# Frequency-Domain Hanning Filter Analysis — Busan Harbor SAR Data

## 1. Objective

The objective of this analysis is to evaluate the impact of applying a **Hanning window in the frequency domain** to a Single Look Complex (SLC) SAR image of Busan Harbor. The goal is to assess changes in image quality, spectral characteristics, and potential implications for downstream processing tasks.

## 2. Figure: Original vs. Filtered SAR Imagery

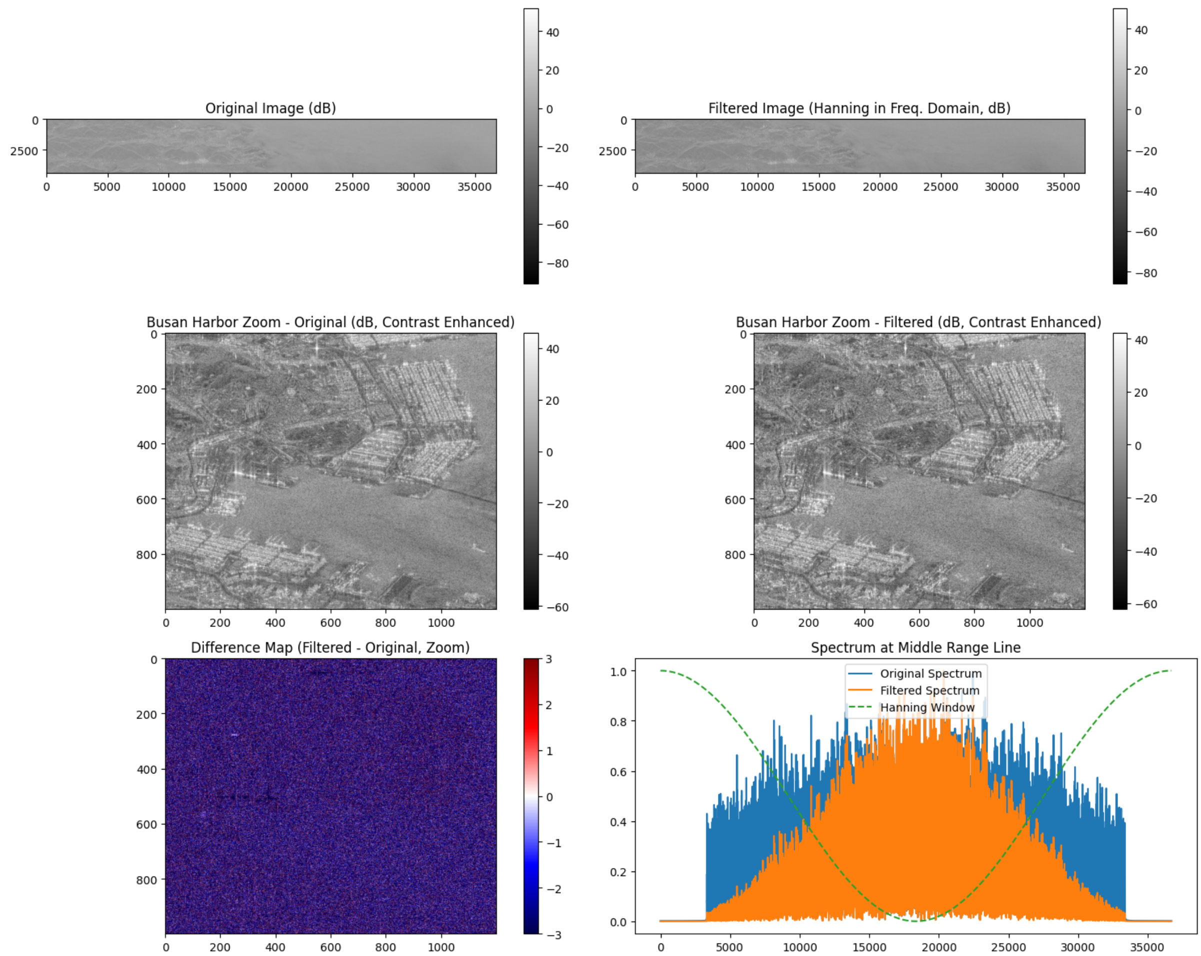


**Figure 1:** Comparison of original and frequency-domain Hanning-filtered SAR images of Busan Harbor.

Top row: full-scene dB-scaled images; middle row: contrast-enhanced zoom on harbor area; bottom left: difference map (Filtered – Original) in dB; bottom right: spectra at mid-range line with applied Hanning window.

## 3. Panel-by-Panel Overview

- **Top-left:** Original full-scene SAR amplitude image (dB scale). This serves as the baseline for all comparisons.
- **Top-right:** Hanning-filtered version in the frequency domain. Global appearance is visually similar, but bright point targets and sharp edges are slightly softened.
- **Middle-left:** Zoom into Busan Harbor (original). Strong returns from ships, docks, and built-up areas are clearly visible with fine speckle texture.
- **Middle-right:** Same zoom area after filtering. Fine details are largely preserved, but speckle texture is mildly reduced.
- **Bottom-left:** Difference map (Filtered – Original, dB). Most differences are within ±3 dB, with slightly larger changes around strong scatterers.
- **Bottom-right:** Spectrum comparison. The filtered spectrum follows the Hanning envelope, showing attenuation at frequency edges and preservation of the central band.

## 4. Key Observations & Interpretation

- The Hanning window **effectively attenuates band-edge frequencies**, reducing spectral side lobes and potential ringing artifacts.
- Peak amplitudes of bright scatterers are **slightly reduced** (by up to ~3 dB), indicating a trade-off between side lobe suppression and resolution/contrast.
- The difference map shows a predominantly **speckle-like change pattern**, confirming that the filter does not introduce spatial shifts or geometric distortions.
- Spectral plots confirm **energy reduction at the band edges**, consistent with expected Hanning behaviour.
- Phase integrity should be preserved as the filter is symmetric and real-valued, but this should be verified if phase-sensitive processing (e.g., InSAR) is intended.

## 5. Practical Implications

- **Target detection:** Slight reduction in SNR for bright scatterers; CFAR thresholds may require adjustment.
- **Classification & feature extraction:** Reduced high-frequency noise can improve stability of feature descriptors, but extremely fine details may be softened.
- **Visual interpretation:** Improved suppression of side lobes yields cleaner imagery with fewer spurious features.
- **Radiometric calibration:** Since total spectral energy is reduced, calibration may be required if absolute radiometry is important.

## 6. Recommendations

- Use the Hanning window when sidelobe suppression is a priority and slight resolution loss is acceptable.
- For applications requiring maximum resolution, consider a less aggressive taper (e.g., Hamming) or post-filter sharpening.
- If absolute amplitude preservation is needed, apply a normalisation factor to compensate for energy loss.
- For further improvement, evaluate **adaptive spectral tapers** that respond to the local SNR profile.

## 7. Conclusion

The frequency-domain Hanning filter successfully suppresses spectral side lobes with minimal distortion to the scene geometry. The trade-off is a minor reduction in contrast and effective resolution, particularly for bright scatterers. Overall, this approach is well-suited for scenarios where visual clarity and sidelobe control outweigh the marginal loss in detail.