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Synthetic Aperture Radar Imaging

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Abstract- In this paper we introduce new synthetic aperture radar (SAR) imaging modality which can provide a high resolution map of the spatial distribution of targets and terrain using a significantly reduced number of needed transmitted and /or received electromagnetic waveforms. This new imaging scheme requires no new hardware components and allows the aperture to be compressed. It also presents many new applications and advantages which include strong resistance to counter measures and interception, imaging much wider swaths and reduced on-board storage requirements.

Keywords- SAR.

I. INTRODUCTION

Synthetic Aperture Radar (SAR) systems are all weather, night and day, imaging systems. Automatic interpretation of information in SAR images is very difficult because SAR images are affected by a noise like arises characteristic called speckle that arises from an imaging device. SAR is usually implemented by mounting a single beam-forming antenna on a moving platform such as an aircraft or spacecraft, from which a target scene is repeatedly illuminated with pulses of radio waves at wavelengths anywhere from ammeter down to millimetres. The many echo waveforms received successively at different antenna positions are detected and stored and then post-processed together to resolve elements in an image of the target region. SAR is applied widely in many areas such as military, agriculture and ocean. The figure.1 shows the resolution limit of stripmap SAR. The speckle noise in SAR images can be removed using an image restoration technique called despeckling. In statistical image processing an image can be viewed as the realization of a joint probability density function. This paper presents the state – of the art methods for information extraction and their comparison in efficiency of despeckling and information extraction. The central idea of SAR processing is based upon matched filtering of the received signal in both the range and azimuth directions. Matched filtering is possible because the acquired SAR data modulated in these directions with appropriate phase functions. The modulation in range is provided by the phase encoding of transmitted pulse, while the modulation in azimuth is created by the motion in the signal. The point targets are arrayed in Cartesian type coordinate system space defined by range, azimuth, and altitude as analogs of x, y and z directions. The figure.2 shows the cross range imaging geometry.

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The transmitted radar signal x(t), is assumed to be a chirp pulse (linearly frequency modulated signal) given by rec cosfKt where f0=9.36GHz, pulse duration Tr=25µs, (frequency bandwidth of the chirp=300MHz), Kr is the range of the FM rate, measured MHz/ µs.
The transmitted radar signal as a course with a linearly ramping up frequency over a transmit duration followed by a null duration.

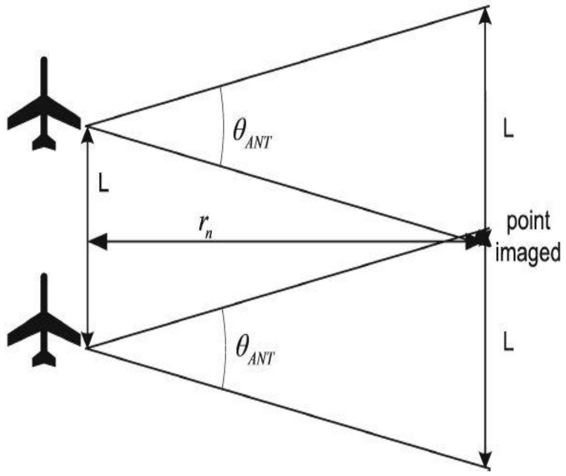

Figure.1 Resolution limit of Stripmap SAR

The transmit window is called the pulse envelope, and defines the duration of the transmission. During the receive duration, the antenna waits to receive reflected radar signals from the targets contained in a one dimensional range slice echo as function of quick time. One over the combined

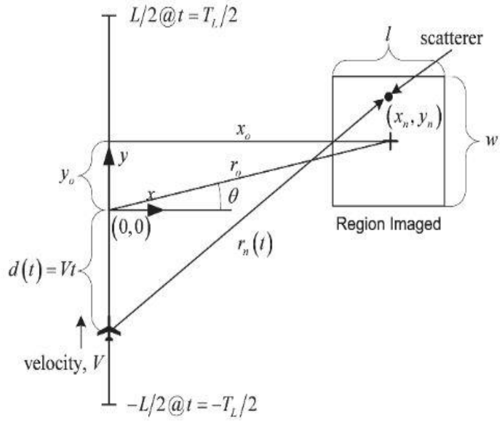

Figure2. Cross range imaging Geometry

transmit and receive duration is called the pulse repetition frequency, PRF, and defines the amount of pulses transmitted per second. The chirp signal is complex and has complex envelope

$g(t)x(t)=g(t)\exp(j2\pi f_0\tau)$

Let point scatterer has a dimension, smaller than the wavelength =c/v0 be located at a distance R-range away from the radar. The radar platform has a velocity v.

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The point is seen at the evaluation angle and azimuth angle from the antenna main pointing direction. The received echo is proportional to the transmitted wave and delayed by the round-trip delay 2R/C, In the receiver the echo signal is coherently demodulated i.e. carrier frequency is removed, resulting echo signal of the pointer scatterer. The phase term depends on R,governs the interference of echoes from different scatterers. The shape of the pulse envelope g(τ) determines the range resolution of the radar, it is the ability of radar to distinguish two scatterers at slightly different ranges.

$g(\tau)= \mathrm{sinc}(\tau B)$

The achievable range resolution is defined as half power width of g(τ). The chirp functions can be compressed to a sinc function by correlation with a chirp function with the same frequency rate, thus leading to the resolution.

II. SAR FOCUSSING

The focus was on improving the computational efficiency and accuracy of the SAR simulation so that it could be applied to more complex, time-sensitive two dimensional targets[1]. All these simulations can be roughly categorized into three groups. The first group works in time domain. It creates a high-precision raw data set. However, this method has low computational efficiency. The second group concentrates on the raw data generation of extended scenes that operates in the two-dimensional frequency domain. The third group can simulate SAR raw data by using inverse imaging algorithm in hybrid domain. The SAR system is conventional pulsed radar, which takes advantage of the relative motion between the sensor and target to synthesize a very long antenna and to achieve a high cross-range (azimuth) resolution. Each echo retains both its amplitude and its phase. It is usual to adopt the complex envelope representation in which the received signal is complex, with its real and imaginary parts obtained through quadrature demodulation from the incoming band pass signal. This means the trajectory migrates through rangecells during the exposure time of the target in signal memory; hence, the name ”Range Cell Migration” or RCM. This migration complicates the processing, but ironically, it is an essential feature of SAR[2]. This variation of slant range with time imposes an FM characteristic on the signal in azimuth direction. The hyperbolic form of the slant range equation can be expanded in a power series, resulting in a linear RCM component.

A quadrature RCM component and higher order terms. The first generation of satellite SAR processors used the power series expansion of the range equation in the time domain and the range Doppler domain. Later it was discovered that the hyperbolic form could be kept in all domains, thereby improving the processing accuracy, however, the power series expansion is sometimes useful for analysis purposes. The range Doppler algorithm was the first algorithm developed for civilian SAR satellite processing[3]. It is still the most widely used algorithm because of its favourable trade-off between maturity, simplicity, efficiency and accuracy. However, under certain conditions, its two disadvantages can become apparent. First, a high computing load is experienced when a long kennel is used to obtain high accuracy in the RCM Correction (RCMC) operation. Second, it is not easy to incorporate the azimuth frequency dependence of SRC, which can limit its accuracy in certain high squint and wide-aperture cases? A chirp is a signal in which the frequency increases (up-chirp) or decreases (down-chirp) with time. The chirp-scaling algorithm was developed specifically to eliminate the interpolator used for RCMC[4]. It is based on scaling principle whereby a frequency modulation is applied to a chirp encoded signal to achieve a shift or scaling of the signal. Using this chirp-scaling principle, the required range-variant RCMC shift can be implemented by using phase multiples instead of a time-domain interpolator. The algorithm has the additional benefit Secondary Range Compression (SRC) can be made in azimuth frequency dependent. This benefit arises because the data available in two-dimensional frequency domain at a convenient stage in the processing. This “chip scaling” principle, the required range variant RCMC shift can be implemented; using phase multiples instead of a time domain interpolator. The algorithm has the additional benefit that SRC can be made azimuth frequency dependent. This benefit arises because the data are available in the two dimensional frequency domain at a convenient stage in the processing.

Parameter	Value
Width of image area, *W*	50 m
Depth of image area, *l*	50 m
Range to image area center, r_0	20 Km
SAR wavelength,	0.03m
Aircraft velocity, *V*	50 m/s
Synthetic array length, *L*	600 m
Number of scatterers, N_s	3
Scatterer locations, (x_n, y_n) (m)	$(r_o,0)$, $(r_o,20)$, $(r_o,-1.25)$
Scatterer powers,*Psn* (w)	1,0.25,0.09

By using Chirp Scaling principle, linear FM signal multiplied by correlated FM signal (CS factor), and result is stilla FM signal, only the phase center and the frequency modulation rate changes. After range is compressed with new FM rate, displacement occurs at the location of the signal, which makes target range curvature in frequency domain that has the same shape in different range. This is the purpose of chirp scaling equalize all the range migration trajectories to a reference range.

III. SIMULATION

SAR simulation is a useful tool for design, mission planning, processing algorithm testing, and inversion algorithm design. The table 1 show the parameters used for the present work. It produces simulative echo and images, is a very important for many purposes like testing different image formation algorithms, studying the interaction of electromagnetic waves with a scene that is being imaged, testing and validating of different system design parameters and economical method in research of SAR systems. The simulation is the simulated received signal before any processing with exception of the down-converter. It also plays a significant role in studies concerning noise and clutter rejection and contributes toward optimizing SAR system parameters.

To simulate SAR raw data, a chip Scaling method is used.

0This method first stretches the input surface reflectivity of the target in the azimuth and range direction respectively. Then it derives the raw data by inverse equalizing the signal based on CS principle. This method avoids the time-domain integral operation and improves the computational efficiency. The platform in this simulation is an antenna attached to a plane travelling at an orbital velocity, along the azimuth direction and at the midpoint in the flight, the distance to the target equals the range of closest approach or minimumrange to target.

As a satellite platform is used in the simulation, the curvature of the earth is considered negligible and the orbital velocity is approximately equal to the platform velocity. The figure 3.4 shows the Normalized radiation Pattern vs. Beam Steering Angle and Linear plot of base band signal.

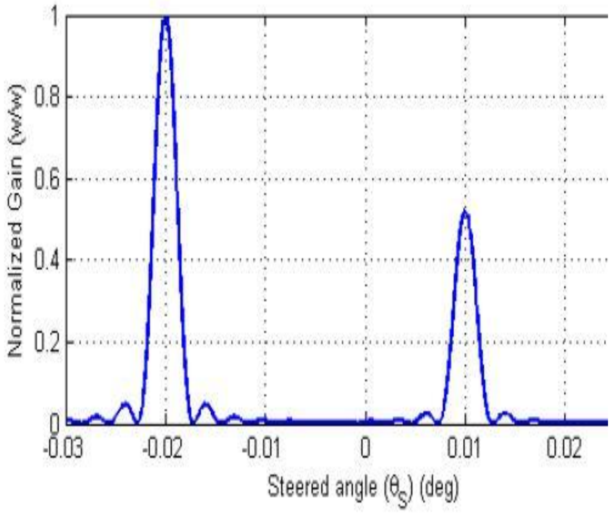

Figure.3 Normalized radiation pattern vs. Beam steering angle-Two targets located at -0.02 and 0.01deg

IV. CONCLUSION

SAR can produce high-resolution two-dimensional images of mapped areas. In this work, the image plane is defined by the velocity vector and antenna beam axis. The image orthogonal coordinate are range and cross range (azimuth). Thee amplitude and phase of the received signals are collected for the duration of an integration time after which the signal is processed. We observed that, high range resolution can be achieved by the use of wide bandwidth transmitted pulses. The pulse repetition frequency of the SAR is constrained within bounds established by the geometry and signal ambiguity limits. SAR operation requires relative motion between radar and target. We assumed nominal velocity values for signal processing.

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