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Research paper

Detection and imaging of ground targets based on new approaches in radar imaging implementation in SOC technology

Syeda Salma Fatima* and Deepa Madathil

Department of Sensor and Biomedical Technology, School of Electronics Engineering, VIT Vellore
**Corresponding author E-mail: sdsalmafatima@gmail.com*

Abstract

SAR system collects the image by sending signals on to the ground and collecting the reflected signals from the stationary target that is present on the ground. Here we have used Doppler Algorithm, by continuously moving the antenna in order to get clear resolution. This paper presents simulation for 2D rectangular shaped targets that are present on the ground. We have given two-dimensional, grayscale target image as an input to perform simulation and we obtain a two-dimensional line profile with the help of reflected signals.

Keywords:*DA; RCMC; RDA; SAR & Strip Map SAR.*

I. Introduction:

Synthetic aperture radar gives the quality output by using the movement of antenna by comparing with the stationary target that is present on the ground. A small transceiver placed on the side of a plane wing, once the target is set as a wider beam will be produced. The more extensive the bar on the object, the more troublesome it is to recognize when reflections are originating from the object and along these lines. The target characteristics can be find by improving the resolution by utilizing a larger transceiver antenna. A transceiver is mounted on a moving plane wing platform and when observed from the ground with respect to the target, many beams can be sent from and received by the antenna of the transceiver and when these reflections are analyzed together, an image with wider resolution can be generated with the help of the Range Doppler Algorithm (RDA). The Doppler Algorithm (DA) uses filtering technique by matching the template reflections from ideal radar scattering with the raw SAR signal to generate an image of the object [1-10].

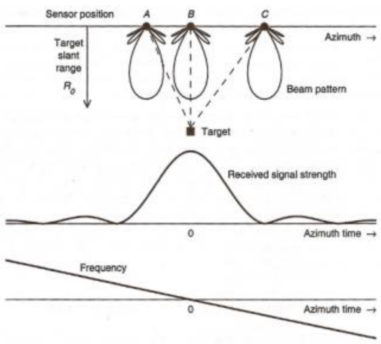

Fig 1: Doppler frequency of the target

II. SAR Image Simulation:

The main plan here is to specific 2D SAR Image calculation and associated terms employed in MATLAB Simulation. The object is really imaged and collected from point of radar scatters. The point targets are arranged in a Cartesian class of correlate system space determined by the range, angle and elevation as correspondent of X, Y and Z directions. The elevation orientation is to take out in the 2D simulation. An antenna fixed to an aircraft progress at an orbital velocity or speed (V_s), is simulated along the angle orientation and at the centrum in the flight, the span to the object equals the range of near or lowest range to object, (R_o) in the simulation and expressed by (X_c) as mentioned in Fig. 2. [7-9]

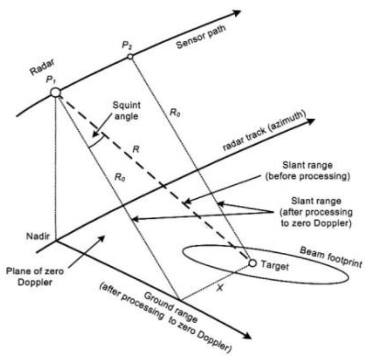

Fig. 2: SAR Geometry computation.

Simulation results are obtained by using an aircraft, the deflection of the earth is contemplated unimportant and the orbital speed is almost equivalent to podium velocity (V_r). The speed of the radar ray across the ground is (V_g). For an earth orbiting satellite case, $V_s$is around 6%high,V_r and V_g would be 6 % less than V_r. Strip map SAR is mentioned in Fig. 2, because the radar dish is a circular in a stable orientation through the time span of the flight. As the platform travel across the angle, the radar ray cleans down the bottom. The portion of the measuring system ray touching the bottom, display within the circles to the correct is termed “the ray footprint”. The beam breadth is round shape elongate from the antenna to the ray footprint. Objects in the ray footprint return radar signals which are then collected by the antenna. The secured radar reflections are sort out with the Range Doppler Antenna (RDA), to get the final SAR image. [4], [9], [14,]

III. Relay of SAR signal

Let us suppose, the transmission of radar signal $S_{tx}(t)$ is of the shape of expression (i) in below simulation. The signal is a function of vary/range time (t), the carrier frequency (f_o) is 4.5 GHz, the chirrup pulse time span (T_r) is 2.5µs and the range chirrup or F_m rate (K_r) is +40 MHz/µs, is called as up-chirrup as it is positive. The signal bandwidth (B_o) in expression (ii) below mentioned, it is 100MHz and the range resolution (ρ_r) in below expression (iii) mentioned, which is around 1.5m.

$$S_{tx}(t) = rect\left(\frac{t}{T_r}\right) Cos\{2\pi f_o + \pi f_r t^2\ \}$$

$$=W_r(t) Cos\{2\pi f_o + \pi frt^2\} \quad --(i)$$

$$B_o = |K_r|T_r \qquad ---(ii)$$

$$\rho_r \approx \frac{\frac{C}{2.1}}{|K_r|T_r} = \frac{C}{2B_o} \quad ---(iii)$$

The transmission radar signal as a cosine with a continuous raise up frequency higher than a transmit time span accompany by a null receive time span as outlined in Fig. 4. The transmit window is termed the pulse envelope (W_r), and interpret the time span of the transmission. [1-3].

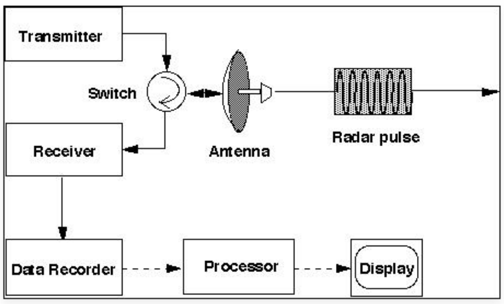

Fig. 3: Radar Pulse Transmission.

In Fig. 4, the enormity of the measuring system signal at the antenna within the time of transmit and receive time spans are unit drawn in sequence. One across the integrated send and receive time span is termed “the pulse repetition frequency (PRF)”, and determines the quantity of pulses transmitted per second. The PRF for the simulation is 300 Hz and time span of the simulation is 3 seconds. This is equivalent to 900 transmitted radar pulses across the time span of the simulation. The output shape of the magnitude of each vary slice reflection as a function of range and angle is called “the raw SAR signal space”. [3-6]

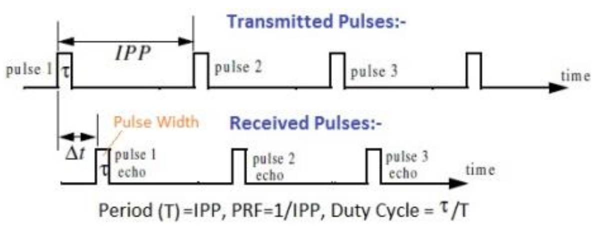

Fig. 4: Movement of SAR Antenna.

IV. Conventional SAR signal

The raw SAR received radar signal$S_{rx}(t, \eta)$, shown in below expression (iv) after constructing demodulation which takes out the high frequency carrier wave and takes the signal to baseband. This is a 3D signal with 2 time proportions and the time proportions are quick time (t) [range time] and slow time (η) [azimuth time]. Expression (iv) is mentioned below as an aggregate of the reflections from M different point objects. The MATLAB utilizes this expression to create all of the reflections across the time span of the flight. Construction demodulation origin the signal to be unreal, have a phase and a magnitude. In order to construct demodulation, the signal is the truly relay signal, which is time retarded, diminished, change in the phase of waveform magnitude altered due to angle beam design influence and has additive white Gaussian noise (AWGN) annexed. This signal appeared in expression (v). [1-4]

$$S_{rx}(t,\eta) = \sum_{m=0}^{M-1} \{\, F_m W_r\left(t - \frac{2R_m(\eta)}{C}\right) W_a(\eta - \eta_c)\ e - j4\pi\left(\frac{f_o R_m(\eta)}{c}\right) + j\pi K_r\left(t - \frac{2R_m(\eta)}{C}\right)^2 \} + \eta_m(t,\eta) \quad ---(iv)$$

$$S_{rx}(t,\eta) = \sum_{m=0}^{M-1} \{\, F_m W_r\left(t - \frac{2R_m(\eta)}{C}\right) W_a(\eta - \eta_c) \cos[2\pi f_o\left(t - \frac{R_m(\eta)}{C}\right) + \pi K_r\left(t - \frac{2R_m(\eta)}{C}\right)^2 + \Psi\} + \eta_m(t,\eta) \qquad ---(v))$$

The time retard is $\left(t - \frac{2R_m(\eta)}{C}\right)$, the depletion factor from reflection at the object is F_m, the phase shift from reflection at the object is Ψ, the azimuth beam design magnitude influence is $W_a(\eta - \eta_c)$ and the additive white Gaussian noise is $\eta_m(t - \eta)$.

V. Range Doppler algorithm

The raw SAR information computed from expression (iv) to bring out the SAR final image within the RDA systems. The RDA complete matched filtering one at a time within the Fourier reworked range and angle domains. The Fourier transforms are computed by quick Fourier transforms for developing time potency and range cell migration correction is to execute within the range time and angle/azimuth frequency domain. This domain is termed “the range Doppler domain” and do the RCMC during this domain to method the attribute of the rule, when analysed to totally different SAR method algorithms [2]. The RDA final processed diagram is appeared in below Fig. 5. The 2 D signal is initially evaluated as a series range time signals for each angle sample. For each range signalling encounters matched filtering within the range frequency or angle time domain across the vary FFT's requested to the range time signals. Following each signal is changed into the range time or angle time domain, the output is that the vary compacted signal whereas the matched filtering can attain within the vary frequency domain. So as to secure angle compression, angle matched filtering should be executed. The vary compressed signal is then controlled into a sequence of signals with reference to angle time at dissimilar vary samples. Each angle signal is Fourier reworked by angle FFT and RCMC is complete prior to angle matched filtering within the vary Doppler tdomain. The final object image is secured over angle matched filtering of each signal and angle inverse Fast Fourier transforms. More insight perusing of those procedure and sample RDA steps on single purpose object in 2 D computation SAR as follows. [2-5]

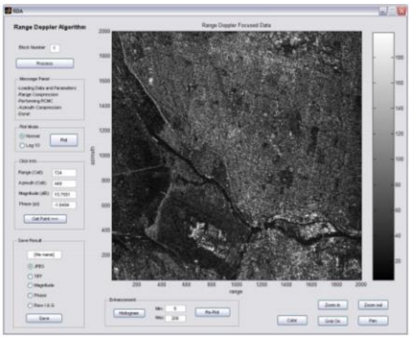

Fig. 5: RDA final processed data.

Apart from the matched filtering, the distinct major component of the RDA is the RCMC (Rang Cell Migration Correction). RCMC is required due to the deliberately exaggerated (hyperbolic) trend with respect to azimuth time (ɳ) of the swift slant range $R_m(\eta)$ as generating RCM. The RCM with regard to azimuth frequency (f_η) within the Range-Doppler domain, vary with time and angle in frequency domain, as mentioned in Expression (vi) because it is computed within the simulation. In the simulation methodology, the estimation in expression (vi) is shut for transient squint angles. The angle frequency is sort through its computation with expression (vii) by utilizing the angle F_m rate (K_a) In the simulation, the RCM is rounded to nearest whole number because the moving should be thought of in separate “cells” to be corrected for time span of the RCMC operation. The cells are transfer to counter RCM within the angle frequency domain advance to angle matched filtering to execute RCMC. [1-5]

$$R_{rd(f_n)} = \frac{R_{om}}{\sqrt{1.C^2\, f_\eta^2/4V_r^2 f_o^2}} \approx \lambda^2 R_{om} f_\eta^2/8V_r^2 \quad \text{---- (vi)}$$

$$f_n \approx -K_a \eta \approx 2V_r^2 \eta/\lambda R_{om} \quad \text{---- (vii)}$$

Initially, the 2D SAR signal area is computed by utilizing expression (iv). AWGN can be noticed all over the image area, the SAR echoes are appeared over the entire angle and also at the center of the range. The SAR echo vigour is extend higher than the angle succeeding a sinc square decompose structure available the beam focus intersection time as projected, that is because of the Doppler shift. The sinc square face tbands don't seem to be noticeable because of the flight time span being restricted to 3 seconds and the highest squint angle 0.859°. [4-11]

VI. SOC implementation of complex multiplier of range FFT

a. Complex multiplication

It is a theory of special functions, such as elliptic, abelian tasks of many complex variables, fulfilling additional recognitions and taking expressly computed unique merits at precise points. Complex multiplication is also utilized in arithmetical number theory, permitting a few alternatives of cyclotomic fields to be fetch across to broad areas of application. [18]

b. SOC technology

SoC is a system on chip technology that has been implemented in 22 nm technology by using Zynq-7000 series chip. The main objective of implementing the SoC technology is to reduce the power and delays, which are shown in below Fig. 6,7,8,9 &10.

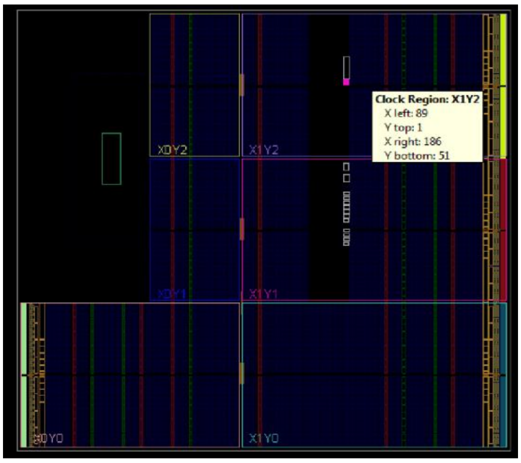

Fig. 6: Complex Multiplier_ SOC.

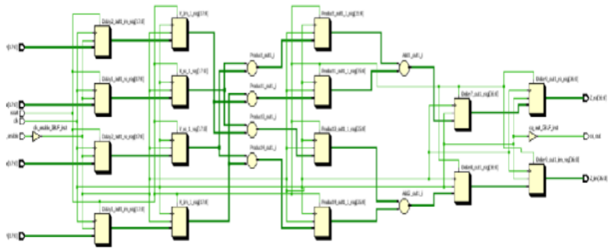

Fig. 7: Complex Multiplier Schematic.

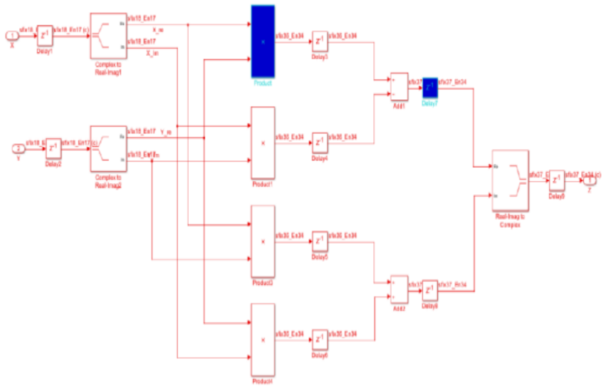

Fig. 8: Critical _Path.

S.No	Total On Chip Power(Watt)	Dynamic Power(Watt)	Thermal Margin °C
01	0.119	0.001	58.6

Fig. 9: Power report.

Setup Time (ns):

S.No	Worst Negative Slack(ns)
01	96.981

Hold Time (ns):

S.No	Worst Hold Slack(ns)
01	0.337

Pulse Width (ns):

S.No	Worst Pulse width Slack(ns)
01	49.500

Fig. 10: Timing report.

VII. Conclusion

Two dimensional simulation has been done for a target which is stationary on the ground and its image has been captured by SAR device. During the operation of the processor, which is present in SAR consumes more power and time delay. Hence in order to overcome this problem the main complex multiplication module of the SAR processor has been implemented by using Zynq -7000 series SoC technology and achieved power of 99% reduction [on-chip power] at a temperature of 58.6 OC and the speed achieved is 49.500 ns. Further this design can be extended from 2D to 3D on Stationary ground target.

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