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Synthetic Aperture Radar (SAR) Imaging using Global Back Projection (GBP) Algorithm For Airborne Radar Systems

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***Abstract*— The paper is a study of the Global back-projection algorithm (GBP) known to be a fundamental time domain algorithm for image retrieval in Synthetic Aperture Radar (SAR). Although frequency domain algorithms are convenient to use and understand yet they have some inherent drawbacks and require various compensation techniques. As a time-domain algorithm, GBP possesses inherent advantages such as perfect motion compensation, unlimited scene size, wide bandwidth and ability to handle long integration angles. Although GBP reproduces SAR images on pixel-to-pixel basis, the processing time for GBP is reduced significantly. For GBP, the number of operations required to process an N×N SAR image with N aperture positions is proportional to N^3. A detailed explanation on how to implement GBP in Matlab in order to retrieve a SAR image is provided. Matlab provides various in built functionalities as well as image processing toolbox which assists in performing signal processing operations along with an easy evaluation of the result.**

Since the image construction takes place on a pixel to pixel basis a lot of computations are involved, however we obtain a high quality image. Also many of the frequency domain algorithms although quick, suffer from distortion due to motion. But GBP possesses inherent motion compensation techniques which provides images of high accuracy. Thus the objective of the project to prove the efficiency of the time domain algorithms as an effective alternative to frequency domain algorithm will be substantiated using a few simulations.

***Index Terms*— Global back projection algorithm, Synthetic Aperture Radar.**

I. Introduction

Synthetic aperture radar (SAR) can generate high-resolution images using a short antenna and a large bandwidth [1] [2]. SAR creates images by transmitting and receiving electromagnetic waves and differentiating objects based on the radar echoes returned from them. Images can be created day or night and in inclement weather since radar does not depend on light to create images. A common method for collecting data with SAR is to attach a short antenna to an aircraft. This antenna sends out electromagnetic pulses as the aircraft moves, enabling synthesis of a long linear array. Since a longer antenna provides finer resolution than a short antenna, this linear array provides finer resolution than a single antenna position. If the antenna is kept orthogonal to the motion of the aircraft for the duration of the flight, then the SAR operating mode is denoted as strip map.

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Several algorithms have been proposed for strip map image reconstruction of SAR data in both the time domain and frequency domain [3]. A particular time-domain algorithm known as back-projection is able to reconstruct well-focused images, even with non-ideal motion such as when the aircraft does not fly on a straight track. There are many algorithms in frequency domain which are used to reconstruct the SAR images, however each of these algorithms possess some inherent drawbacks. Therefore separate error compensation methods have to be used to increase the accuracy. This increases the burden on the algorithm affecting its accuracy. But time domain algorithm such as GBP provides inherent compensation techniques to account for the errors reducing this burden. Also it is possible to obtain highly accurate images because the images are reconstructed on a pixel to pixel basis. A raw signal was generated using MATLAB (version-7.9). Then the image was reproduced using Global Back Projection (GBP) algorithm and the results were tabulated and plotted.

II. Global Back Projection Algorithm

Basically the raw data signal for the single point target is being loaded into the algorithm to carry out the structural processing. The data control flows in such a way that the target parameters and the platform parameters helps to determine the aspect angles and the Range for the single point target. Then the synthetic aperture array is formed and the back projection algorithm is applied for every SAR positions. The sampling time is the necessary factor for the synthetic aperture array processing. The data acquisition is defined. Finally the image processing has to be implemented to develop the Global Back Projection output.

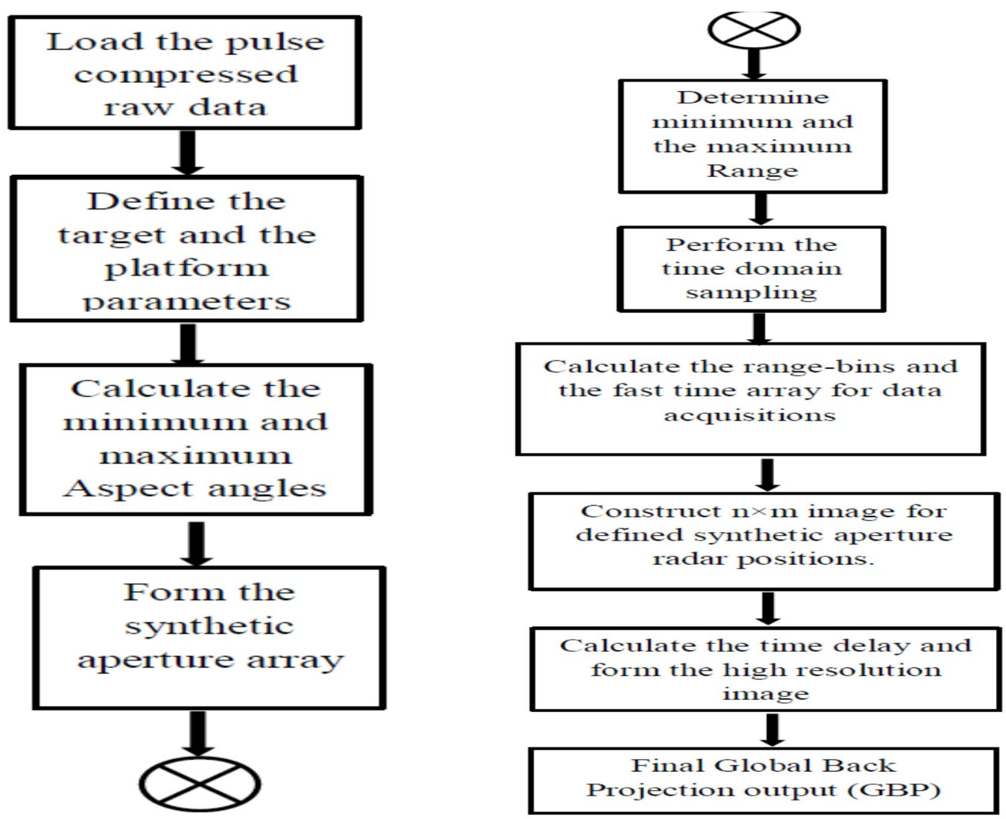

Figure 1. Flow of the Global Back Projection algorithm

III. Proposed System

A. Software Design of Global Back Projection Algorithm

- Global Back Projection Algorithm is being developed with help of the simulation on MATLAB-version 9 platform in windows XP.
- The very basic requirements for the raw data generation are the input parameters which have to be initialized at the beginning. So, depending on the input parameters provided. The various factors would be considered for the development of the raw data.
  Define the range and the cross range distances of the target area and also define a target area specification which helps to determine the minimum aspect angles and the maximum aspect angles.
- The control flow of the input parameters helps to find the minimum aspect angle. It can be found for the conditions of yc-y0-L<0. With this condition we determine the minimum and the maximum aspect angles respectively.
- Then form the sub-aperture array by calculating the spacing between the consecutive two sub aperture points. And at each sub aperture points we define the chirp pulse duration and modified chirp carrier.
- The data acquisition would be occurring for every range-bins from every particular SAR points. So by considering this data acquisitions occurring, now generate the echoed signal data matrix which supports the image formation. This echoed signal array keeps the trace of every synthetic aperture array points and the data acquisition occurring at every point. So, the complete image formation is found in array echoed signal matrices.
- Now for formation of the single point raw data generation we need to define the delay at each SAR points. To form the raw data, it should be a matched filter output which involves the FFT computation. And define the rectangular window formation for developing the raw data which basically involves the IFFT shifts of the data and finally the ASCII values are being mapped on to the data matrix. The data matrix is being arranged for the various SAR points which generates 256*256 resolution image. In this the arrangement of all the echoed matrices onto the excel sheet which highlights all the data acquisition occurring at all the points.
- Now we have to the form the code for the global back projection in which the input parameter is provided as the single stationary point target raw data for the algorithm. Before the image formation stage, at every SAR points we define the fast time array after the matched filtering process which has been occurred.
- The control flows when this fast time array assignment is being occurred in the range bins of every SAR positions. So during the final image formation, the data matrix provides the clue regarding how the process would be occurring at every stage by utilization of these data which is calculated for all the SAR points.
- Each time when the control flows from the generated raw data, the data acquisition and the fast time array at each SAR points is determined and thus helps to form a high resolution image of 256*256.
- Finally the array is stored in particular defined 2-dimensional assigned parameter which shows the final image array formed and this array provides all the calculation incurred at every stage of the processing of the raw data. And a high resolution image is formed by utilization of the MATLAB image processing toolbox.

B. Flow of the Program

The flow of the algorithm follows up by providing the pulse compressed raw data signal for a single point target. It is necessary to provide the platform and the target parameters to our GBP algorithm. In our GBP algorithm it provides the detail of how sub aperture is obtained. The Global Back Projection block is the main block where the complete flow of our algorithm is explained in detail.

The image formation block also gives the explanation that how the image formation is occurring in the algorithm. The image formation involves the image formation tool box as explained earlier. The main aim of our algorithm is to provide the high resolution image for the single point target. So the target formation involves the computations at all the synthetic aperture array formed with respect to the 2d imaging.

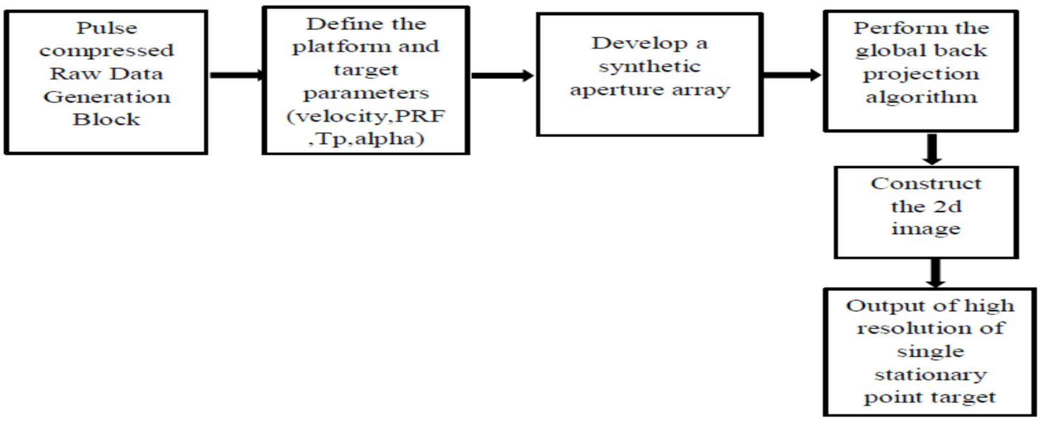

Figure 2. Flow of the program

IV. EXPERIMENTS AND RESULTS

A Single Point Target Raw Data Generation

It shows about the results obtained during the raw data generation for the single point target and the application of the Global Back Projection Algorithm for the same raw data signal.

Fig 3 describes about the received signal obtained for the single point target after the matched filtering process. The plot for the target is represented in time domain vs the amplitude. So the peak obtained in the plot helps us to know the presence of the point target

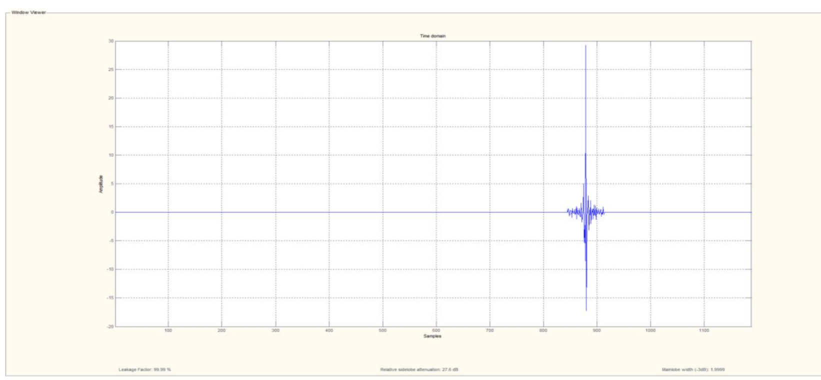

Figure 3 Plot of received signal after matched filtering for point target

B Single Point Target Implementation using GBP

To proceed in this algorithm it is important to load our data matrix into which it need to process our raw data and find the desired output.

In this algorithm implementation stage, all the received signals had been compressed and then they were arranged in a matrix form to make it suitable for the data processing part. Matched filtering had to be performed for the pulse compression. The matched filter is the time-reversed and complex conjugate form of the transmitted signal.

During output stages we must basically define the image matrix to be initialized by zeros and then a "for loop" is run for every synthetic aperture radar positions to calculated the image formation at each points. It must also be noted that for every SAR positions a N*N pixels image has to be generated.

At the image formation stage, the output obtained at all the SAR points are being evaluated and keeps on adding further at all various positions to develop a very high resolution image to form a single point. The following figure 4 shows how the single point target is plotted down.

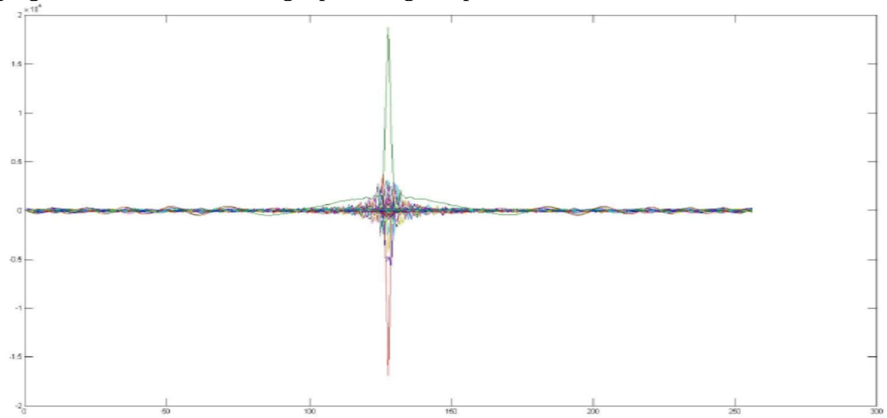

Figure 4 Generation of the single point target using GBP algorithm

The goal of any image formation algorithm is to gather information from the target by transmit and receive signals and then forming the image of that very point target by processing the signal data. In GBP, a SAR image is directly produced from the radar echo data. There is no intermediate step between data acquisition and final image formation in this method.

C. Multi-Point Target Raw Data Generation

It has been discussed about the results obtained during the raw data generation for the multi-point target and the application of the Global Back Projection Algorithm for the same raw data signal.

Figure5 describes about the received signal obtained for the single point target after the matched filtering process. To define the multi-point target we shall form n-targets to defined area such that the radar would scan those particular defined area for targets recognition. The plot for the target is represented in time domain vs. the amplitude.

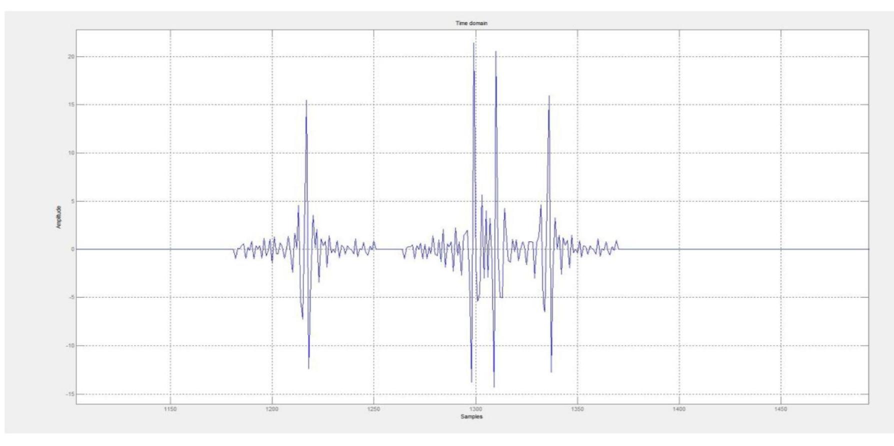

Figure 5 Plot of received signal after matched filtering for multi-point targets

D. Multi-Point Target Implementation using GBP

To generate a image grid to produce a high resolution of image for the developed single point target and hence the output is to be plotted down.

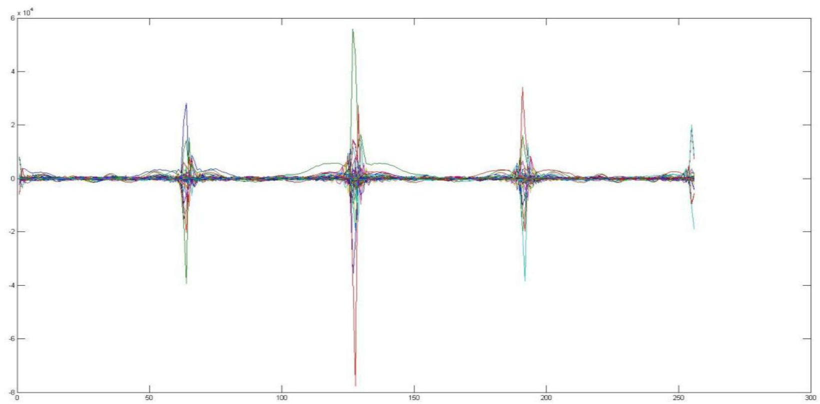

Figure 6 Generation of the multi-point target using GBP algorithm.

V. CONCLUSION

This paper clearly provides a detailed insight into the understanding of the time domain algorithm namely 'GLOBAL BACK PROJECTION'. This paper highlights the various general concepts of radar technology, different types of radars and the various image processing algorithms. Conventionally frequency domain algorithms are considered to be the most convenient as they are easy to implement and understand. However a close look into these algorithms such as RDA, RMA and chirp scaling exposes the inherent defects which require additional algorithms for error correction. In this paper we generated a chirp signal using the raw data and we have also generated the image using Global back projection algorithm. GBP provides inherent motion compensation reducing additional burden on the image formation algorithm. GBP is also able to map unlimited scene sizes. Another important advantage of GBP is its ability to handle large integration angles. Also this time domain algorithm is able to reproduce images of high quality. This paper clearly establishes the advantage of the time domain algorithms over frequency domain thus opening up a new scope for development.

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