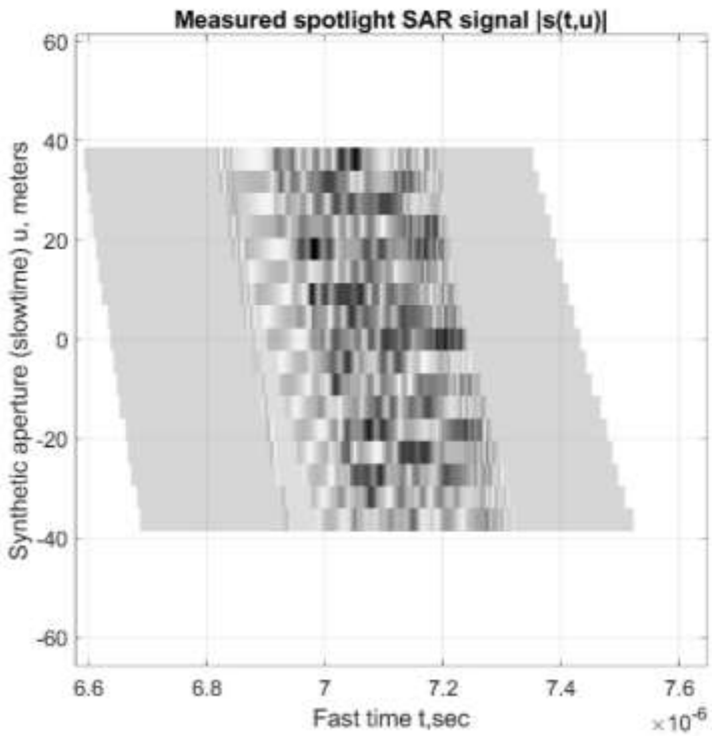
EE562 PROJECT #4

A spotlight SAR system is considered. The chirp signal has a pulse duration T_p = 0.25 μs, carrier frequency f_c = 200MHz, baseband bandwidth f_0 = 50MHz. The center of the target area was given at (1000,300). The desired target area was within [X_c-X_0, X_c+X_0] in range and [Y_c-Y_0, Y_c+Y_0] in cross-range, where X_0=20 and Y_0=60. Since L=40 < Y_0, it required zero-padding of SAR signal in u domain. The 9 targets were defined and out of which only 4 was within the target area and could be detected. Later each procedure was performed and various reconstruction methods were implemented. The results obtained are displayed below.

P4.1

Result

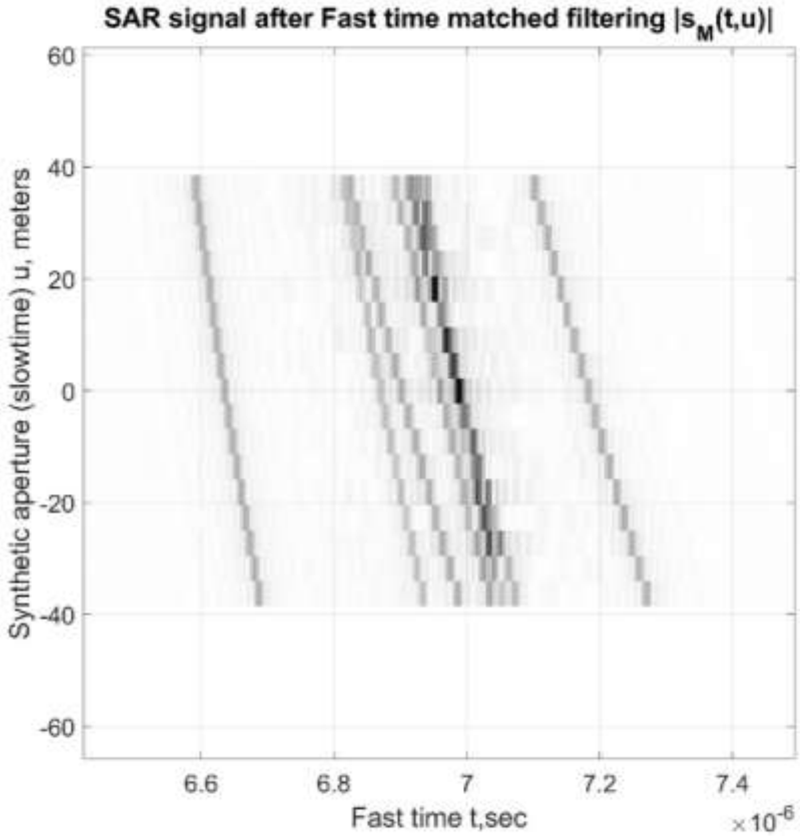


Analysis

The slow time domain and the fast time domain parameters were defined. After that the SAR signal was realized in the fast time domain. Then fast time baseband conversion was performed by multiplying the SAR signal with exp(-j*w_c*t). The absolute value of this signal was taken and plotted against t. It can be seen that the targets are not clearly distinguishable in the output. This is because the p(t) did not have a sharp blip in the fast time domain and possessed a longer duration. Hence it is difficult to visualize the (t,u) domain SAR signature of the each target separately, causing overlaps.

P4.2

Result

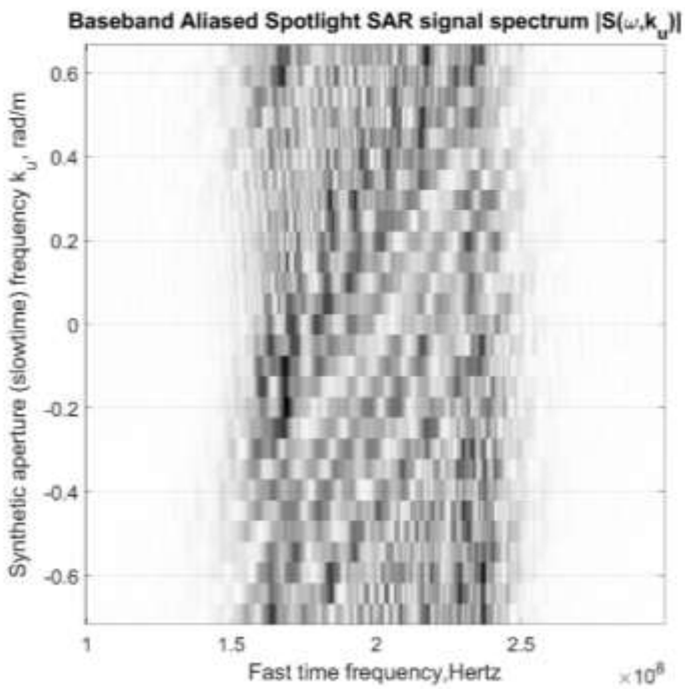


Analysis

In order to visualize the target SAR signal properly, the matched filtering is performed on the signal. It is obtained by convoluting the fast time baseband converted signal with the conjugate of the chirp signal p(t). But since multiplication is simpler than convolution, the signals are converted in frequency domain, multiplied and then converted back to the time domain. This is plotted with respect to the fast time t. The targets are more distinguishable than the previous result.

P4.3

Result

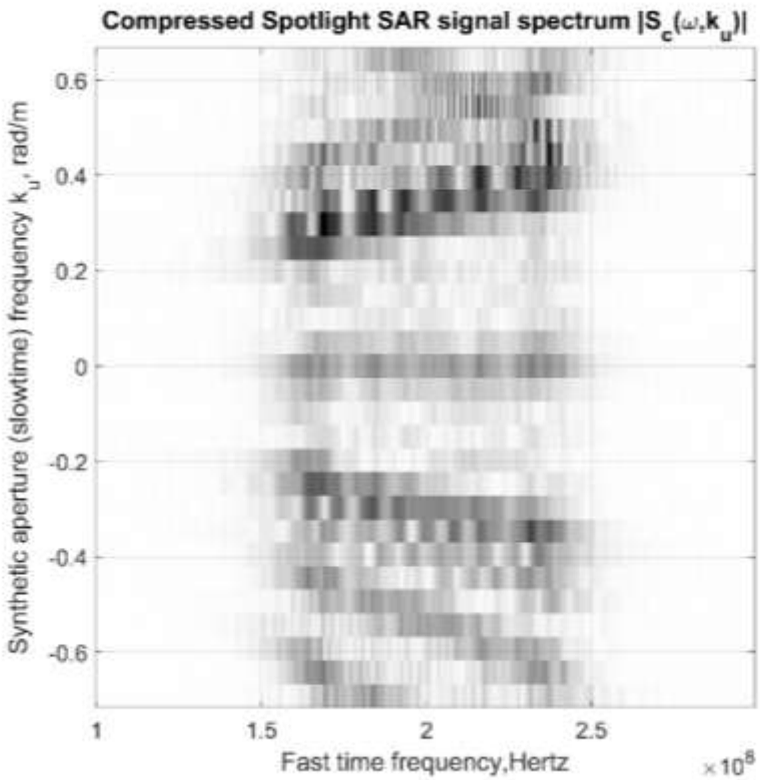


Analysis

Now, the result after the slow time and the fast time Fourier transform is plotted. In that t is converted to w domain and u is converted to k_u domain. So the overall, signal can be denoted as $S(w,k_u)$. The absolute value of this signal is plotted with fast time frequency and is known as the spectrum of the baseband aliased spotlight SAR signal.

P4.4

Result

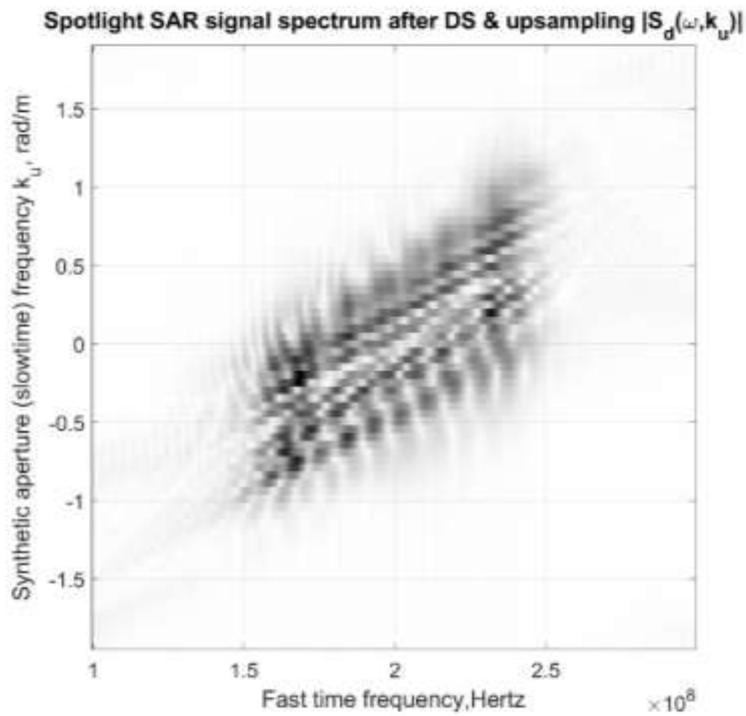


Analysis

In order to obtain the compressed spotlight SAR signal spectrum, the Doppler aliased measured data was multiplied with the reference signal $S_0(w,k_u)$ = exp(-j*2*k*sqrt(X_c^2+(Y_c^2 – u)^2) + j*2*k*R_c). The fourier transform was taken and the absolute value of it was plotted with the fast time frequency. It can be clearly seen that the data has been compressed compared to the previous result which was much more intense.

P4.5

Result

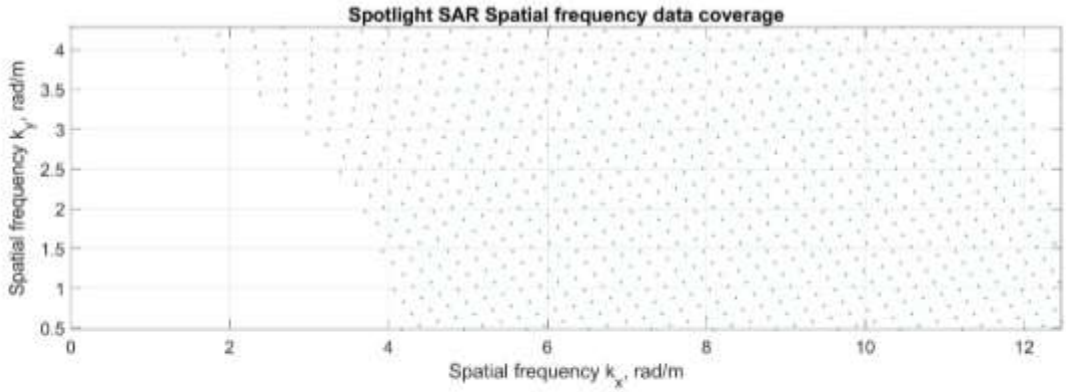


Analysis

The compressed signal is converted into polar format. This is then sent for digital spotlight filtering. This filtering is done to suppress the echoed signal outside the desired target area. The digital spotlight filtering is done by multiplying the polar format signal with the window function that is defined. Later zero padding in the k_u domain is done for slow time upsampling. The signal is now decompressed in the slow time domain as $s_d(w,u)=s_{cd}(w,u)*s_0(w,u)$. The absolute of this signal is plotted against the fast time frequency.

P4.6

Result

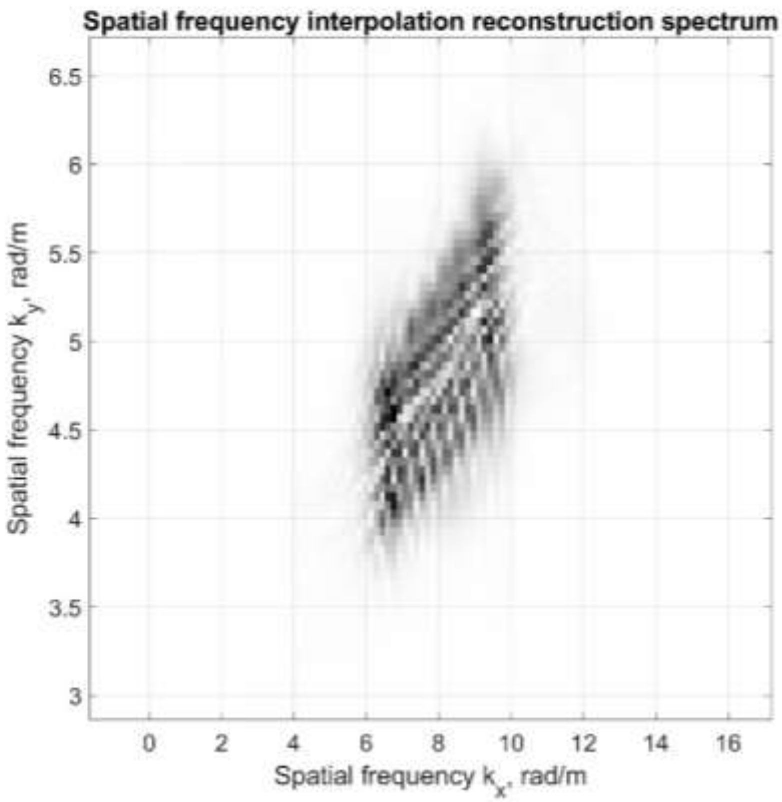


Analysis

The SAR signal reconstruction is performed in this step. The graph shows the data coverage by plotting the spatial frequency k_x versus k_y. In this $k_y = k_u$, and the array is n x m matrix. Similarly, $k_x = \text{sqrt}(4*k^2 - k_u^2)$. It can also be formed via $F_b[k_x(w,k_u), k_y(w,k_u)] = S(w,k_u). S_0^*(w,k_u)$. The obtained result is mapping from (w,k_u) domain into (k_x,k_y) domain. The measurement provides evenly spaced samples of $S(w,k_u)$ on a rectangular grid in that domain. We require the knowledge of this result to retrieve a sampled version of f(x,y) via 2-dimensional inverse FFTs.

P4.7

Result



Analysis

This gives the result of the 2D matched filtering and interpolation. Interpolation is performed in the k_x domain. The interpolation equation is,

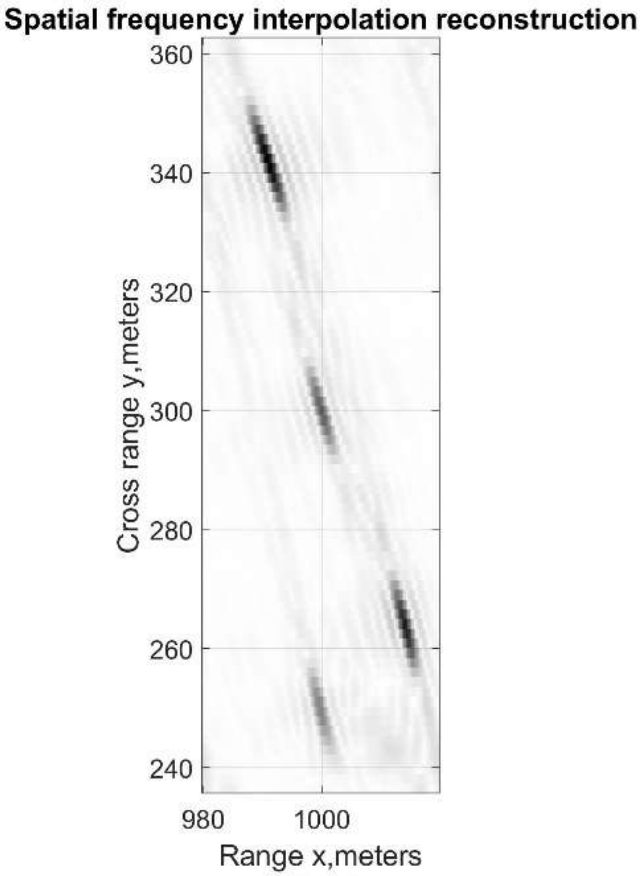
$$F(k_x, k_{ymn}) = \sum_n F(n\Delta k_x, k_{ymn}) \cdot h(k_x - n\Delta k_x)$$

The interpolated spatial frequency domain image F(kx,ky) is plotted. Here F is the interpolated spectrum. Thus the Spatial frequency interpolation reconstruction spectrum is obtained by 3 steps,

- Fourier transform of s(t,u) to get $S(w,k_u)$
- Multiplying the previous output with the $S_0^*(w,k_u)$, to get the target area conversion that is centered at (0,0)
- Finally interpolation is performed based on the procedure discussed above

P4.8

Result

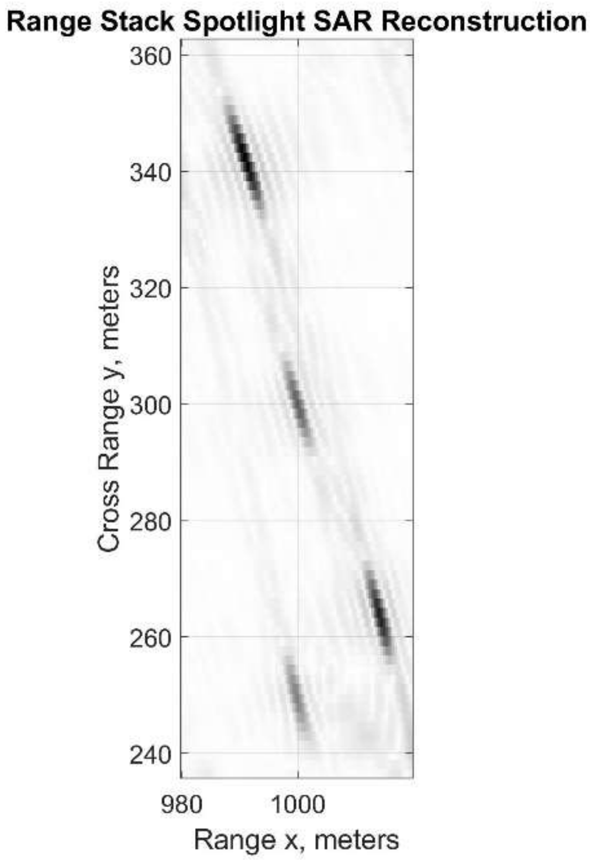


Analysis

The last step in the Spatial frequency interpolation reconstruction is to perform inverse Fourier transform on the $F(k_x,k_y)$ signal to obtain $f(x,y)$. Performing this gives us the result displayed above. We can clearly see the 4 targets distinctly. Out of the 9 targets only 4 are seen because only there 4 lie within the target range and the rest was suppressed in the preprocessing steps.

P4.9

Result



Analysis

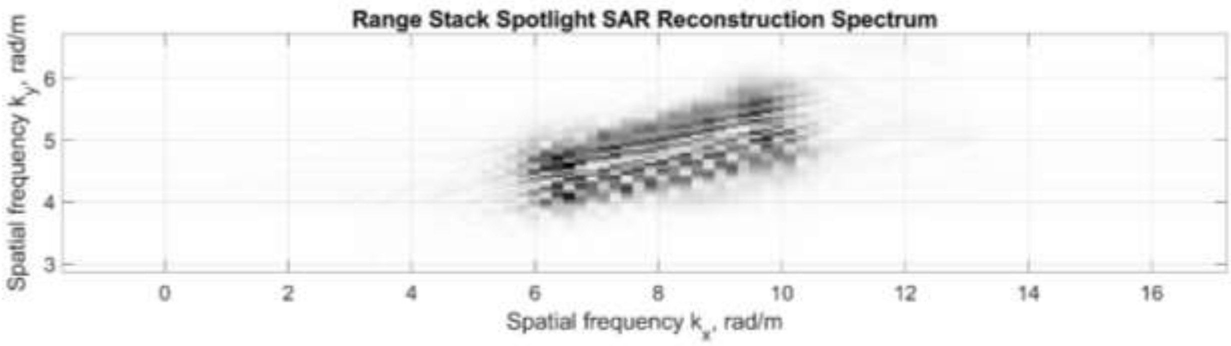
There are 2 algorithms for implementing the reconstructing f(x,y) at the desired range bins. The first algorithm is Fast-time Slow-time matched filtering and the second is Slow-time Fast-time matched filtering. The algorithm 1 is less computationally intensive than algorithm 2. It requires only one inverse DFT from k_y to y domain. The following steps are done in algorithm 1:

- Fourier transform of s(t,u) to get $S(w,k_u)$
- Then matched filtering is done at the range x
- Integrating the signal with respect to w
- Assigning the k_y to k_u i.e $k_y = k_u$
- Finally, performing inverse fourier transform to convert in y domain.
- Same is repeated for each x

Doing this gives the result in which the 4 targets within the range are spotted.

P4.10

Result

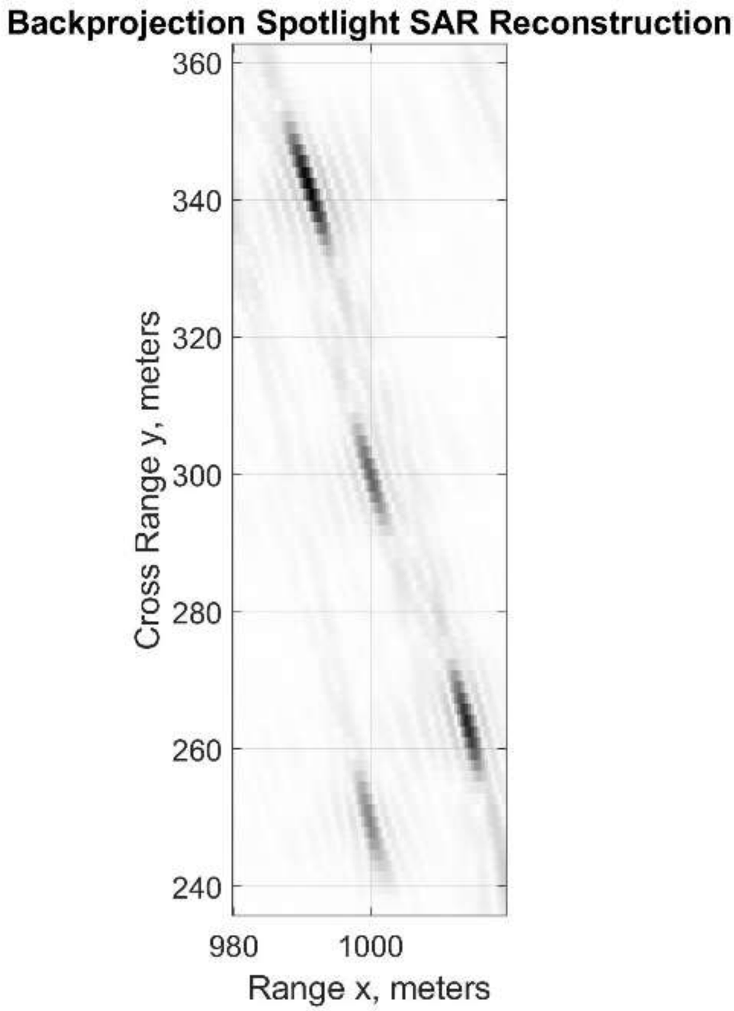


Analysis

First Fourier transform with respect to y is done then the Fourier transform with respect to x is performed. Then the absolute value is taken. This gives the spectrum of the range stack spotlight SAR reconstruction is obtained. As mentioned earlier, it is in the range [Xc-X0, Xc+X0] and cross range [Yc-Y0, Yc+Y0].

P4.11

Result



Analysis

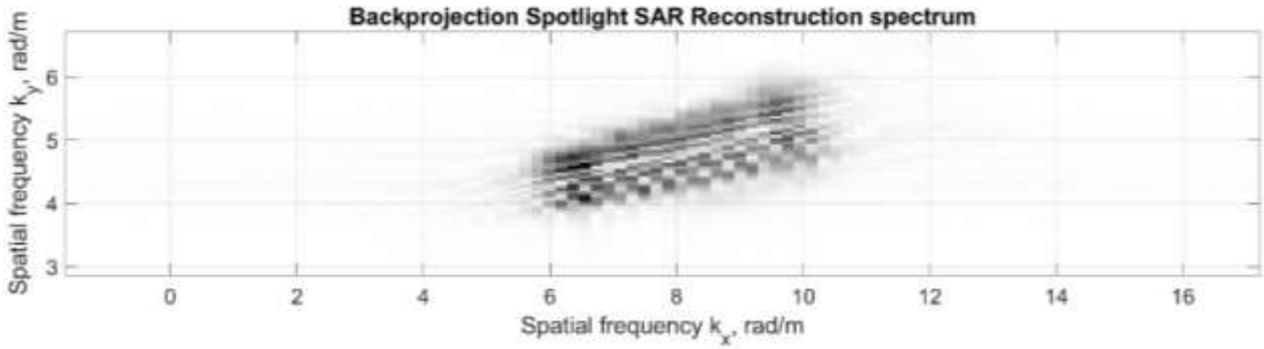
Digital reconstruction can also be done using the Time Domain Correlation or Back projection. But in TDC, there is high computational cost due to the 2D discrete sum that is performed for correlation. So back projection algorithm can be preferred. The following steps are involved:

- Fast time matched filtering of the SAR signal by, $s_M(t,u) = s(t,u).p^*(-t)$
- Interpolation is performed in the fast time domain i.e. $t = t_{ij}(u)$, to get $s_M(t_{ij}(u),u)$
- Integration of the previous output is done with respect to u
- Repeat the same for each (x,y)

The plotting of the f(x,y) spots the 4 target that lies within the target range.

P4.12

Result



Analysis

To form the target function at a given grid point (x_i,y_j) in the spatial domain, the data $s_M(t,u)$ is added at the fast time bias that corresponds to the location of that point for all synthetic aperture locations u. The spectrum is obtained by performing Fourier transform on the reconstructed signal from the previous procedure. 2D Fourier transform is done, first with respect to y then with respect to x. Finally, the obtained result is plotted.