Spotlight SAR Simulation and Reconstruction

Consider a spotlight SAR system. The radar transmits a chirp signal with pulse duration $T_p = 0.25\mu s$, carrier frequency $f_c = 200$MHz and baseband bandwidth $f_0 = 50$MHz. The center of the target area is at $(X_c, Y_c) = (1000, 300)$. The desired target area is within $[X_c - X_0, X_c + X_0]$ in range, and within $[Y_c - Y_0, Y_c + Y_0]$ in cross-range, with $X_0 = 20$ and $Y_0 = 60$. Let $L = 40 < Y_0$, which requires zero-padding of SAR signal in u domain.

Nine targets are located at $(X_c + x_n, Y_c + y_n)$ with reflectivity σ_n, $n = 1, 2, \cdots, 9$, where

$x_1 = 0,$	$y_1 = 0,$	$\sigma_1 = 1;$
$x_2 = 0.7X_0,$	$y_2 = -0.6Y_0,$	$\sigma_2 = 1.4;$
$x_3 = 0,$	$y_3 = -0.85Y_0,$	$\sigma_3 = 0.8;$
$x_4 = -0.5X_0,$	$y_4 = 0.75Y_0,$	$\sigma_4 = 1;$
$x_5 = -0.4X_0,$	$y_5 = 0.65Y_0,$	$\sigma_5 = 1;$
$x_6 = -1.2X_0,$	$y_6 = 0.75Y_0,$	$\sigma_6 = 1;$
$x_7 = 0.5X_0,$	$y_7 = 1.25Y_0,$	$\sigma_7 = 1;$
$x_8 = 1.1X_0,$	$y_8 = -1.1Y_0,$	$\sigma_8 = 1;$
$x_9 = -1.2X_0,$	$y_9 = -1.75Y_0,$	$\sigma_9 = 1.$

Find Δ_{uc} and assign a 10% guard band such that $\Delta_{uc} \leftarrow \Delta_{uc}/1.2$. Find the minimum and maximum aspect angles θ_{min} and θ_{max}. Find Δ_u and assign a 20% guard band such that $\Delta_u \leftarrow \Delta_u/1.4$. Find the minimum and the maximum distances from the radar to the target, r_{min} and r_{max}, the fast-time gate $[T_s, T_f]$, the fast-time interval $T = T_f - T_s$, and assign a 10% guard band such that $T_s \leftarrow T_s - 0.1T$ and $T_f \leftarrow T_f + 0.1T$, then readjust the fast-time interval T with the new T_s and T_f. Find the minimum fast-time interval T_{min} for processing the SAR data. Let the time-domain sample spacing be $\Delta_t = \frac{1}{4f_0}$ (guard band factor 2), and let the slow-time carrier frequency be $2k_c \sin\theta_c$.

Perform digital reconstruction using three methods, the spatial frequency interpolation, range stacking, and backprojection.

Complete Matlab programming that generates the following results. Submit a printed report that includes 1. Figures of the results; 2. Analysis of the results (describe your observations and provide analysis of these observations); 3. Attach the Matlab code for all problems. In addition, submit the Matlab code that can be compiled to generate all the results in one .zip file to yl72@buffalo.edu.

Note: this is an individual project and please complete the project independently.

P4.1 Plot the magnitude of the measured spotlight SAR signal $|s(t,u)|$ after fast-time baseband conversion.

P4.2 The fast-time matched filter is $p_0(t) = p(t - T_c)$, where $T_c = 2R_c/c$, $R_c = \sqrt{X_c^2 + Y_c^2}$. Perform fast-time baseband matched filtering. Plot the magnitude of the matched filtered output $|s_M(t,u)|$.

P4.3 Plot the spectrum $|S(\omega, k_u)|$ of the baseband aliased spotlight SAR signal.

P4.4 The Doppler-aliased measured data are compressed with reference signal $s_0(\omega, u) = \exp[-j2k\sqrt{X_c^2 + (Y_c - u_{ic})^2} + j2kR_c]$. Plot the spectrum $|S_c(\omega, k_u)|$ of the compressed spotlight SAR signal.

P4.5 Perform polar format processing, digital spotlight filtering, k_u-domain zero-padding for upsampling ($\Delta_{uc} \rightarrow \Delta_u$), slow-time decompression, followed by slow-time baseband conversion. Plot the resulting signal's spectrum $|S_d(\omega, k_u)|$.

P4.6 Plot the spotlight SAR spatial frequency data coverage.

P4.7 Spatial frequency interpolation spotlight SAR reconstruction spectrum.

P4.8 Spatial frequency interpolation spotlight SAR reconstruction.

P4.9 Range stack spotlight SAR reconstruction.

P4.10 Range stack spotlight SAR reconstruction spectrum.

P4.11 Backprojection spotlight SAR reconstruction.

P4.12 Backprojection spotlight SAR reconstruction spectrum.