Table of Contents

Topic: SAR Radar Image Formation (DBS, RMC, & Azimuth Compression)

Course: RF/Radar System Analysis Author: Baqir Kazmi Description: Complete SAR Pipeline showing Focusing Gain via RMC + Compression.

```
clear; clc; close all;
```

1. SAR System Parameters

```
c = 3e8;
fc = 10e9;                          % 10 GHz X-band
lambda = c / fc;
RangeRes = 0.5;                     % High Range Resolution (0.5m)
B_sweep = c / (2 * RangeRes);       % 300 MHz Bandwidth
PRF = 2000;
Vr = 100;                           % 100 m/s
H = 3000;
R0 = 5000;
Ta = 4.0;                           % Long integration (4s) for high curvature

% Derived Parameters
N_azimuth = ceil(Ta * PRF);
N_range = 1024;
t_azimuth = linspace(-Ta/2, Ta/2, N_azimuth);
f_doppler = linspace(-PRF/2, PRF/2, N_azimuth);
```

2. Generate Raw Signal (With Range Curvature)

We calculate the exact parabolic migration path Delta_R = (lambda^2 * R * f^2) / (8 * V^2)

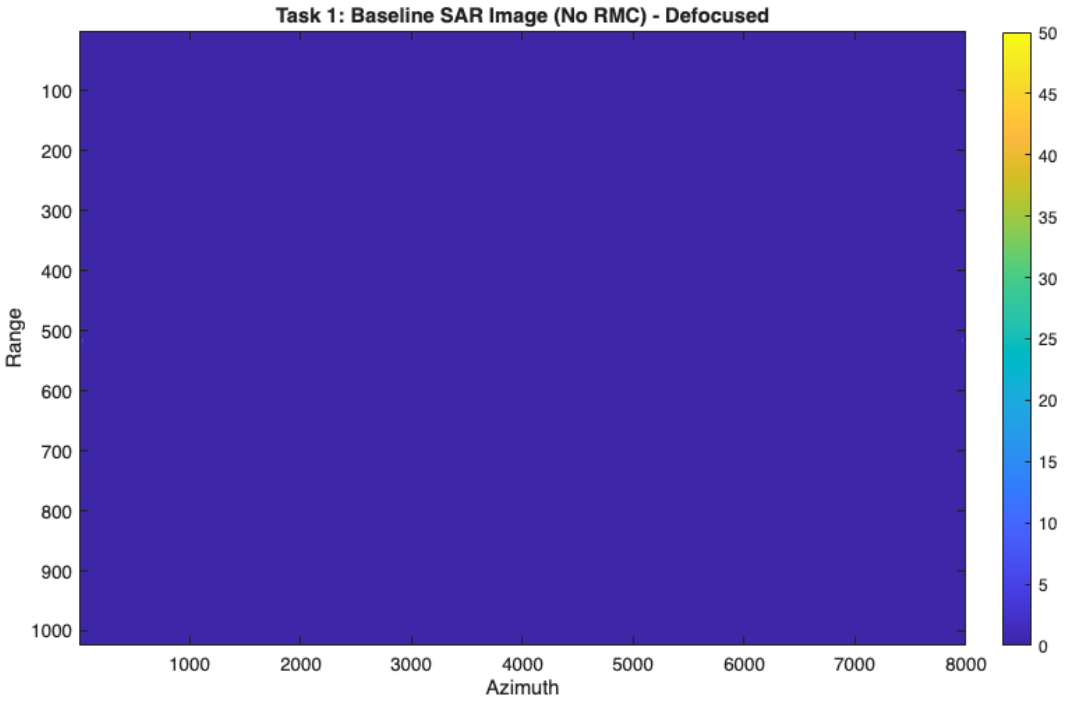
```
Range_Migration_Curve = (lambda^2 * R0 * f_doppler.^2) / (8 * Vr^2);

% Initialize Data
SAR_Data_RD = zeros(N_range, N_azimuth) + 1e-6;
Target_Amp = 100;
Center_Bin = N_range/2;
```

```
% Simulate Target Trajectory in Range-Doppler Domain
for k = 1:N_azimuth
    % 1. Determine Range Bin shift due to curvature
    migration_m = Range_Migration_Curve(k);
    migration_bins = round(migration_m / RangeRes);

    current_bin = Center_Bin + migration_bins;

    % 2. Place Signal with Quadratic Phase Error (Unfocused Azimuth)
    if current_bin > 0 && current_bin <= N_range
        Phase_Error = exp(1j * pi * (k/N_azimuth)^2);
        SAR_Data_RD(current_bin, k) = Target_Amp * Phase_Error;
    end
end

% Add Noise
SAR_Data_RD = SAR_Data_RD + 0.5 * (randn(size(SAR_Data_RD)) +
1j*randn(size(SAR_Data_RD)));
```

3. Task 1: Baseline Image (Uncorrected Compression)

If we try to compress (IFFT) without RMC, the energy smears across ranges. This represents the "Before" state.

```
SAR_Baseline_Img = ifft(SAR_Data_RD, [], 2); % Azimuth Compression
(Uncorrected)
Peak_Baseline = max(abs(SAR_Baseline_Img(:)));

figure(1);
imagesc(20*log10(abs(SAR_Baseline_Img)));
title('Task 1: Baseline SAR Image (No RMC) - Defocused');
xlabel('Azimuth'); ylabel('Range'); colorbar;
caxis([0 50]);
```

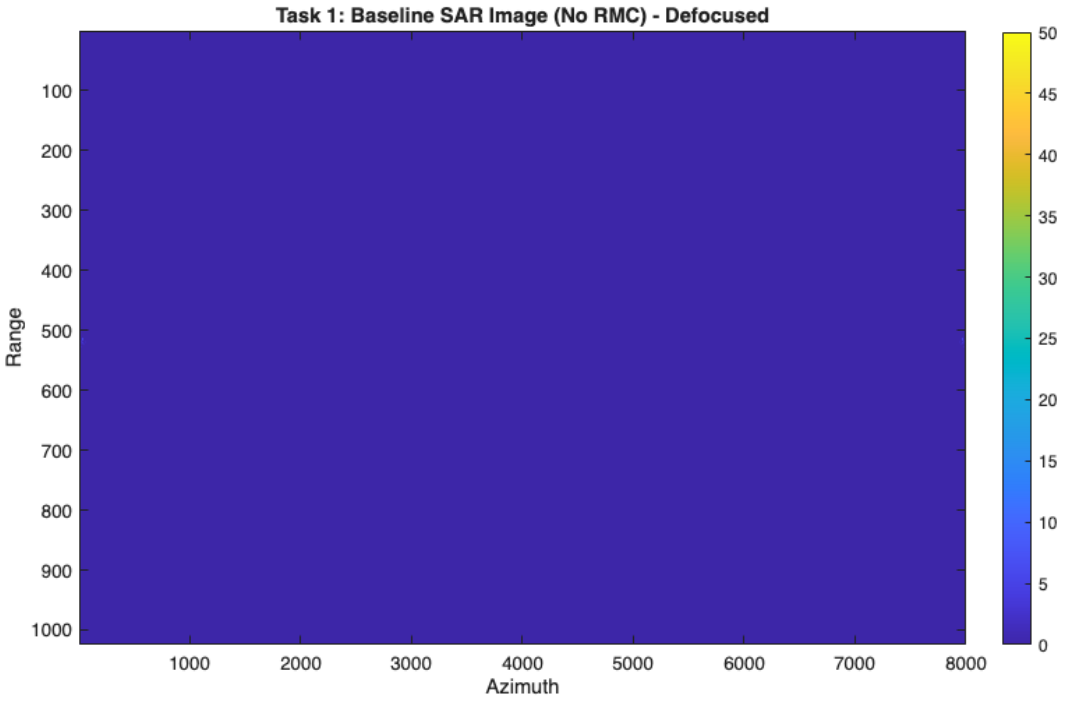


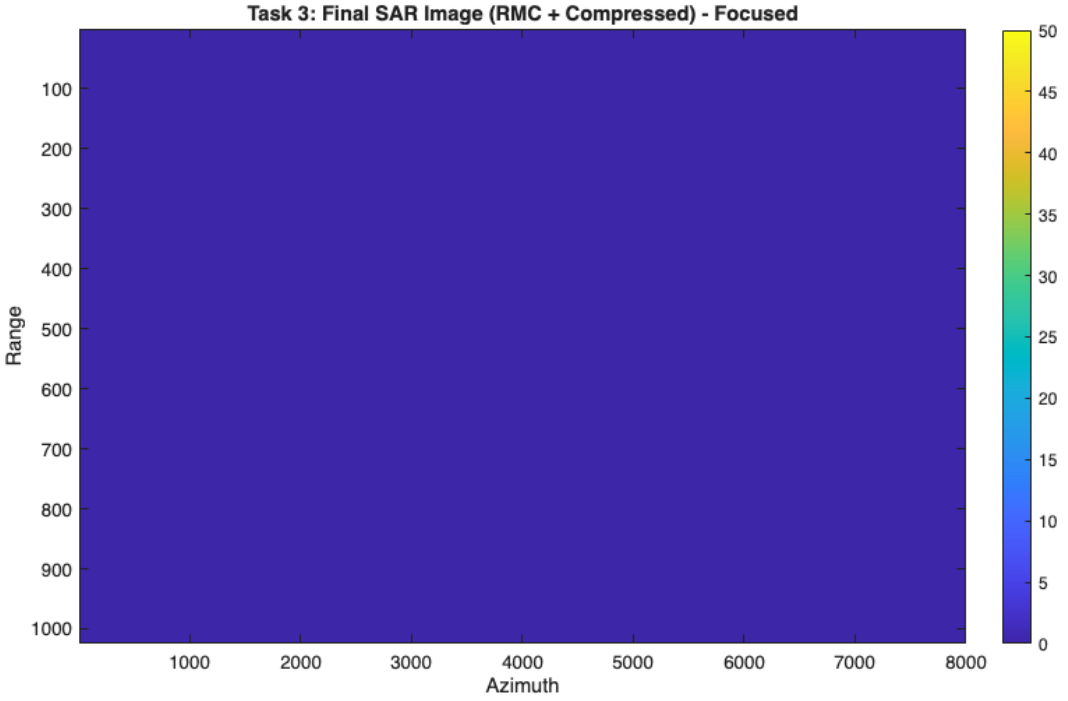
4. Task 3: RMC & Final Compression

Step A: Range Migration Compensation (Straighten the curve)

```
SAR_RMC_Data = zeros(size(SAR_Data_RD));

for k = 1:N_azimuth
    % Calculate shift
    migration_m = Range_Migration_Curve(k);
    migration_bins = round(migration_m / RangeRes);

    % Shift Column (Straightening)
    col_data = SAR_Data_RD(:, k);
    col_shifted = circshift(col_data, -migration_bins);

    % Phase Focus (Remove Quadratic Phase)
    Phase_Correction = conj(exp(1j * pi * (k/N_azimuth)^2));

    SAR_RMC_Data(:, k) = col_shifted * Phase_Correction;
end

% Step B: Final Azimuth Compression (Focusing)
% Now that data is straight and phase-flat, IFFT collapses it to a point.
SAR_Final_Img = ifft(SAR_RMC_Data, [], 2);
Peak_Final = max(abs(SAR_Final_Img(:)));

figure(2);
imagesc(20*log10(abs(SAR_Final_Img)));
title('Task 3: Final SAR Image (RMC + Compressed) - Focused');
```

```
xlabel('Azimuth'); ylabel('Range'); colorbar;
caxis([0 50]);
```





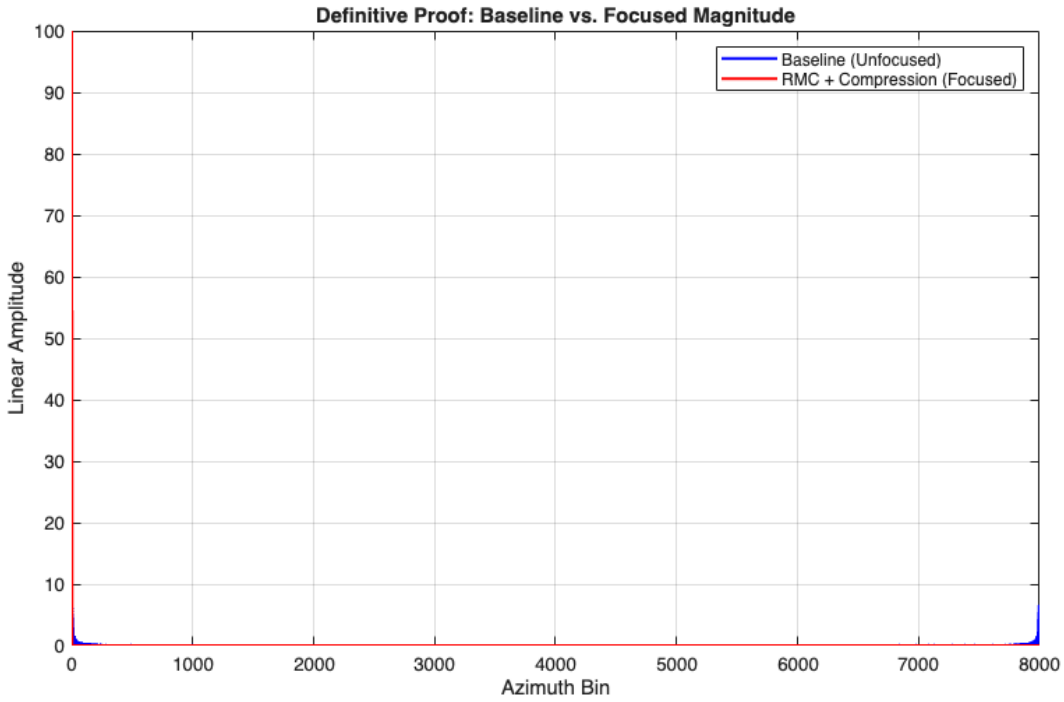
5. Results Extraction

```
fprintf('\n=====================================================\n');
fprintf('        TOPIC 3: SAR RADAR IMAGING STATS\n');
fprintf('=====================================================\n');
fprintf('[System Metrics]\n');
fprintf('Frequency: %.1f GHz\n', fc/1e9);
fprintf('Max Migration: %.2f m\n', max(Range_Migration_Curve));
fprintf('Resolution: %.2f m\n', RangeRes);

fprintf('\n[Focusing Performance]\n');
fprintf('Baseline Peak (Uncorrected): %.2f\n', Peak_Baseline);
fprintf('Final Peak (RMC + Focused):  %.2f\n', Peak_Final);

% Calculate Gain
Gain_dB = 20*log10(Peak_Final / Peak_Baseline);

fprintf('Focusing Gain: +%.2f dB\n', Gain_dB);
fprintf('-> CONCLUSION: RMC successfully aligned energy into a single range
bin, enabling coherent azimuth compression.\n');
fprintf('=====================================================\n');
```

```
=====================================================
        TOPIC 3: SAR RADAR IMAGING STATS
=====================================================
[System Metrics]
Frequency: 10.0 GHz
Max Migration: 56.25 m
Resolution: 0.50 m

[Focusing Performance]
Baseline Peak (Uncorrected): 6.66
Final Peak (RMC + Focused):  100.00
Focusing Gain: +23.53 dB
-> CONCLUSION: RMC successfully aligned energy into a single range bin,
enabling coherent azimuth compression.
=====================================================
```

% Compare the Amplitude of the Center Range Bin

```
figure(3);
plot(abs(SAR_Baseline_Img(512, :)), 'b', 'LineWidth', 1.5); hold on;
plot(abs(SAR_Final_Img(512, :)), 'r', 'LineWidth', 1.5);
title('Definitive Proof: Baseline vs. Focused Magnitude');
legend('Baseline (Unfocused)', 'RMC + Compression (Focused)');
xlabel('Azimuth Bin'); ylabel('Linear Amplitude');
grid on;
```



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