiple processor based DSP system. Journal of microcomputer applications (1992) 15, pp. 327-346.

[2] Barber B.C., 1985. Theory of Digital imaging from orbital synthetic aperture radar. Int. Journal of Remote sensing, 1985, Vol. 6, No. 7, pp. 1009-1057.

[3] Bennet J.R., Widmer P. and Cumming I.G., 1980. A Real-Time Airborne SAR processor. ESA-SP-1031, 1980, pp. 15-23.

[4] Curlander J.C. and Mcdonough R.N., 1991. Synthetic Aperture Radar- Systems and Signal Processing. J. Wiley & Sons, U.S.A, pp. 210-248.

[5] Dall J., Jorgensen J.H., Christensen E.L. and Madsen S.N., 1992. A real-time processor for the Danish airborne SAR. IEE Proceedings-F, Vol. 139, No. 2, April 1992, pp.115-121.

[6] Madsen, S.N., 1989. Estimating the Doppler centroid of SAR data. IEEE Transactions on Aerospace and Electronic Systems, Vol. AES-25, No. 2, March 1989, pp. 134-140.

[7] SAC/ISRO Internal report, 1990a. Analysis of Depth of focus, Magnitude detection and Look registration for Airborne SAR.

[8] SAC/ISRO Internal report, 1990b. A Conceptual Overview of Autofocus.

[9] SAC/ISRO Internal report, 1991a. Modified Algorithm for Doppler Centroid Estimation for airborne Synthetic Aperture Radar.

[10] SAC/ISRO Internal report, 1991b. Effects of motion errors, compensation and simulation of image parameters for airborne SAR.

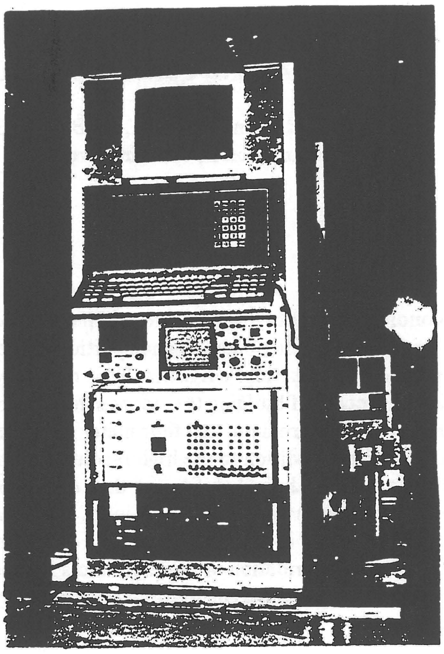

Figure 4: RTPD unit mounted in one of the ASAR racks

PARAMETER	VALUE	
(A) DHCU		
ADC SNR (Both I/ Q Channels)	36 dB	
Effective No. of ADC bits	6 bits	
PRF	499.86 Hz (Nominal)	
Range Sample Spacing	4.87 meters	
Raw Data rate	37 Mbits/sec.	
(B) RTPD	**Narrow Swath**	**Full Swath**
Slant Range Resolution	6.35 meters	50.80 meters
Azimuth Resolution	5.04 meters	40.32 meters
Processed Range gates	512	4096
Range Sample Spacing	4.87 meters	38.94 meters
Azimuth Sample Spacing	3.6 meters	28.80 meters
Depth of Focus	50 range cells	400 range cells
Input Doppler Bandwidth	184 Hz	184 Hz
Input PRF (Nominal)	500 Hz	500 Hz
Pre-filter	31 taps, FIR, Kaiser	31 taps, FIR, Kaiser
Pre-filter Bandwidth	78 Hz	78 Hz
Pre-filter Ratio	5	5
Look-filter	31 taps, FIR, Kaiser	31 taps, FIR, Kaiser
Look Bandwidth	26 Hz	26 Hz
Look-filter Ratio	3	3
Minimum Azimuth Chirp rate	16.742 Hz/sec.	16.742 Hz/sec.
Azimuth Correlator length	13 to 52 Complex	13 to 52 Complex
Effective Output line rate	33.333 Hz	4.17 Hz
Look Misregistration	± 1 pixel	± 1 pixel
Quick Look Image Size	2.5 Kms. x 1.8 Kms.	20 Kms x 15 Kms.
Quick Look Image dynamic range	48 dB	48 dB
DCE/Autofocus update rate	1.953 Hz	1.953 Hz
Azimuth ISLR	- 10 dB	- 10 dB
Azimuth PSLR	- 16 dB	- 16 dB
Radiometric Resolution	- 4 dB	- 4 dB
Processing Throughput	30 MOPs	30 MOPs
Display format	512 x 512 pixels	512 x 512 pixels

Table 5: Important processing and performance parameters of DASP system for ASAR.