Spectral Analysis of Ku band SAR data

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Abstract:

Analysis of SAR data especially during designer flight trials requires the right data analysis tool to assess on the quality of data collected as well as on the system performance of SAR onboard an airborne platform. This paper discusses one such SAR data analysis method popularly known as Spectral Analysis (SA). SA method generates SAR images with maximum area coverage illuminated with real beam antenna and provides information on SAR waveform characteristics in range and azimuth. This paper discusses on the analysis and results obtained by employing SA method on the collected raw data during SAR flight trial on Dornier aircraft.

Keywords: *SAR, Spectral Analysis, Doppler bandwidth, Antenna beam direction*

I. INTRODUCTION

Synthetic Aperture Radar (SAR) is a microwave imaging radar system that generates high resolution grey scale images of ground area in all-weather, day/night conditions. In SAR, the range resolution depends on the radar waveform bandwidth and azimuth resolution depends on antenna azimuth beamwidth. SAR operates with wide bandwidth waveform to produce fine resolution in range. Since there is a limitation on the physical aperture size of the antenna that can be deployed on aerial platforms, to generate high resolution in azimuth, SAR as its name implies, synthesizes long aperture by the forward motion of the platform, illuminating the area of interest to be imaged. To generate SAR images of the terrain, SAR system should be able to bring the low reflectivity target response from the minimum detectable signal level to a level above the system noise floor. Hence the SAR system should be designed to have sufficient gain to achieve this requirement. SAR system gain is apportioned to transmitter gain, antenna gain and signal processing gain. In order to realize the radar system with moderate transmitted power and antenna gain, SAR should be designed with an appropriate signal and image processing methodology that is capable of maximizing the processing gain. This constraint leads to choosing the correct signal processing algorithm for analysing the received SAR data especially from low reflectivity targets such as barren land, grassland, asphalted road, airstrip etc. Spectral Analysis is one such technique used for SAR data analysis that is used to generate SAR images with smaller data size and minimum processing time during SAR experimental flight trials.

This paper is divided into four sections. Ku band airborne SAR system and its modes of operation are briefly described in section II. , SAR parameters that characterise the SAR waveform in range and azimuth directions are explained in section IV. Description of SA algorithm is presented in section V. Results of analysis carried out on SAR data collected with Ku band airborne SAR system is presented in Section VI followed by conclusion in section VII.

II. KU BAND AIRBORNE SAR SYSTEM AND MODES OF OPERATION

Ku band SAR system is developed by LRDE, DRDO for medium range operation on airborne platforms. Modes of operation of SAR include Stripmap and Spotlight imaging modes and Ground Moving Target Indication mode. This system operates with medium transmit power and high antenna gain to give a maximum of 12 km swath coverage at an operational slant range of 40 Km.

III. SAR IMAGING

SAR signal processor forms the 2D high resolution image of target scene area from the collected radar returns. The phase of the target returns are the function of target slant range, target reflection property, platform motion and unknown or non-measurable random errors of the system and the platform trajectory during SAR data collection. As a first step, signal pre-processing is carried out followed by compression in range dimension. Range compression is established by convolving each pulse with range reference function. This is followed by azimuth compression where the azimuth samples corresponding to each range bin are convolved with the azimuth reference function. The selection of reference function is based on the velocity of the aircraft, operating frequency and the range at which the azimuth compression is carried out.

IV. SAR PARAMETERS

Parameters measured from the received SAR data using spectral analysis method will enable characterization of SAR system.

1. Waveform Parameters

SAR image quality such as resolution and focusing in range direction is defined by the SAR Tx waveform. The waveform parameters such as bandwidth, DC component and droop etc. can be measured from the range spectrum of SAR data.

2. Doppler Parameters

SAR image quality in azimuth direction is defined by the Doppler/Azimuth spectrum of the received data. The azimuth parameters such as Doppler bandwidth, Doppler centroid and droop etc. can be measured from the azimuth spectrum of SAR data. The associated equations and explanation for measuring these parameters are given in [1].

V. SPECTRAL ANALYSIS METHOD FOR SAR IMAGE FORMATION

Spectral Analysis involves digital matched filtering using FFT in range direction and spectral analysis processing in azimuth direction. This method compresses the entire beam footprint area in azimuth with the minimum length of aircraft travelled distance equal to synthetic aperture length (SAL). Processing involves one complex multiplication and one FFT. Hence it is more advantageous for quick look analysis of SAR data during flight trials and enables the designer to properly infer on the system performance of SAR.

VI. RESULTS FROM KU BAND SAR DATA

1. SAR parameters measured from Ku band SAR data

Range and azimuth spectrum of Ku band SAR raw data collected during flight trials are computed by performing FFT in range and azimuth respectively. DC component observed in the spectrum is removed from the raw data as preprocessing before image formation. Range and azimuth spectrum obtained with and without DC components are shown in the figures 1 to 8 respectively.

It was observed that spectrum from low SNR data is dominated by DC component. Conventional RDA analysis on such data does not reveal information on the ground area imaged by SAR. However, after applying SA analysis on the same data, ground features were clearly found visible in the images. From the spectrum of high SNR data waveform parameters such as waveform bandwidth along with Doppler bandwidth and Doppler centroid were measured. Measured parameters are tabulated in table 1. All the measured parameters are matching with the designed parameters as given in [2] except the Doppler centroid. Although the SAR data is collected with the antenna pointing 90° with respect to the velocity of the aircraft, the spectrum clearly indicates a shift in the antenna boresight resulting in a nonzero Doppler centroid value on the azimuth returns. This shift is taken care of in SA method and the focused images are shown in figures 9 and 10 respectively.

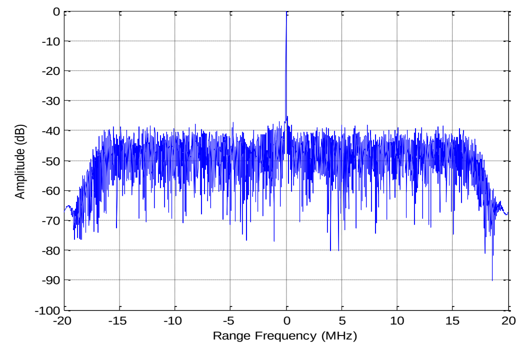

Figure 1. Range Spectrum of SAR data with DC component in low SNR data

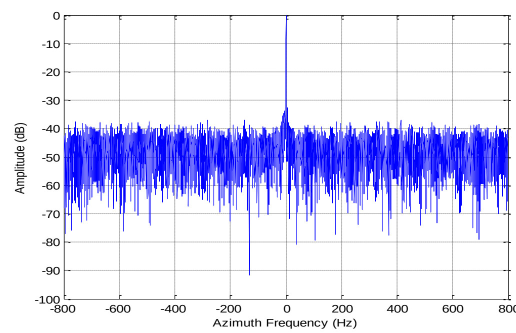

Figure 2. Azimuth Spectrum of SAR data with DC component in low SNR data

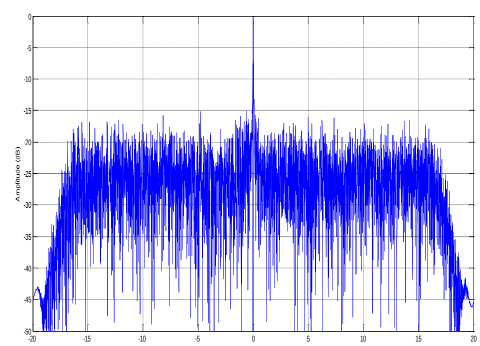

Figure 3. Range Spectrum of SAR data after DC component removed in low SNR data

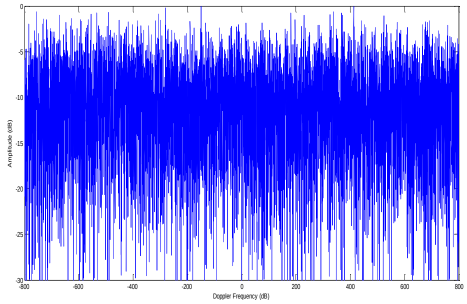

Figure 4. Azimuth Spectrum after DC component removed in low SNR data

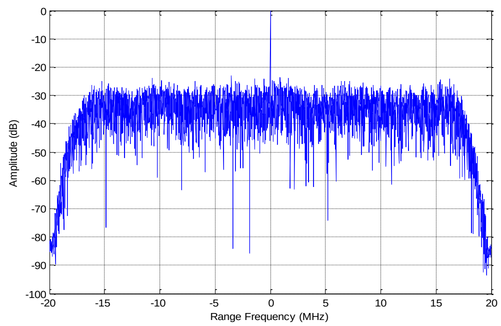

Figure 5. Range Spectrum of SAR data with DC component in high SNR data

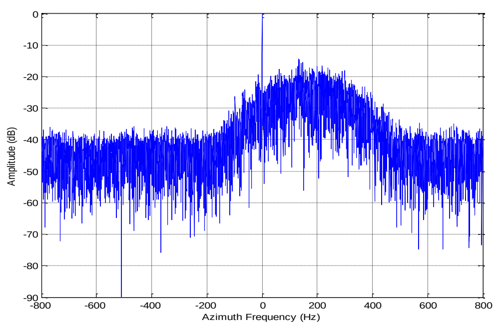

Figure 6. Azimuth Spectrum of SAR data with DC component in high SNR data

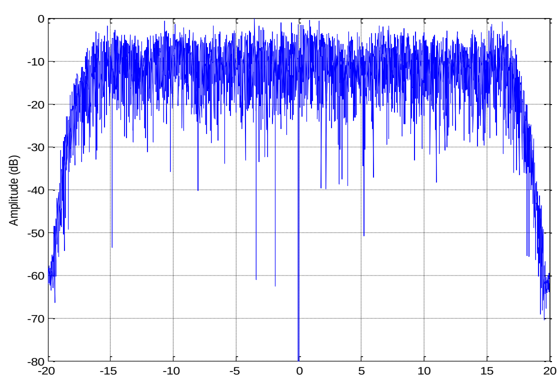

Figure 7. Range Spectrum of SAR data after DC component removed in low SNR data

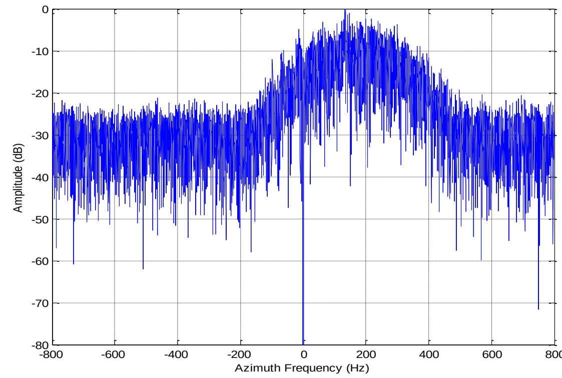

Figure 8. Azimuth Spectrum after DC component removed in low SNR data

Table 1: Major SAR Parameters measured from Range & Azimuth Spectrum

Sl.No.	SAR Parameter	Measured value from data
1	Waveform bandwidth	36 MHz
2	Waveform droop	0dB
3	Doppler bandwidth	700Hz
4	Doppler centroid	200Hz

2. SAR images from low SNR SAR data

SAR data was processed for image formation using SA and Range Doppler Algorithm (RDA) after removing DC component. The SAR images are given in figures Fig 9-12.

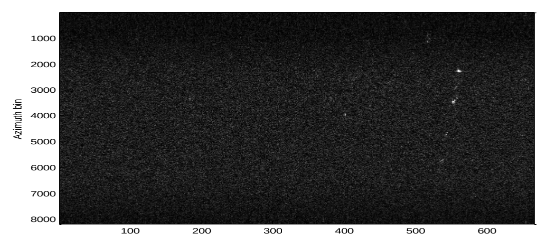

Figure 9. SAR image formed by RDA from low SNR data

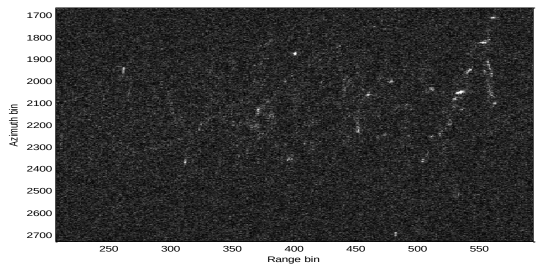

Figure 10. SAR image formed by SA method from low SNR data

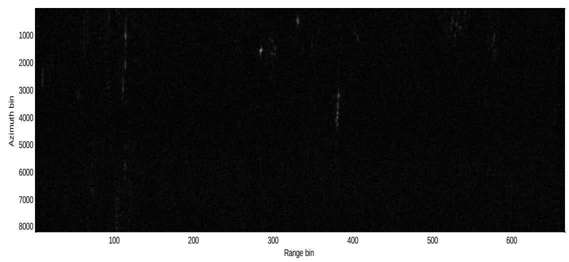

Figure 11. SAR image formed by RDA from high SNR data

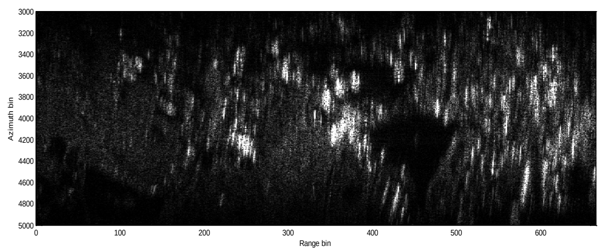

Figure 12. SAR image formed by SA from low SNR data

VII. CONCLUSION

Spectral analysis method provides maximum information even for the low SNR SAR data with minimum number of pulses and with the minimum number of computation stages. This is one of the quick processing methods for analyzing SAR data especially during initial flight trials.

REFERENCES

[1]. Ian G.Cumming, Frank H. Wong, "Digital Processing of Synthetic Aperture Radar Data- Algorithms and Implementation", Artech House, 2005.

[2]. "PDR document of SAR for UAV", LRDE, DRDO

ACKNOWLEDGEMENT

The project team is thankful to DO Radar V for his support and Director, LRDE for his constant encouragement.

BIODATA

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