# Passive Radar Processing Chain Specification

This document specifies a complete passive bistatic radar (PBR) processing chain based on KrakenSDR with Explicit Clutter Cancellation (ECA). The description is expressed using GNU Radio–style named blocks but is intended as a system-level specification rather than a concrete implementation.

## Top-Level Logical Block Diagram

```
KrakenSDR Source (5ch coherent IQ)
        |
DC Block + IQ Balance (per channel)
        |
Sample Clock / Time Alignment (fractional delay + phase)
        |
Frequency Translate + Decimate (channel of interest)
        |
        +--> Reference Conditioning (AGC / Whitening) ---------+
        |                                                      |
        +--> Surveillance Conditioning #1 -------------------- |
        +--> Surveillance Conditioning #2 -------------------- |--> ECA Clutter Cancel
        +--> Surveillance Conditioning #3 -------------------- |
        +--> Surveillance Conditioning #4 -------------------- |
                                                               |
                                  +---------------------------+---------------------------+-------------------
                                  |                           |                           |
                           Range-Doppler (CAF) #1      Range-Doppler (CAF) #2      Range-Doppler (CAF) #3
                                  |                           |                           |
                                  +---------------------------+----------- Multi-channel Fusion -----------+--
                                                                      |
                                                                 CFAR Detector
                                                                      |
                                                              Detection Clustering
                                                                      |
                                                                   Tracker
                                                                      |
                                                           Angle / AoA Estimation
                                                                      |
                                                           Geolocation (Bistatic)
                                                                      |
                                                              Display / Logging
```

## Signal Representation and Assumptions

All signals are complex analytic (I/Q) streams. KrakenSDR provides five phase-coherent channels: one reference channel and four surveillance channels. All subsequent processing preserves complex baseband representation and inter-channel coherence.

## KrakenSDR Source

Purpose: Acquire five synchronous RF channels. Outputs complex baseband streams with a common sample rate. Efficiency requires zero-copy buffering and coherent timestamping.

## DC Block and IQ Balance

Purpose: Remove DC offsets and LO leakage and correct IQ imbalance. Implementation should use low-order IIR DC blockers and optional fixed IQ correction matrices.

## Sample Clock and Time Alignment

Purpose: Achieve sub-sample alignment between reference and surveillance channels. This includes integer delay, fractional delay, and phase offset compensation, updated on a slow control loop.

## Frequency Translation and Decimation

Purpose: Isolate the illuminator-of-opportunity bandwidth and reduce computational load. Implemented using polyphase FIR or PFB-based decimation to preserve phase coherence.

## Reference and Surveillance Conditioning

Purpose: Normalize amplitudes and optionally whiten spectra to improve numerical conditioning of ECA and CAF. AGC must be slow relative to CPI duration to avoid Doppler distortion.

## ECA Clutter Cancellation

Purpose: Remove direct-path and multipath clutter from surveillance channels using the reference channel. Each surveillance channel is modeled as a linear convolution of delayed reference copies, estimated via adaptive or block least-squares methods.

```
y_k[n] = s_k[n] - sum_{l=0}^{L-1} w_{k,l} * r[n-l]
```

Efficient implementations rely on FFT-based adaptive filtering or regularized Wiener solutions with diagonal loading. The block outputs clutter-suppressed surveillance channels.

## Range-Doppler / Cross-Ambiguity Processing

Purpose: Compute bistatic delay-Doppler maps using FFT-based cross-ambiguity functions. Overlap-save FFT correlation and batched FFT plans are required for efficiency.

## Multi-Channel Fusion

Purpose: Combine evidence from four surveillance channels, either noncoherently or coherently when calibration permits.

## Detection, Tracking, and Estimation

CFAR detection converts range-Doppler maps into detections. Clustering reduces multiple hits to plots. Tracking maintains target states over time. AoA estimation exploits the four-channel array geometry. Geolocation solves bistatic equations when transmitter and receiver geometry are known.

## Efficiency and Implementation Requirements

The hot path must be vectorized and implemented in C++ or GPU kernels. FFT plans must be reused. Memory layout must be contiguous and aligned. Numerical stability requires regularization and careful conditioning.

## Conclusion

This specification defines a complete, efficient, and operationally realistic passive radar processing chain suitable for KrakenSDR-based systems.