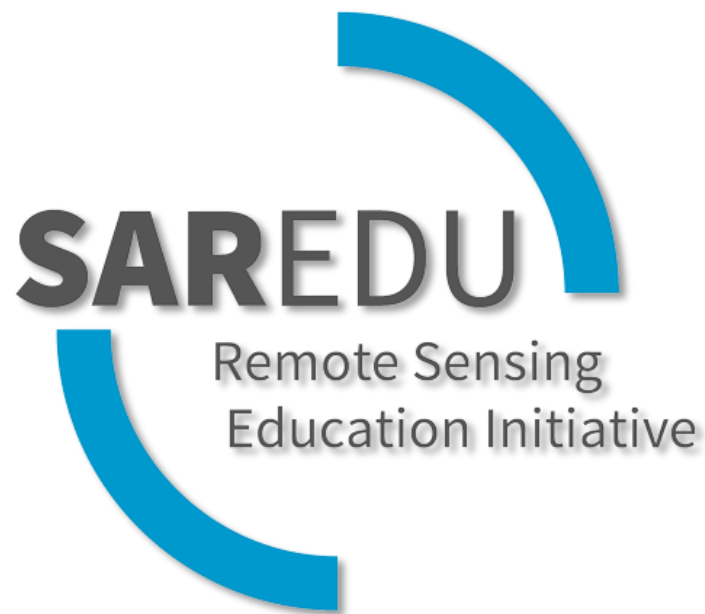




SAR image focusing with MATLAB



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Required files

Function	Filename	Path
Documentation		
<i>Tutorial Guide</i>	<i>SAR-EDU_Tutorial_Focussing_Matlab.pdf</i>	<i>/Readme</i>
Data		
<i>ERS Sample Data</i>	<i>ERS.mat</i>	<i>/Data&MFiles/Data</i>
<i>Test Image</i>	<i>Test_Image.mat</i>	<i>/Data&MFiles/Data</i>
Executables		
<i>Walkthrough</i>	<i>SAR_focussing_tutorial_temp.m</i>	<i>/Data&MFiles/Executables</i>
<i>Solution</i>	<i>SAR_focussing_tutorial_solution.m</i>	<i>/Data&MFiles/Executables</i>

1 Basics

Raw synthetic aperture radar (SAR) data in uncompressed form has to be focused in order to be able to be used for further processing steps, like the generation of digital elevation models (DEM). The provided data is a scene of the European ERS mission, given as raw data in uncompressed form (dimension: 2048 x 2048). We thank ESA and DLR for providing the ERS raw data. All parameters needed for the SAR image compression are summarized in table 1. The focusing is conducted by correlating the raw data with a reference function in range (“range chirp”) and azimuth direction (“azimuth chirp”), respectively.

Basic contents of the source code for focusing are already available in a MATLAB file (“SAR_focusing_tutorial_temp.m”):

- Loading of raw data/ definition of sensor parameters
- Routines for displaying the raw data, azimuth/range chirps, and the compressed image.
- “Multi looking”: The spatial resolution of the ERS data is different in azimuth and range. Hence, a box car filter, having a size of 5x1 pixels, can be applied to the focused data in order to provide approximately “quadratic” pixels.

2 Problem

In the course of this tutorial, two core elements are to be integrated into the source code for enabling SAR image focusing:

- A.) Definition of reference functions in azimuth and range direction.
 - Definition of signal chirps: fill the vectors „azimuth_chirp“ and „range_chirp“ with values. Keep in mind, that the chirps of duration t_a und τ_c do not fully cover the vectors, i.e. the chirps have to be positioned centrally within both vectors.
 - Transform both reference functions to the frequency domain (MATLAB command **fft**)
 - Define the chirps for correlation in frequency domain (MATLAB command **conj**).
- B.) Correlation of raw data with reference functions in frequency domain. Correlating the data is conducted line-by-line in azimuth and range direction, respectively, following the scheme:
 - Selection and Fourier-Transform of raw data line.
 - Multiply with reference chirp in frequency domain.
 - Inverse Fourier-Transformation (**ifft**) and sorting of values (**fftshift**).
 - Entry focused data line in new image.
 - Continue with next raw data line ...

3 Control:

Apply the MATLAB code to the test dataset without multilooking (matrix „Test_Image.mat“, dimension: 1100 x 1700 pixels) for checking the correctness of programming. If your code is free from errors, you should be able to read the content of the resulting image (dimension: 1100 x 1700 pixels).

Table 1: ERS sensor parameters

	Parameters		Value	Unit
Parameters for range compression	Range sampling frequency	f_s	$18.962468 * 10^6$	s^{-1}
	Chirp rate	K_r	$4.18989015 * 10^{11}$	s^{-2}
	Chirp length	τ_c	$37,12 * 10^{-6}$	s
Parameters for azimuth compression	Velocity parameter	V	7098.0194	m/s
	Wavelength	λ	0.05656	m
	Range to target at broadside time $t = 0$	R_0	852358.15	m
	Aperture time	t_a	0.6	s
	Pulse repetition frequency	PRF	1679.902	s^{-1}

4 Required formulas:

Range Chirp: $u(\tau) = \exp(i \cdot \pi \cdot K_r \cdot \tau^2)$ for $-\frac{\tau_c}{2} < \tau < \frac{\tau_c}{2}$
with step width $\Delta\tau = \frac{1}{f_s}$

Azimuth Chirp: $u(t) = \exp(i \cdot \pi \cdot K_a \cdot t^2)$ for $-\frac{t_a}{2} < t < \frac{t_a}{2}$
with step width $\Delta t = \frac{1}{PRF}$

(Simplified assumption for tutorial: symmetric chirp due to Doppler-Centroid = 0 Hz)

Frequency modulation rate in azimuth (FM rate): $K_a = -2 \frac{V^2}{\lambda R_0}$

5 MATLAB commands in source code:

- Fourier transform (FT): $y = \text{fft}(x)$
- Inverse fourier transform (IFT): $y = \text{ifft}(x)$
- Sort data in space domain after IFT: $y = \text{ifftshift}(x)$
- Complex conjugated: $z_c = \text{conj}(z)$
- Round up to next integer: $\text{ceil}(x)$
- Scale and display data
 - o $\text{imagesc}(\text{data})$: plot matrix as image
 - o $\text{abs}(\text{data})$: amplitude; $\text{real}(\text{data})$ real; $\text{angle}(\text{data})$ phase angle; $\text{imag}(\text{data})$ imaginary part of complex number
 - o $\text{colormap}(\text{'gray'})$: display data using gray values
 - o $\text{caxis}([0 \text{ max}])$: define interval of values which covers gray values on the visualized image; Image „Test_Image“: $\text{max} = 2.1807 \cdot 10^8$, Image „ERS“: $\text{max} = 10000$