

**Channel order selection in blind deconvolution
based on eigenvector characteristics
and
Using normal modes
in conjunction with multipath compression
for source signal identification**

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Blind Deconvolution

Part 1

Look at the eigen-decomposition of a matrix

It is not Principal Component Analysis

Part 2

Take advantage of the uniformly continuous solution to the Helmholtz equation

It is not just another averaging technique

Part one

$$Ax = \lambda x$$

λ is the eigenVALUE

x is the eigenVECTOR

Which one gives the most information ?

Determination of filter length or channel order estimation.

All methods based on some matrix of received signals.

Established approaches use eigenvalues

Subspace (SS)- Rietsch, Slock, Moulines, Tong

Akaike Theoretic Criterion (ATC)- Akaike, Wax, Kailath

Canonical Angles of Subspaces (CAS)- Liavas, Regalia, Delmas

(special thanks to Weber, Waldhorst, Schulz, & Bohme)

Not-established Characteristics of Eigen-Vectors Approach (CEVA)

Hints given by Ralph Wiggins (1978) and H.F. Kaiser (1958)

Matrix example with three probability distributions

M1= normally distributed vectors 200 long x 10 wide

M2= uniformly distributed vectors 200 long x 30 wide

M3= Typical underwater acoustic signals 200 long x 60 wide

$M = [M1 \ M2 \ M3]$ is 200 x 100 matrix.

$S = M^T M$ is 100 x 100 matrix.

Find the eigenvalues and eigenvectors and see what information they give.

In MATLAB the **eigen-decomposition** comes back **ordered**

SubSpace approach - Form eigenspace for $S = M^T M$

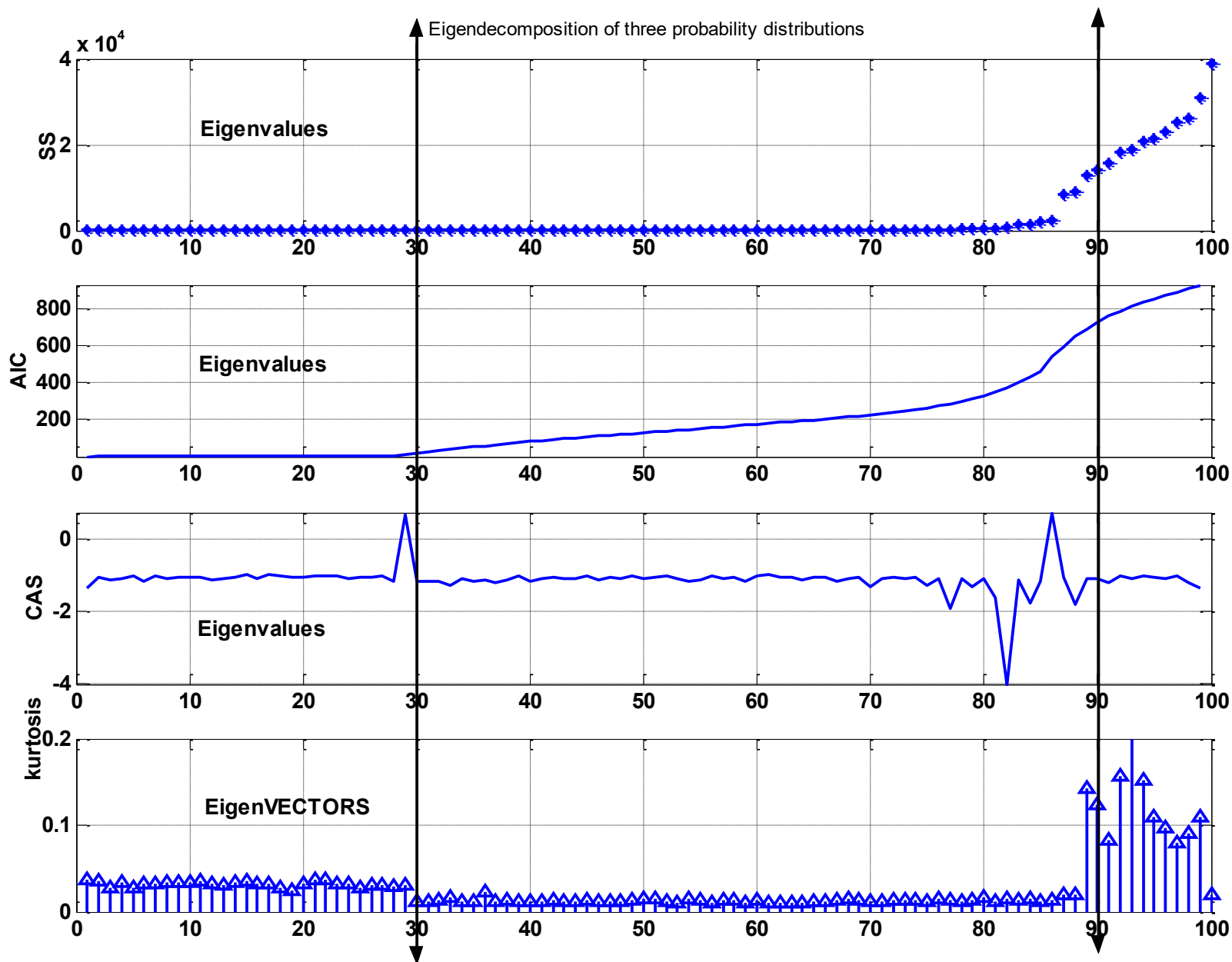
Observe the eigenvalues

ATC approach -
$$ATC(k) = -2 \log \left[\frac{\prod_{i=k+1}^p \lambda_i^{1/(p-k)}}{\frac{1}{p-k} \sum_{i=k+1}^p \lambda_i} \right]^{(p-k)}$$

CAS approach -
$$r(q) = \frac{\lambda_{q+1}}{\lambda_q - 2\lambda_{q+1}}$$

Eigenvector approach – Ask each vector to describe its' kurtosis

Eigendecomposition of three probability distributions



Now we turn to more of an
Acoustics and Communications
type problem

Figure 1a - LFM source signal

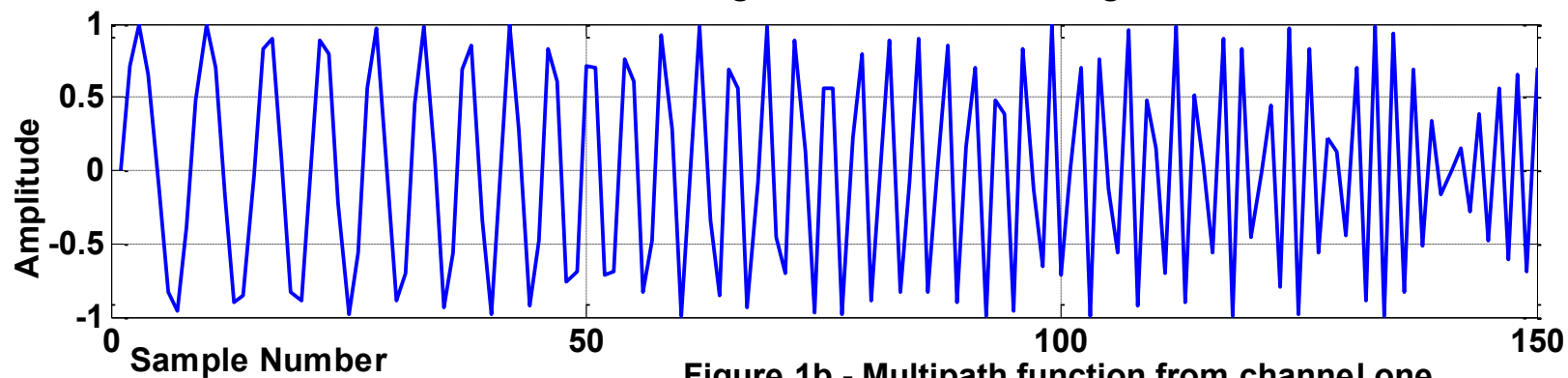


Figure 1b - Multipath function from channel one

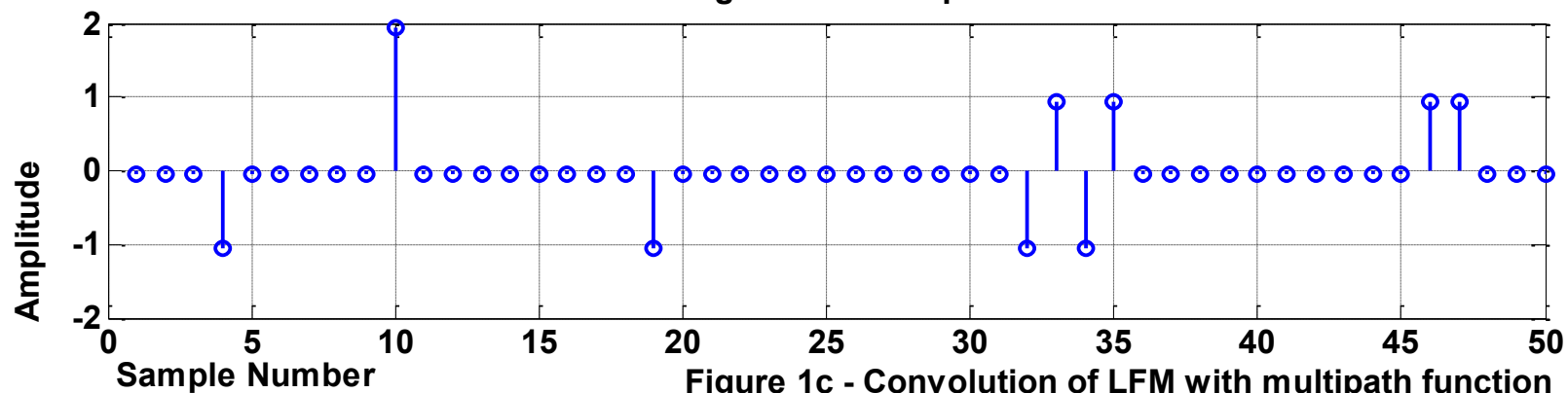
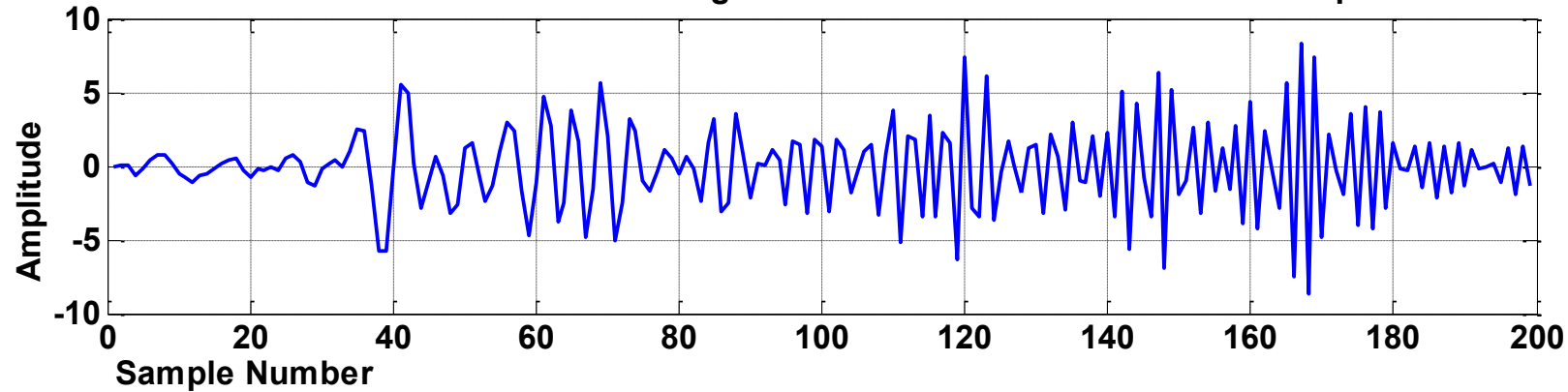


Figure 1c - Convolution of LFM with multipath function



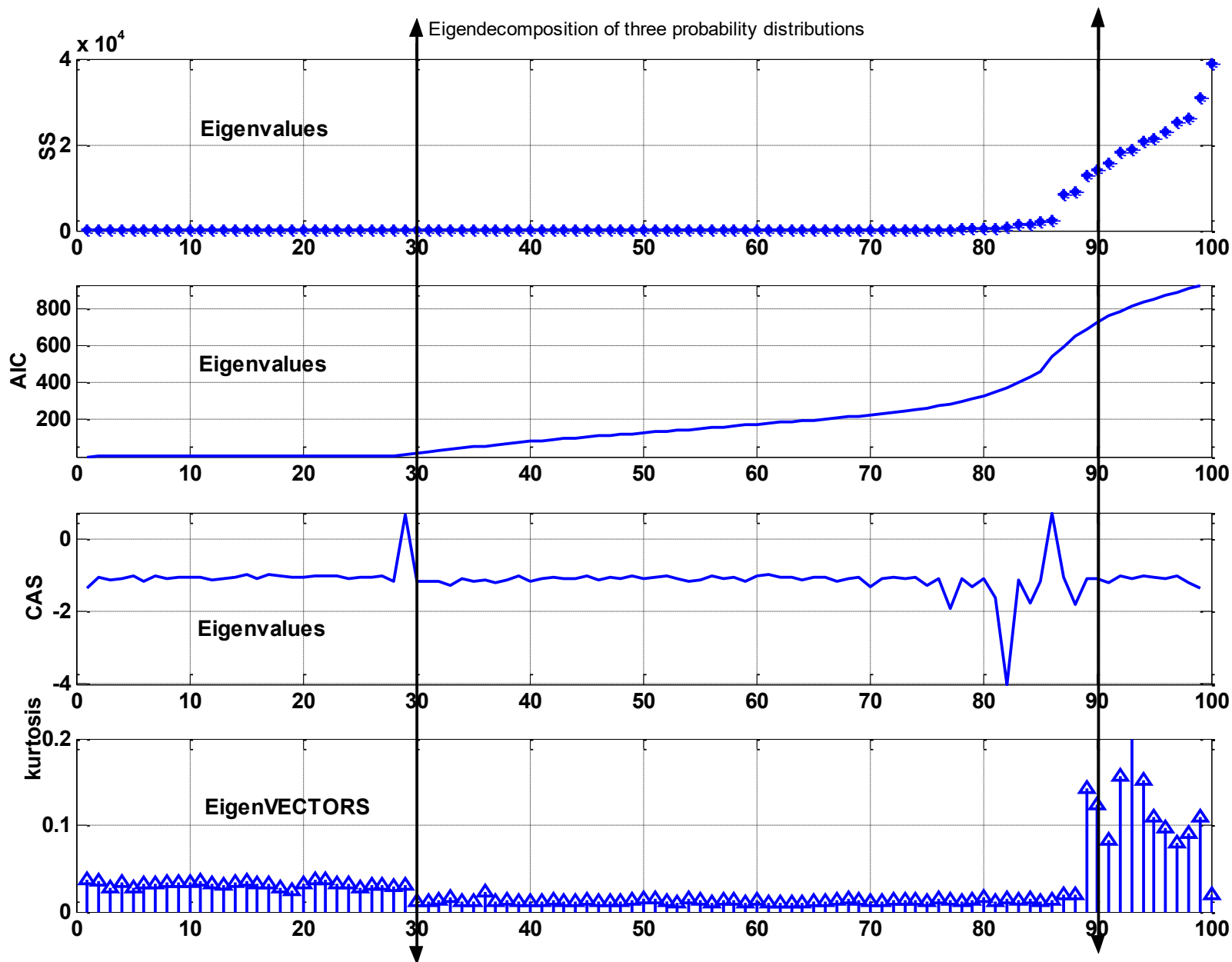
A form suggested by Rietsch. $\mathbf{Yg} = \mathbf{0g}$

$$\begin{bmatrix} Y_2 & -Y_1 & 0 & 0 \\ Y_3 & 0 & -Y_1 & 0 \\ Y_4 & 0 & 0 & -Y_1 \\ 0 & Y_3 & -Y_2 & 0 \\ 0 & Y_4 & 0 & -Y_2 \\ 0 & 0 & Y_4 & -Y_3 \end{bmatrix} \cdot \begin{bmatrix} g_1 \\ g_2 \\ g_3 \\ g_4 \end{bmatrix} = \vec{0}$$

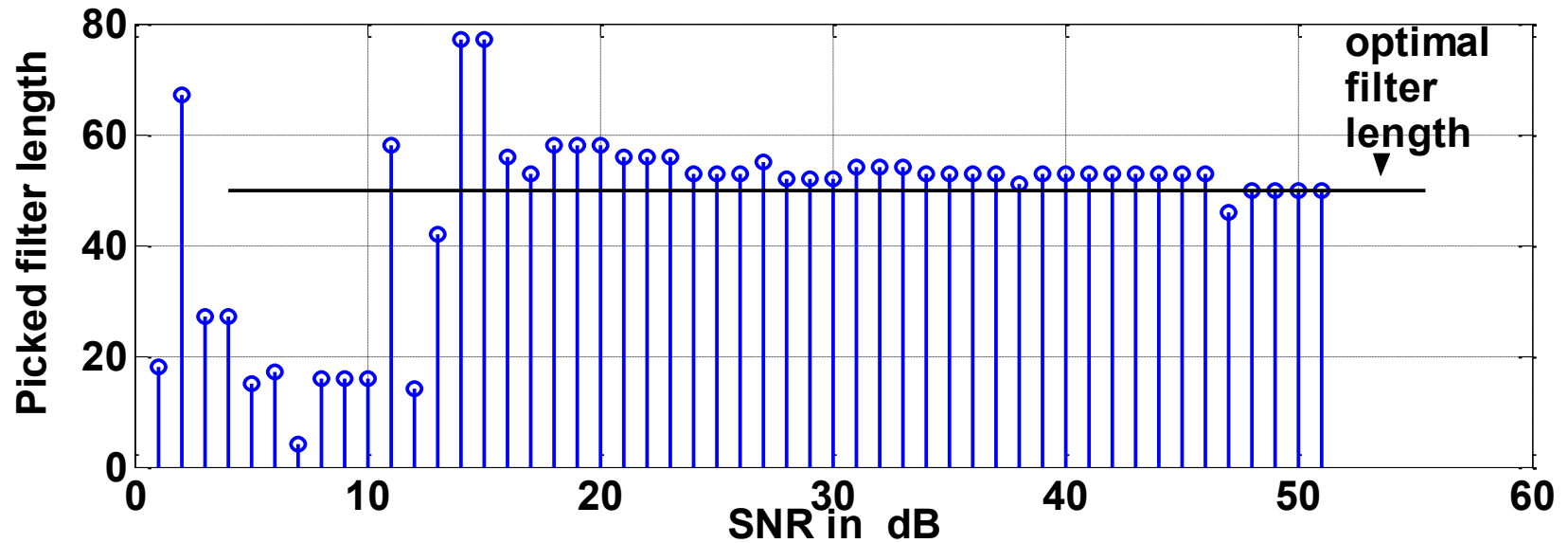
Each Y_i is a convolution matrix which contains the common source signal that establishes the null space.

Each g_i is a multipath function.

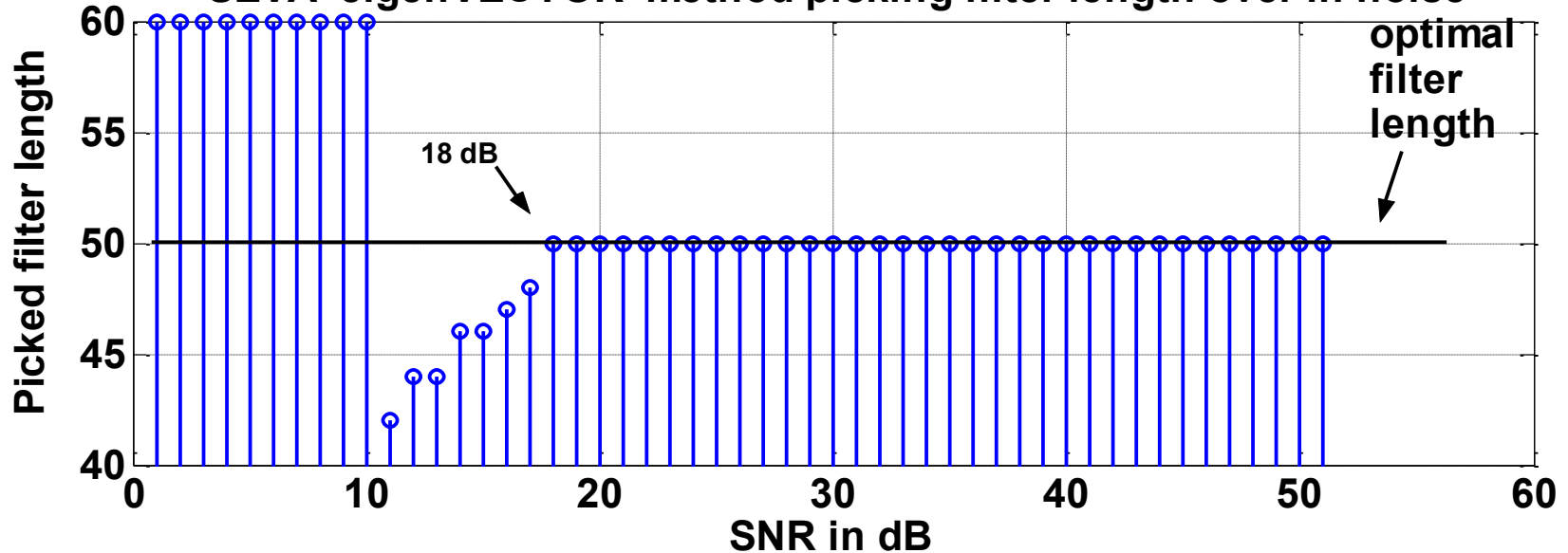
Eigendecomposition of three probability distributions



CAS eigenVALUE method picking filter length in noise



SEVA eigenVECTOR method picking filter length over in noise



Conclusion to part 1: Channel order selection

- *eigenVALUES* only tell how tall an eigenvector stands.
- *eigenVECTORS* tell you in which direction they point.
- Independent subspaces have distinct character.
- The members of a subspace have a common character.
- *The goal is to find a characteristic the eigenvectors differ on.*

Part 2

Source identification by signal processing in a shallow water environment

Put away the eigen-decomposition
discussion

Use simulated Green's Functions from J. Ianiello's MATLAB version of M. Porter's KRAKEN code.

Environmental conditions found in northern Gulf of Mexico:

- 100 meters of water
- 100 meters of sediment
- Underlying bedrock
- Water, sediment, and rock each have constant density
- Depth dependent sound speed profile
- 50 modes

The Solution to the Helmholtz Equation:

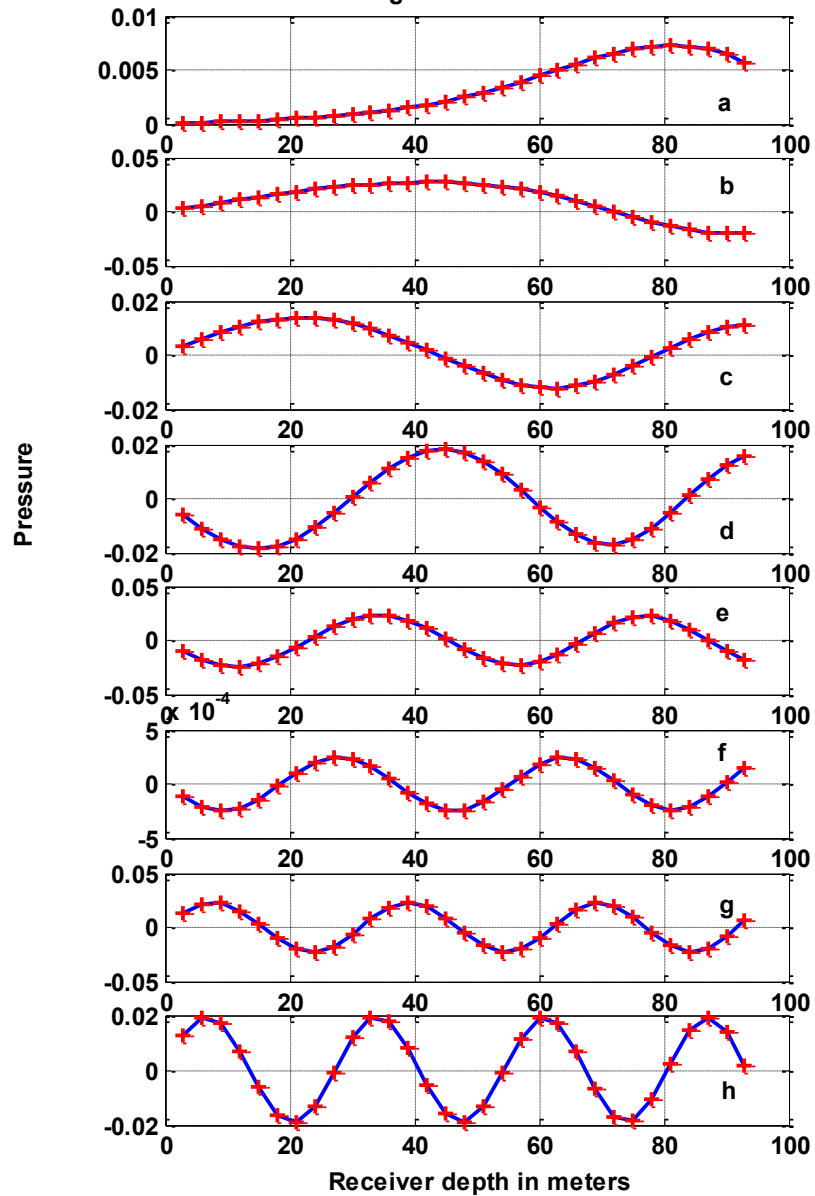
$$p(r, z) = \frac{i}{\rho(z_s) \sqrt{8\pi r}} e^{\frac{-i\pi}{4}} \sum_{m=1}^M \Phi_m(z) \Phi_m(z_s) \frac{e^{ik_{rm}|r|}}{\sqrt{k_{rm}}}$$

is *uniformly continuous* in range and depth.

Such a function *resists rapid changes*.

This property makes it easy to *track* the pressure.

Figures 16 a - 16 h



Figures 16 i - 16 p

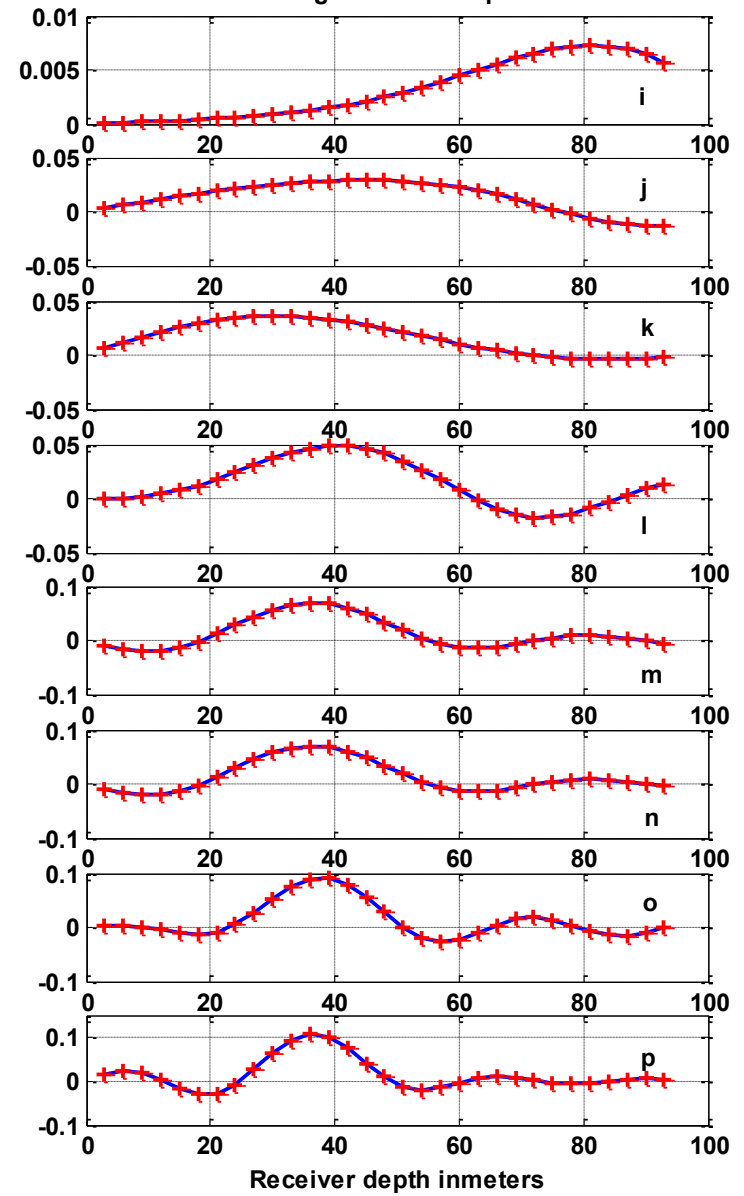


Figure 20 Maximum pressure distribution

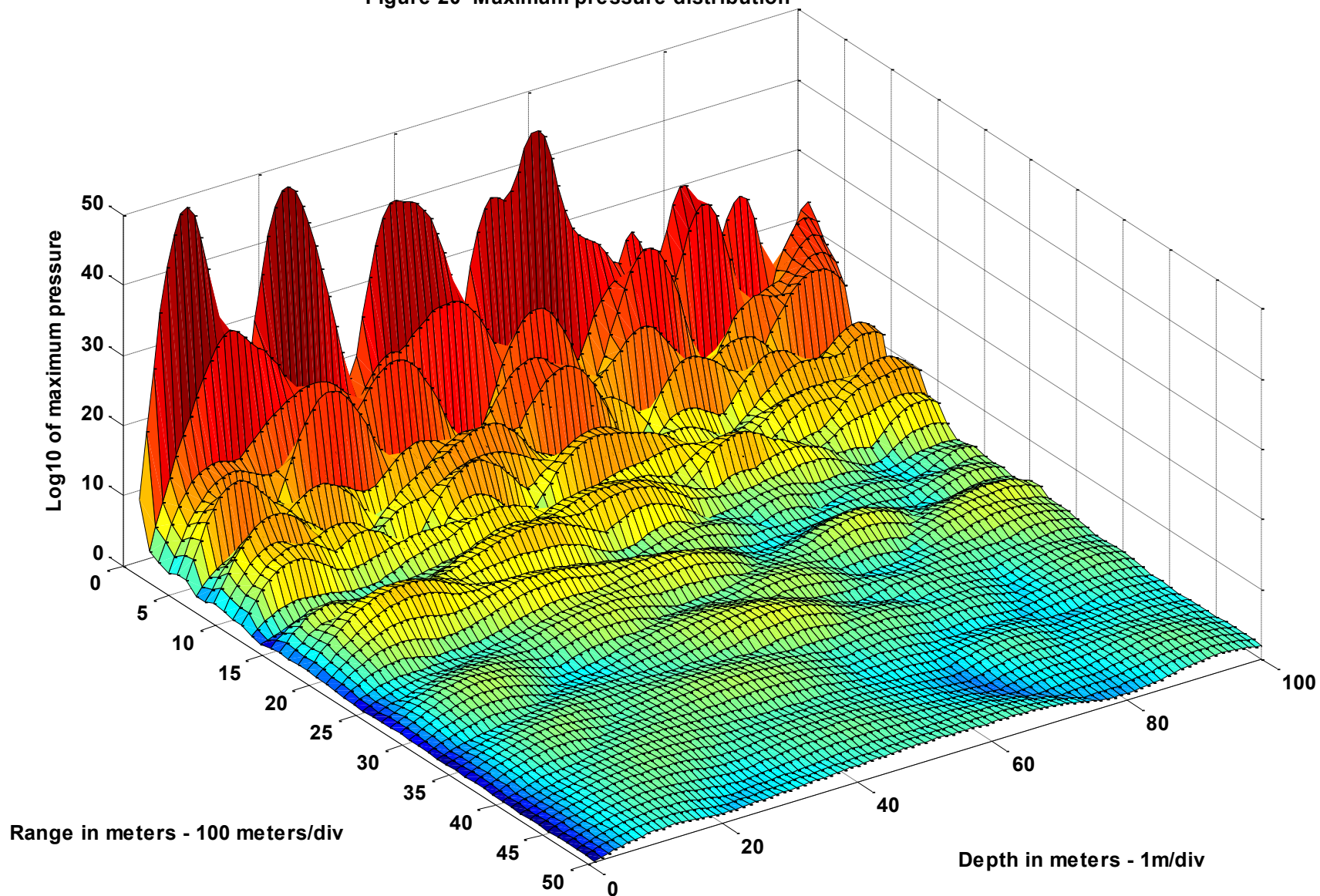


Figure 23a - 23c - Example @ 50 meters depth and 2500 m range

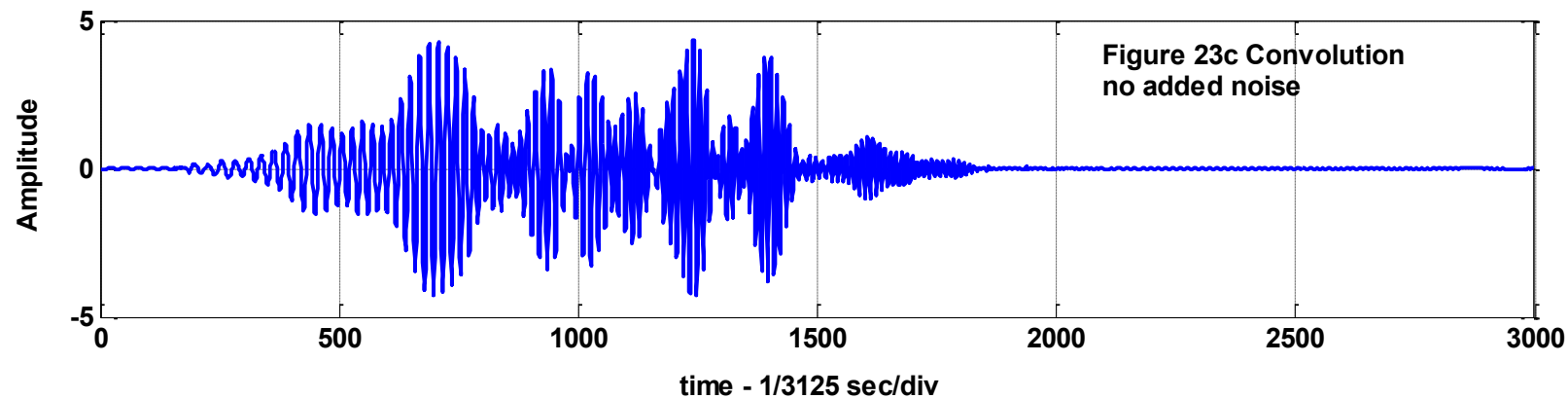
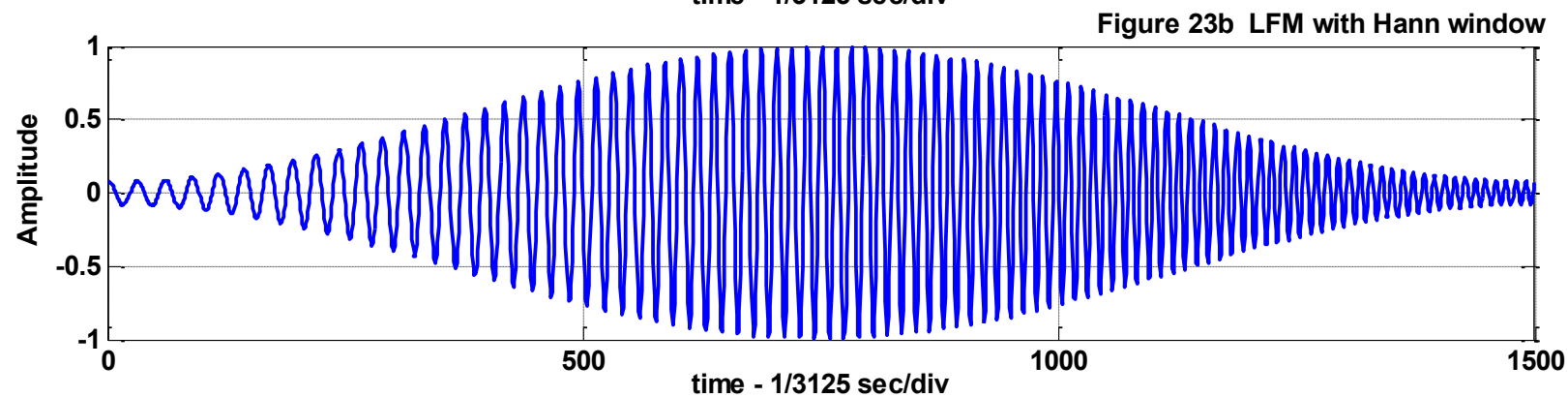
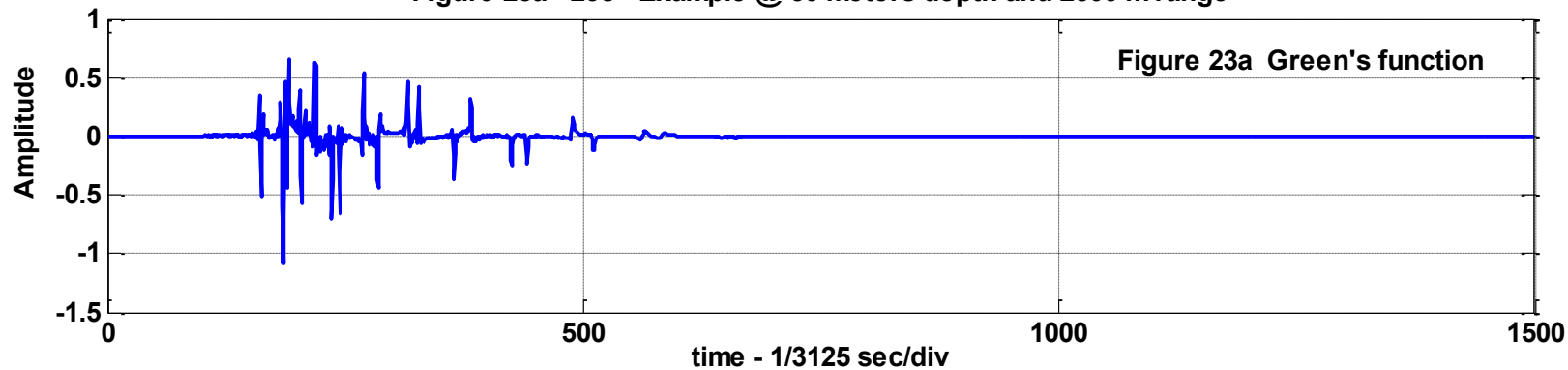
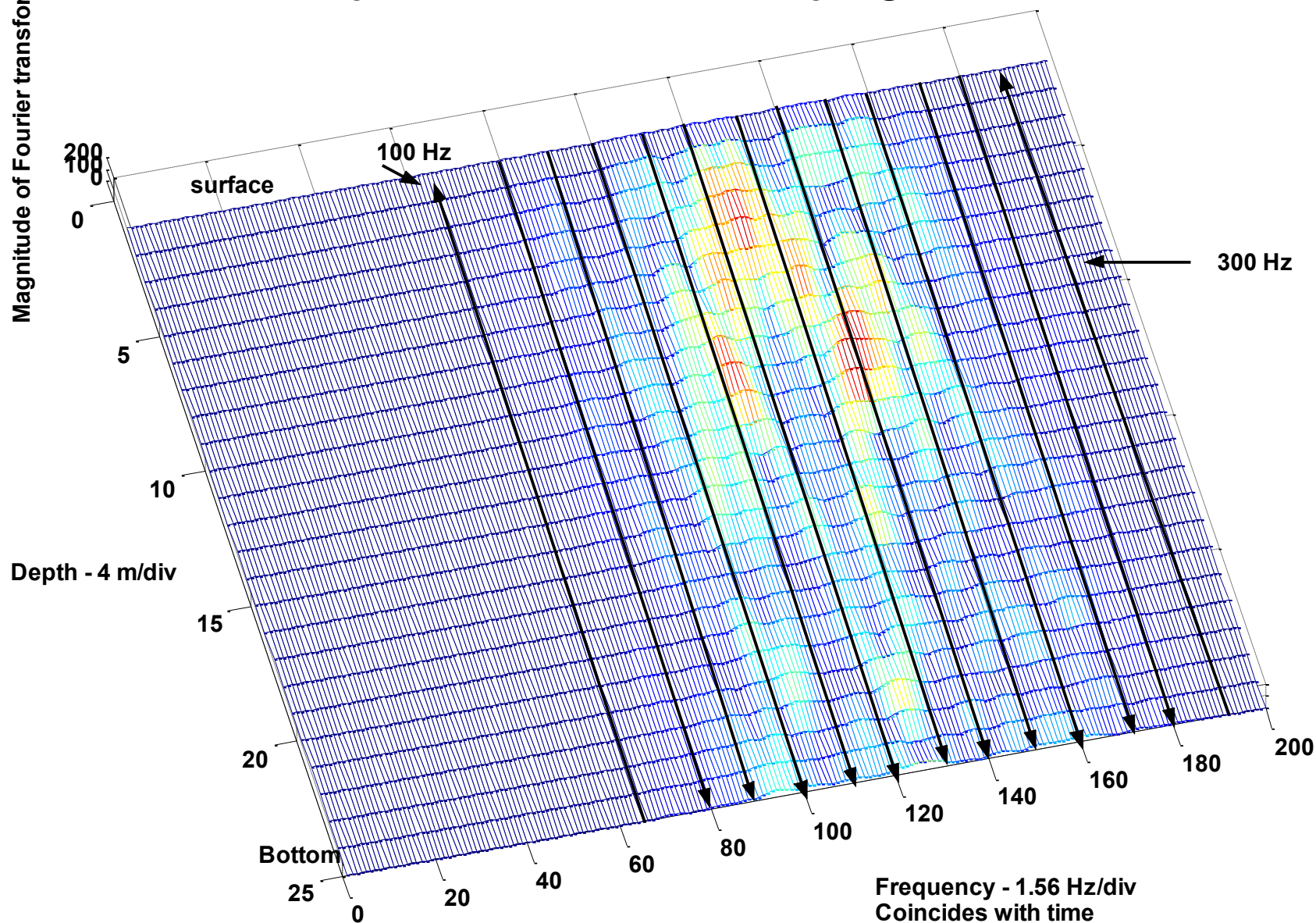


Figure 22 - Fourier transforms of received signals @ 2500 meters



Two methods are presented here:

1. Averaging the Fourier transforms of 100 received signals, using the whole signal. ***BLACK MAGIC***
-

2. Uniformly **tracking** the over **short blocks of time**

Average of maximum pressures is refined and above the noise

Track the frequency with the supremum of maximum pressures

3. Recording the dominant depth

Figure 28 - Average of Fourier transforms from each received Signal @ SNR 10 dB

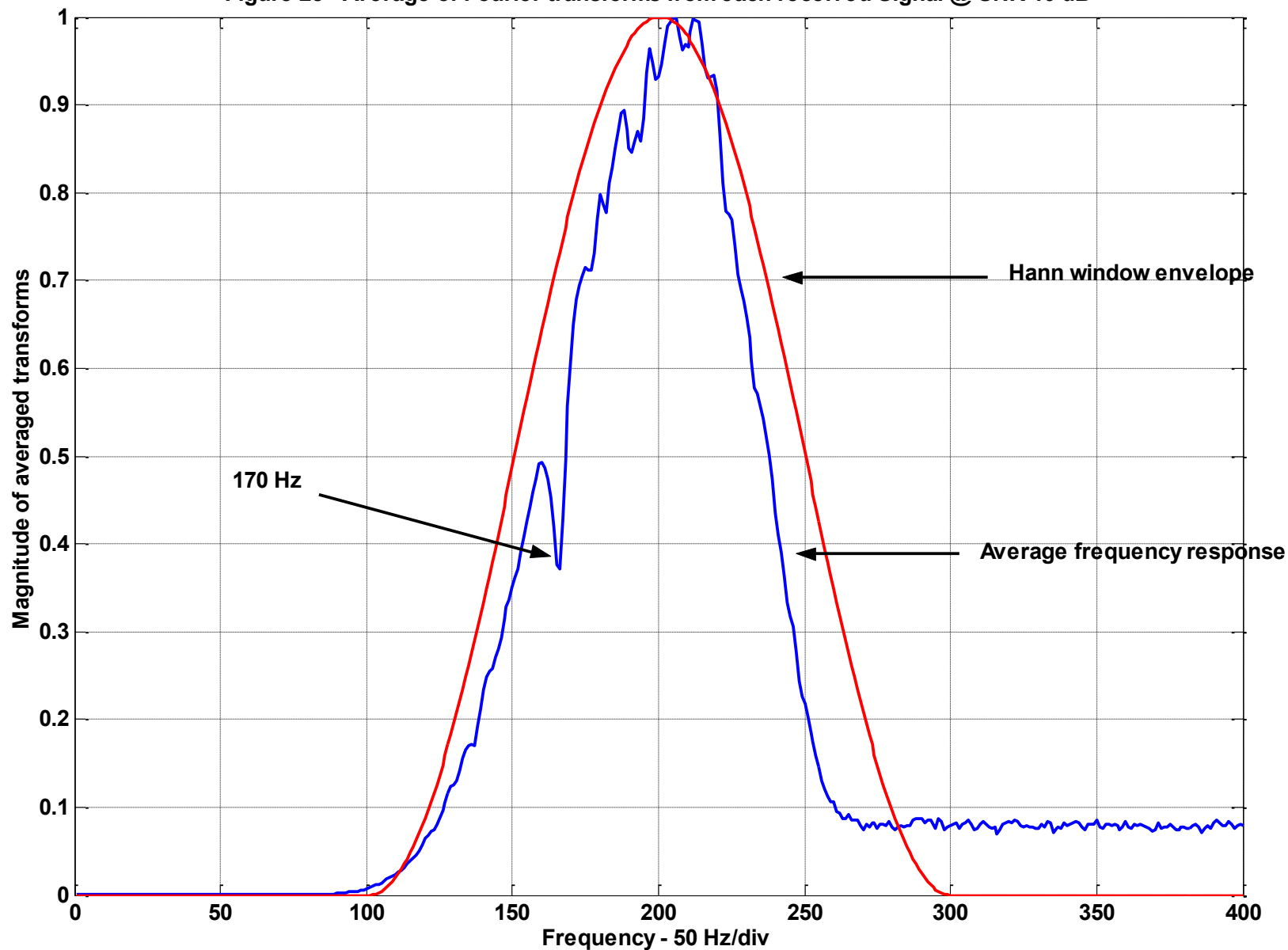


Figure 25 - Comparison of Choices for Magnitude Over 30 data sets

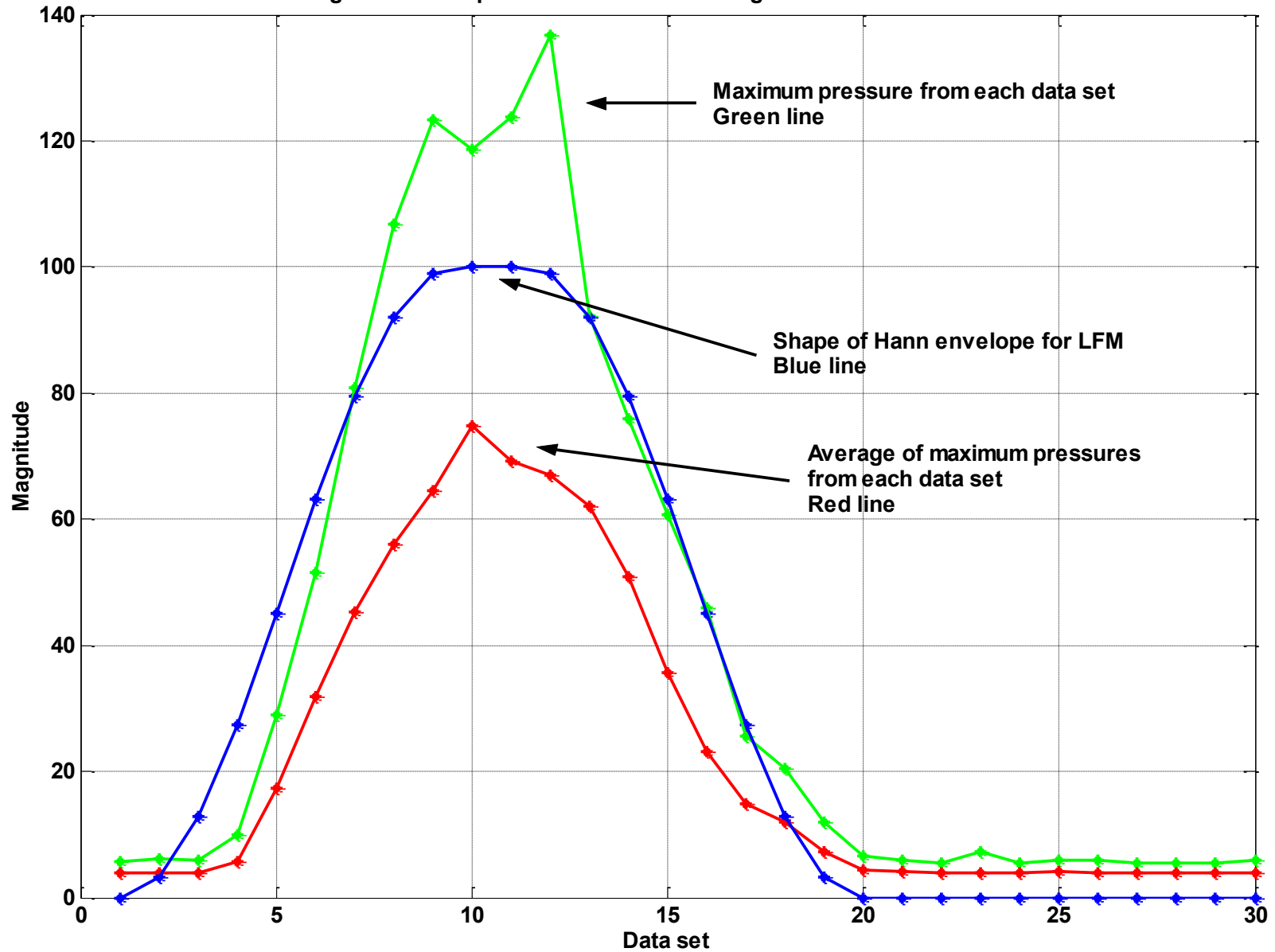


Figure 26 - Comparison of Choices for Frequency Over 30 Data Sets

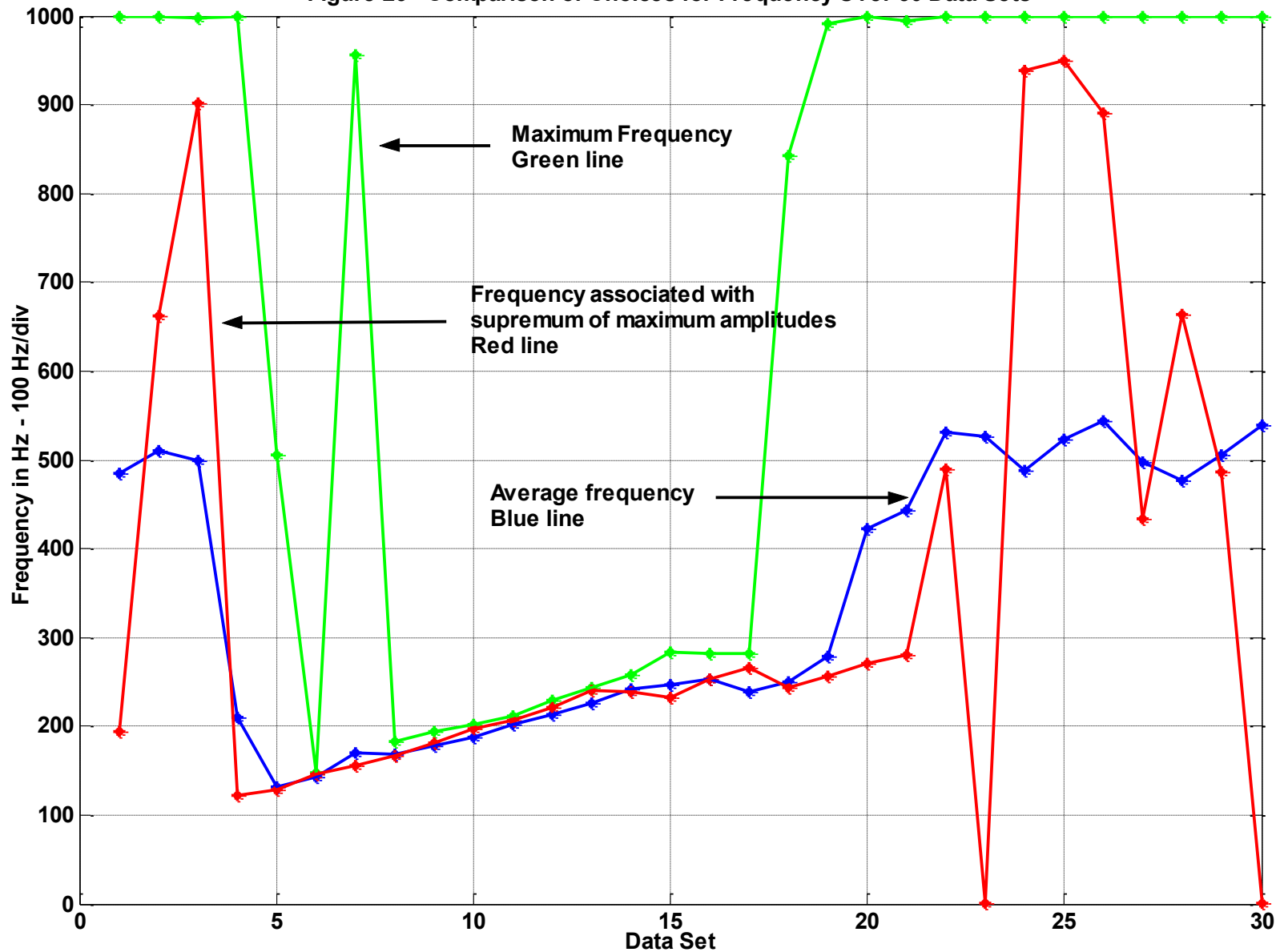
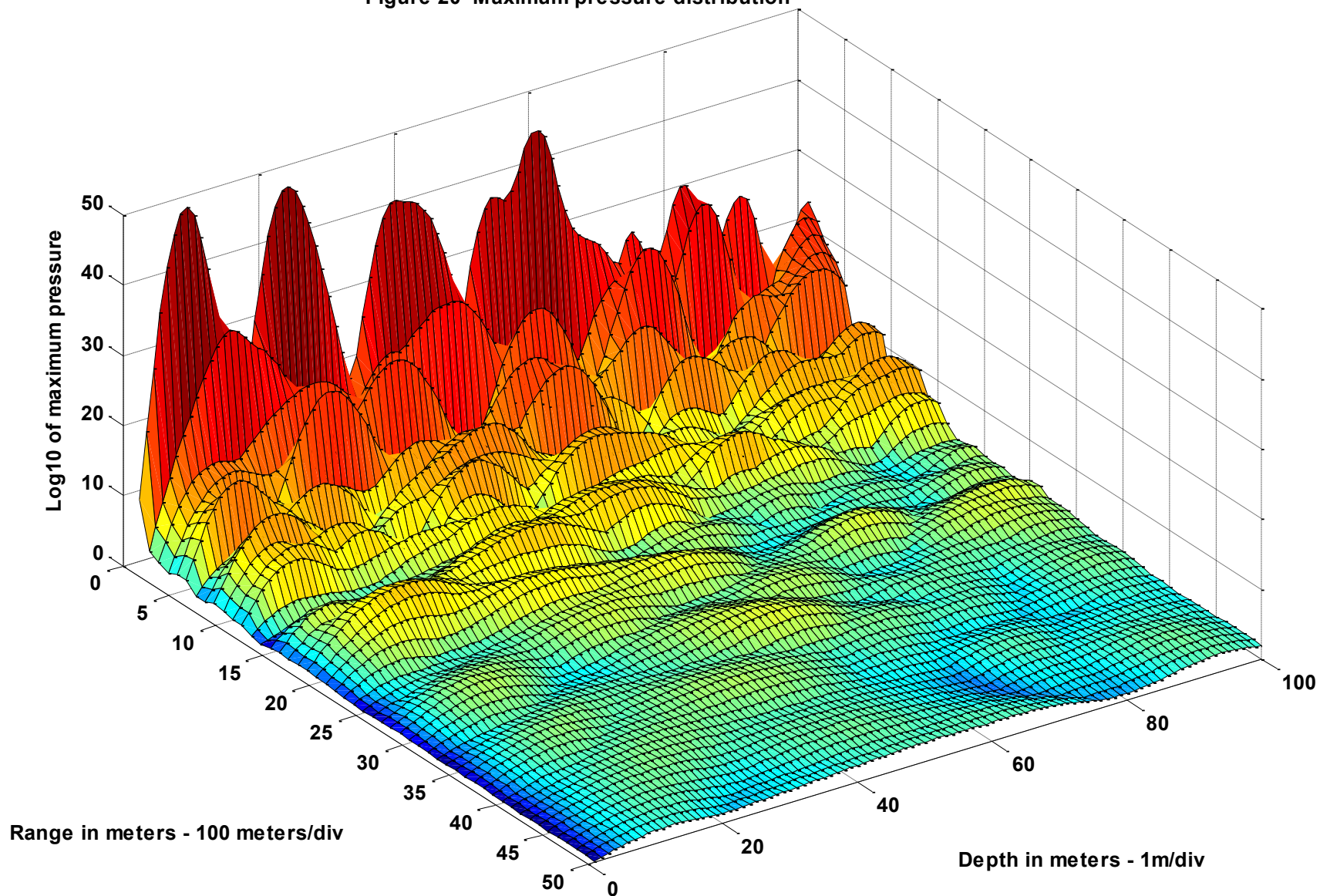


Figure 20 Maximum pressure distribution



Feature : *Tracking a signal* as it arrives

Benefit : Only need to track the maximum pressures.
Throw the rest out. It is contaminated.
The signal is more stationary in frequency.

Benefit of the benefit : Keep your head above noise

The real goal

State – Space model

Thank you

Acoustical Society of America

from the

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at

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James Larue