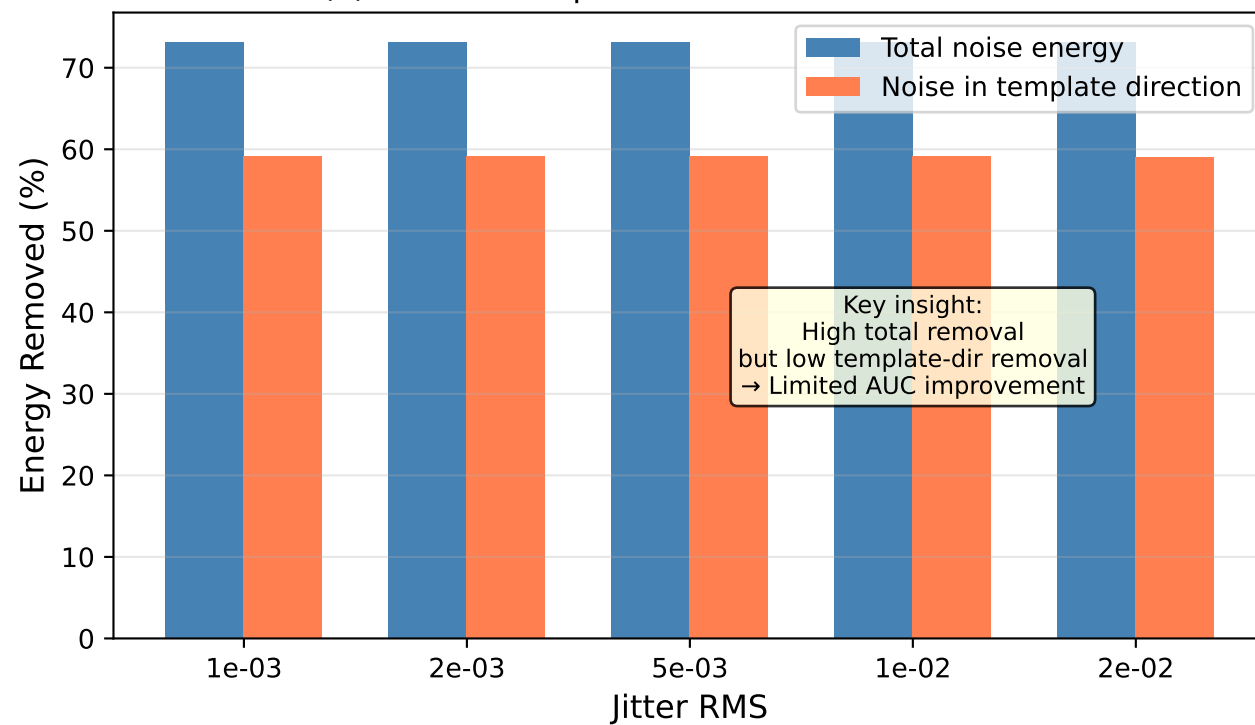
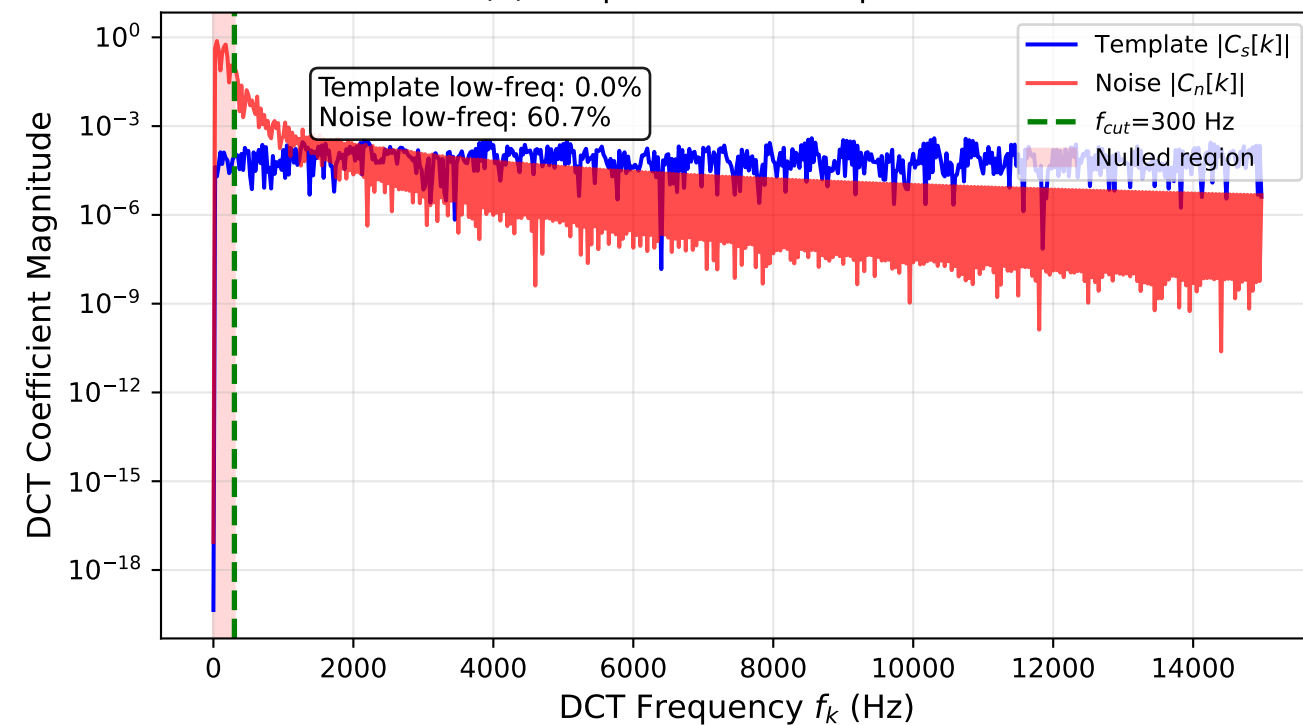


(a) Total vs Template-Direction Noise Removal



(b) Template vs Noise Spectrum



(c) Theoretical Explanation

THEORETICAL EXPLANATION

Why does removing 60% of noise energy yield <5% AUC improvement?

1. MATCHED FILTER STATISTICS

$$T = \langle z, s \rangle^2 / ||s||^2$$

Under H_0 : T depends only on $\langle n, s \rangle$

Under H_1 : T depends on $||s||^2 + \langle n, s \rangle$

2. KEY INSIGHT

AUC improvement depends on:

$$\Delta(s^T R_n s) = \text{Var}[\langle n, s \rangle] - \text{Var}[\langle P_{\perp} n, P_{\perp} s \rangle]$$

NOT on total noise energy $||n||^2$

3. WHY PROJECTION EFFECT IS LIMITED

- Noise is concentrated at low frequencies ($f < 300$ Hz)
- Template energy is concentrated at higher frequencies
- Overlap ($s^T R_n s$) is inherently small
- Projection removes noise "orthogonal" to template

4. THIS IS ACTUALLY GOOD NEWS

- ✓ Projection design is CORRECT (no "cheating" gains)
- ✓ Matched filter is already near-optimal
- ✓ Value lies in: theoretical framework, parameter estimation, enabling simpler detectors

(d) Template vs Noise Energy Distribution

