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NMSBA Seismic Imagery: Tribulations & Current Progress

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Overview

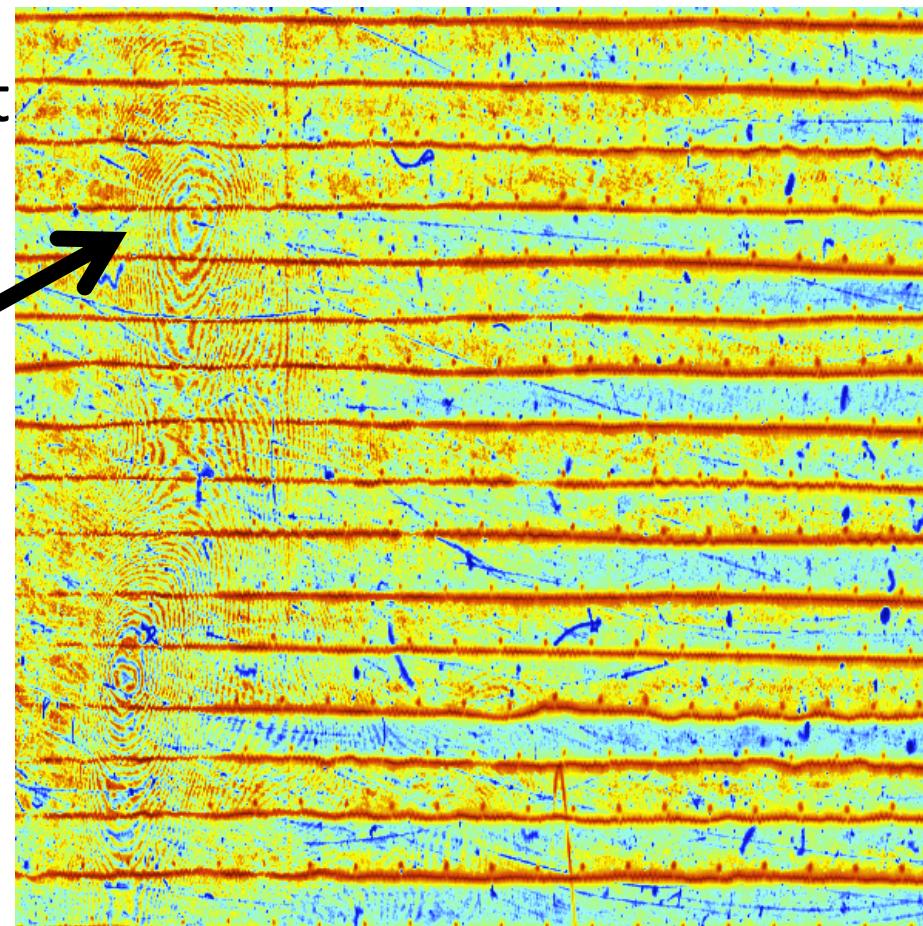
- Obvious issues
- Image timing mark results
- Proposed trace enhancement methods
- Future work and Conclusions
- Background Information

Issues with Seismic Imagery

- Noise (Newton Rings)
- Scratches
- Timing Marks
- Uneven contrast / blotches
- Dimming Traces as activity increases
- Information Boxes / “dog tags” / Border

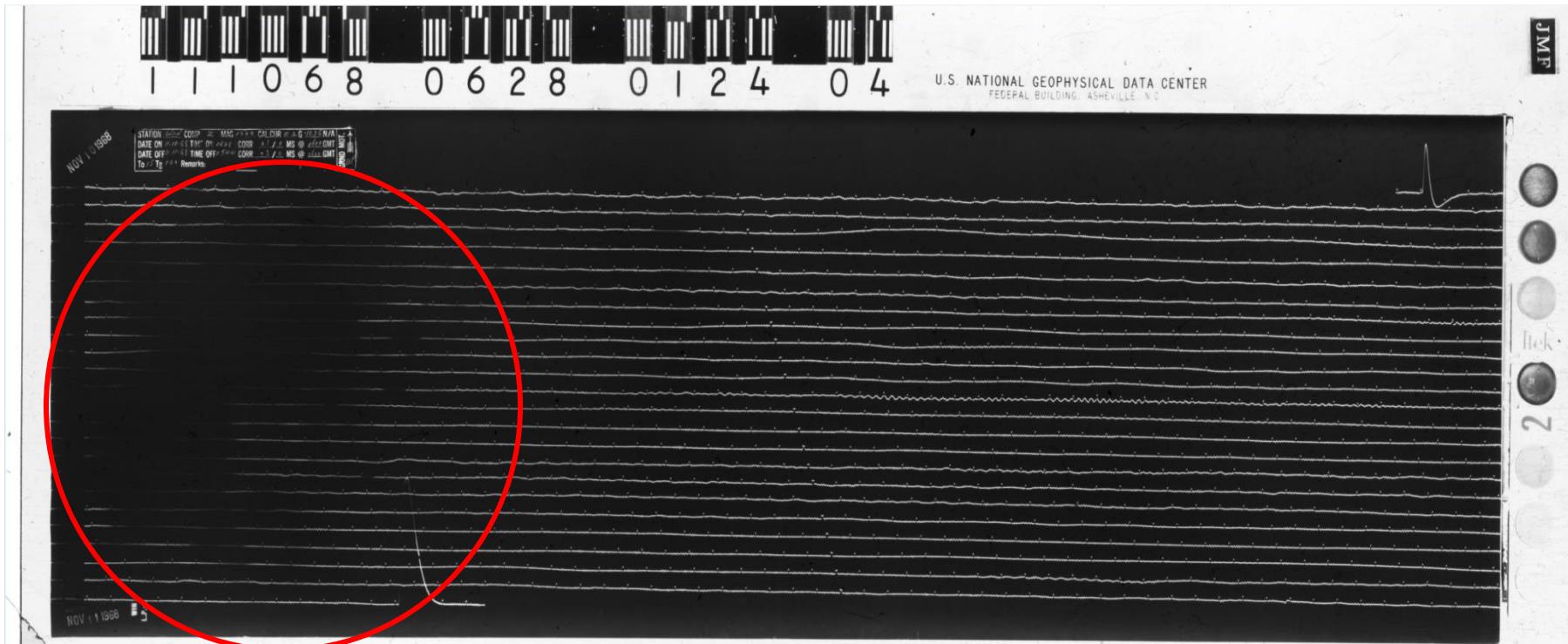
Noise and Scratches

- Noise adds layer of complexity to trace detection algorithms. (Speckle)
- Scratches sometimes cut through traces
- Newton rings disrupt traces as well



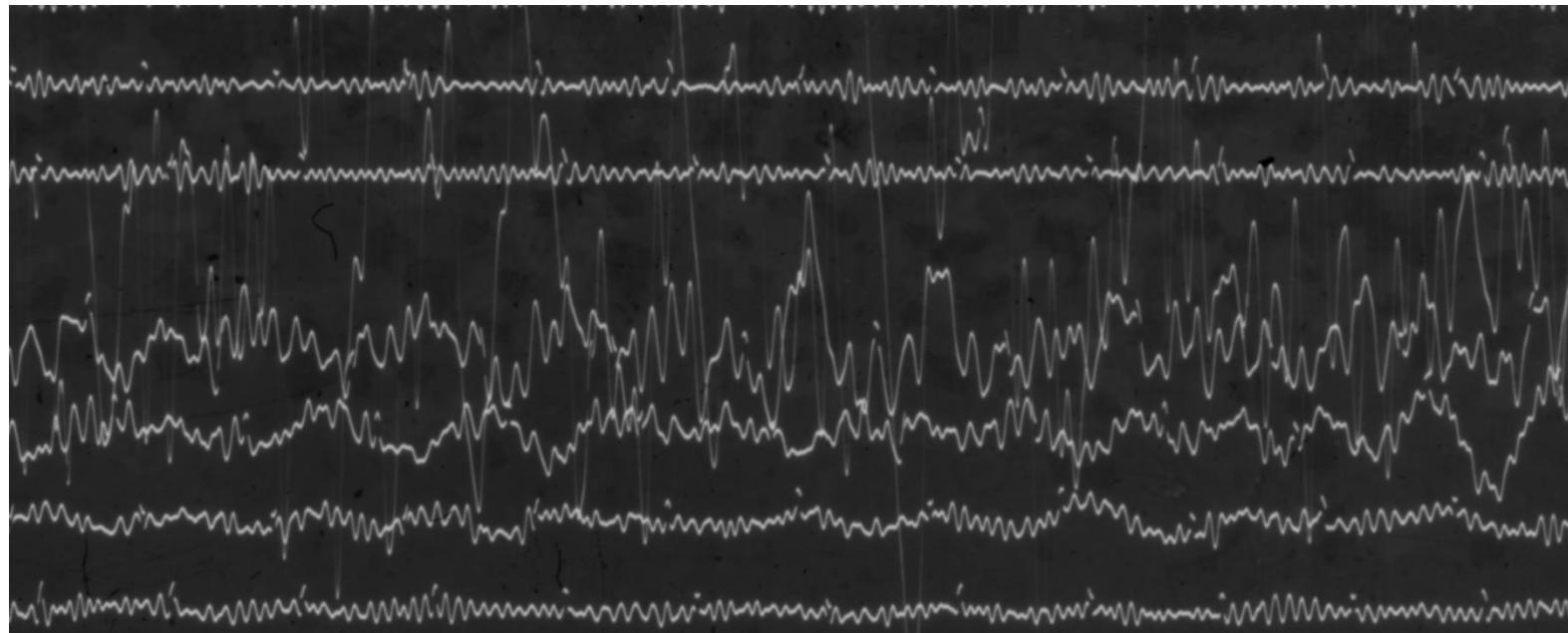
Uneven Contrast

- Blotchy areas create uneven contrast
- Global thresholding is unreasonable



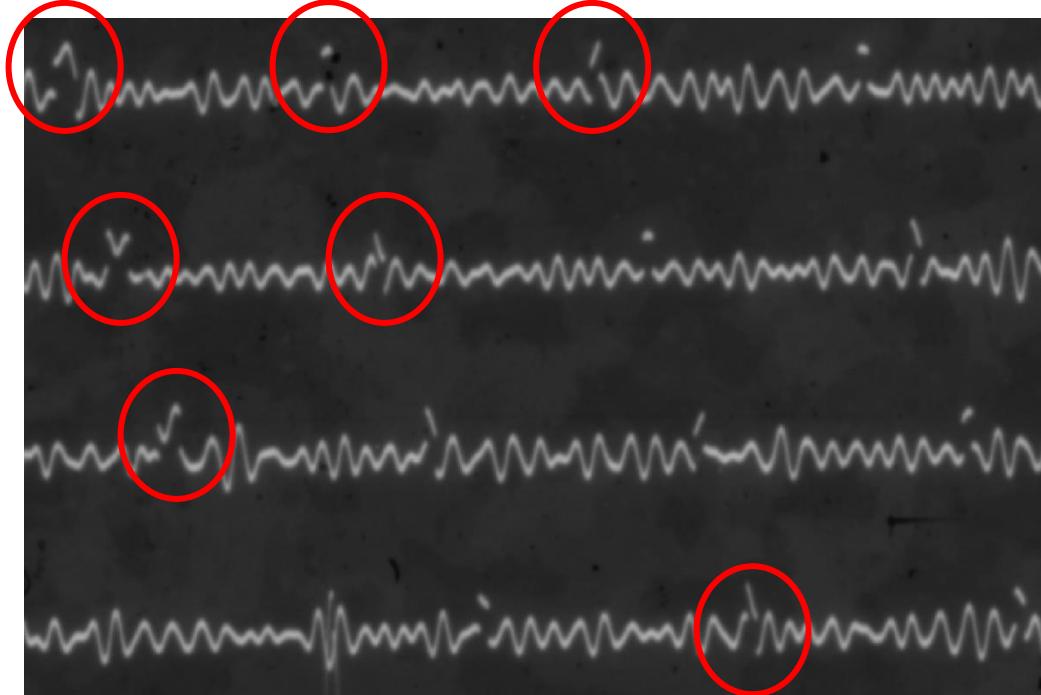
Dim/Faint Traces

- Increasing activity results in dimmer traces.
- Proportional to trace slope



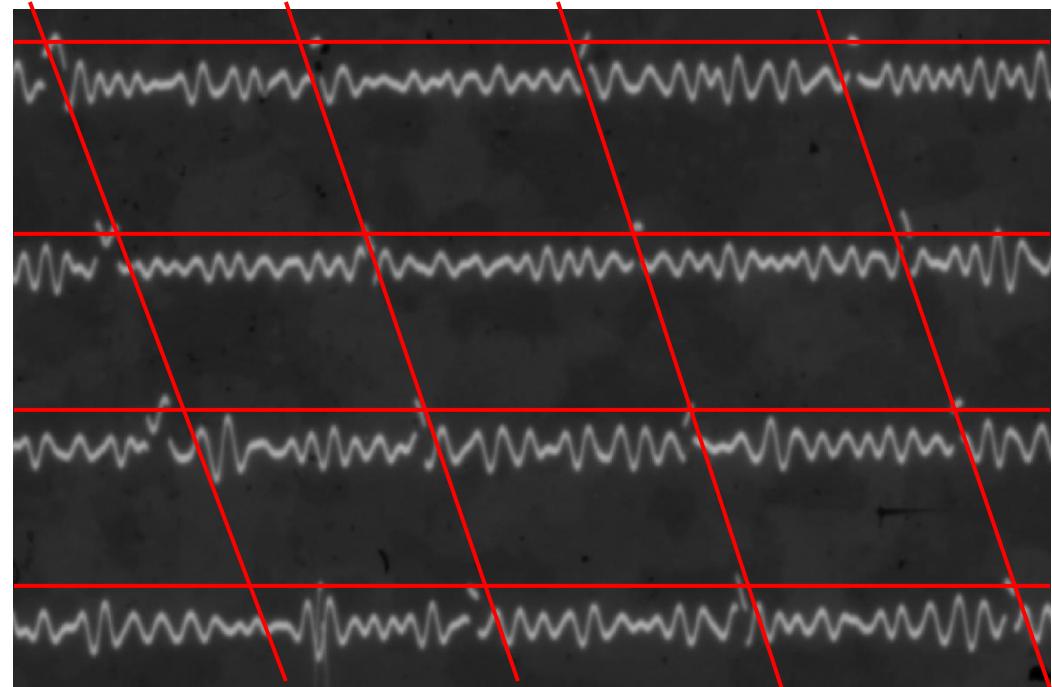
Timing Marks

- Every set amount of time, markings are offsetted by a certain amount.
- They provide timing data as well as signal data



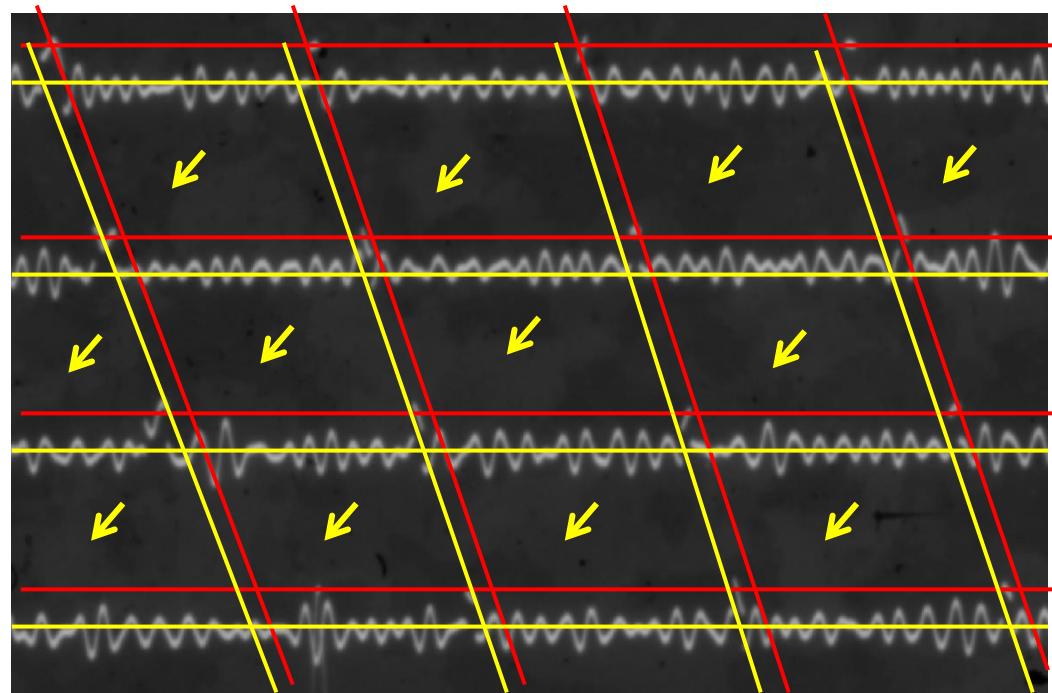
Timing Marks

- Usually in a fairly uniform “lattice”



Timing Marks

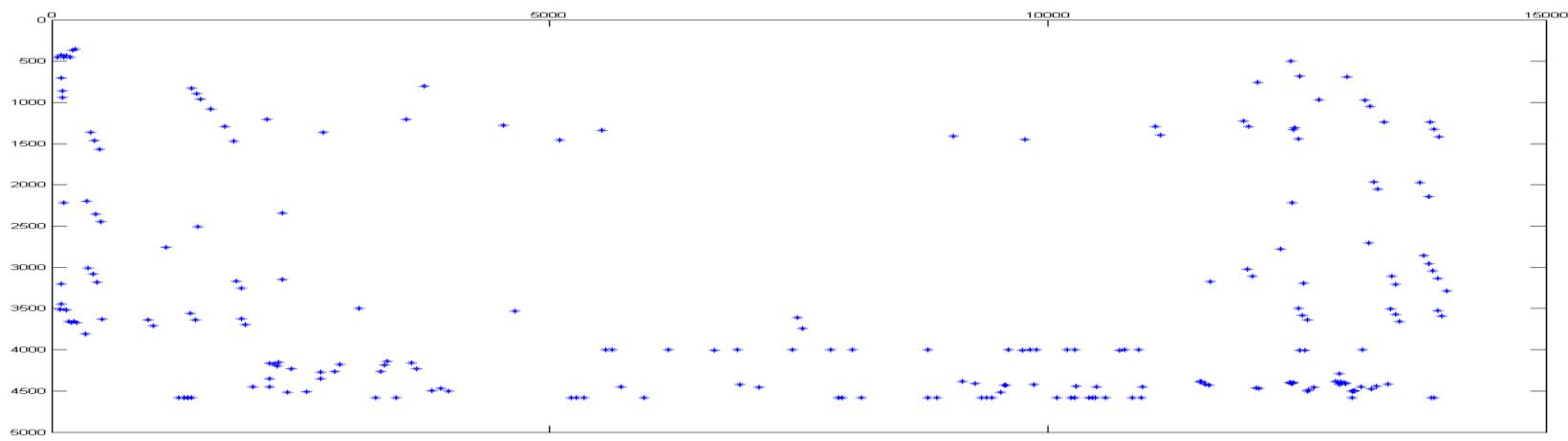
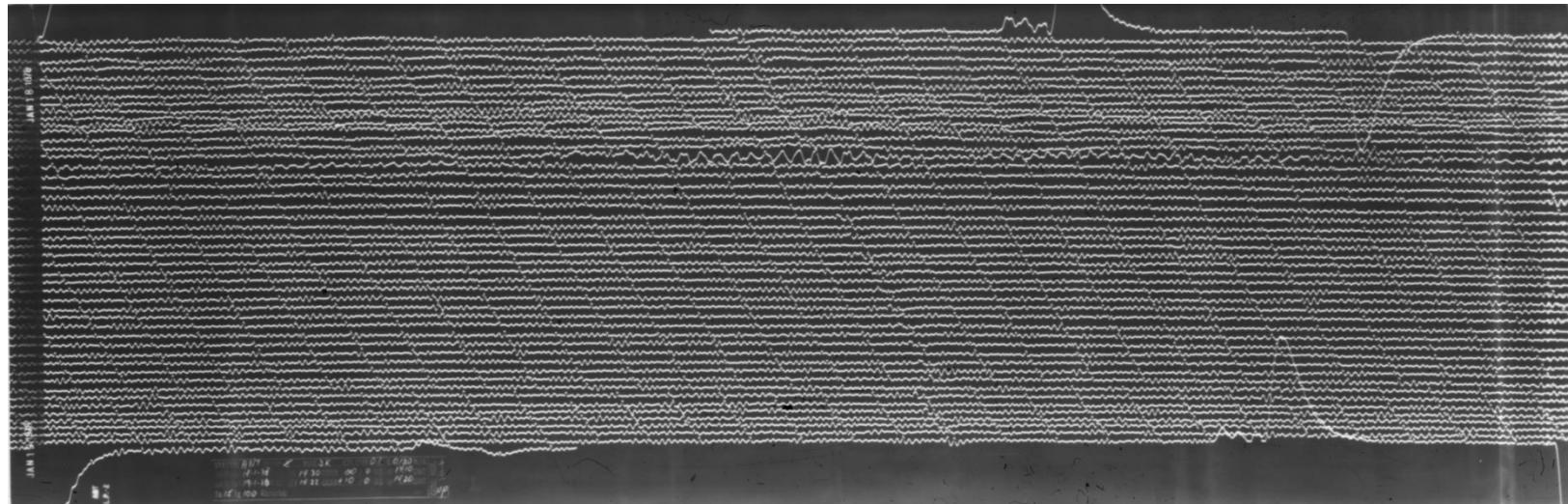
- Usually in a fairly uniform “lattice”
- Original thoughts were to model the lattice and extrapolate where unknown timing marks were based off of Known timing marks
- Then Shift the lattice down into rightful position



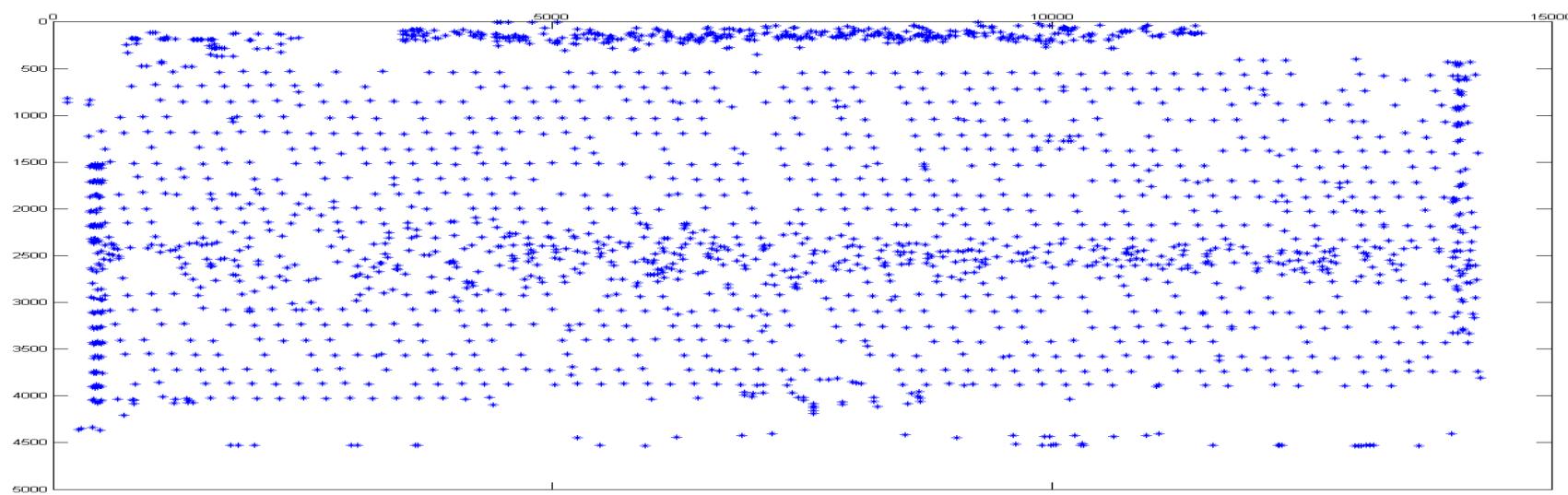
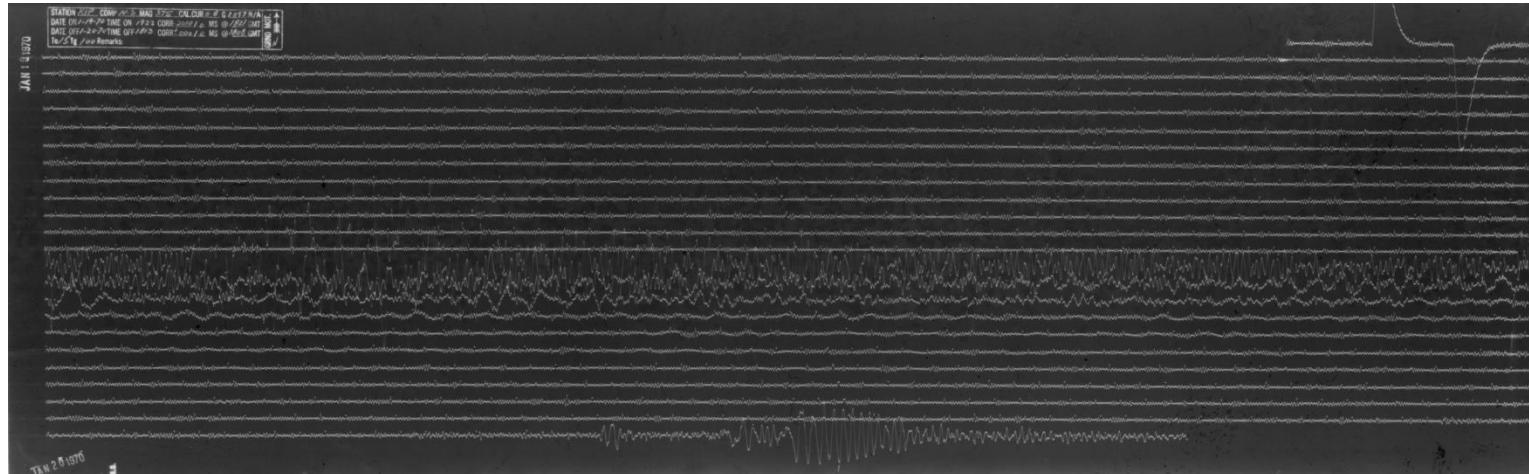
Timing Mark Detection Algorithm

1. Cropping of the unimportant information (at this point in time) [\[4\]](#)
2. Bilateral filtering to reduce noise in the signal and bring out trace edges. (Worked better for noise reduction than detail enhancement) [\[1\]](#) [\[2\]](#)
3. Local binary conversion using block processing with Otsu's method. (Local adaptive methods work better than global) [\[3\]](#) [\[5\]](#)
4. Obtain binary clusters/connected components [\[6\]](#)
5. Using current threshold of [50, 150] pixels gets a “good” amount of timing marks in each image.
6. Find centroids of timing mark binary blotches

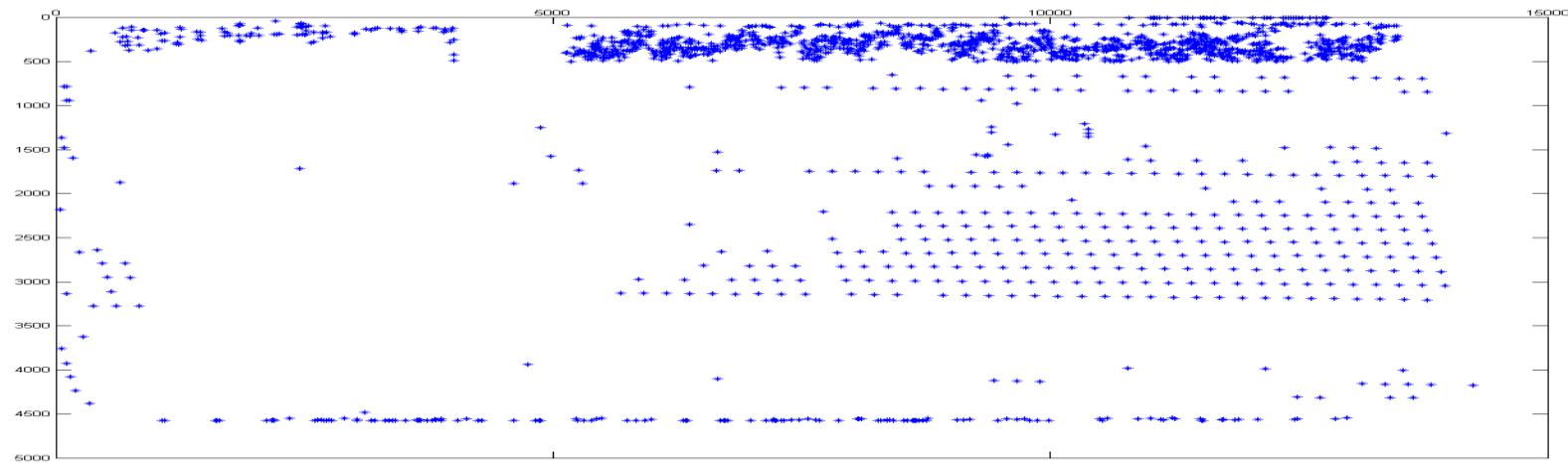
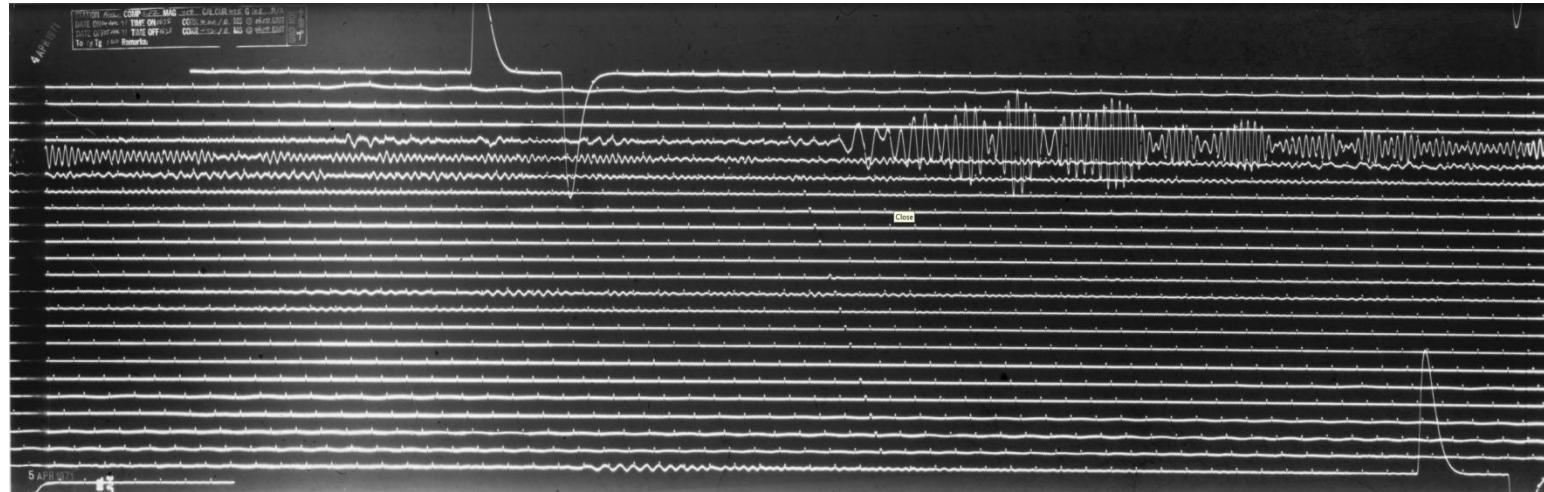
Results 1 of 7



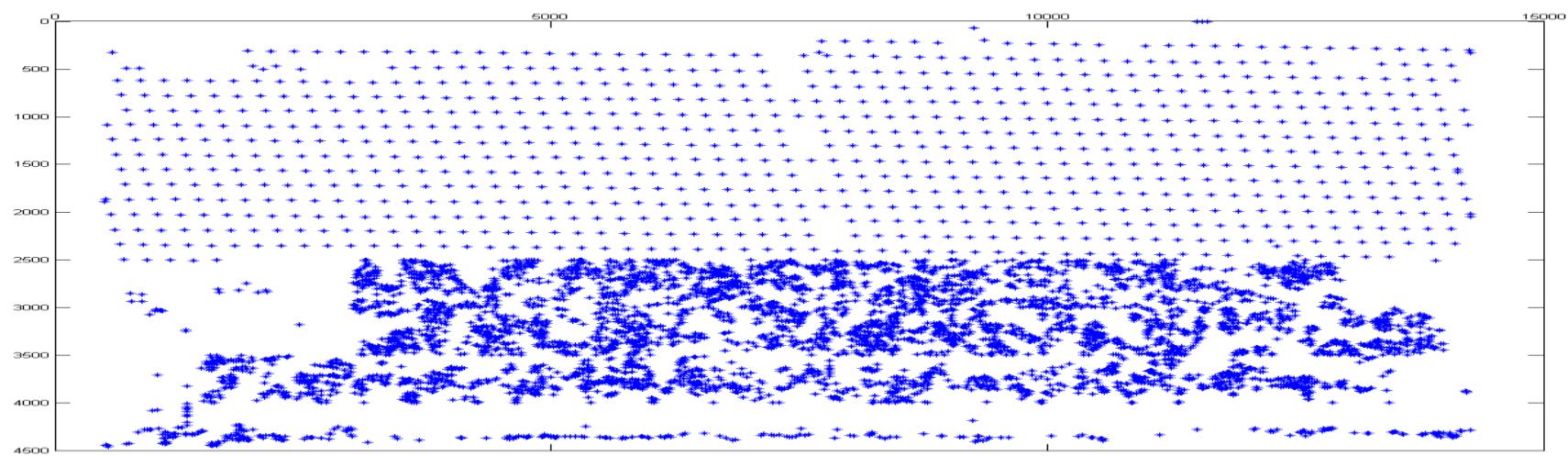
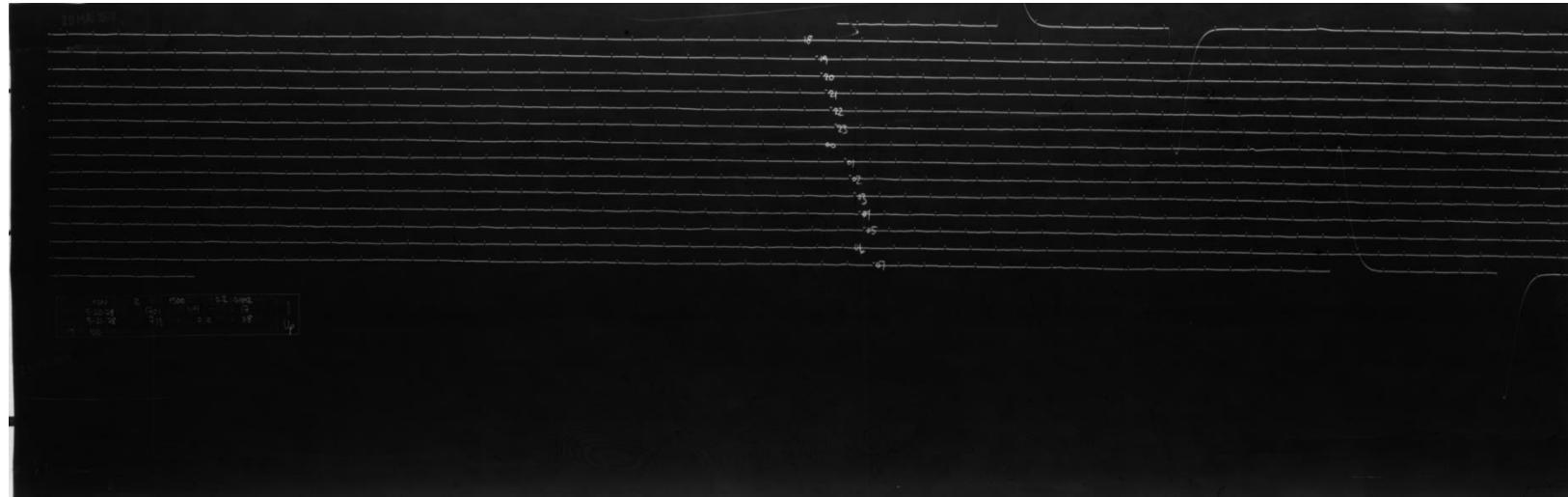
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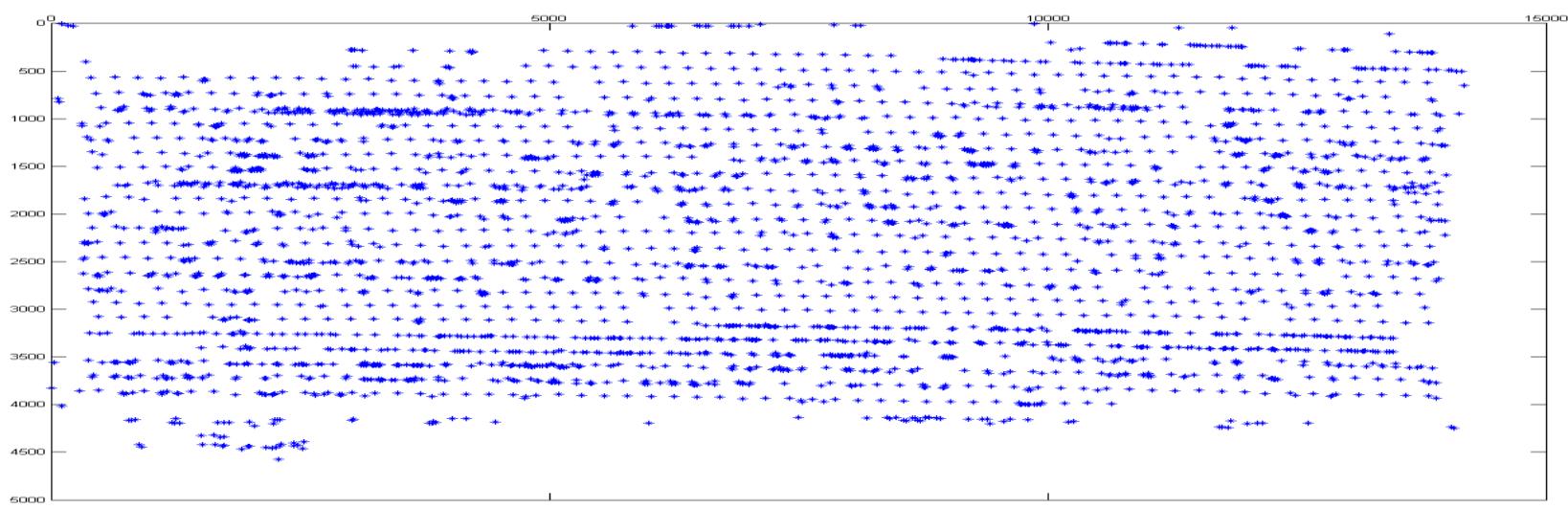
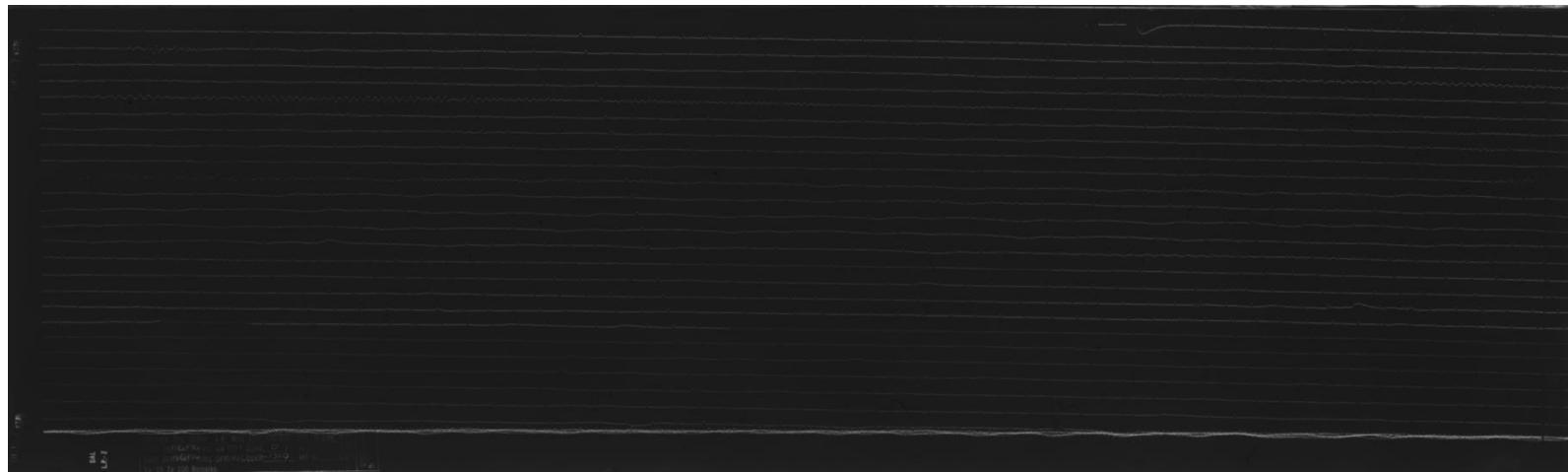
Results 3 of 7



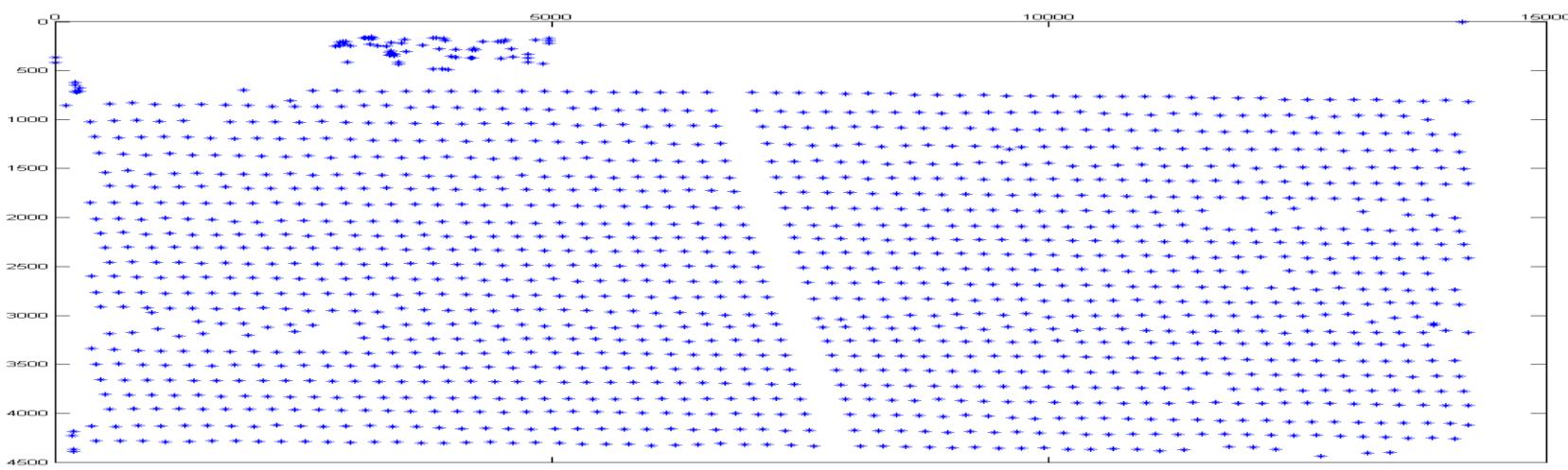
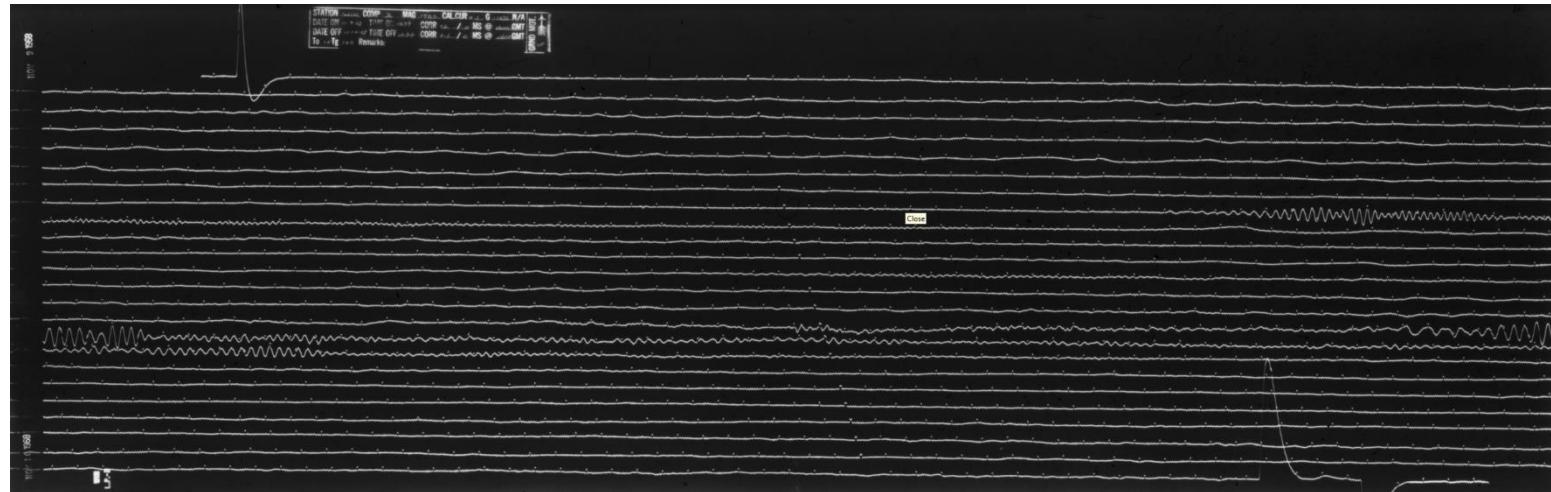
Results 4 of 7



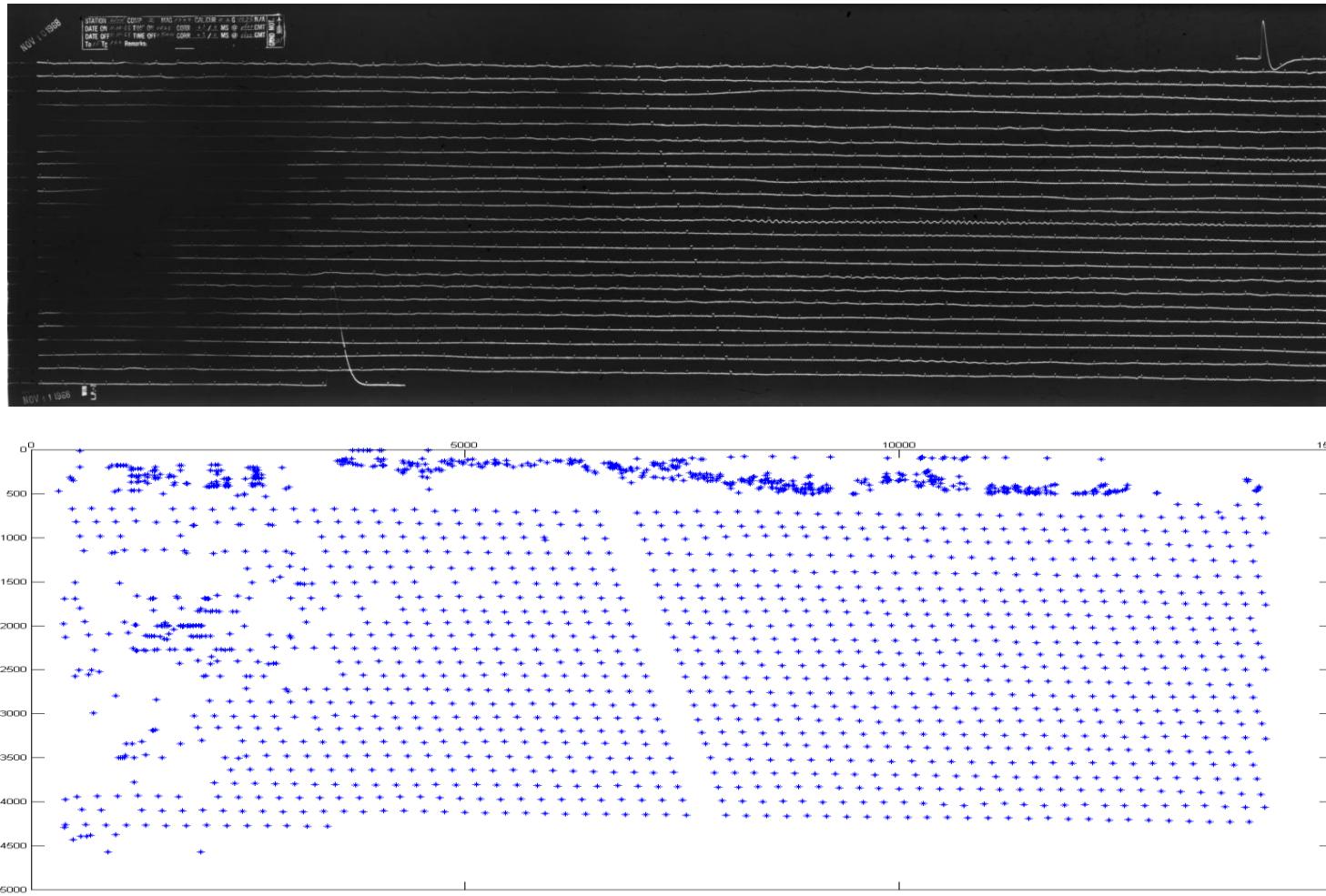
Results 5 of 7



Results 6 of 7



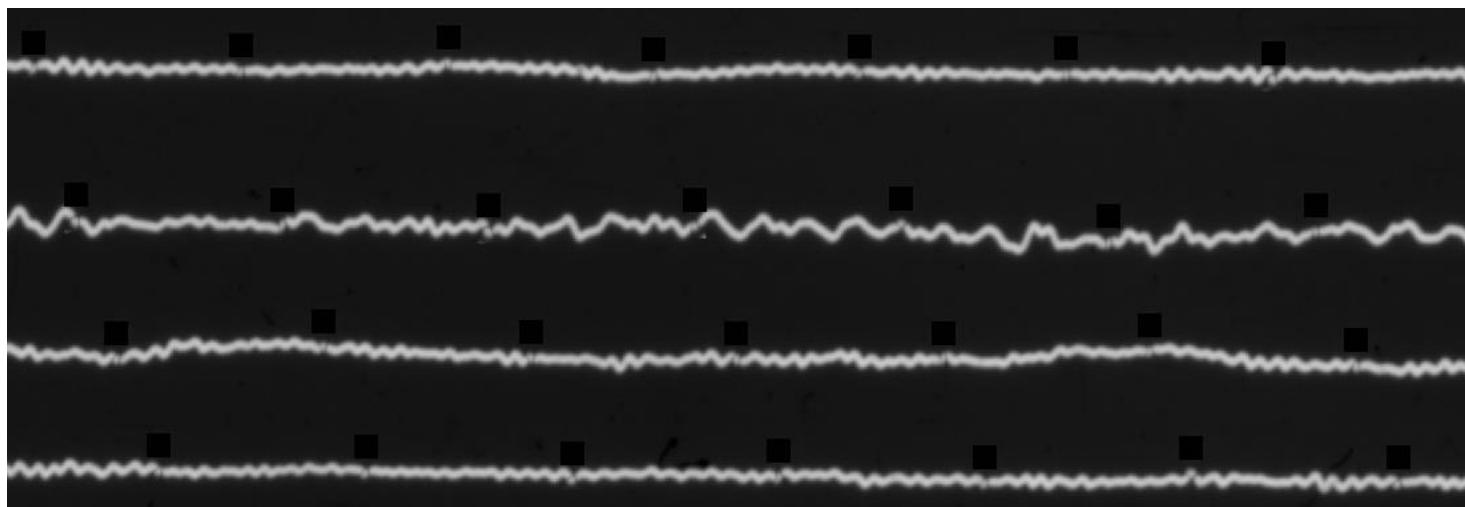
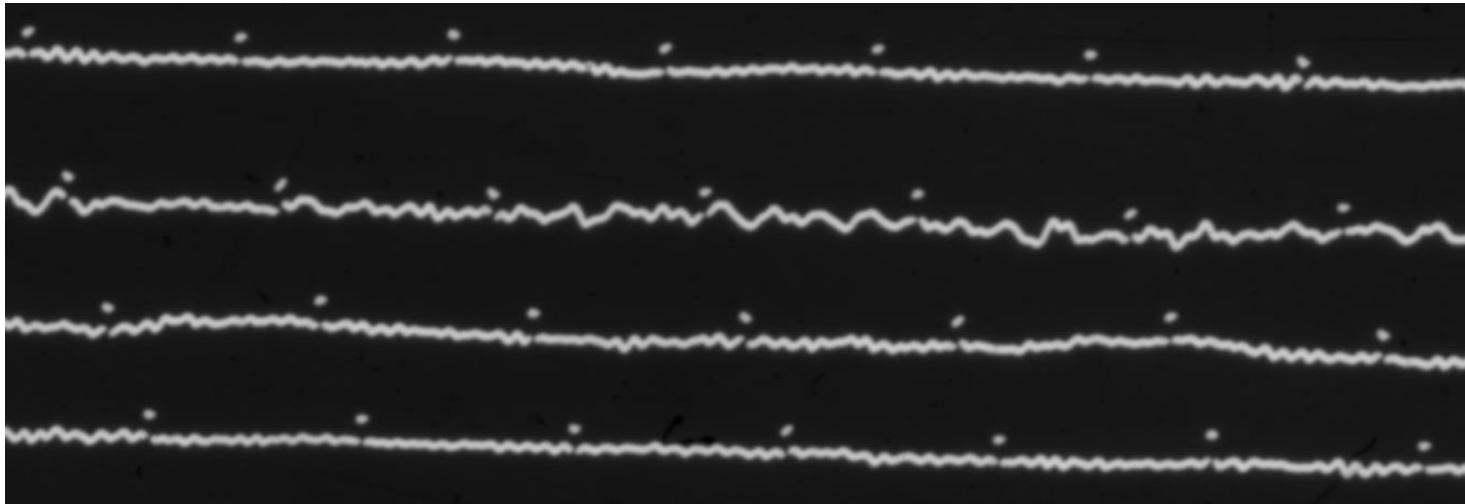
Results 7 of 7



“Chip” and Translate Method

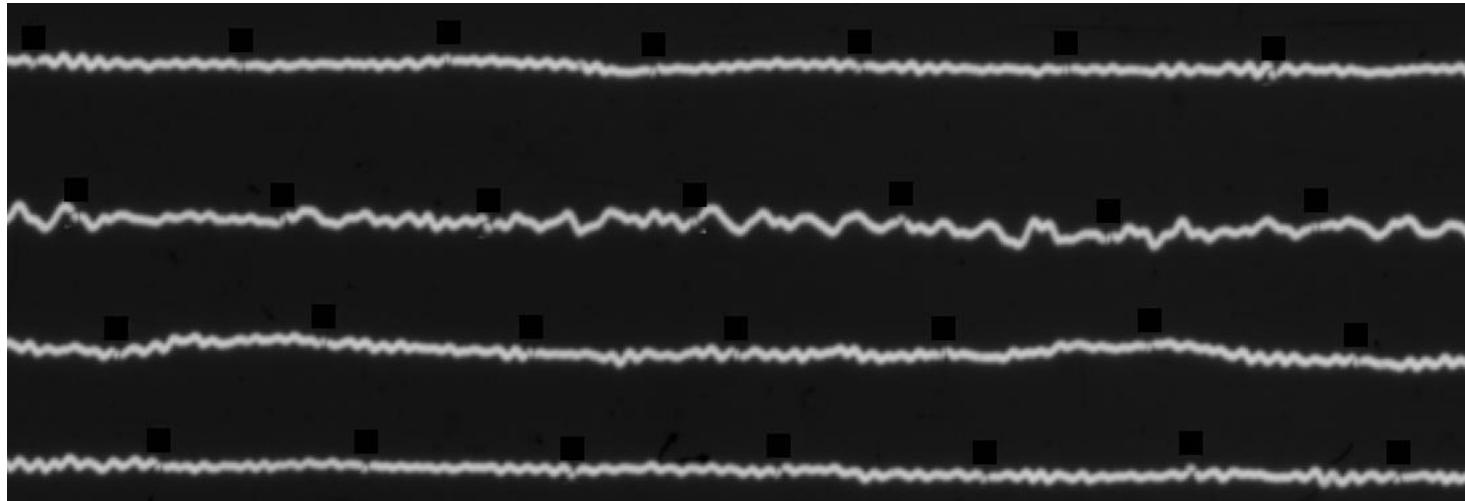
- “Chip” out the detected timing marks and translate the chip by an offset
- Offset is currently -35 pixels vertically
- For fused image, take maximum between chip and original signal being overlayed

“Chip” and Translate Results



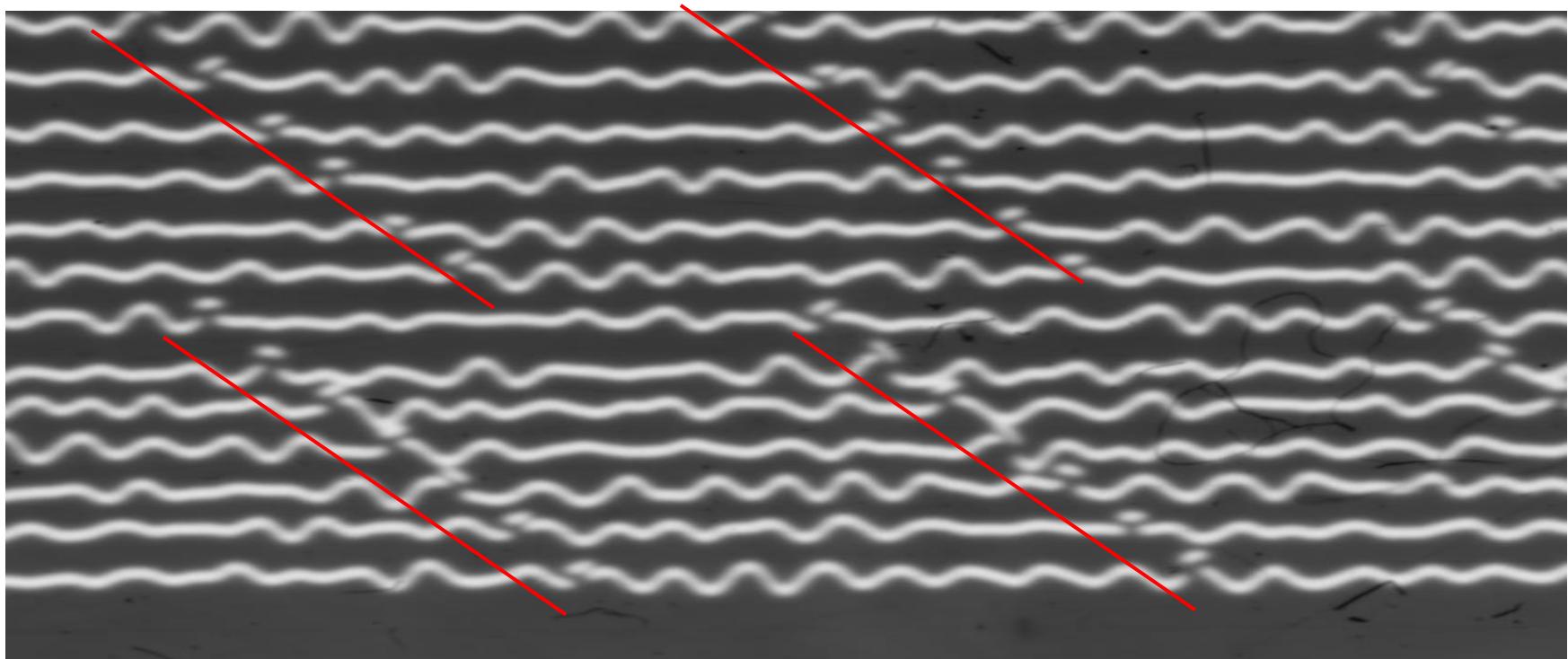
“Chip” and Translate Results

- Works well where timing mark detection works well.
- Mixes well with original signal.
- ****Idea**** dilate and erode to find areas where signals are missing, then do an adaptive local translation per each timing mark for better results.



Current Issue with “Lattice” translation method

- Offset lattices ([Image 1](#))



Current Problems with “Lattice” translation method

- As activity increases, timing offset gets thrown forward or backward in time. ([Image 3](#)) [ratio between activity and timing mark time offset]
- Negative slope = negative in time
- Positive slope = positive in time



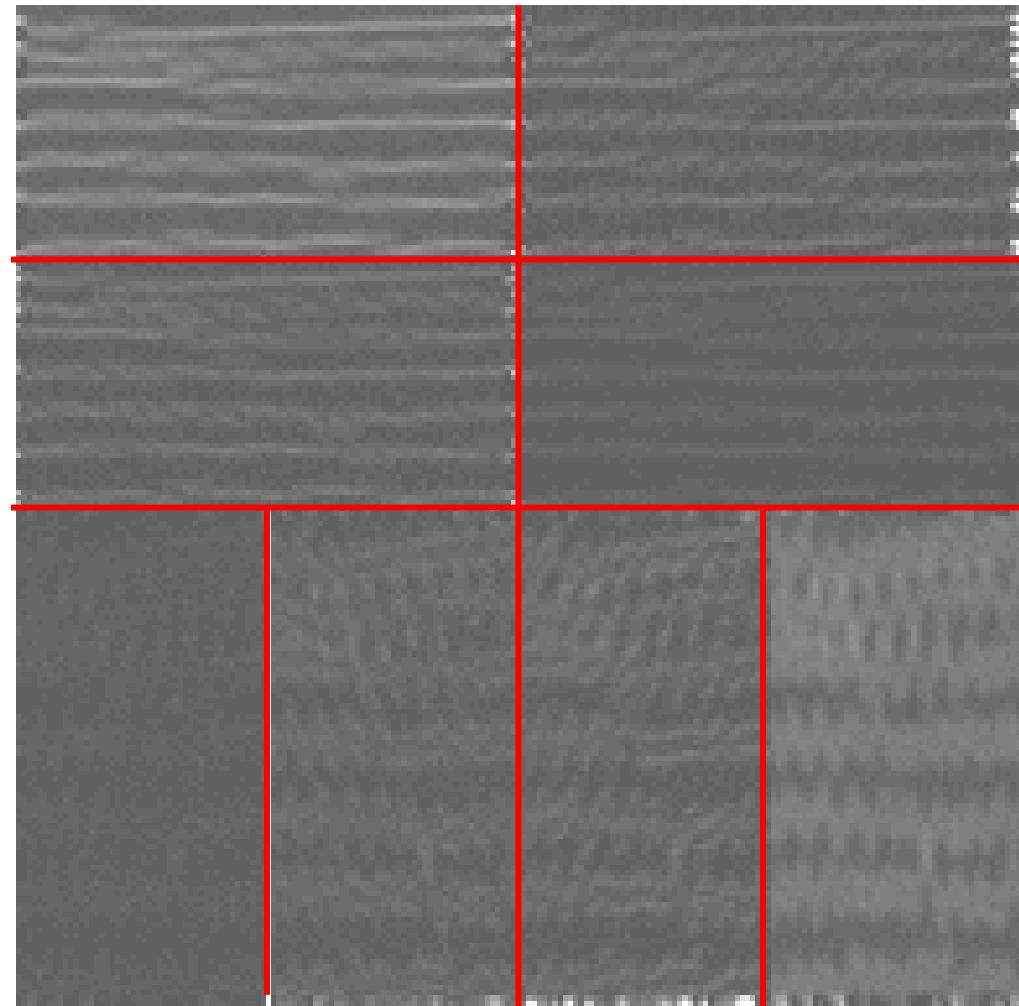
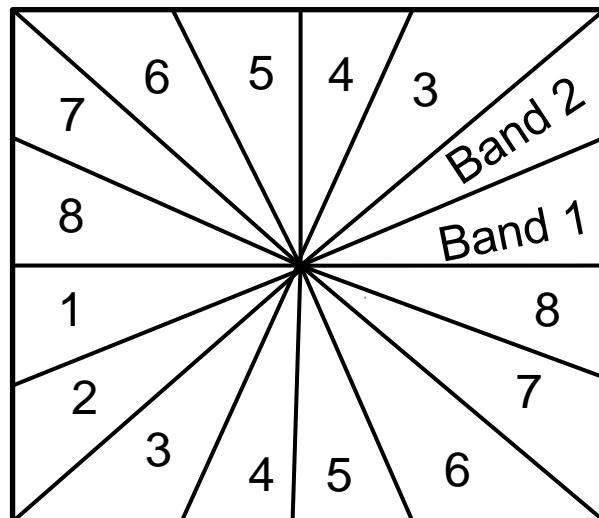
Trace Enhancement with Contourlets



- Contourlet transform is a directional Multiresolution Image Representation [\[9\]](#) [\[10\]](#) [\[11\]](#) [\[13\]](#)
- Takes original Image and breaks up into 2^n directional sub bands
- Noise level drops in sub bands by a factor of 2^n

Contourlet Decomposition

- Bands in frequency domain relate to linear oriented features in spacial domain by 90°



Problems with Countourlet Transform

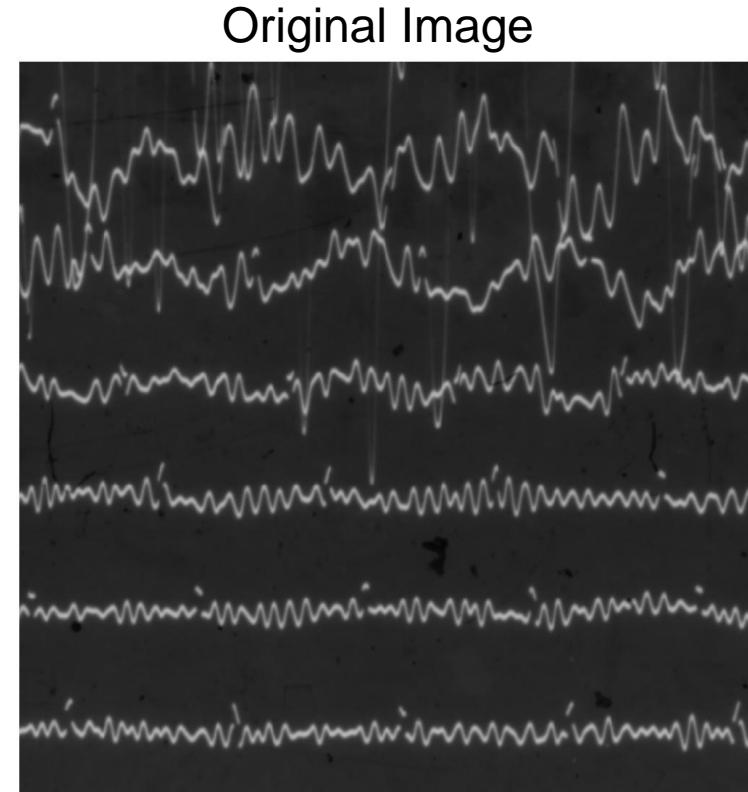
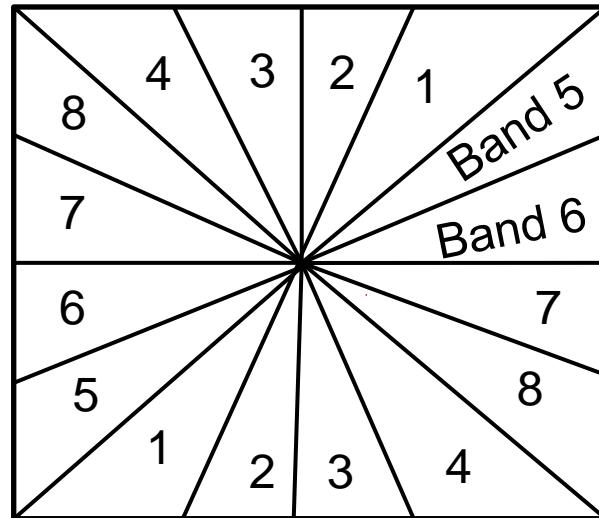


- Aliasing effects in the directional sub bands.
- Decreased resolution due to down sampling and decimation
- Non-uniform resolution across sub band images
- But...

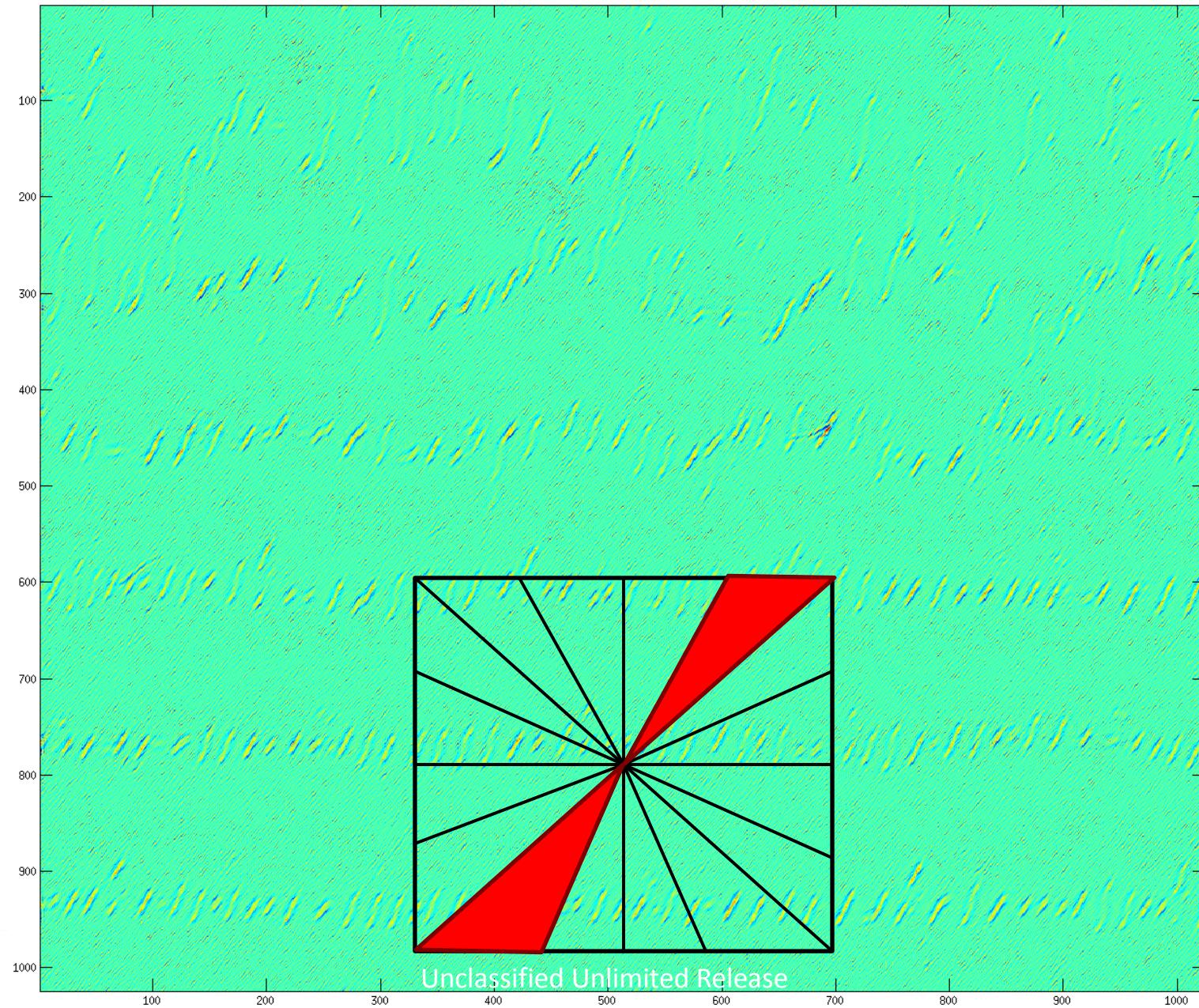
Non-Subsampled Contourlet

Decomposition

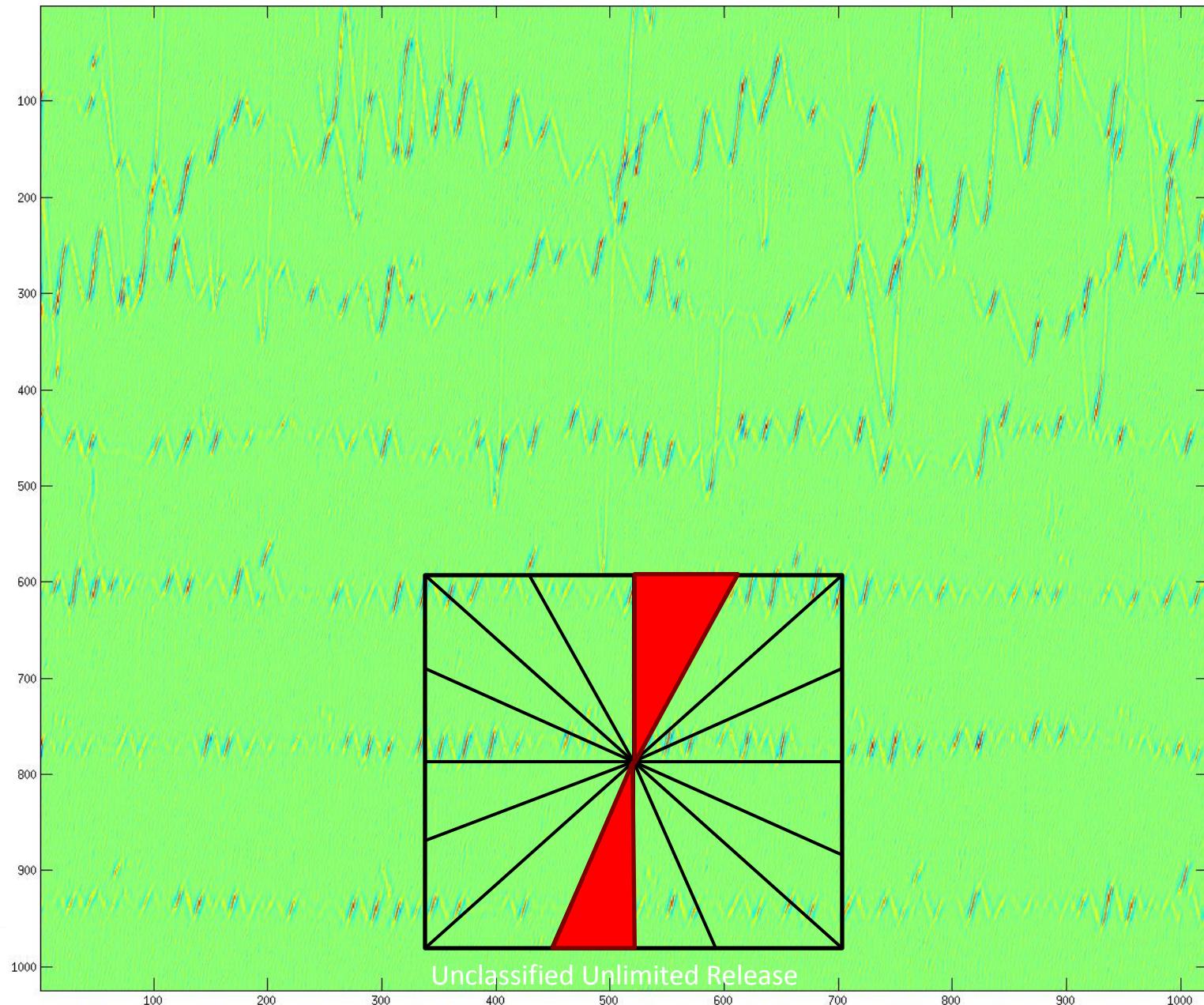
- No aliasing, sub bands are full resolution. [\[12\]](#) [\[14\]](#)



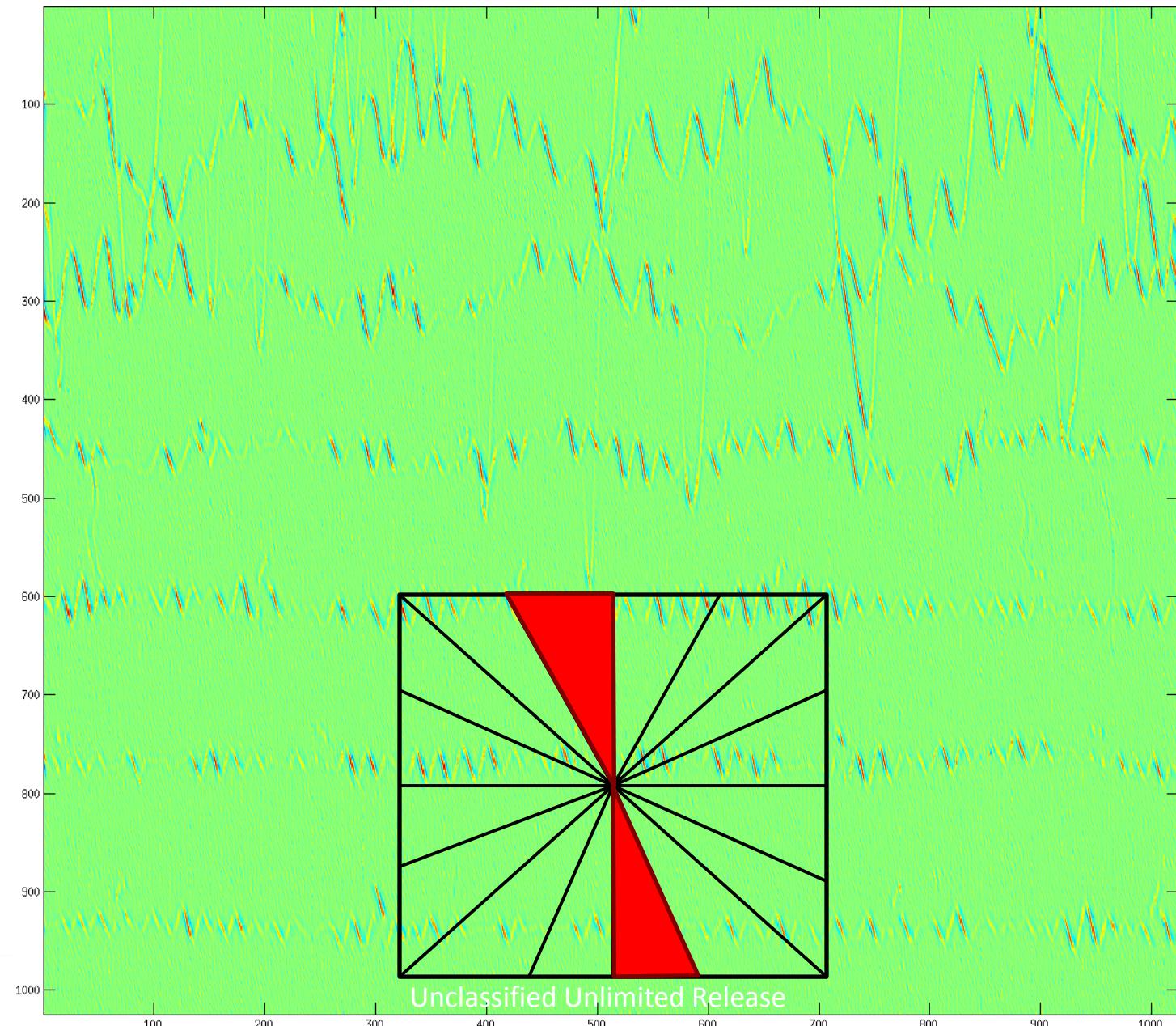
Sub Band 1



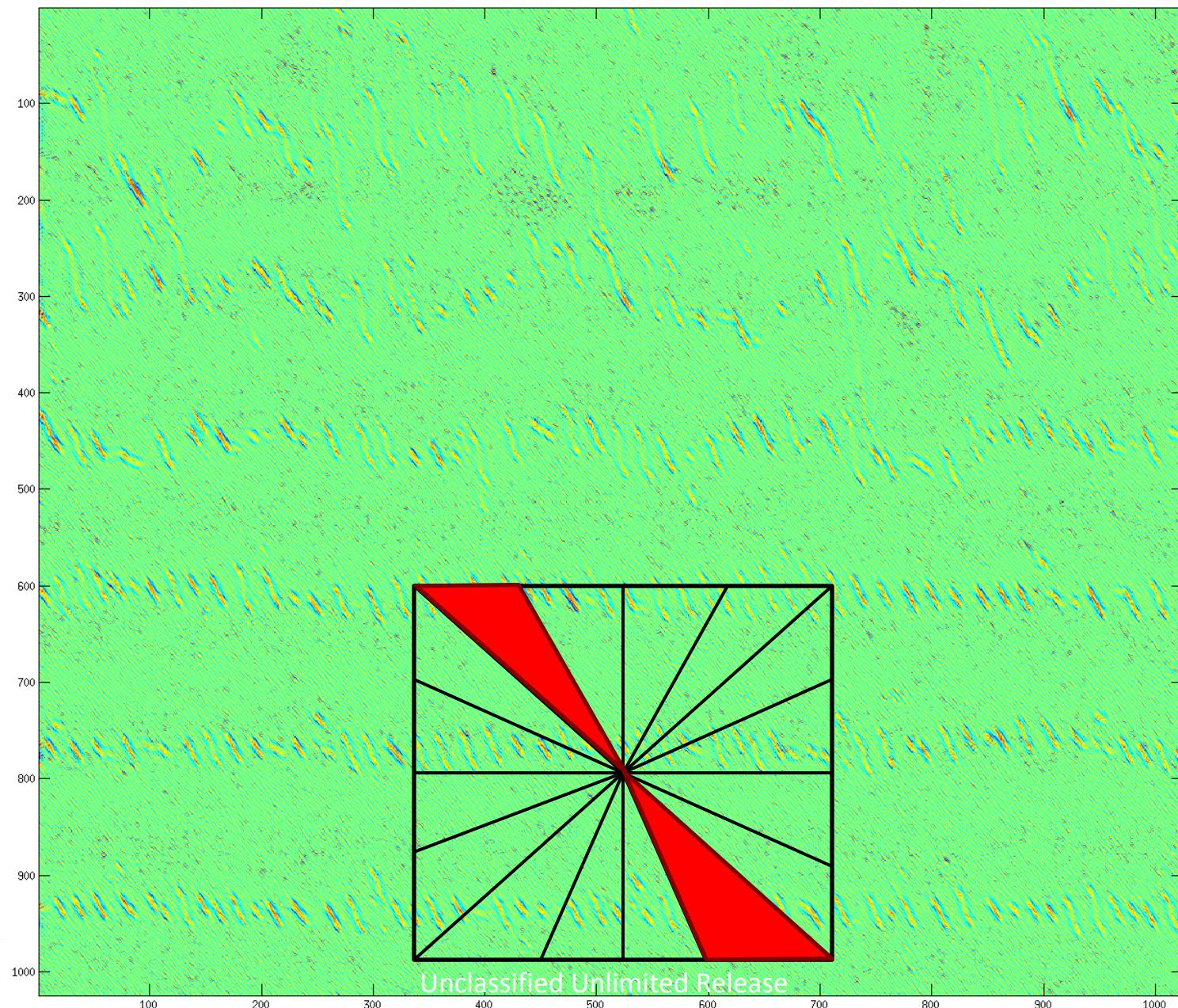
Sub Band 2



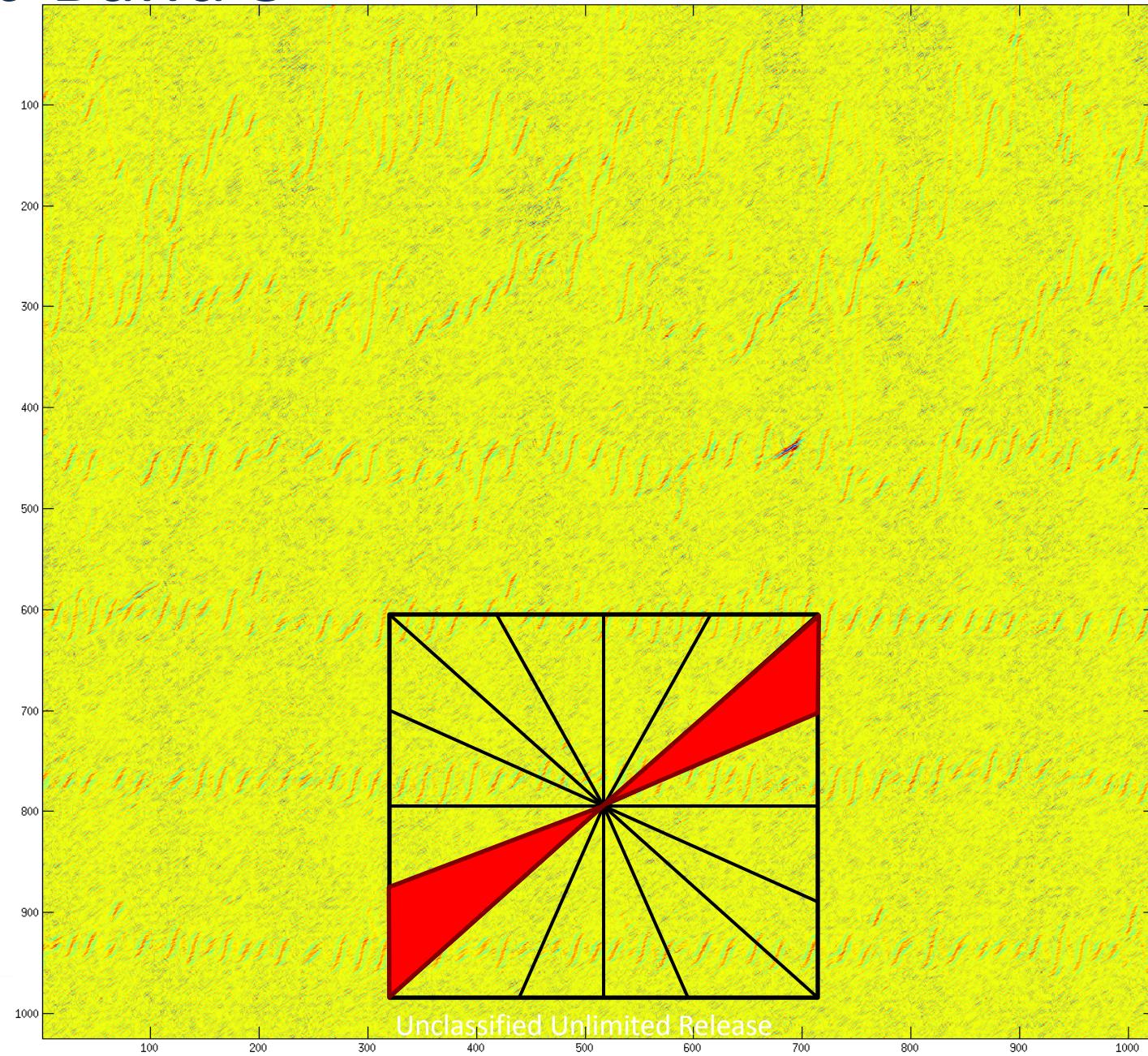
Sub Band 3



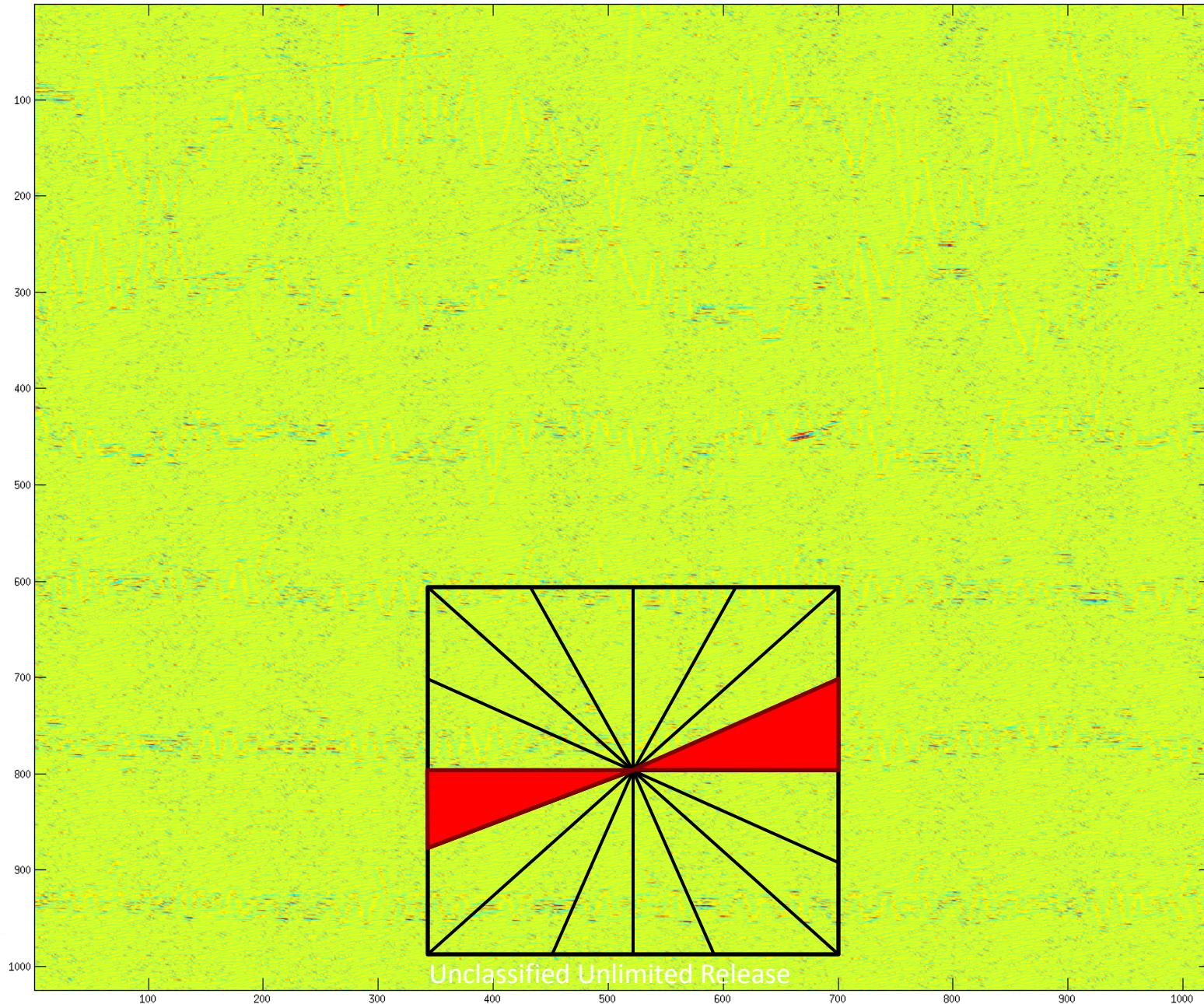
Sub Band 4



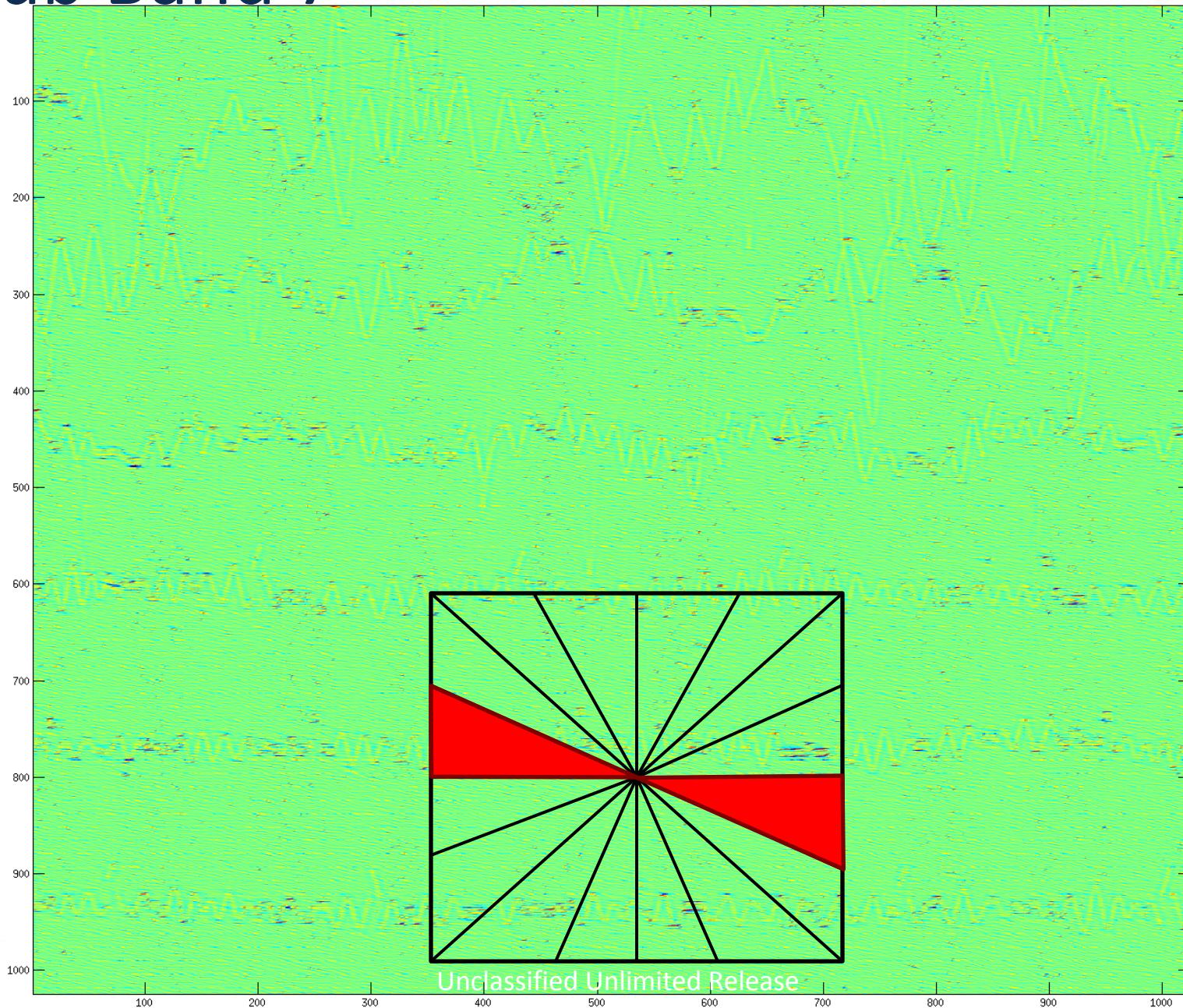
Sub Band 5



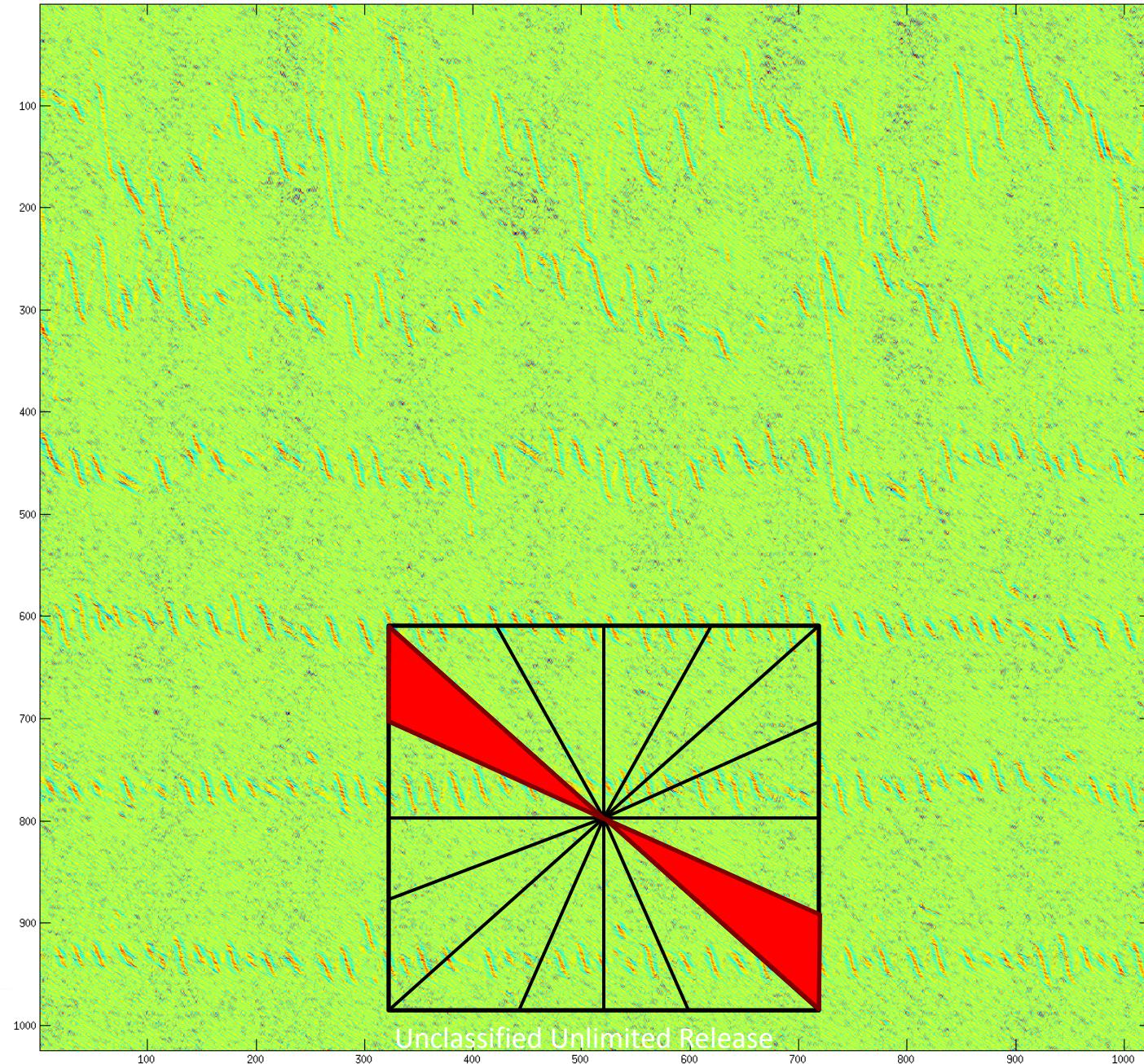
Sub Band 6



Sub Band 7



Sub Band 8

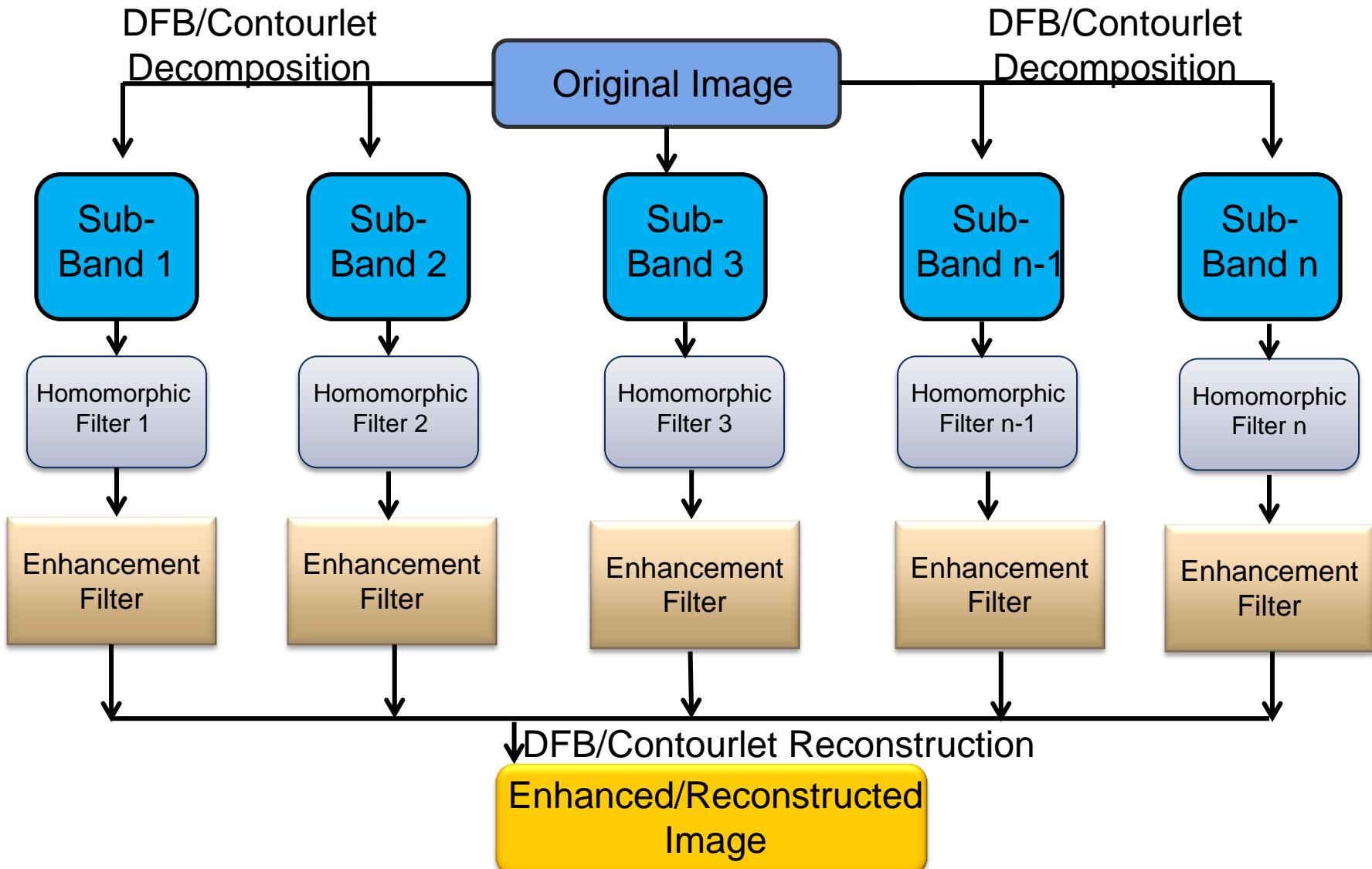


Hessian Matrix/DFB Trace Enhancement



- Inspired by vessel and fingerprint image enhancement methods. [\[15\]](#) [\[16\]](#) [\[17\]](#) [\[18\]](#)
- 1. Directional decomposition of Image with Directional Filter Banks (DFB)
- 2. Homomorphic filtering
- 3. Rotated Hessian Eigenvalue Analysis across multiple sized Gaussian modeled traces
- 4. Trace detection
- 5. Enhanced directional Images
- 6. Image reconstruction

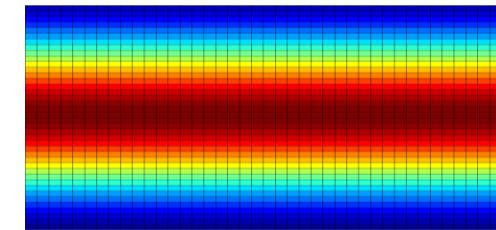
Hessian Matrix/ DFB Trace Enhancement



Enhancement Filter [18]

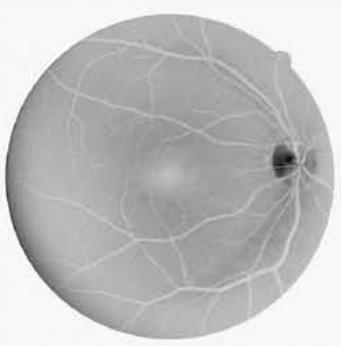
Enhancement
Filter

1. Calculate Rotated Hessian Matrix $H(Ii_{(x,y)}, \sigma_j, \theta_i) = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$ for directional sub-band Image at each pixel. (Optimized noise sensitivity)
2. Model a Trace as a Gaussian with σ_j
3. When $R = \left| \frac{h_{11}}{h_{22}} \right| \ll 1 \quad \& \quad h_{22} < 0$ a trace is declared
4. Weighting equation is applied for pixels considered inside of trace.
5. Repeat multi-scale convolution for different scales σ in Range S
6. Enhanced sub-band Image is the max of all calculated scales σ



Comparison of approaches [18]

Original images



(a)

Frangi results



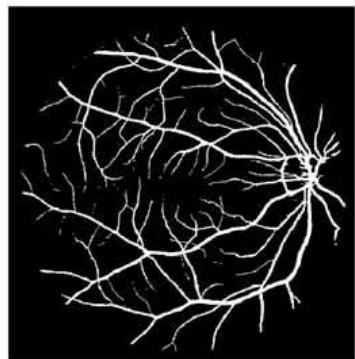
(b) AUC=0.944

Shikata results



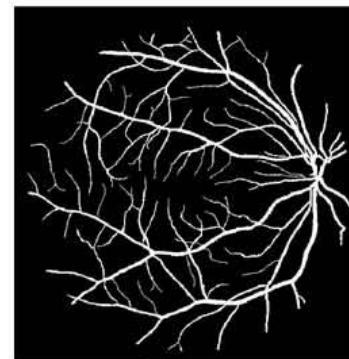
(c) AUC=0.938

DFB-based results



(d) AUC=0.958

Ground truths



(e)



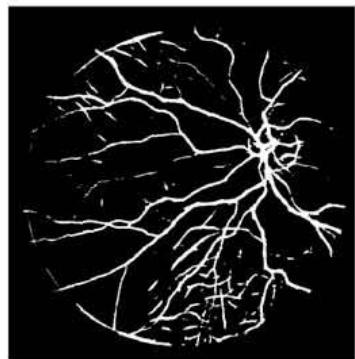
(f)



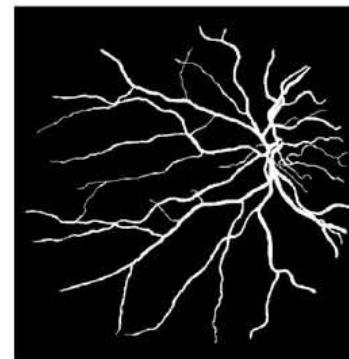
(g) AUC=0.867



(h) AUC=0.858



(i) AUC=0.923



(j)

Advantages of Hessian/DFB Method



- Enhanced thin and weak traces.
- Ability to differentiate between noise and signal
- Iterative Tree Structure
- Accounts for different thickness/contrast signals

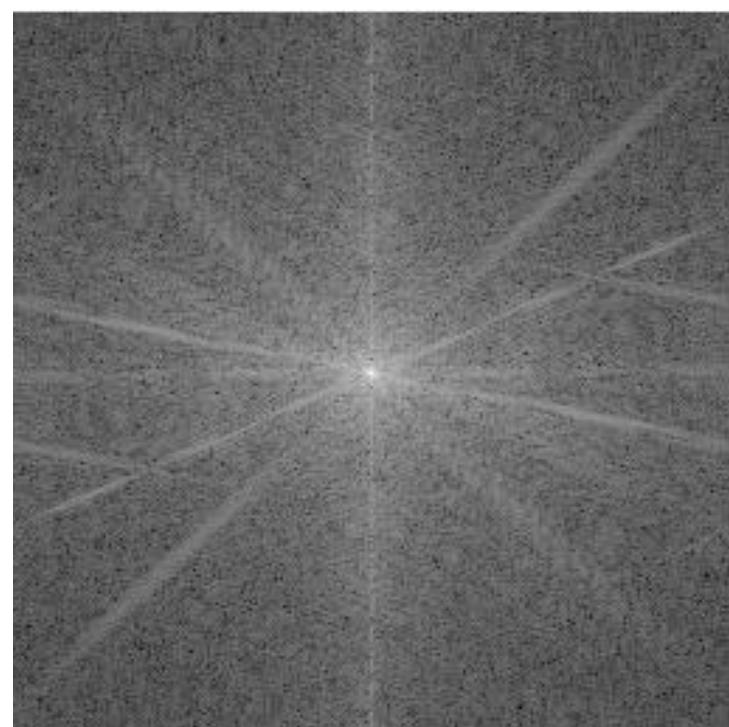
Current pushing Issues I am working on {6/16/14}

- Want a way to statistically calculate most uniform detected timing marks to use as a basis to interpolate/extrapolate.
- Looking at turning images on their side by the angle against the Y-Axis and the “slice” that majority of timing marks match up with
- Chipping out and moving select rows of timing marks (completed 6/18)
- Direction bank filters to pull out faint directional features. Countourlets{6/29}

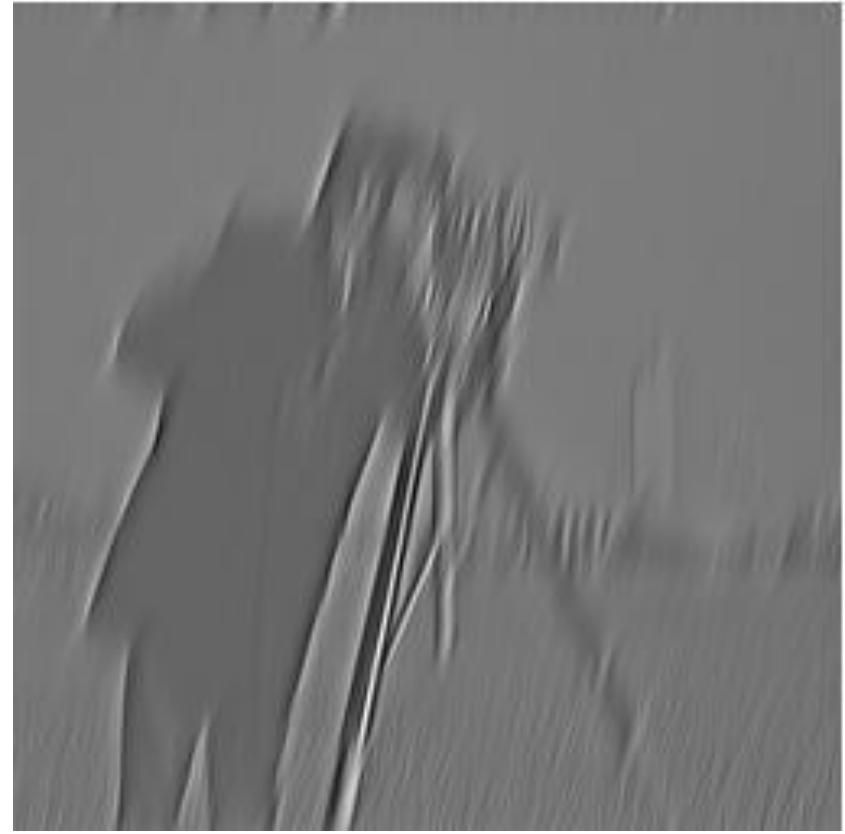
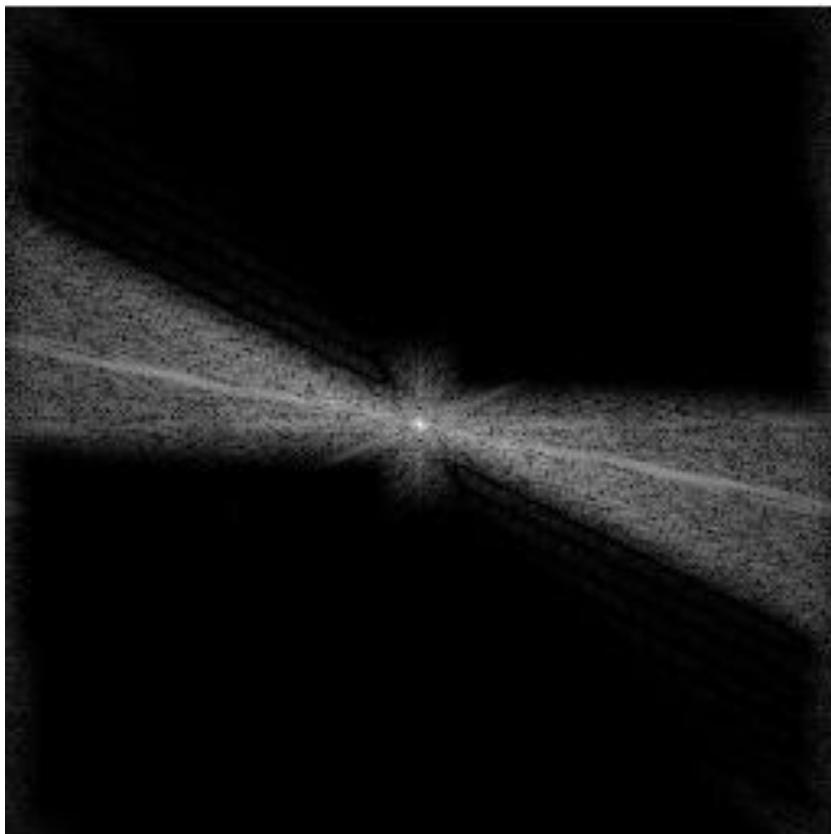
Other Approaches taken

- Local Adaptive Histogram Equalization [\[7\]](#) [\[8\]](#)
- Evens out contrast well, sacrifices valuable data though.
 - Need to specify target histogram distribution. (not currently pursuing)
- Bilateral filtering takes out noise well, but does not exploit features as well as it claims. [\[1\]](#) [\[2\]](#)
 - Standard methods do not work well with thin traces
 - Possible customization of filter to use trace distribution for region differentiation

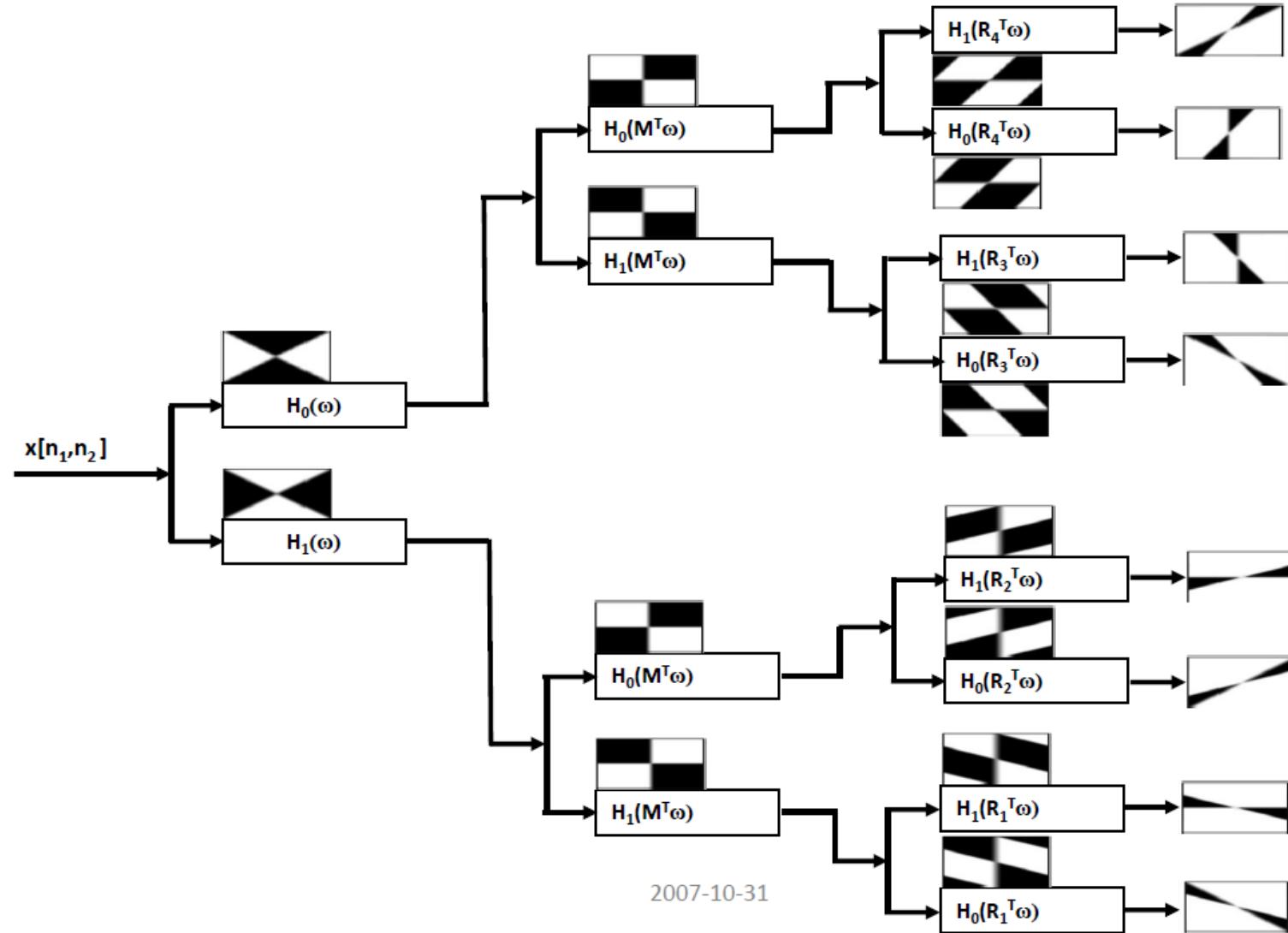
DFB Background [19]



DFB Background [19]



DFB Structure [19]



Cropping of Images (Extra)

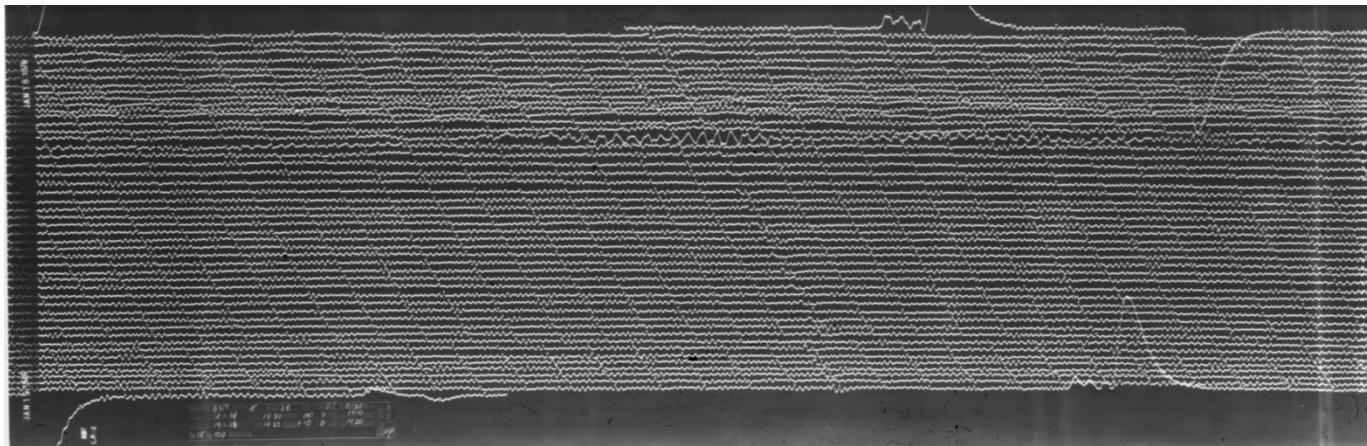
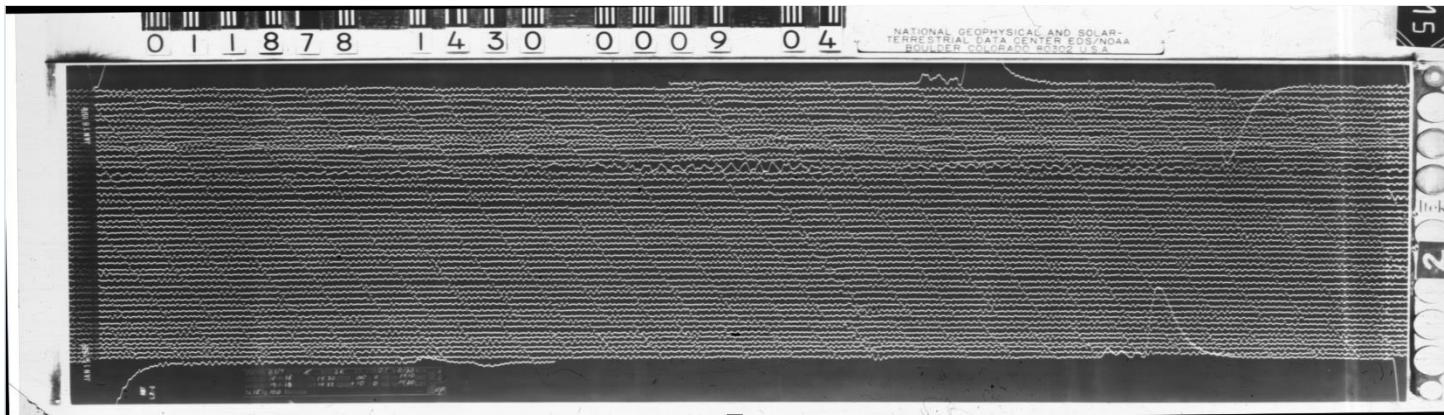


Image references

- Image 1 – 011878_1430_0009_04.png
- Image 2 – 011970_1922_0053_05.png
- Image 3 - 040471_0638_0023_04.png
- Image 4 - 052078_1701_0055_04.png
- Image 5 - 101776_2121_0032_04.png
- Image 6 - 110968_0639_0124_04.png
- Image 7 - 111068_0628_0124_04.png