EARTH OBSERVATION SYMPOSIUM (B1)
Earth Observation Data Management Systems (4)

Author: Mr. Nilesh Desai
Space Applications Centre (ISRO), India, nmdesai@sac.isro.gov.in

Mr. B. Saravanakumar
Indian Space Research Organization (ISRO), India, saravana@sac.isro.gov.in
Mr. Riteshkumar Sharma
SAC-ISRO, India, ritesh@sac.isro.gov.in
Mrs. Shalini Gangele
SAC-ISRO, India, shalinisethia@sac.isro.gov.in
Mr. Ramesh Gameti
SAC-ISRO, India, rameshgameti@sac.isro.gov.in
Mr. Abhishek Kunal
SAC-ISRO, India, abhishek@sac.isro.gov.in
Mr. Jethalal Vachhani
SAC-ISRO, India, jgvachhani@sac.isro.gov.in

ONBOARD SIGNAL PROCESSORS FOR ISRO'S MICROWAVE RADARS

Abstract

Since Mid-1970s, Indian Space Research Organisation's (ISRO) Microwave Remote Sensing Programme (MRSP) has been involved in the design and development of various ground based, airborne and spaceborne microwave sensors like Synthetic Aperture Radar (SAR), Scatterometer, Radiometer and Altimeter.

Synthetic Aperture Radar (SAR) has an unique role to play in mapping and monitoring of large areas affected by natural disasters especially floods, owing to its unique capability to see through clouds as well as all-weather imaging capability. For many civilian and strategic applications, the utility of SAR sensor is primarily governed by its capability to quickly generate radar images of the terrain under observation and mapping. During 1990s, Space Applications Centre, SAC, ISRO, Ahmedabad had developed an Airborne Synthetic Aperture Radar (ASAR) system, with 6 meters resolution, onboard Beechcraft Superking 200 aircraft. Therein, Onboard Quick Look Real-Time SAR signal processing was employed for the first time in 1994-95 in ISRO's C-band Air-borne Synthetic Aperture Radar (ASAR) It was configured around Motorola's DSP56001 fixed point Digital Signal Processor (DSP) based multi-processor architecture. It generated a true multi-look, selectable limited swath (2.5 kms, 3 Azimuth looks, 512 range gates) ASAR image with 6m x 6m resolution or a full-swath (20 Kms) image with reduced resolution (48m x 48m). Subsequently, this RTPD unit was upgraded using custom designed DSP boards based on Analog Devices' 32-bit floating point DSP, ADSP-21020. The Off-line ASAR Processor was based on conventional Range Doppler algorithm along with the motion compensation and mosaicing to obtain the 25 x 25 Kms radar images with 8-10 meters ground resolution.

Subsequently, this C-band Airborne SAR has been replaced with an airborne SAR for Disaster Management (DMSAR), with imaging capabilities of 2m to 30m resolutions, with swath coverage of 6km to 75 kms. DMSAR is presently mounted onboard Beechcraft B-200 aircraft and will be subsequently carried on a jet class aircraft and will be utilized for estimating the extent of damage over large areas (50-75 Km) and also assess the effectiveness of the relief measures undertaken during disasters like floods. Since 2001, apart from DMSAR, SAC/ISRO has been working on the design and development of a multi-mode

space-borne SAR for Radar Imaging Satellite-1 (RISAT-1) mission, which will provide unique imaging opportunities and coverage patterns over India and all other regions of the earth.

One of the major requirements for these RISAT-1 and DMSAR missions is the generation and availability of SAR information or data products in real or near-real time with very fast turn around times. Thus, an acute need was felt to evolve and develop a reconfigurable Multi-Mode Near-Real Time SAR Processor (NRTP) meeting the computational and memory bandwidth requirements for various RISAT-I and DMSAR operating modes. Moreover, it should also be possible to deploy the same NRTP configuration as Quick Look Real Time SAR Processor (QLP) onboard the DMSAR aircraft and at RISAT-1 ground stations.

For DMSAR, this generic SAR Processor operates as a Quick Look SAR Processor (QLP) on-board the aircraft to produce real time full swath DMSAR images and as a ground based Near-Real Time high precision full swath Processor (NRTP). It generates full-swath (6 to 75 Kms) DMSAR images in 2m / 3m / 5m / 10m / 30m resolution SAR operating modes. For RISAT-I mission, this NRTP will generate high resolution Spotlight (10 x 10 Kms) Sliding Spotlight SAR image (10x100 Kms), Stripmap SAR image (3m, 30x30 Kms) and ScanSAR images (25m, 120x120 Kms and 50m, 240x240 Kms) with real time quick look as well as 100 minutes near-real product turn around times. It will also be initially utilized for a quick pre-launch and post-launch validation of RISAT-1 SAR. This full-fledged hardware SAR processor is based on Commercial-Off-The-Shelf (COTS) multiprocessor DSP boards consisting of Analog Device's TigerSHARC DSPs (TS101S/TS201S) and IBM Cell BE Processor, yielding a sustained processing throughput of 10 GFLOPS.

This apart, Onboard or On-Ground Real-time digital signal processing has always been a major and essential requirement in onboard subsystems for microwave sensors like SAR, Scatterometer and Altimeter, as it results in reduction of instrument data rates and turn around time for fast delivery products. Currently flight model development activities are nearing completion for ISRO's three major EO missions involving microwave sensors viz. RISAT-1 SAR, Oceansat-II Scatterometer and Megha-Tropiques' Microwave Analysis and Detection of Rain and Atmospheric Structures (MADRAS) imaging radiometer. One of the salient features of these developments is the usage of various new and advanced digital technology elements for the first time in such complex space-borne radar systems. For RISAT-1 SAR, dual-channel Single Board ultra-high speed Data Acquisition and Compression Subsystem (DACS) has been qualified. It carries out Xilinx Virtex XQVR600 FPGA based onboard real-time SAR data Compression using Block Adaptive Quantisation (BAQ) techniques. A similar design has been implemented and qualified for onboard Data Acquisition and Range Compression (DACS) signal processing for Pencil beam Scatterometer sensor onboard Oceansat-II mission. A prototype Single Board Computer (SBC) based on Analog Devices' ADSP-21020 floating point DSP, currently under qualification for space usage, has also been developed and could also be a candidate hardware for onboard signal processors for Altimeter and Radiometer sensors, proposed for ISRO's future Radar missions.

Scatterometer processor carries out Doppler compensation of the return signal and subsequent filtering, based on multiple Fast Fourier Transform (FFT) for simultaneous estimation of Signal and noise-only energies. These energy estimates are subsequently utilised in ground based processing for finding ocean surface wind speed and direction. Altimeter processor carries out functions like FFT, programmable windowing, phase rotation, power averaging and robust alpha-beta trackers for gain, height and slope, in order to estimate ocean related parameters like significant wave-height, wind speed and mean sea level. Even passive microwave sensors like MADRAS radiometers onboard Megha-Tropiques implement FPGA based signal processing tasks like digital integration, filtering and offset/gain corrections.

This apart, ISRO has also planned a number of future SAR missions in LEO orbits like L-band Polarimetric SAR, X-Band Agile Airborne and Small Satellite SARs. In RISAT-1, SAR raw data compression, based on Block Adaptive Quantizer (BAQ) was employed as a mean to restrict the data volume and rates. However, onboard generation of SAR images would be an ideal option for an operational SAR system, as SAR signal processing will achieve much higher compression ratios than that achieved using raw data compression techniques. Moreover integration of onboard processing capability with the SAR instrument provides substantial improvements in the areas of onboard data handling and storage, ground processing and operation and dissemination of processed data to users. With these obvious advantages provided by onboard SAR processing and based on the experience gained in the design and development of ground based real-time/near real time processors for RISAT-I and DMSAR missions, a real time onboard SAR processor is also being proposed as a technology demonstrator for ISRO's proposed L-Band SAR mission.

This paper describes design requirements, configuration details and salient performance features of

DSP/FPGA based onboard and ground-based real /near-real time signal processors for ISRO's current programmes involving active microwave sensors viz. DMSAR, RISAT-1 SAR, Oceansat-II Scatterometer, Altimeter and Radiometer as well as the details of the proposed technology demonstrator for onboard SAR Processor for ISRO's proposed L-band Polarimetric SAR mission.

Key words: Synthetic Aperture Radar (SAR), RISAT-1, ASAR, DMSAR, Oceansat-II, Scatterometer, Altimeter, Range Compression, Azimuth Signal Processor, Matched filter, Post Processor, DSP, FPGA, ASIC, Doppler, filtering, spectral estimation, FFT.