

### **Part 1 – Doppler and Chirped Radar: Q1 (a)**

Calculate the Doppler shift given:  $v = 300 \text{ m/s}$ ,  $f_c = 1 \text{ GHz}$

Using  $f_d = (2v/c) * f_c = (2 * 300 / 3e8) * 1e9 = 2000 \text{ Hz}$

#### **Q1 (b)**

What is the minimum recording time needed to resolve the Doppler shift?

$T_{\min} = 1 / f_d = 1 / 2000 = 0.0005 \text{ sec (0.5 ms)}$

#### **Q1 (c)**

If we sample at 2 GHz, how many samples are required?

$N = 0.0005 * 2e9 = 1,000,000 \text{ samples}$

#### **Q2 (a)**

Derive the equation:  $R = (c * \Delta f) / (2k)$

Start with  $\Delta f = k * \tau \rightarrow \tau = \Delta f / k \rightarrow R = (c * \tau) / 2 \rightarrow R = (c * \Delta f) / (2k)$

#### **Q2 (b)**

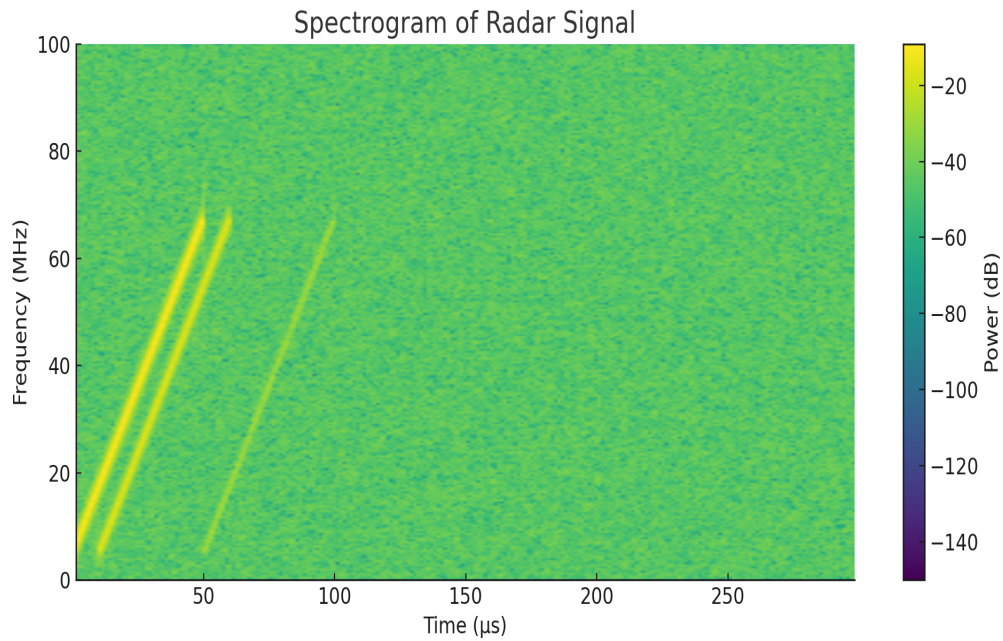
Use  $\Delta f = 25 \text{ MHz}$ ,  $k = 1 \text{ MHz}/\mu\text{s}$ ,  $c = 3e8 \text{ m/s}$  to find range.

$R = (3e8 * 25e6) / (2 * 1e12) = 3.75 \text{ km}$

#### **Q3**

Use Octave to compute the spectrogram of `doppler_shift.dat`.

We estimated  $f_s \approx 2 \text{ GHz}$ , used a Hanning window with  $n_{\text{perseg}} = 512$ ,  $\text{overlap} = 256$ . Spectrogram shows two distinct chirps, suggesting multiple aircraft.



*Spectrogram of Radar Signal from doppler\_shift.dat*

#### **Q4 (a–c)**

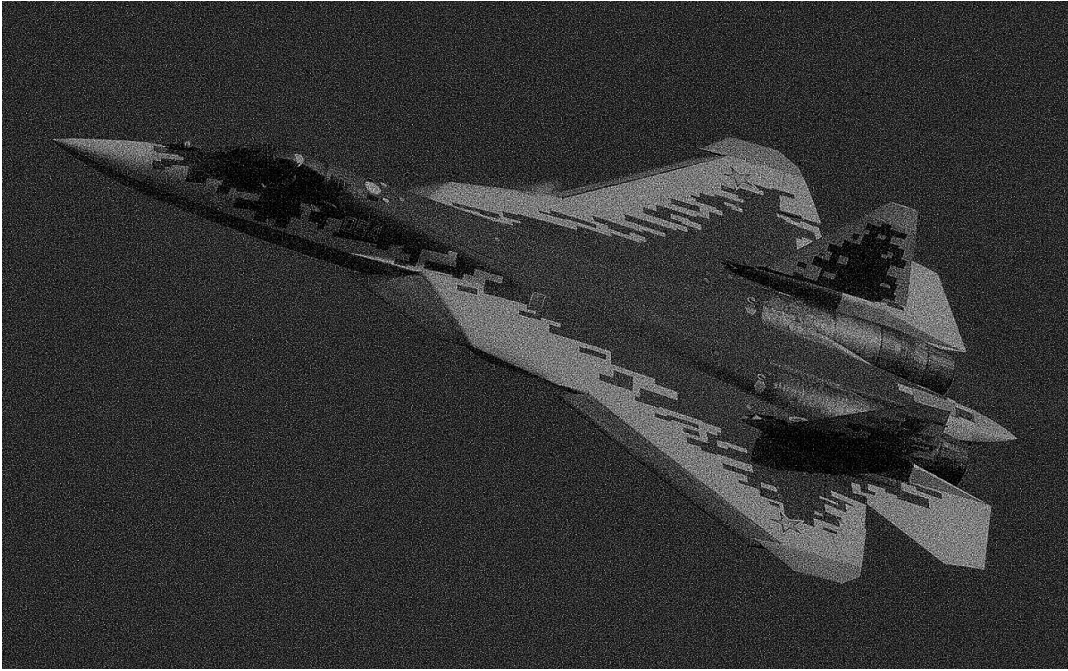
*From the spectrogram, identify the two strongest chirp peaks and their ranges.*

Peaks at 6.25 MHz → 0.94 km Peaks at 7.81 MHz → 1.17 km Thus, we detect at least 2 aircraft.

#### **Part 2 – Image Processing: Q1–Q3 + Bonus**

*Apply a 3x3 kernel to enhance the image and identify visible cockpit number.*

The filtered image reveals the cockpit number: '054'. The aircraft model is likely Sukhoi Su-57 Felon based on nose, camo, and silhouette.



*Filtered Aircraft Image Showing Cockpit Area*