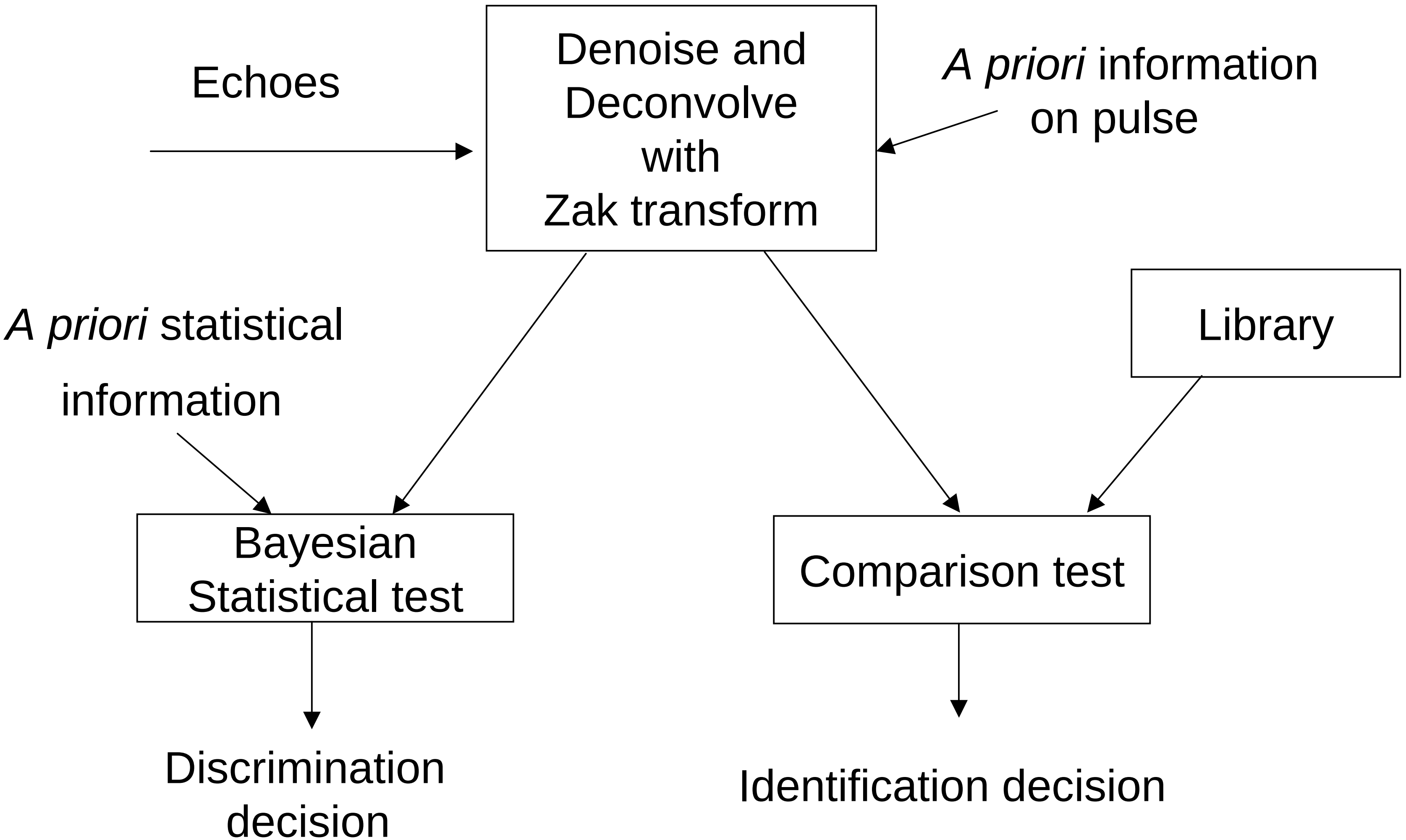
OUTLINE

1. Process Approach
2. Technology Background
3. Deconvolution
4. Algorithm
5. Synthetic Aperture Sonar
6. SBIR Program Steps through the APB Process

THE MISAS APPROACH IS TO

- ✓ Exploit the ability of the ZAK transform to highly resolve an echo in time
- ✓ Use this capability to deconvolve an acoustic echo
- ✓ Increase observability with SAS

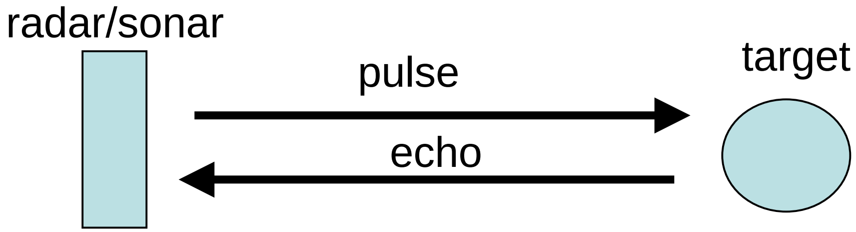
MISAS Subsystem Process Diagram



TECHNOLOGY BACKGROUND

Reflectivity Kernel Estimation

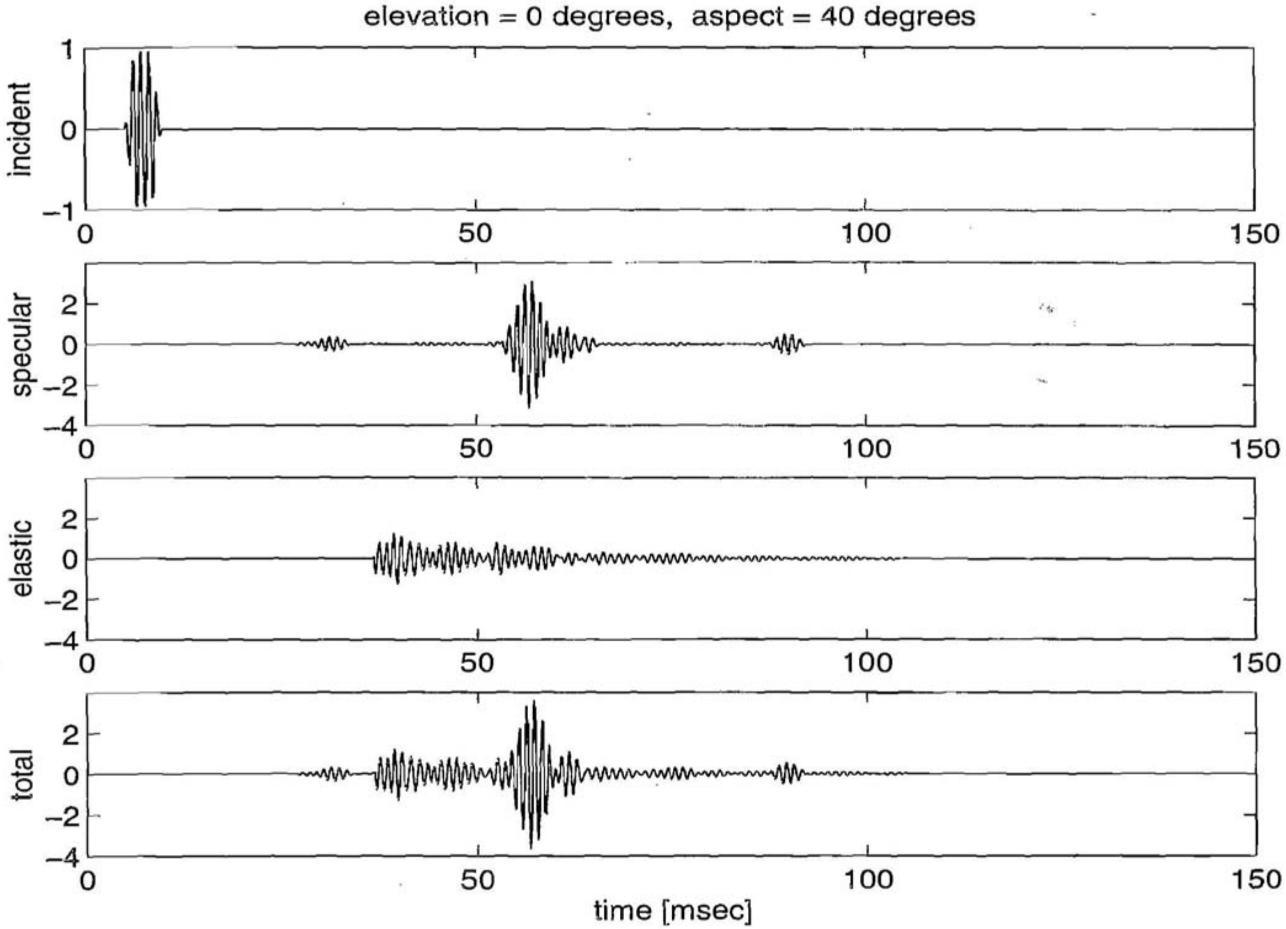
Material properties of target summarized in reflectivity kernel R(t)



echo = convolution of pulse and R + noise

Goal: Recover material information from noisy echo through deconvolution

Echo response for a 1.0kHz 5.0msec CW pulse



Incident Pulse

Reflected Part of Echo

Reradiated Part of Echo

Total Echo

Courtesy of Naval Undersea Warfare Center – Division, Newport, Code 8133 (15 November 2007)

DECONVOLUTION

Deconvolution

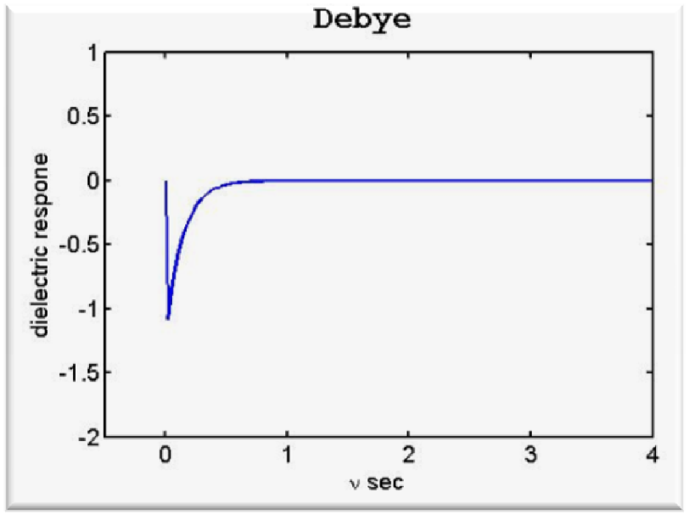
Given the input or “probe” signal, find the Kernel, K, from the received or scattered signal. K characterizes the material

This is an inverse problem. The associated forward problem is: Given K and an input signal s, find the scattered or output signal

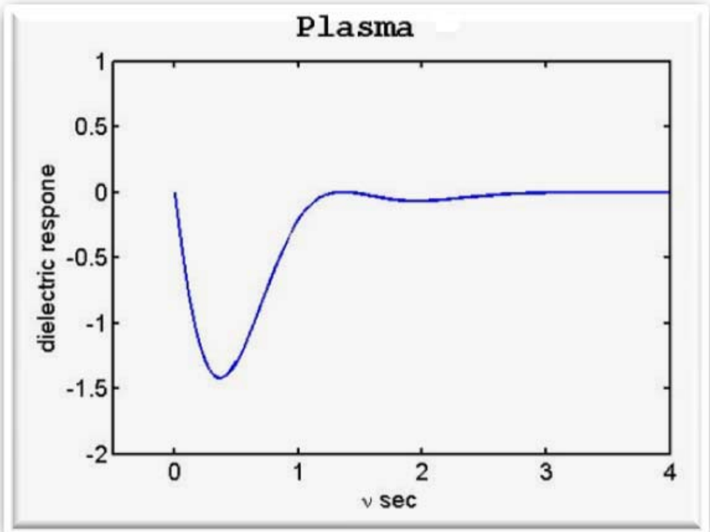
$$f(t) = \int K(t,t')s(t')dx' + noise$$

Output Kernel Input

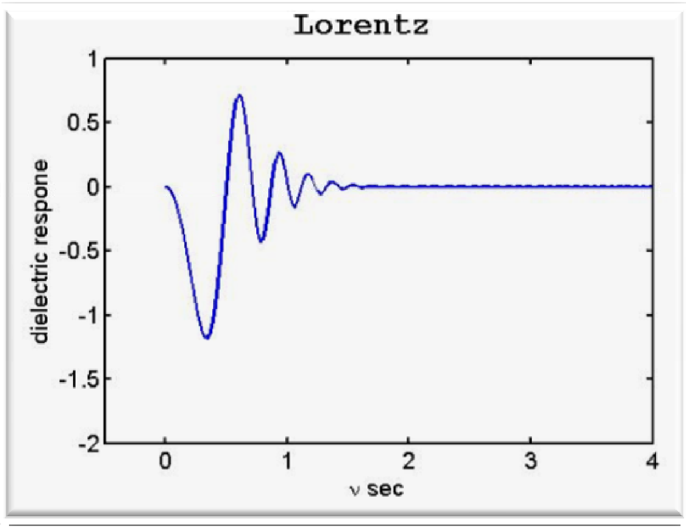
Examples of Reflectivity Kernels



- Water
- Biological tissue
- Radar-absorbing urethane foam



- Atmospheric interference



- Heavy metals
- Composite materials

ALGORITHM

Based on the Zak Transform

Fourier Transform

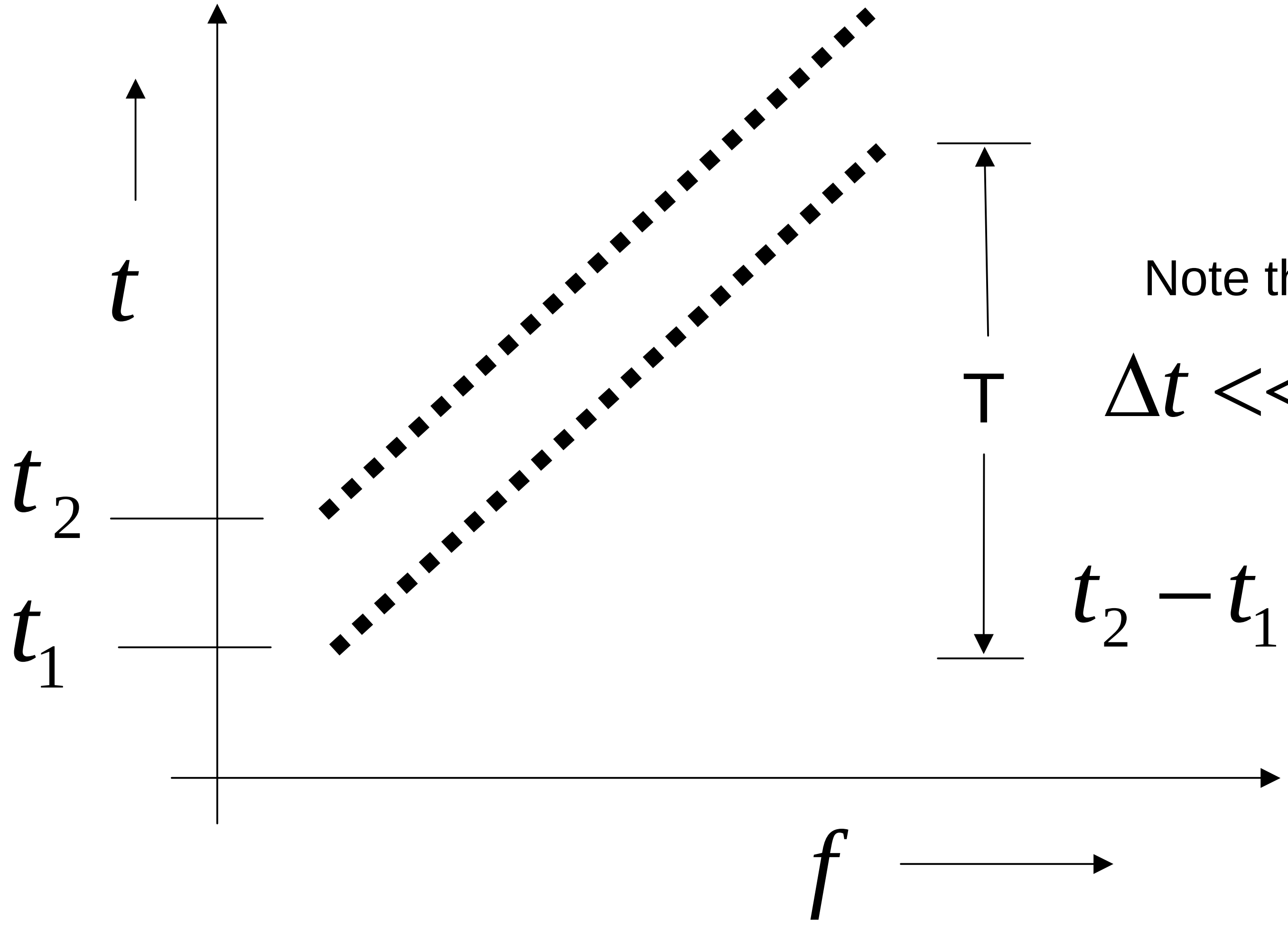
$$f_n = \sum_{k=-\infty}^{+\infty} s(k) e^{-i2\pi \frac{nk}{N}}$$

Zak Transform

$$Z(t_m, f_n) = \sum_{k=-\infty}^{+\infty} s(t_m + k) e^{-i2\pi k f_n}$$

The Zak transform is a time-frequency representation. It is more general than the Fourier transform In that it allows a great deal of flexibility in sampling

Zak time-frequency map
for 2 chirps at critical sampling



Note that

$$\Delta t << T$$

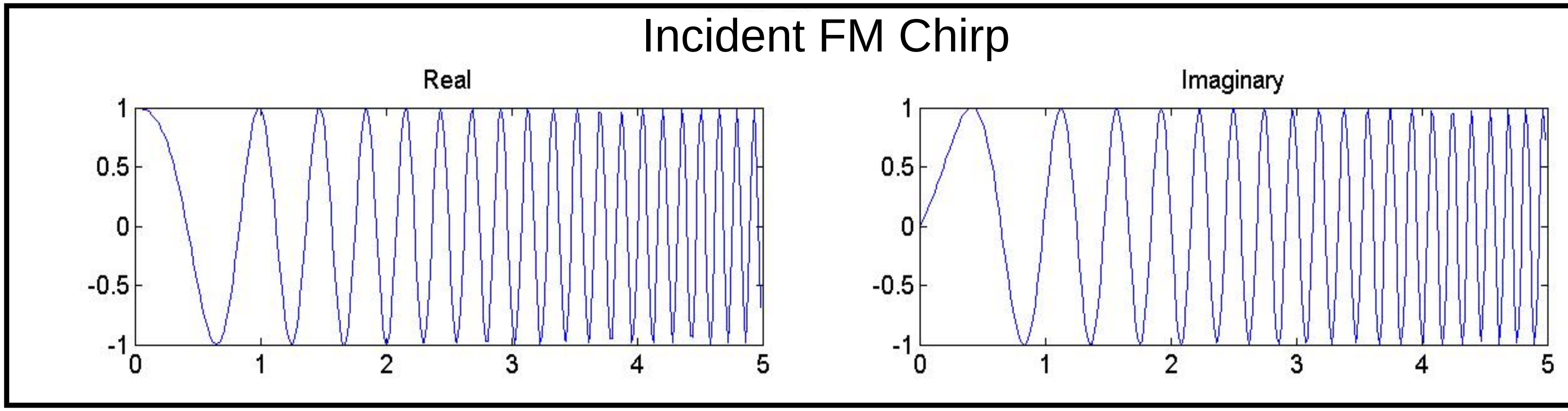
$$t_2 - t_1 = \Delta t$$

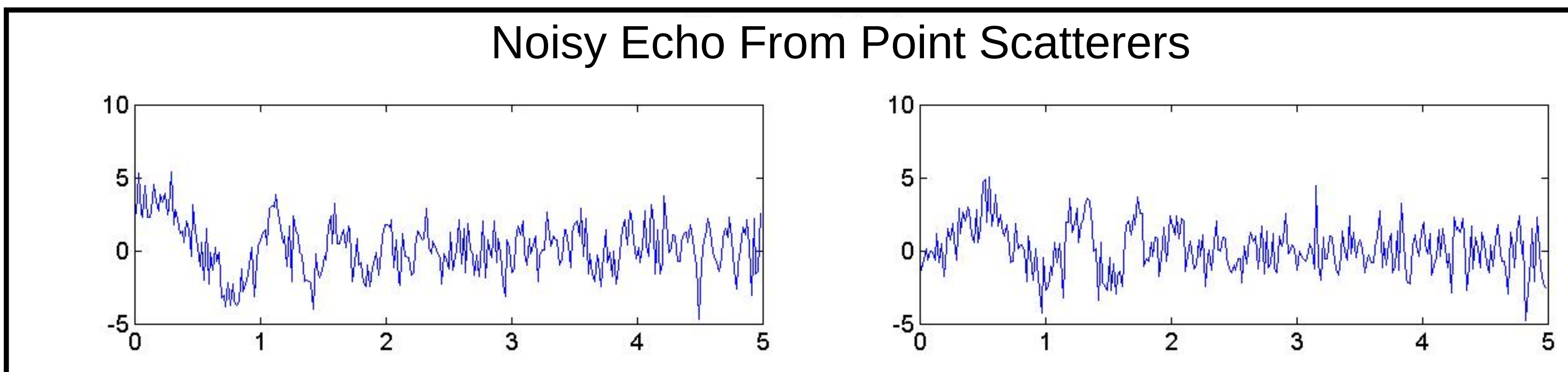
Example For a Multi-Point Scatterer

We consider a multi-point scatterer and a linear frequency modulated (LFM) signal, or "chirp" as the probe.

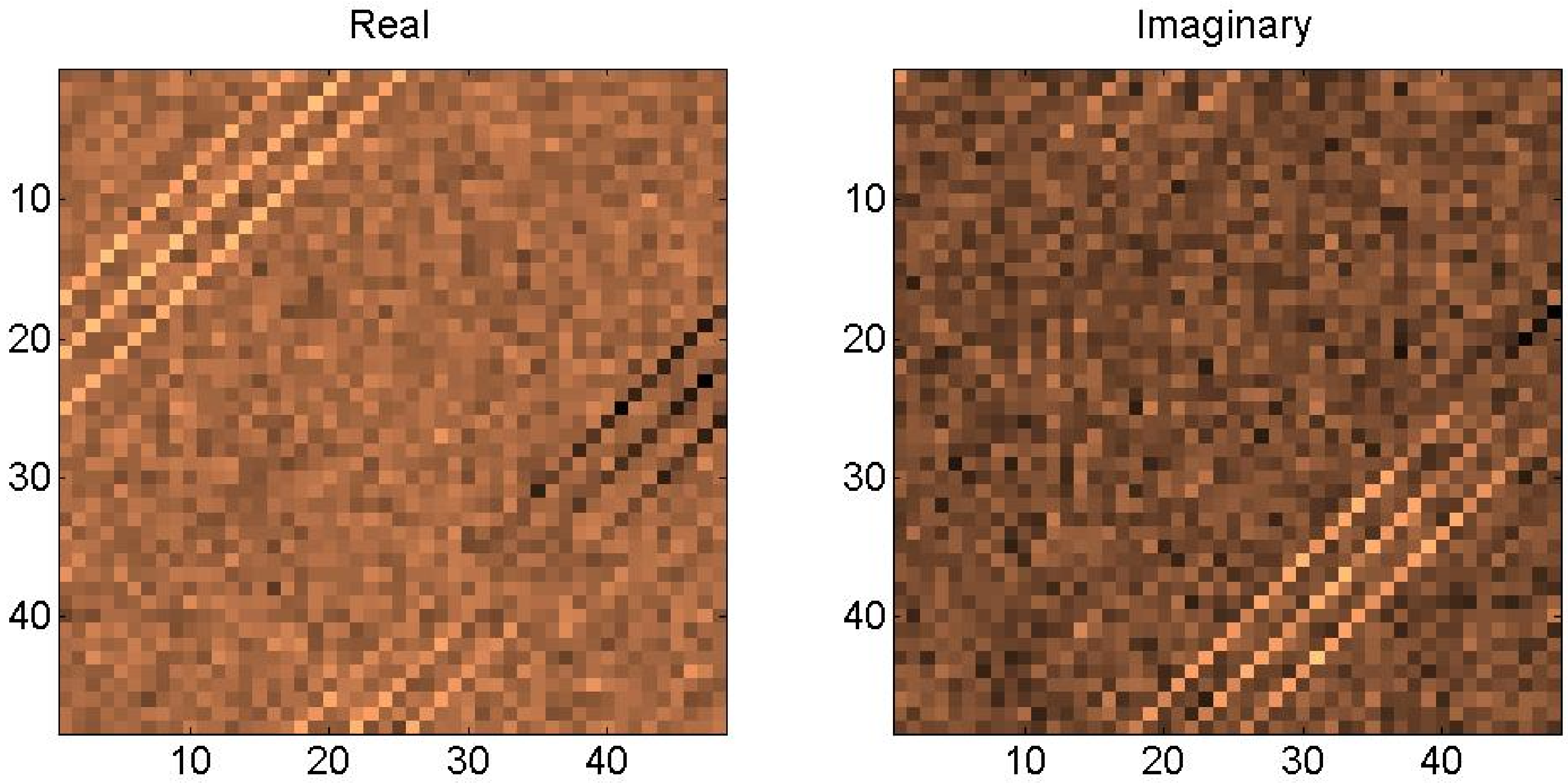
The scattered signal then consists of multiple LFM signals mixed in space and time.

Closely-Spaced Target Separation

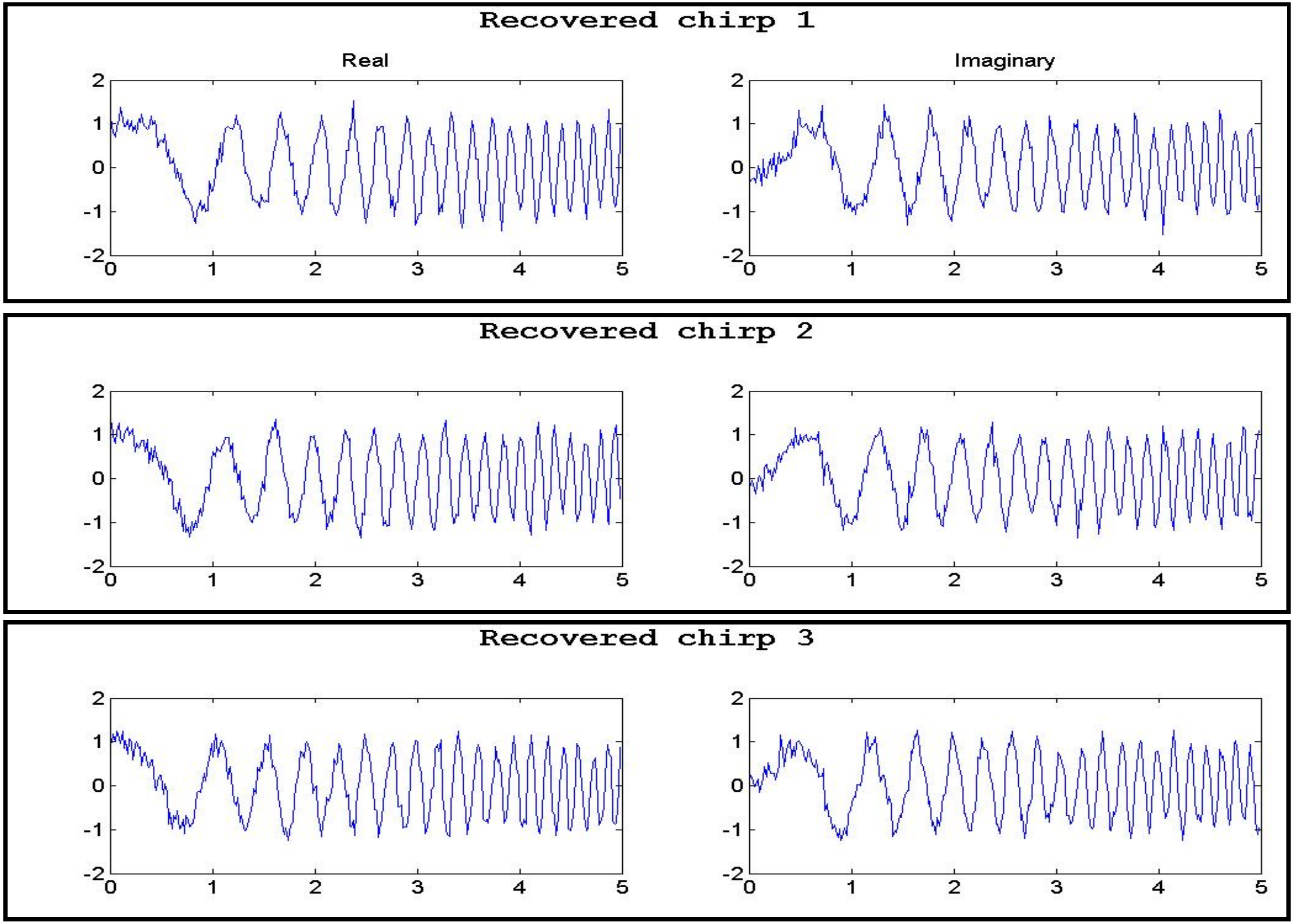




Zak Transform of Noisy Sum



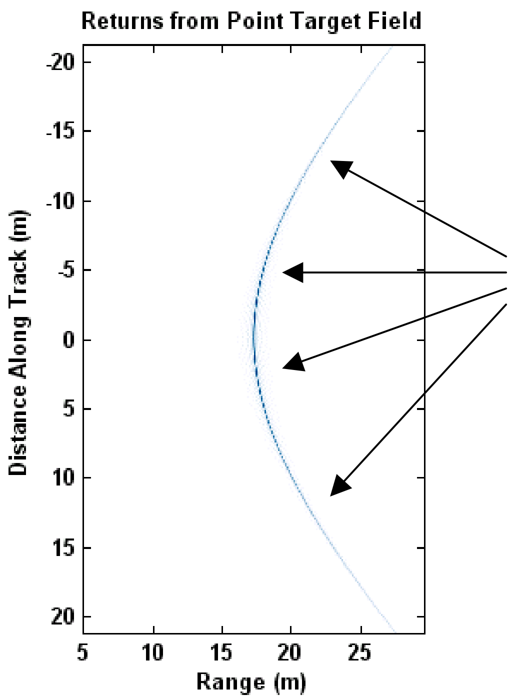
Recovered Decomposition



Improving Observability with Synthetic Aperture Sonar (SAS)

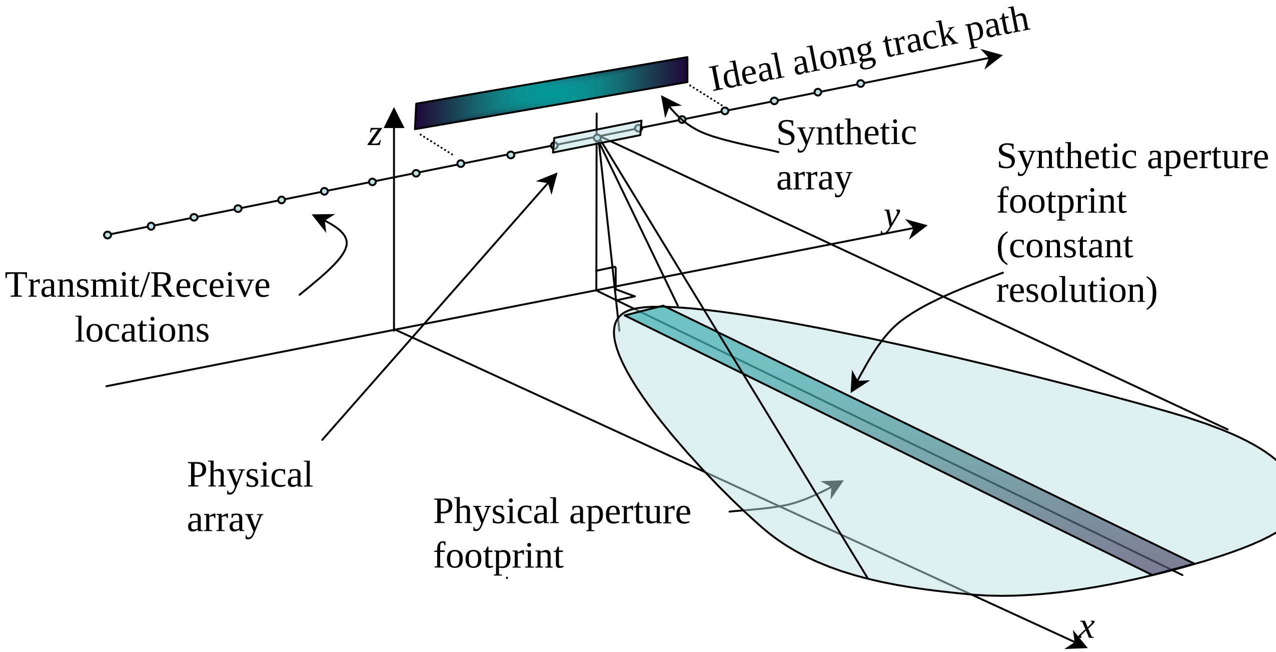
SAS: Multiple Measurements

Use SAS to increase effective pulse duration by combining multiple measurements. Extends algorithm to cases where pulse duration < material relaxation time.



Multiple measurements at different aspects
Increases cross-range resolution and observability

SAS Geometry



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