Aircraft and IQ Data Analysis tool for Synthetic Aperture Radar

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Abstract: *Synthetic Aperture Radar (SAR) system on Dornier class of flying test bed will generate the SAR images on board and records the raw data (IQ format) for post analysis. The recorded data has to be analyzed for algorithm correctness and interpretation purposes. Aircraft and IQ Data Analysis Tool (AIDAT) is developed for airborne SAR (Synthetic Aperture Radar) system. AIDAT is for the purpose of performance and functional requirements conformance and is essential for offline lab level analysis of real time SAR. Using this tool, Aircraft parameters, sub-system synchronization, SAR image formation module and other module involved in real time image generation are verified. The tool generates appropriate analysis results in the form of graphs and detailed parameter listings.*

Key Words: IQ Data Analysis, Aircraft Data Analysis.

I. INTRODUCTION

Synthetic aperture radar (SAR) is an active microwave sensor that transmits in microwave and detects the wave that is reflected back by the objects. SAR is completely different from passive optical sensors. It enables high-resolution, high contrast observation and accurate determination of topographical features when captured from an airplane as it makes use of radar waves to gather data about the earth below. SAR systems take the advantage of the long-range propagation characteristics of radar signals and the complex information processing capability of modern digital electronics to provide the high-resolution imagery. If the radar is attached to a moving platform on an aircraft, it is possible to combine reflected signals along the flight path to synthesize a very long antenna. In synthetic aperture radar (SAR) imaging, microwave pulses are transmitted by such antenna towards the earth surface. The microwave energy of the backscattered signal reflected back to the antenna is measured.

In real synthetic aperture radar imaging[1], an aircraft travelling forward in the flight direction with the nadir directly beneath the platform transmits a microwave beam towards the ground at right angles to the direction of flight revealing a swath which is offset from nadir as shown in figure 1. Typically, the imaging system relies on or across-track dimension perpendicular to the flight direction to measure the range and range resolution from the antenna to the target. The time elapsed between the transmission of a pulse to receiving the echo determines the range or Line-of-Sight, distance. The range resolution of the target is governed by the width of the receiving pulse where the narrower pulses give finer resolution. Another important dimension that imaging system relies on is the azimuth or the along-track dimension parallel to the flight direction and perpendicular to range. The resolution in this direction depends greatly on the azimuth beam width, which is inversely related to antenna size. A smaller antenna tends to generate a larger beam width and the corresponding images will have poor azimuth resolution. To obtain fine azimuth resolution, a physically large antenna is needed to focus the transmitted and received energy into a sharp beam. However, airborne imaging system [2] can still collect data while flying this distance and process the data as if it comes from a physically long antenna; that is to synthesize an extended antenna. A narrow synthetic beam width results from the relatively long synthetic aperture, which gives finer resolution than is possible from a smaller physical antenna.

Synthetic aperture radar (SAR) data are ideal for land surface mapping [3] [6] owing to their high spatial resolution and ability to penetrate clouds and darkness. In military and civilian fields, such as battlefield investigation, flood supervision and so on, the problem of acquiring large-scale airborne SAR imaging scene need to be resolved by image mosaic. Mosaics produced from SAR images serve as valuable base maps, especially in broad remote areas such as rain forest and boreal forest regions. These data sets are extremely valuable for scientific research since in-situ observations are usually sparse and optical remote sensing technologies are often disabled due to cloud coverage.

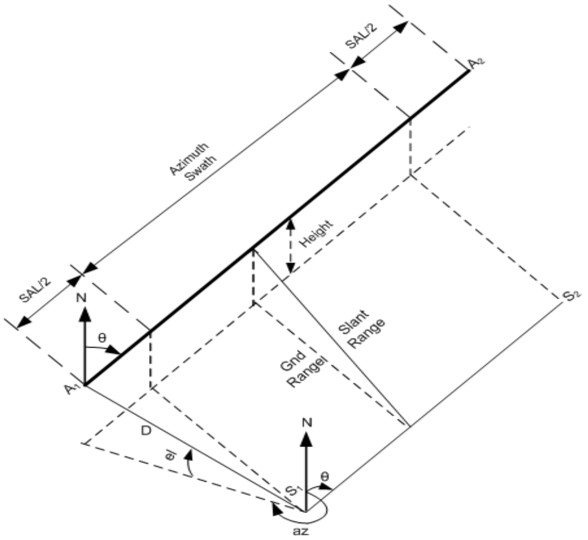

Figure 1 SAR Imaging Geometry

Synthetic Aperture Radar is mounted on the Dornier platform and conducted field trials for testing the radar. The block diagram of the radar with data recorder is shown in figure 2.

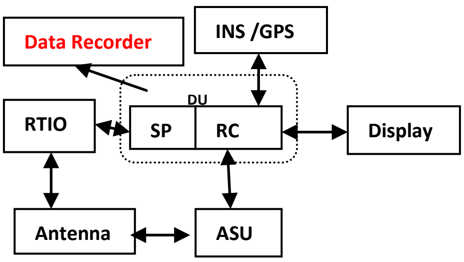

Figure 2 Block diagram of SAR on FTB with data recorder

SP – Signal processor
RC – Radar controller
ASU – Antenna Stabilization unit
RTIO – Realtime input output
DU – Digital Unit

Many sub-systems are involved for the image generation as shown in the figure 2. In order to verify the correctness and reliability of radar an analysis tool is highly required. Based on the SAR sub-system design constraints and users' requirements, customised analysis tools have to be implemented by designer. Aircraft and IQ Data Analysis Tool (AIDAT) is such a SAR data analysis tool.

II. Data extraction Module

The SAR data extraction module was developed to have GUI based software to provide extraction of IQ data and aircraft data recorded in binary format. This tool generates multiple data files to provide easy access to the recorded data. An option is provided to extract required number of pulses or batches of data to reduce the extraction time whenever user wants to confine analysis of smaller data. Aircraft data and message exchanges between various sub-systems of radar can also be extracted and analysed using the tool. It provides us with the complete picture all the message transactions performed during real time image acquisition. It aids in parameter validation and sub-system synchronization checks on the recorded data. AIDAT operates in off line mode to display mission parameters and radar data as multiple graphs and images. Also, the resultant images can be displayed in Image Display and Exploitation Software thereby validating actual sub-systems. It also enables geo-coding of SAR images that can be cross-verified with satellite maps for accuracy.

AIDAT has the capability of indicating the own aircraft platform parameters as well as radar configuration parameters recorded during the mission. AIDAT is a MATLAB [2] based application with complete SAR image formation capability along with other features.

AIDAT was tested with multiple data recorded on board using Ku Band SAR mounted on Dornier platform. Main challenges faced for the SAR IQ data analysis is the handling capability of huge data of the order of 50 GB or more [3]. AIDAT runs on octa-core machine with 32 GB of RAM and one terabyte of secondary space available. In AIDAT, image formation module is same as that implemented on the actual Signal Processor sub-system of SAR so that performance parameter can be quantified off line. AIDAT is capable of handling a data corresponding to maximum swath possible of 12km in imaging mode. The resultant images will be saved in memory before processing for the next batch of image makes the analysis of each image easier.

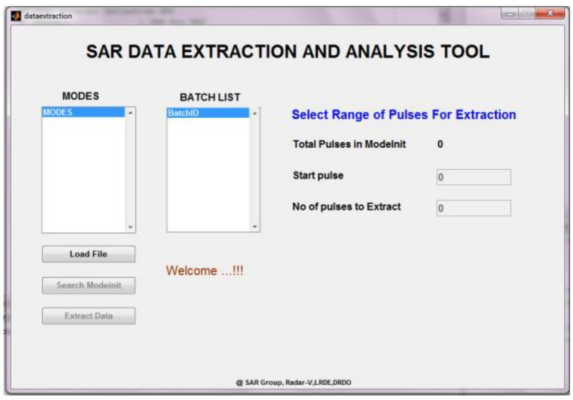

Figure 3 Data extraction tool GUI

III. Aircraft and Scanner Data Analysis

Aircraft data comprise of SAR over Dornier platform parameters obtained from INS/GPS. The aircraft parameters such as latitude, longitude, roll, pitch, yaw and velocity are received over 1553B interface and the recorded in data recorder over LAN interface. Also various subsystem interface message are recorded over LAN, such as mode configuration parameters, message exchanges between Radar controller and Signal processor, antenna positioning unit and image display software. A record of all these messages aids in the analysis of correctness of the sequence of operation and parameter validation during offline analysis. Tool generates complete aircraft trajectory that can be visualized over the geographical map.

In Figure 1 1, depicts one of SAR mode that is strip map mode geometry. The aircraft leg parameters from A1 to A2 are recorded along with radar parameters such as maximum and minimum range of operation, range swath, frequency of operation etc.

In AIDAT, aircraft trajectory can be plotted along with variations in attitude parameters. The figure 4 shows the aircraft trajectory.

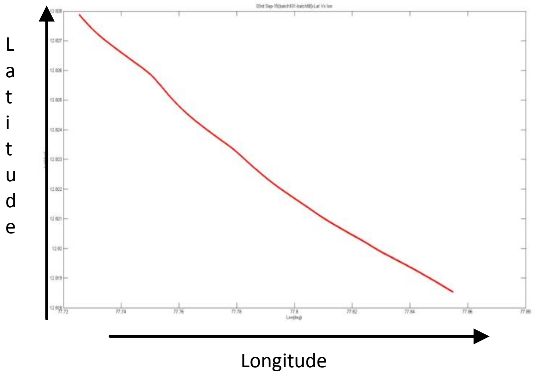

Figure 4 Trajectory of aircraft

This tool also generates the plots of other aircraft parameters such as roll, speed and heading as shown in figure 5,6 and 7 respectively.

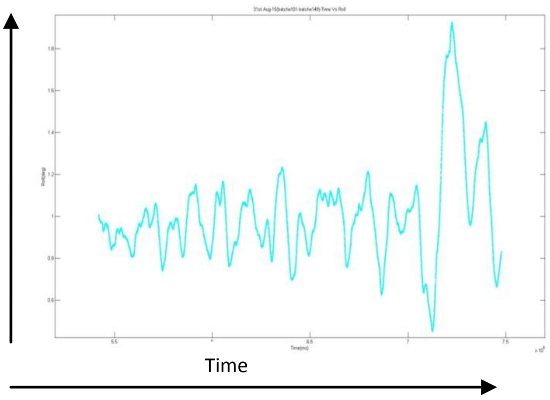

Figure 5 Graph - Time vs roll

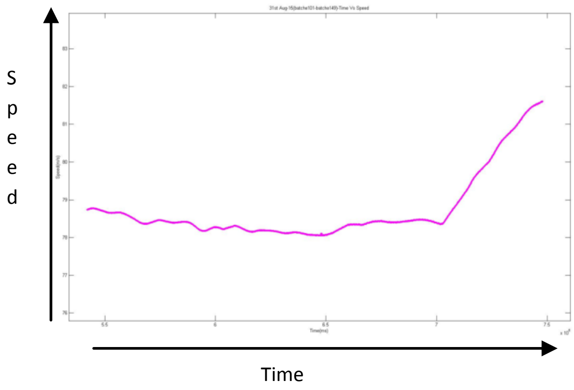

Figure 6 Graph - Time vs speed

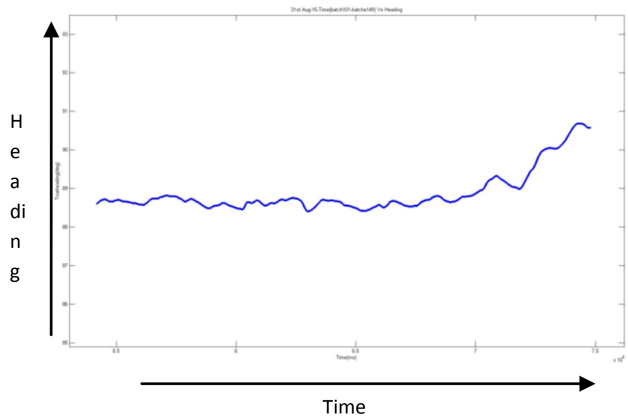

Figure 7 Graph - Time vs heading

Tool presents entire trajectory analysis by providing explicit graphs. Problems such as data miss or velocity, roll, pitch variations during sorties can be analysed with ease.

The scanner parameters such as Elevation and the Azimuth are also plotted using this tool. To correlate the acquired SAR image with the satellite image the scanner parameters are also known. The elevation of the scanner is the look angle of the SAR geometry and the azimuth will be 90 degree with respect to the aircraft heading. If any changes occur in these two parameters the SAR image geometry will be varying. And hence the scanner parameters are also considered for the analysis of SAR data.

IV. IQ Data Analysis

IQ data is the raw radar data which is used to form the SAR image. In this tool, the SAR image formation algorithms are implemented as similar to the SAR image formation algorithm in the hardware on flight. The IQ data extraction tool will extract the IQ data batch wise with overlapping pulses. It forms the image batch wise and mosaic the image batches together to provide complete mission data as the concatenated image. In the

IQ data analysis the number of pulses in a batch, the corresponding navigation data such as Latitude, Longitude, altitude and velocity are associated correctly or not can be checked. The time analysis can be done by using this tool.

The IQ data image formation is done with Range doppler algorithm. The motion compensation algorithm[5] also used to analysis by this tool. Once all the batches are used to form the image, the image mosaicing also tested by using this tool. AIDAT uses vertical tiling in STRIP map mode which can be displayed in image display software thus giving an impression of displaying images, strips after strips as shown below:

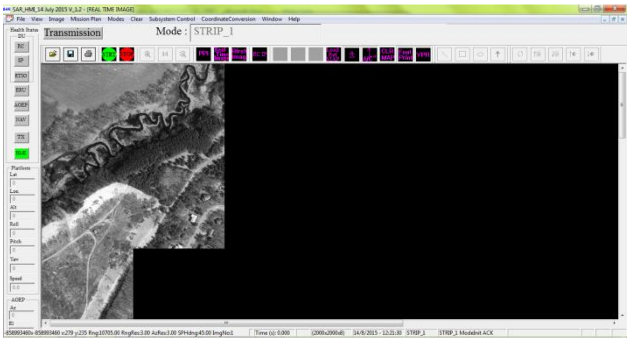

Figure 7 Image display in STRIP map mode

For a selected strip map mode, during the operation, range swath and azimuth swath are extracted from mode parameters recorded in real time. Based on the aircraft direction the SAR image mosaicking is performed and tested. The mosaicked image is finally considered for geocoding with the reference of aircraft data tagged with every batch. Based on the geometry of the SAR mission considering the parameters of the INS/GPS and scanner, the ground coordinates are calculated and geotagged for each pixel of the image based on the resolution of the pixel which depends on the mode of operation.

In figure 8 the satellite image for an area of interest of about 6km in range and 6 km in azimuth is given and in the figure 9 the equivalent SAR image of about 6km in range and 6 km in azimuth is given. The features of the SAR images are compared with the satellite images. The resolution of the SAR image, swath area of the SAR image formed and also the geometric errors can be corrected by this comparison.

Figure 8 Satellite image of the region of interest

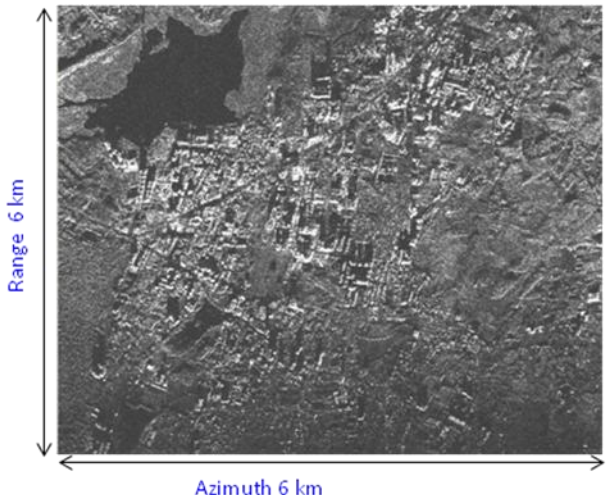

Figure 9 SAR image of the region of interest

V CONCLUSION AND FUTURE REMARKS

Aircraft and IQ Data Analysis Tool (AIDAT) is developed and tested for airborne SAR system for visualizing and analysing the SAR images offline in lab. The image formation modules, aircraft trajectory plotting, subsystem interactions and message transactions are implemented and tested using this tool. The pulse misses, the interpulse interval, Navigation data tagging delay are also calculated by using this tool. This tool is extended to the analysis of synchronization of different subsystems such as RC, SP, INS/GPS and Scanner. The offline formed images can also be transferred to the real time Image Display and exploitation software. The analysis tool is also equipped with image post processing techniques such as speckle filtering techniques, geo-rectification with reference images and object detection methods.

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