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HIGH RESOLUTION BOTTOM CHARACTERIZATION

4 MAY 1993

D. MIKLOVIC

CONTRACT NO.: MDA972-91-C-0063

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94-S-4742

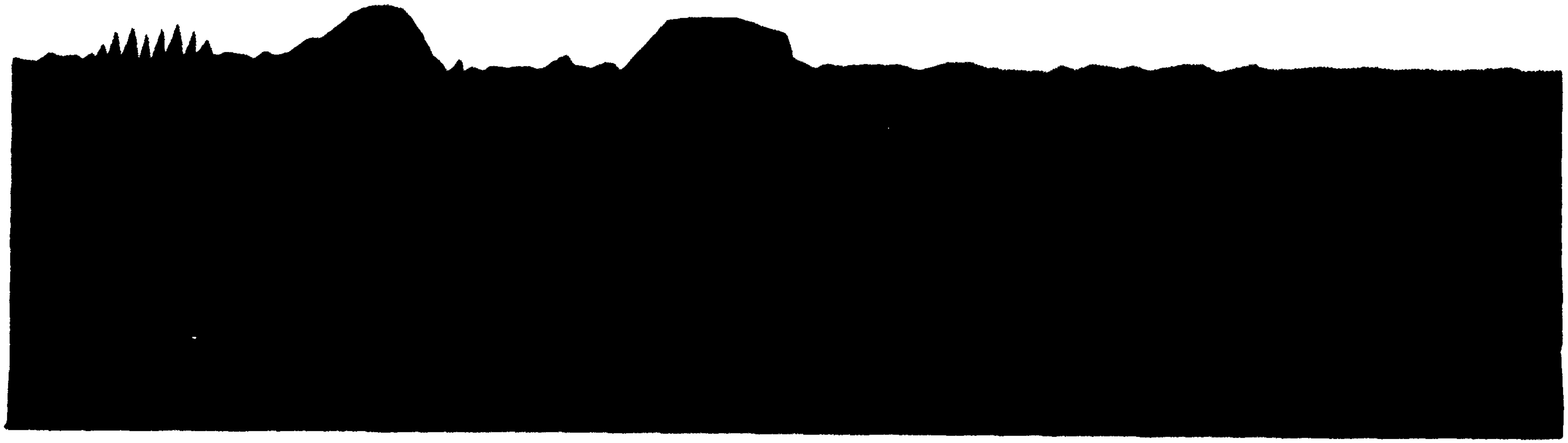
ADVANCED PROCESSING FOR BOTTOM CHARACTERIZATION

Goal: Identify and quantify dominant scattering mechanisms in bottom limited environments.

Approach

- Produce precision high resolution scattering maps using broadband nearfield sparse array technology
- Identify classes of scattering by acoustic color
- Simultaneously measure bottom characteristics using broadband probe-pulse forward scattering technology.

BOTTOM CLUTTER HYPOTHESIS TESTING



ROUGHNESS INHOMEGENEITY	TILT MODULATION	OUTCROPPING	SUB-BOTTOM INHOMOGENEITY	GAS POCKET
• $\sim k^4 S(k)$ • broadband • blue spectrum • left-right symmetry	• θ^4 slope dependence • asymmetric	red-blue-red spatial color pattern	red spectrum related to depth	• narrow band • low frequency • shadow zone

WASPS

Areté's Wideband Acoustic Scattering Processor System

Incorporates advanced processing and imaging technology into a unique and important tool for low and mid-frequency applications.

Features

- Full spectrum capability without nested arrays
- Very high resolution in 3D (range, cross-range, depth)
- Precision imaging of acoustic scene
- Acoustic color classification

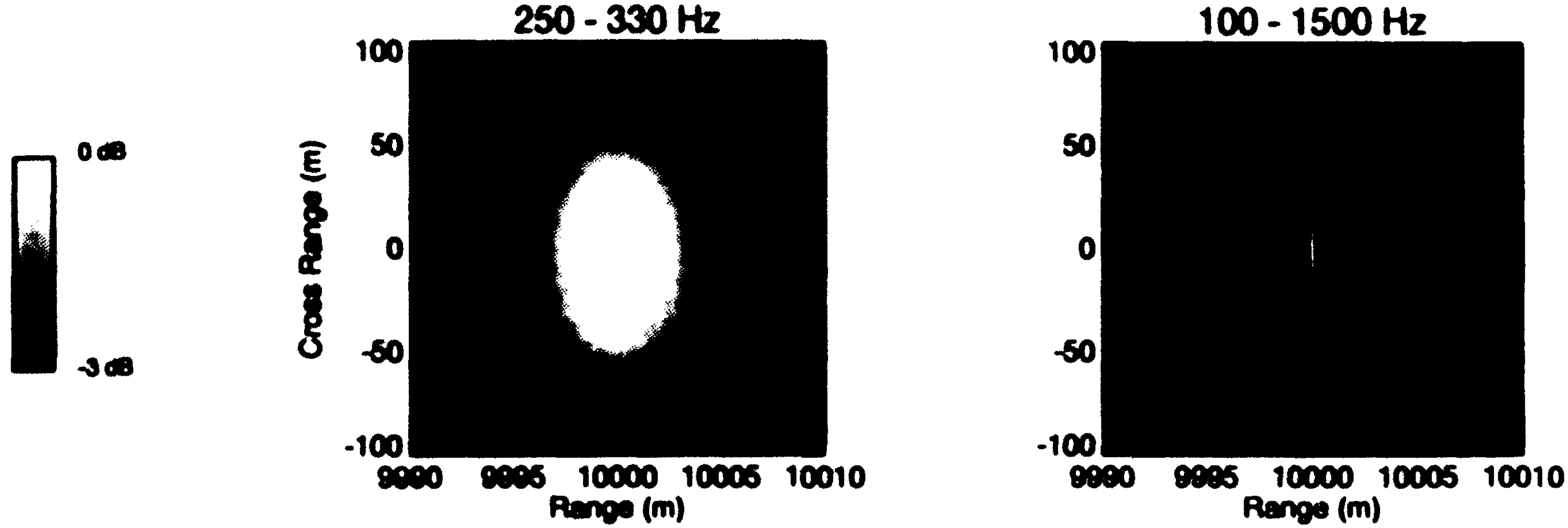
Viability

- Can exploit any array configuration
- Concepts validated on Navy and ARPA systems
- Computational requirements within capability of emerging small, low-cost multiprocessor systems.

WASPS UNIQUE TECHNOLOGY

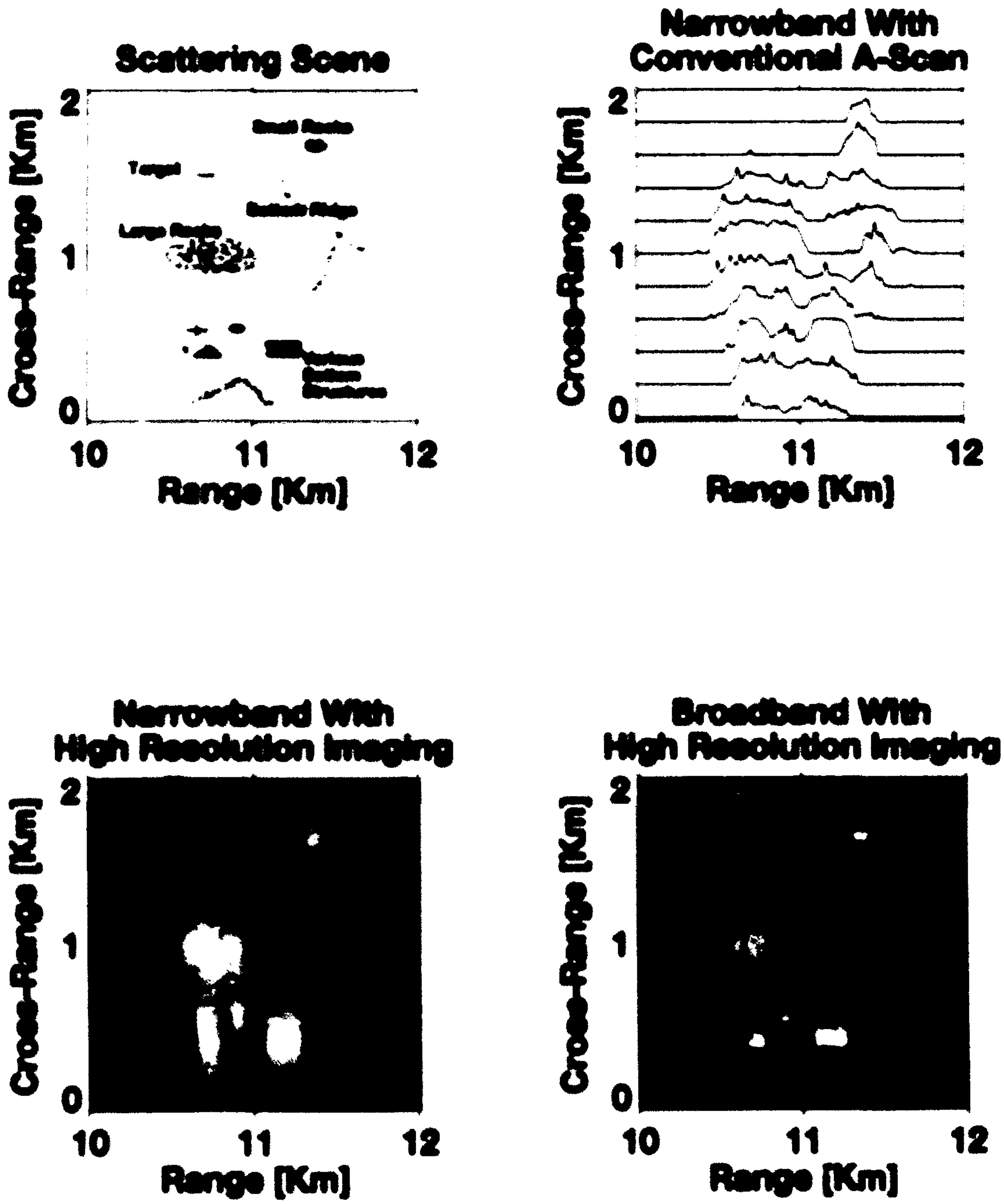
Technique	Effect	Utility
BROADBAND BEAMFORMING (≤ 200 % BANDWIDTH)	- Maximum temporal resolution - Full spectrum coverage - Uses all signal energy	- LFA multipath estimation - Frequency Diversity - Maximal SNR for impulsive sources
SPARSE ARRAYS	- Significantly increase angular resolution - Not restricted to λ/2 sensor spacing	- Classification based on 2D structure - Conventional arrays can be used - Increased AG for nested configuration
NEAR FIELD FOCUSING	- Full array gain and resolution at any range	- Use in short range (5-10 nmi) shallow water applications - Acoustic microscope (< 1 nmi)
EXPLOSIVE WAVEFORM DECONVOLUTION	- Increases temporal resolution to the inverse bandwidth	- LFA multipath classification with explosives
ARRAY AUTO-COHERING	- Localizes array position	- Full gain without elaborate measurement systems - Left-right resolution
HIGH RESOLUTION IMAGING	- Natural presentation of acoustic scene	- Rapid operator assimilation of data
SPECTRAL COLOR SEGMENTATION	- Presents relative frequency content of scatterers	- Target and environmental classification
INCOHERENT DEPTH ESTIMATION	- Determine contact depth	- Classification and localization without matched field replica
MULTIPROCESSOR ARCHITECTURE AND HARDWARE	- Near real time throughput	- Small, low cost processor systems

Theoretical 3 dB Resolution Cell: CST MFA

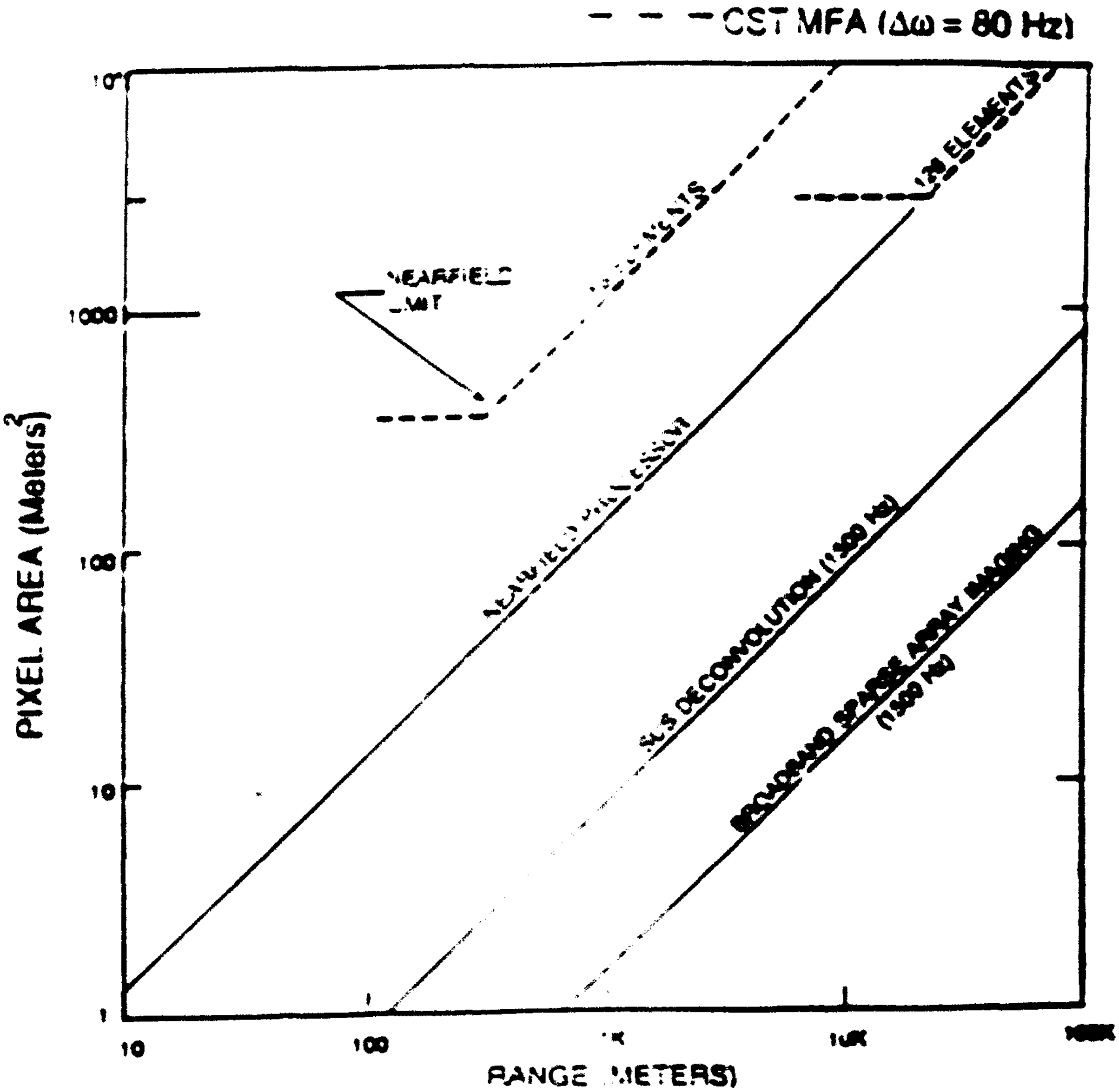


	250 - 330 Hz	100 - 1500 Hz
Beampattern:	$\lvert b(\theta,\omega)\rvert^2$	$\left\lvert \int b(\theta,\omega) e^{i\omega t} d\omega \right\rvert^2$
Angular Resolution:	$\frac{\lambda}{L} = 0.93$ deg.	$\sqrt{2}\frac{c}{L\Delta\omega} = 0.27$ deg.
Sidelobe:	$\frac{1}{N^2} = -42$ dB	$\frac{1}{N^2} = -42$ dB

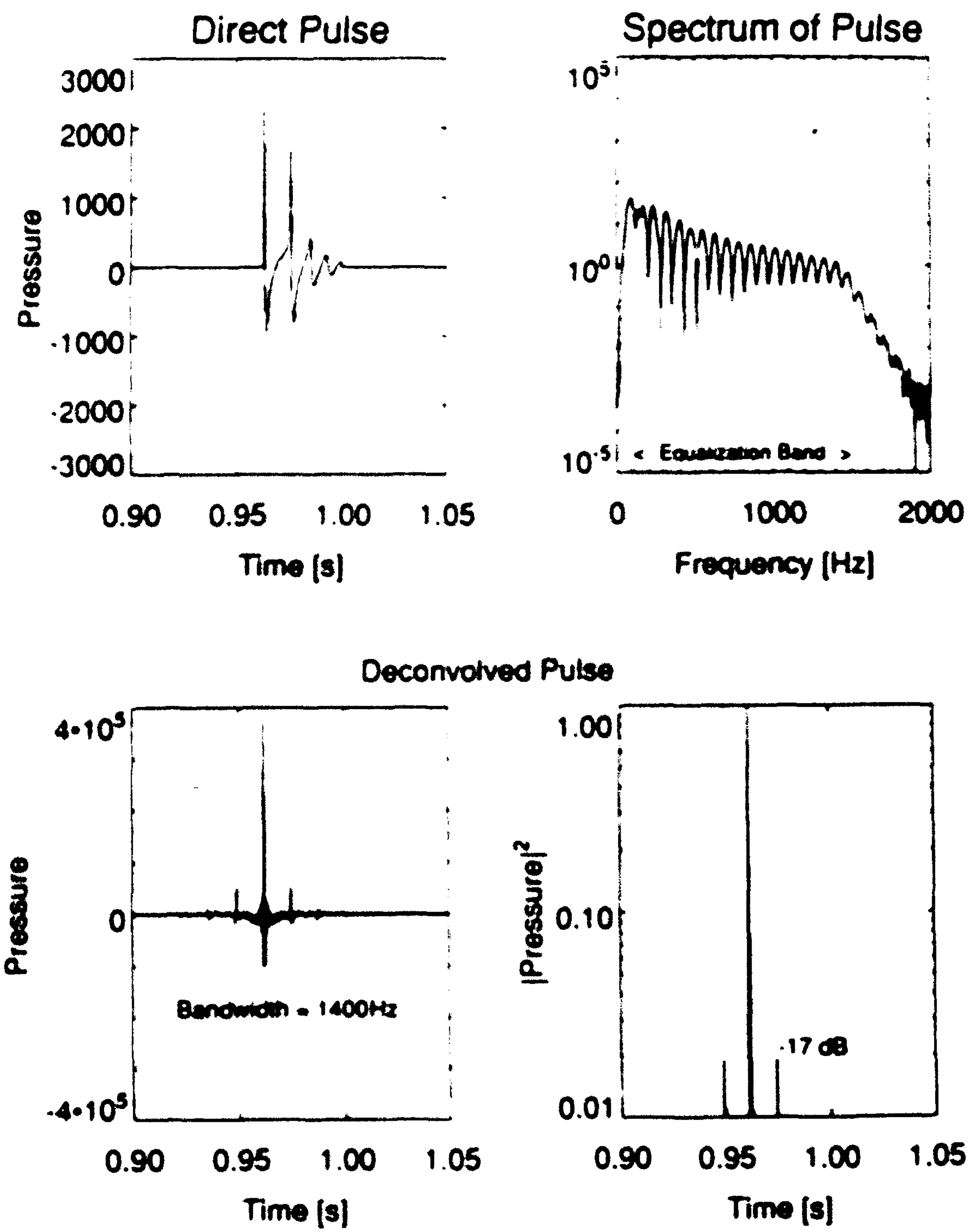
Simulated Results For
The CST MFA Receiver



THEORETICAL EFFECTS OF PROCESSING TECHNIQUES ON SPATIAL RESOLUTION OF CLUTTER

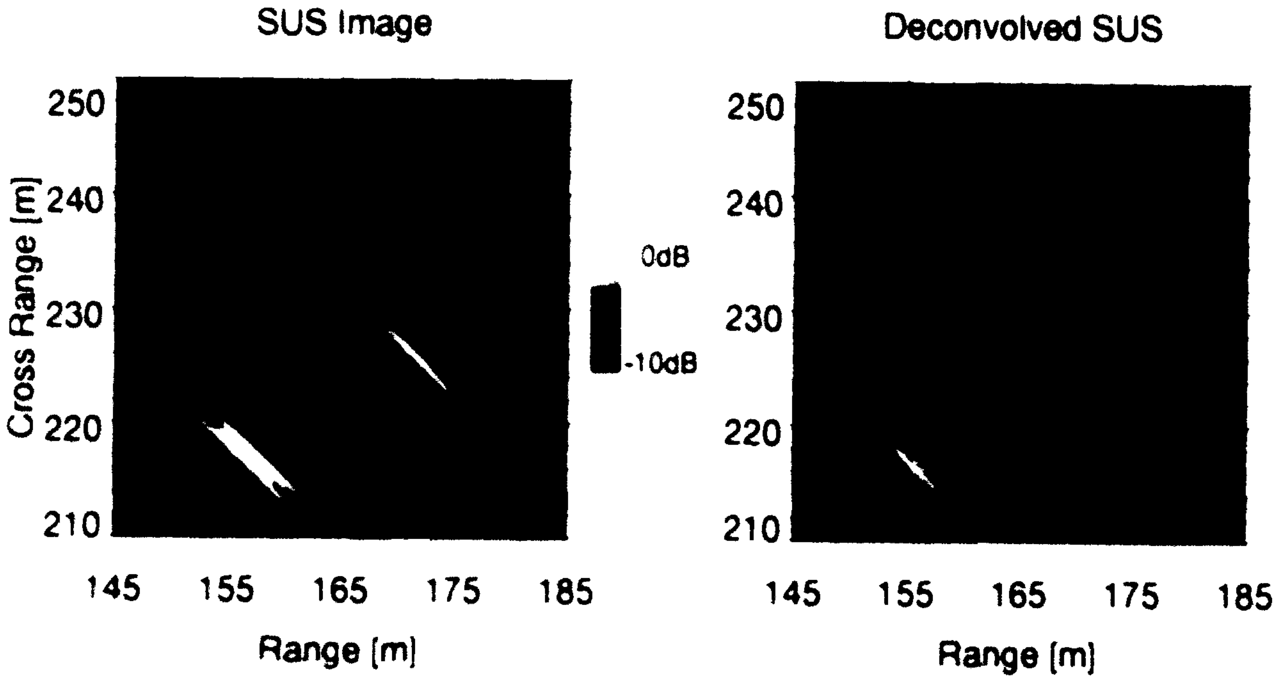


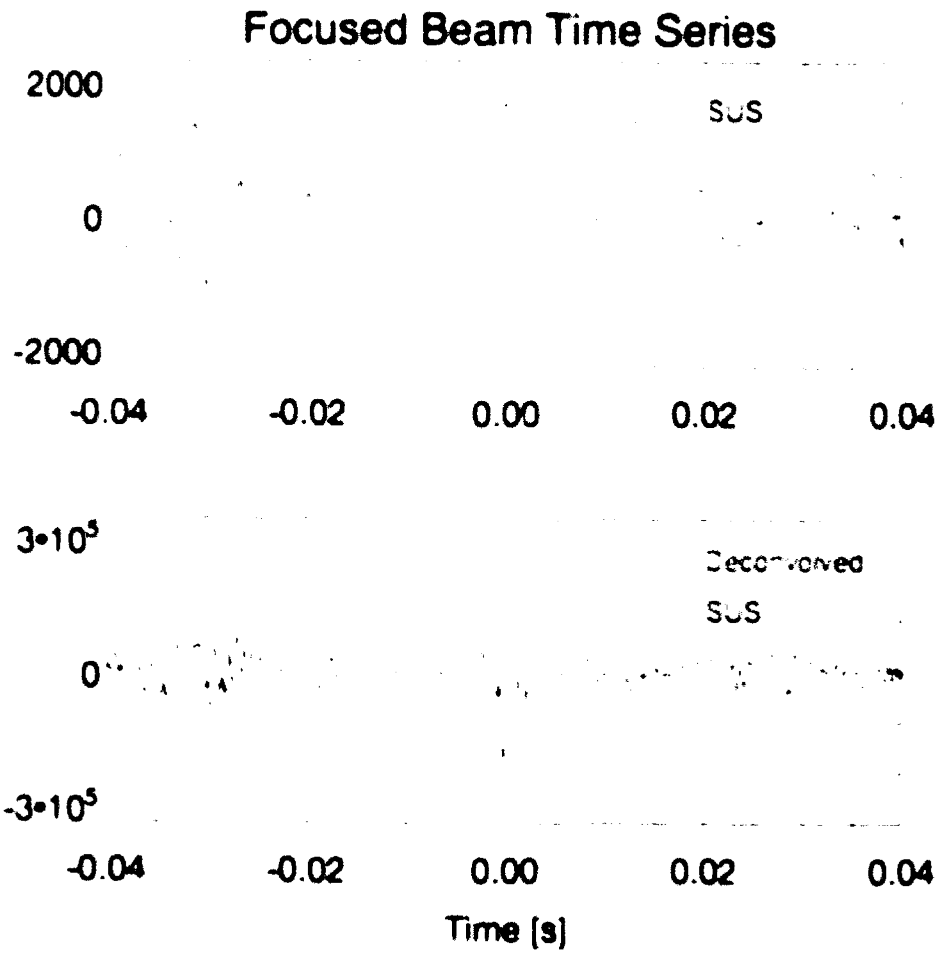
SUS Deconvolution



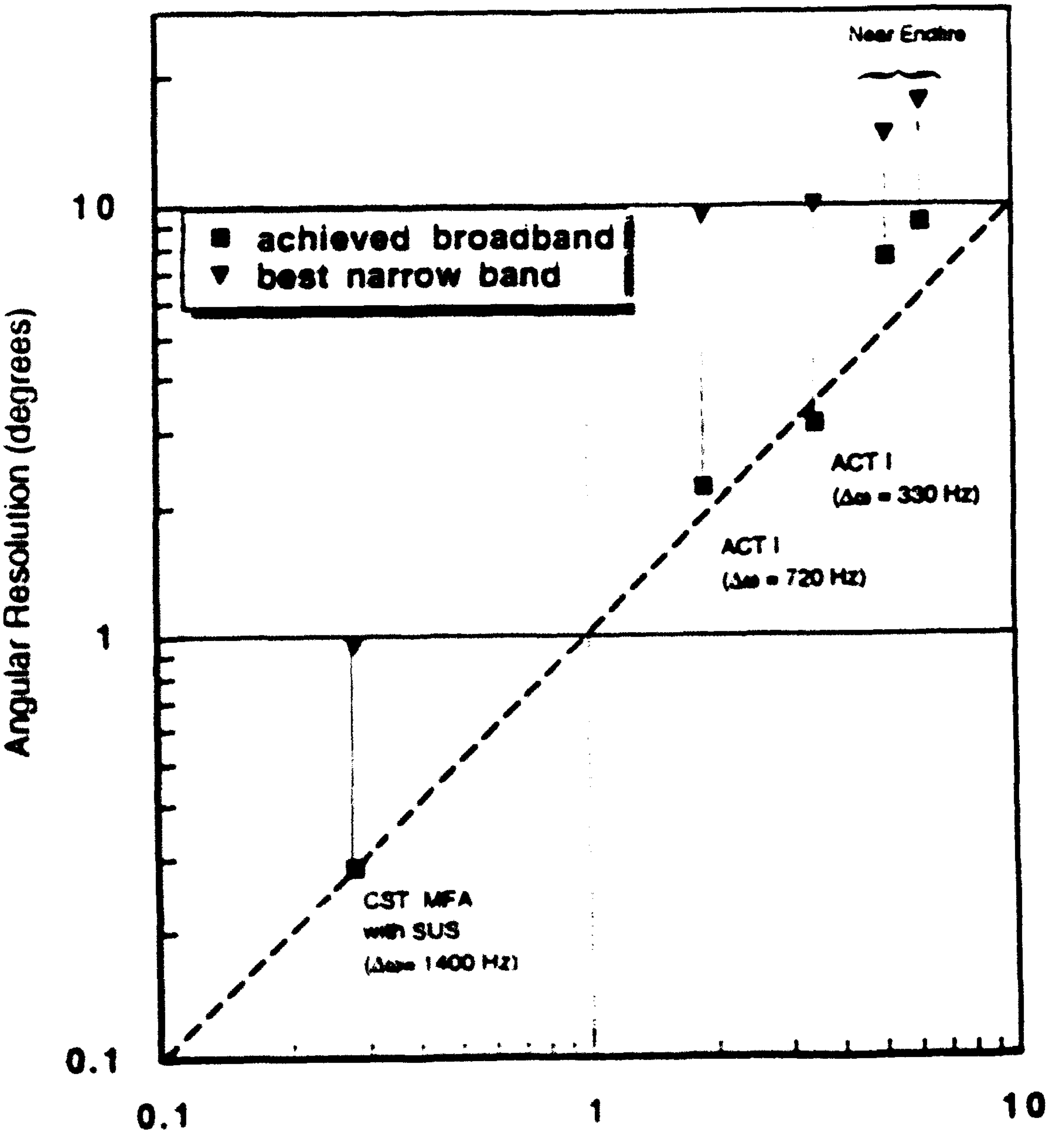
SUSR_STO/CST4/gp1a 14Aug91

Effect of SUS Deconvolution





COMPARISON OF ACHIEVED VS THEORETICAL ANGULAR RESOLUTION (U)

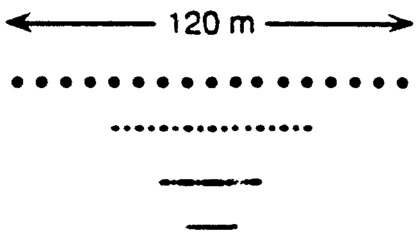


$$\sqrt{2}\ \frac{c}{L\Delta\omega}\ \text{(degrees)}$$

BROADBAND SPARSE ARRAY ECONOMY

Bandwidth : 100 - 1600 Hz
DI : 12 dB

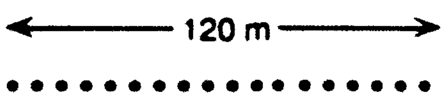
Classical Nested Octave Design



Band	Sensor Spacing
100 - 200 Hz	$\Delta x = 7.5$ m
200 - 400 Hz	$\Delta x = 3.8$ m
400 - 800 Hz	$\Delta x = 1.9$ m
800 -1600 Hz	$\Delta x = .9$ m

Number of Sensors: 41

Broadband Sparse Array Design



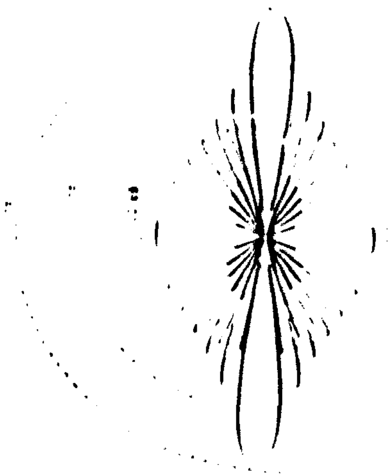
Band	Sensor Spacing
100 -1600 Hz	$\Delta x = 7.5$ m

Number of Sensors : 17

COMPARISON OF NARROWBAND AND BROADBAND BEAMPATTERNS

13 Element Array Cut @ 100 Hz

CW @ 100 Hz

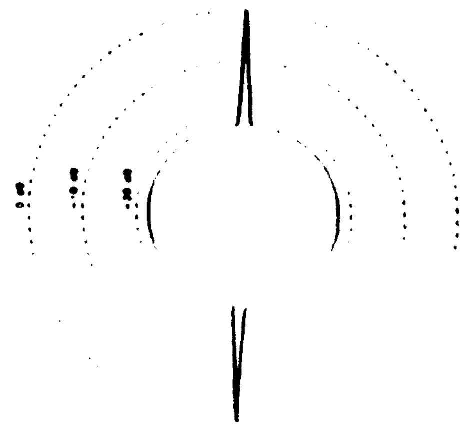


(a)

CW @ 300 Hz

(b)

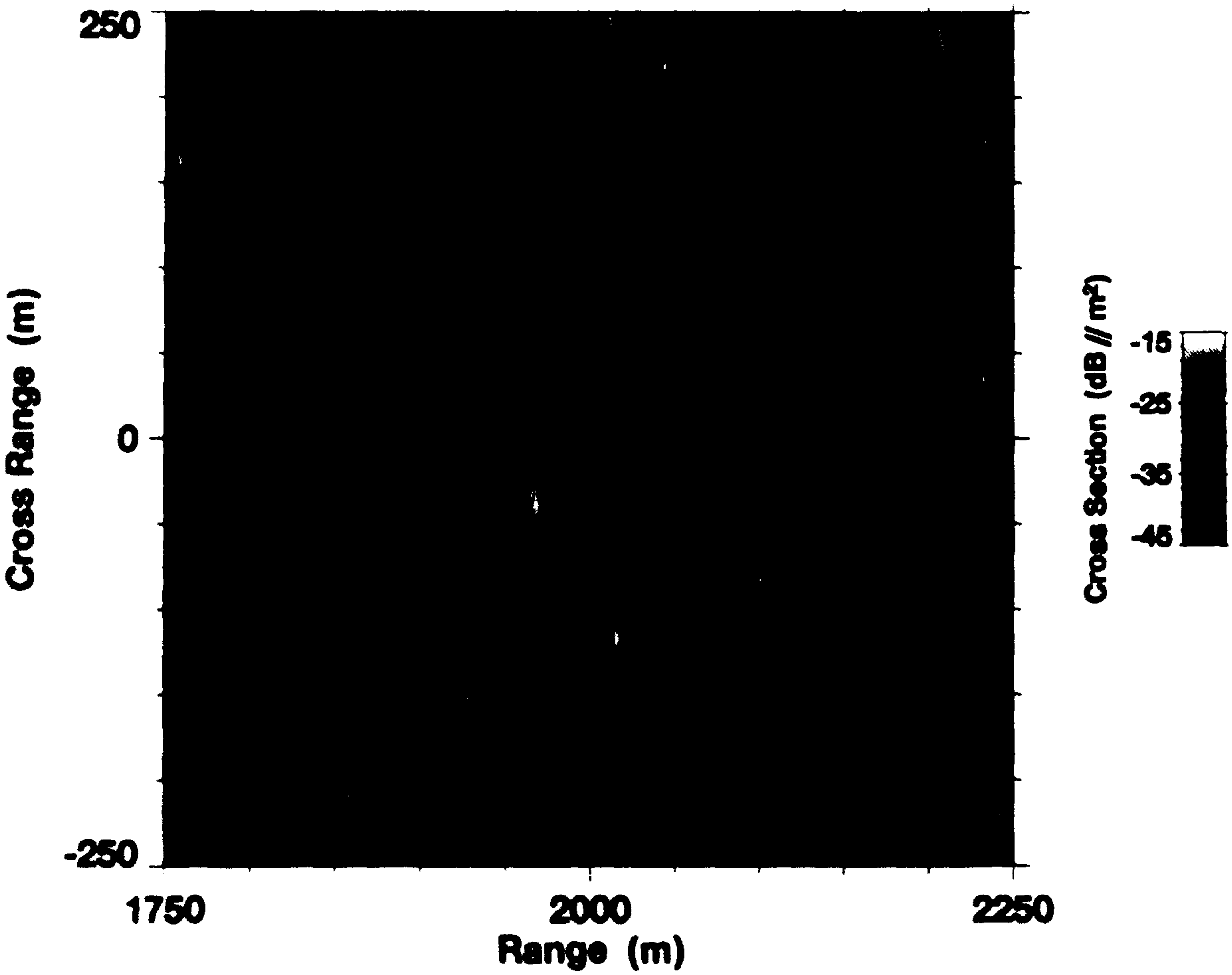
100 - 1500 Hz @ t = 0



(c)

	(a)	(b)	(c)
3 dB Beamwidth	9.5 deg	Ambiguous	1.4 deg
Sidelobe Level	-22 dB	-22 dB	-22 dB

CST7 Surface Reverberation
14 m/s Wind, Sea State 5

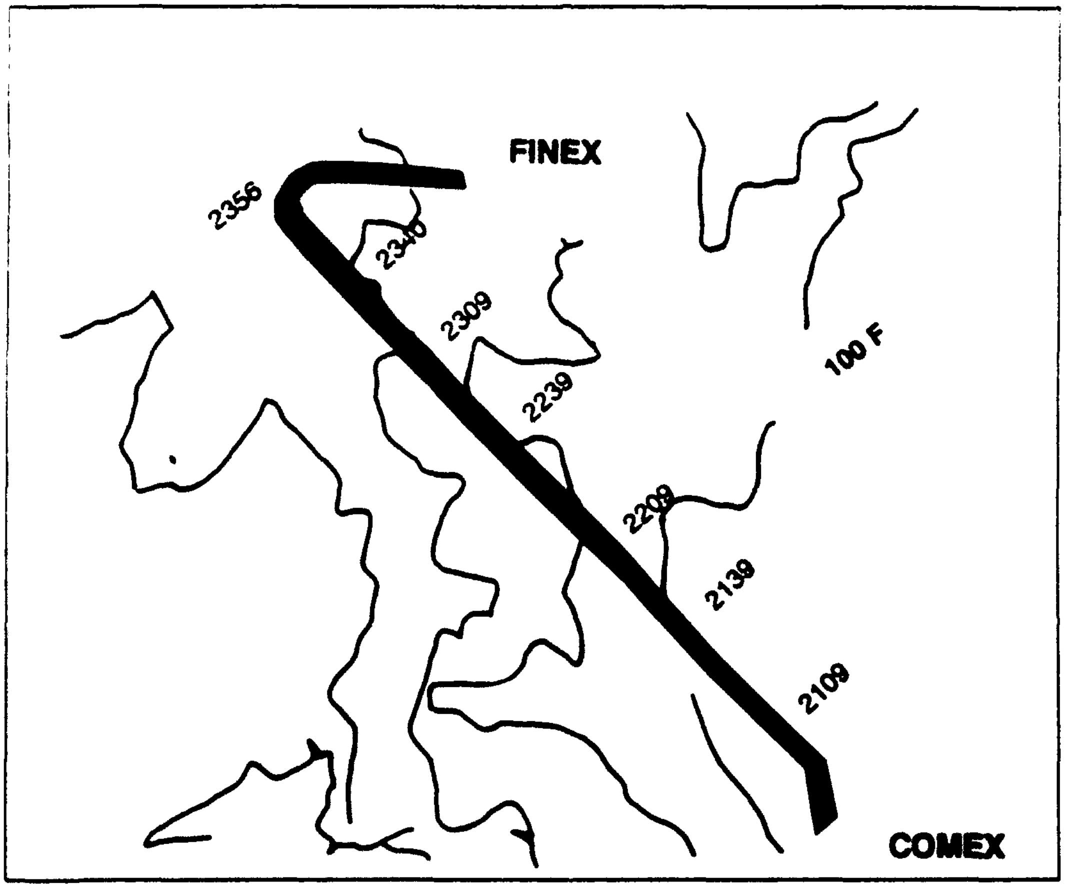


Tue Apr 13 13:38:16 1993

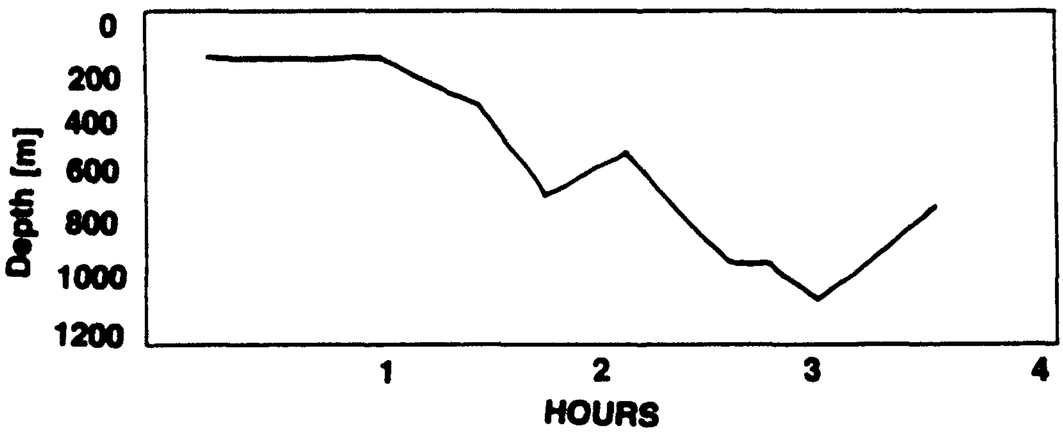
~debbie/adair/s12b04rv.ps

CST-7 PHASE 3 RUN 21A

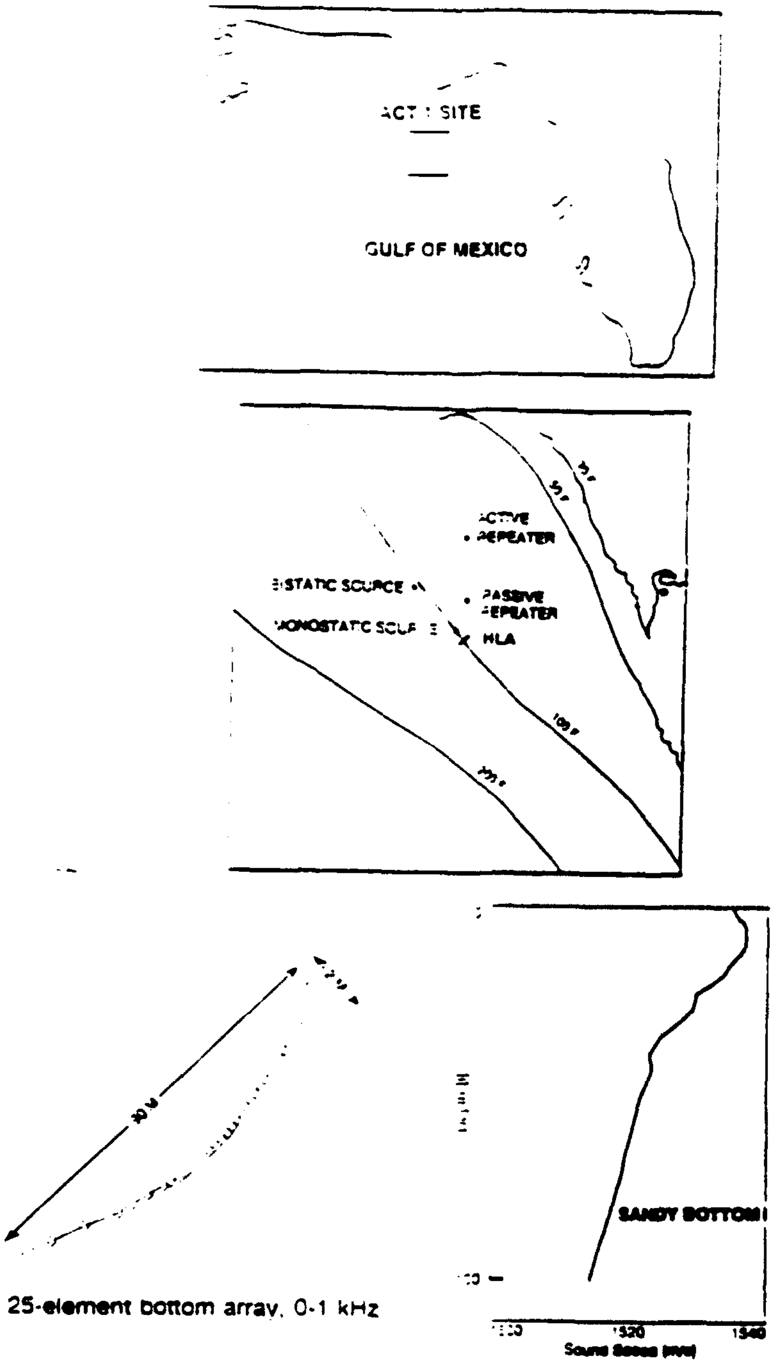
RUN TRACK



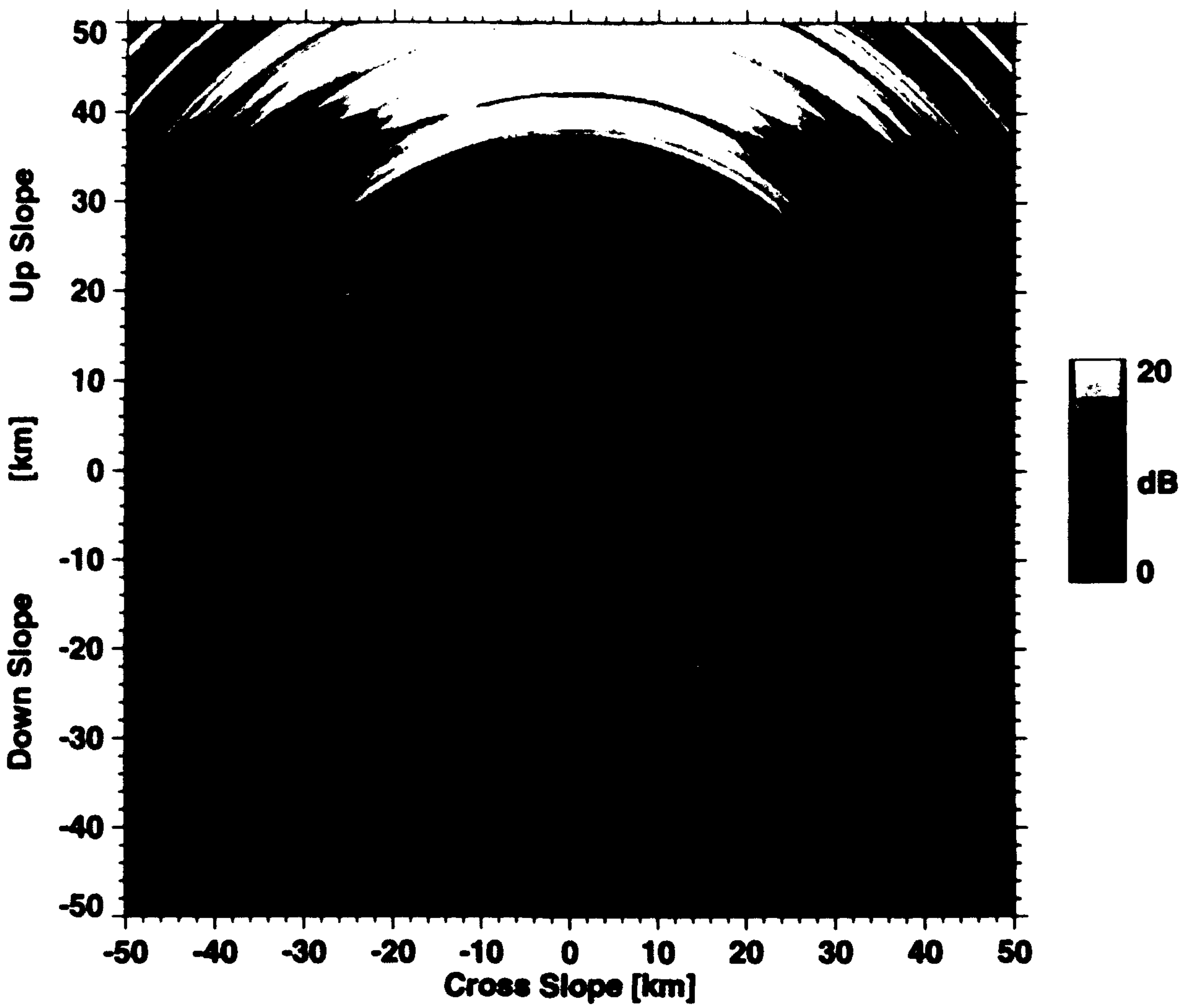
DEPTH TRACK



DARPA ACT 1 CONFIGURATION



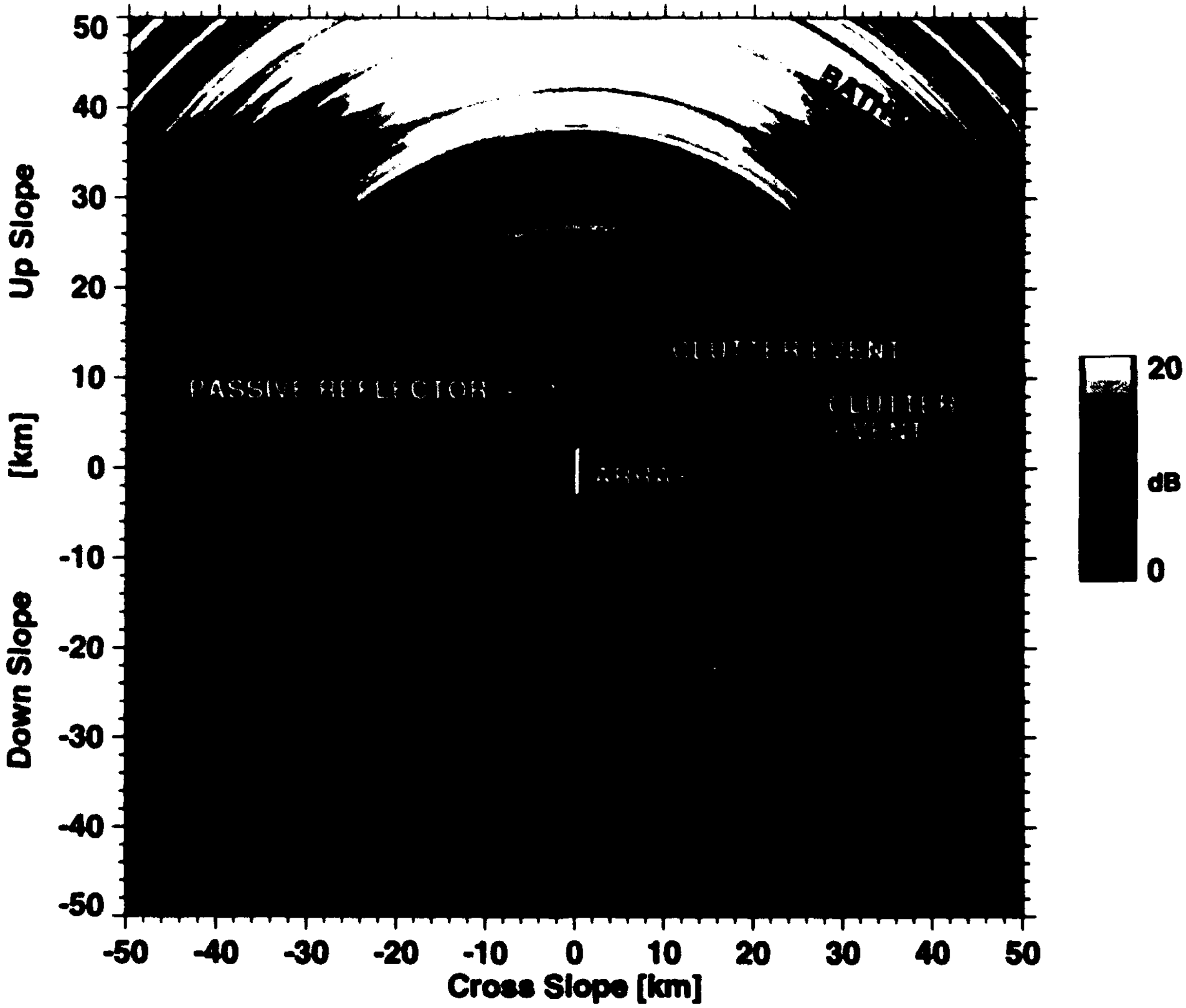
DARPA ACT1 TEST
WIDEBAND SCATTERING
30-400HZ



Fri Dec 11 20:09:50 1992

ONT3bw.ps

DARPA ACT1 TEST
WIDEBAND SCATTERING
30-400HZ



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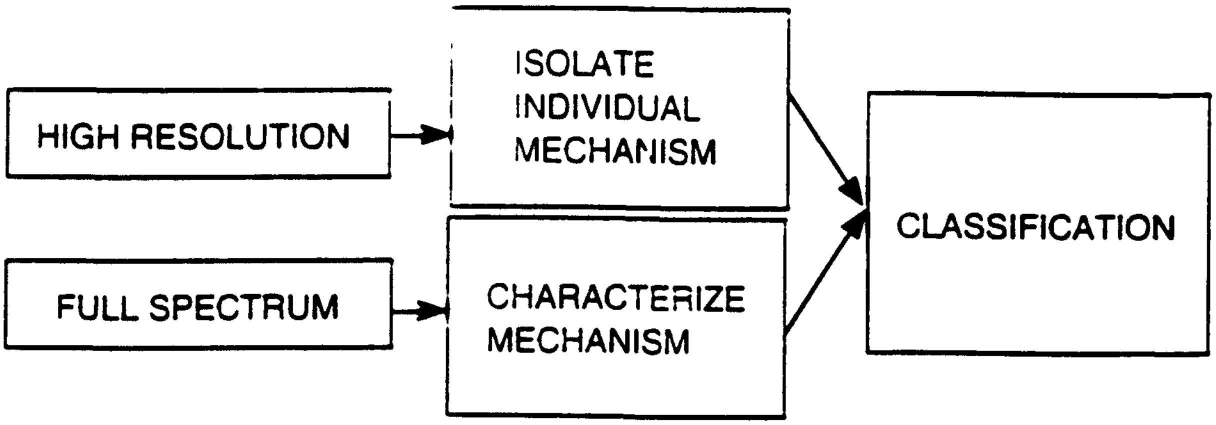
FULL SPECTRUM FOR CLASSIFICATION

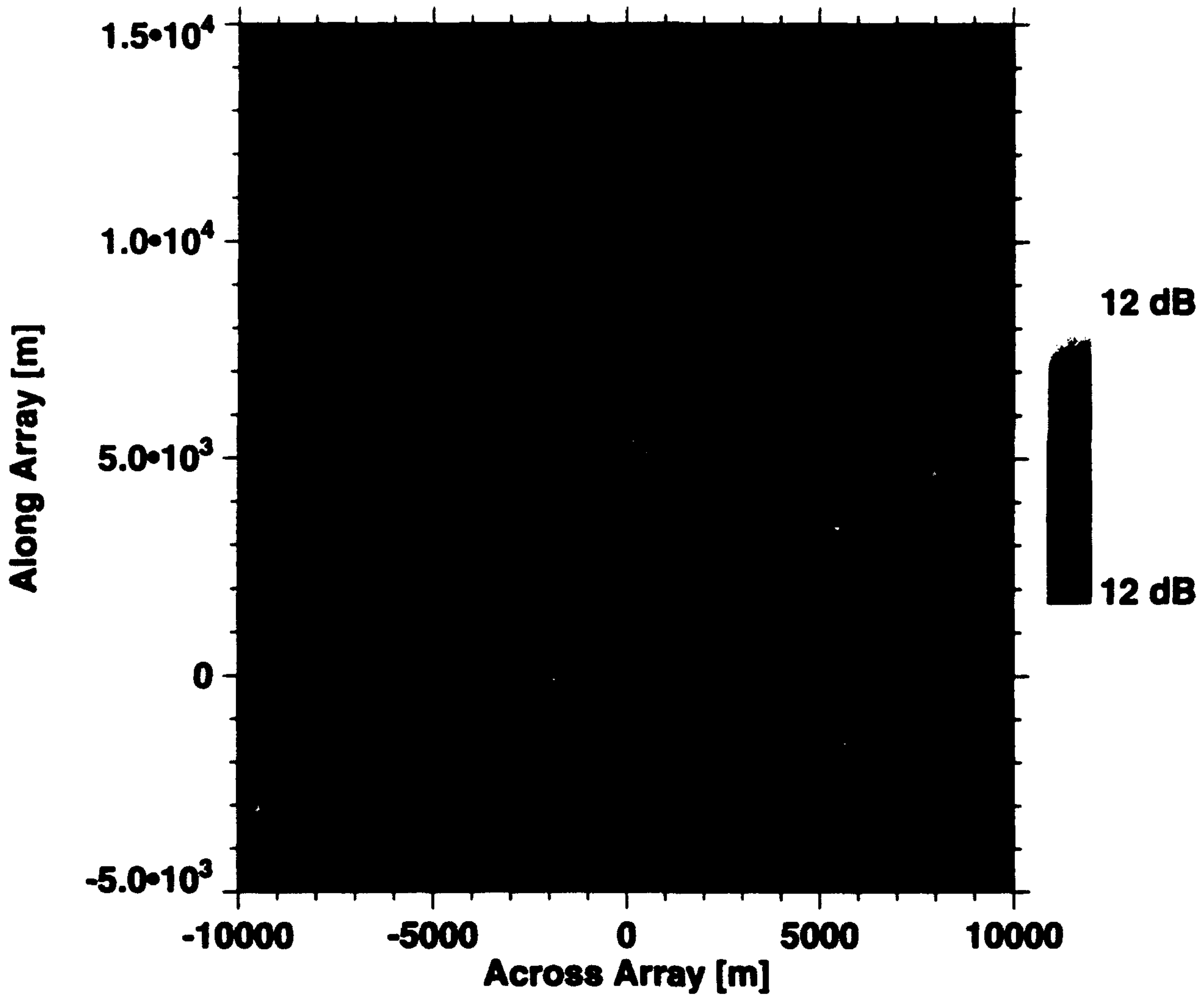
Potential contacts should have distinguishing spectral characteristics



Scattering Process	Characteristic
sub-bottom features	low frequency
bottom interface	reflects bottom correlation scale
biologics	Rayleigh scattering and swim bladder resonance
near-surface bubbles	reflects plume details
data glitches	"white noise"
targets	reflects complex elastic structure

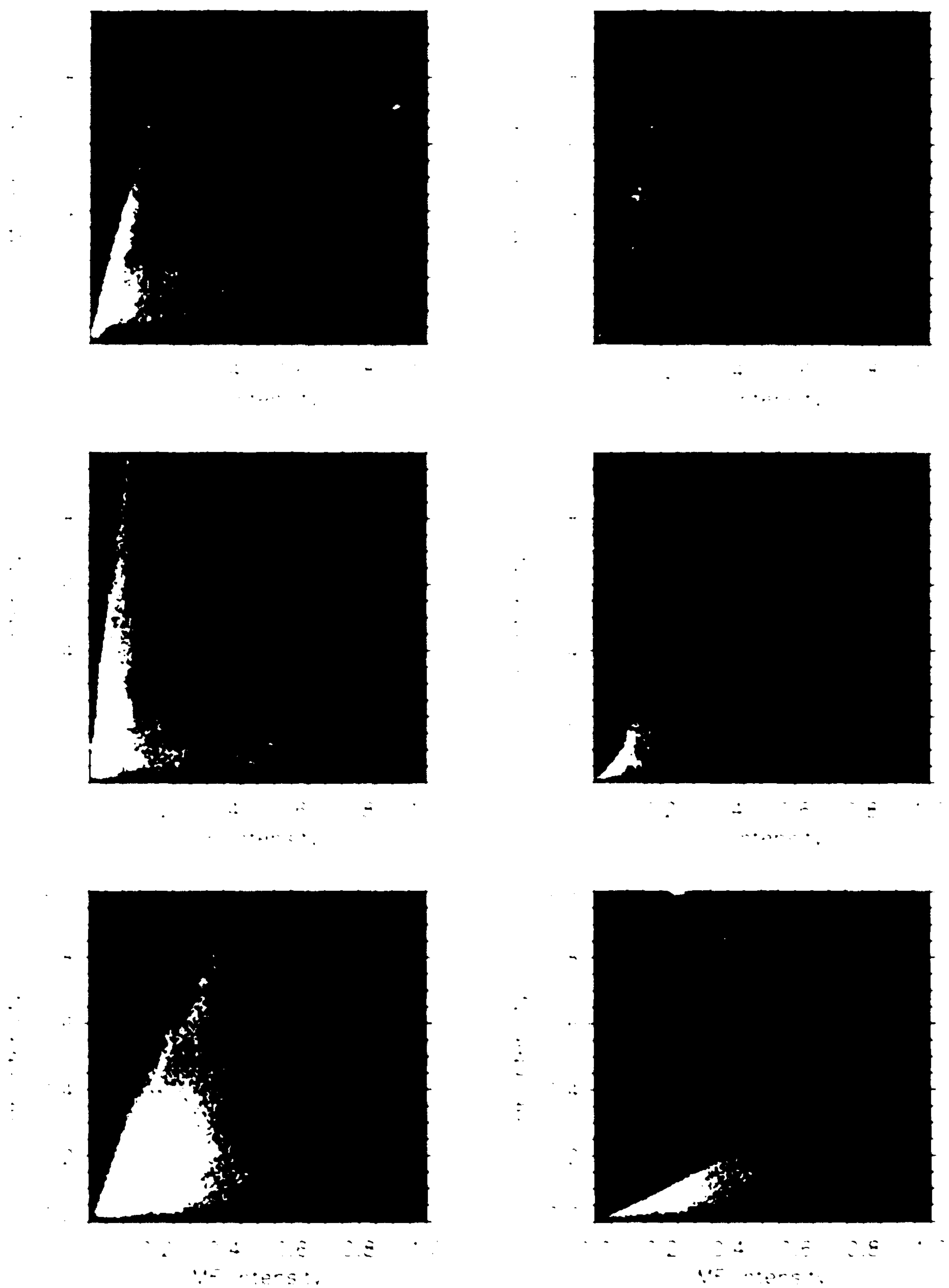
TWO-SIDED BROADBAND IMAGING

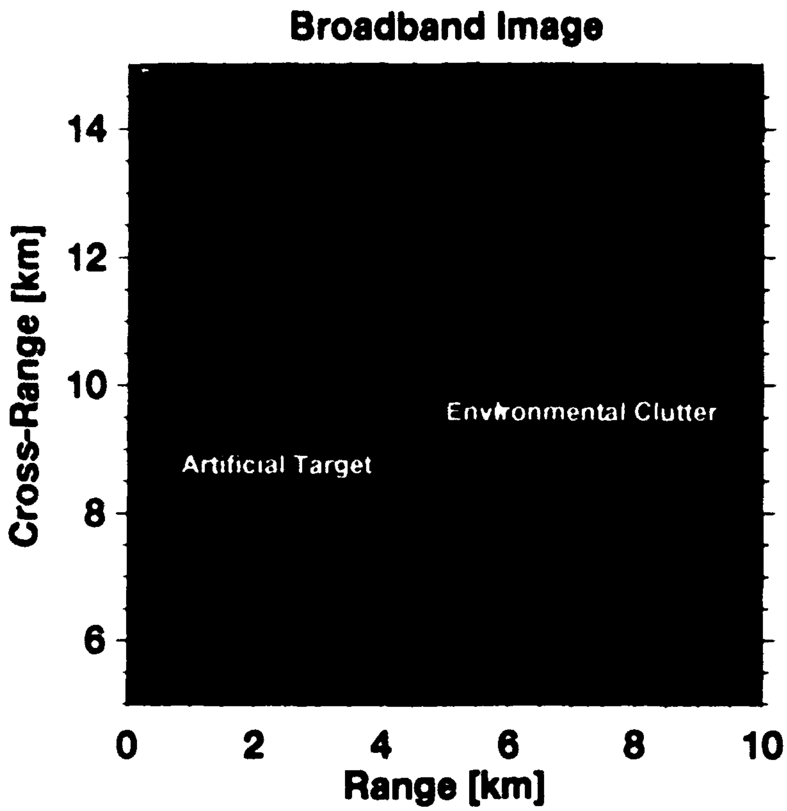
UNDOA on Left, False Alarm on Right

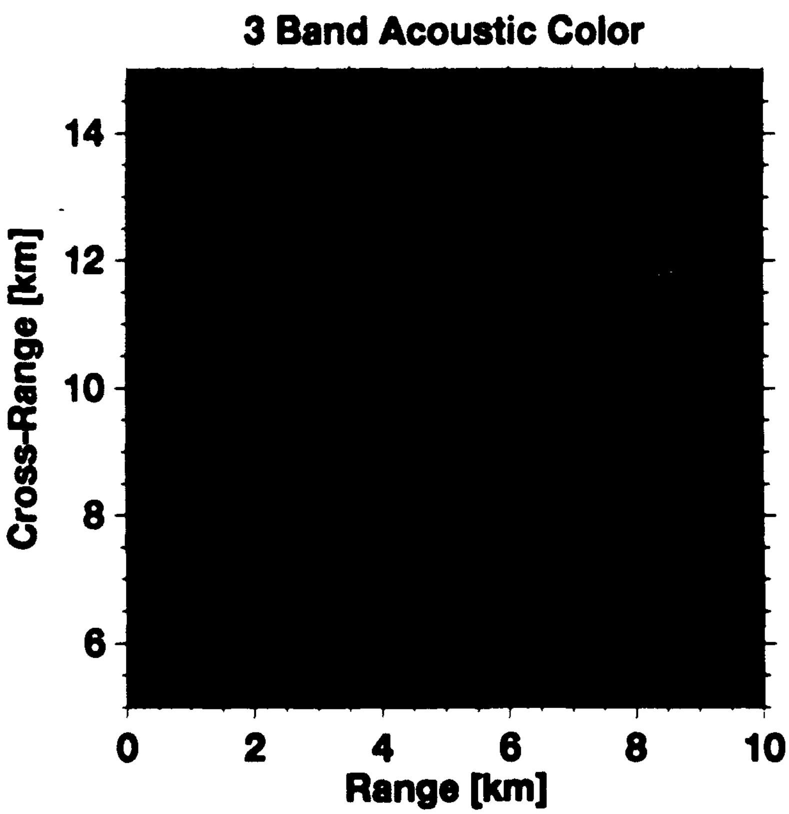


Wed Oct 28 08:07:25 1992

Shot: mr1h6







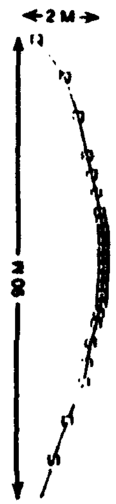
plot2.ps

Figure 4 Two scattering events with similar spatial structure which can be classified using their spectral content. Data from ARPAs ACT I Gulf of Mexico Test.

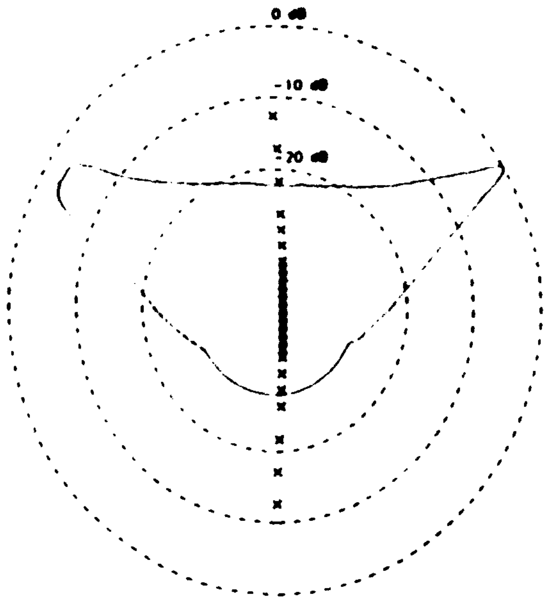
EXAMPLE OF LEFT-RIGHT AMBIGUITY RESOLUTION WITH WASPS

Active: 100 - 400 Hz

Array Asymmetry

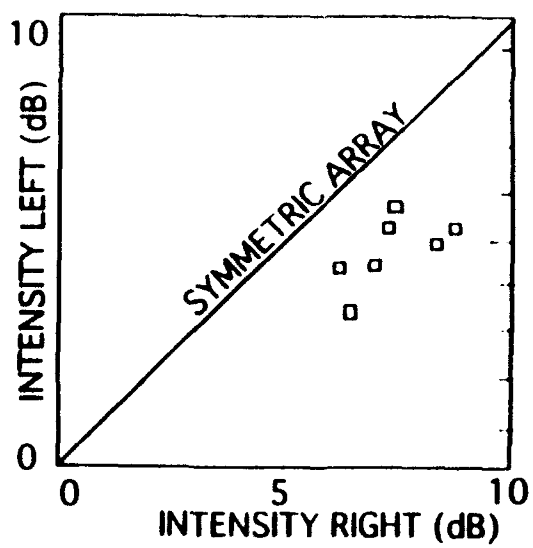


Two-Sided Beampattern

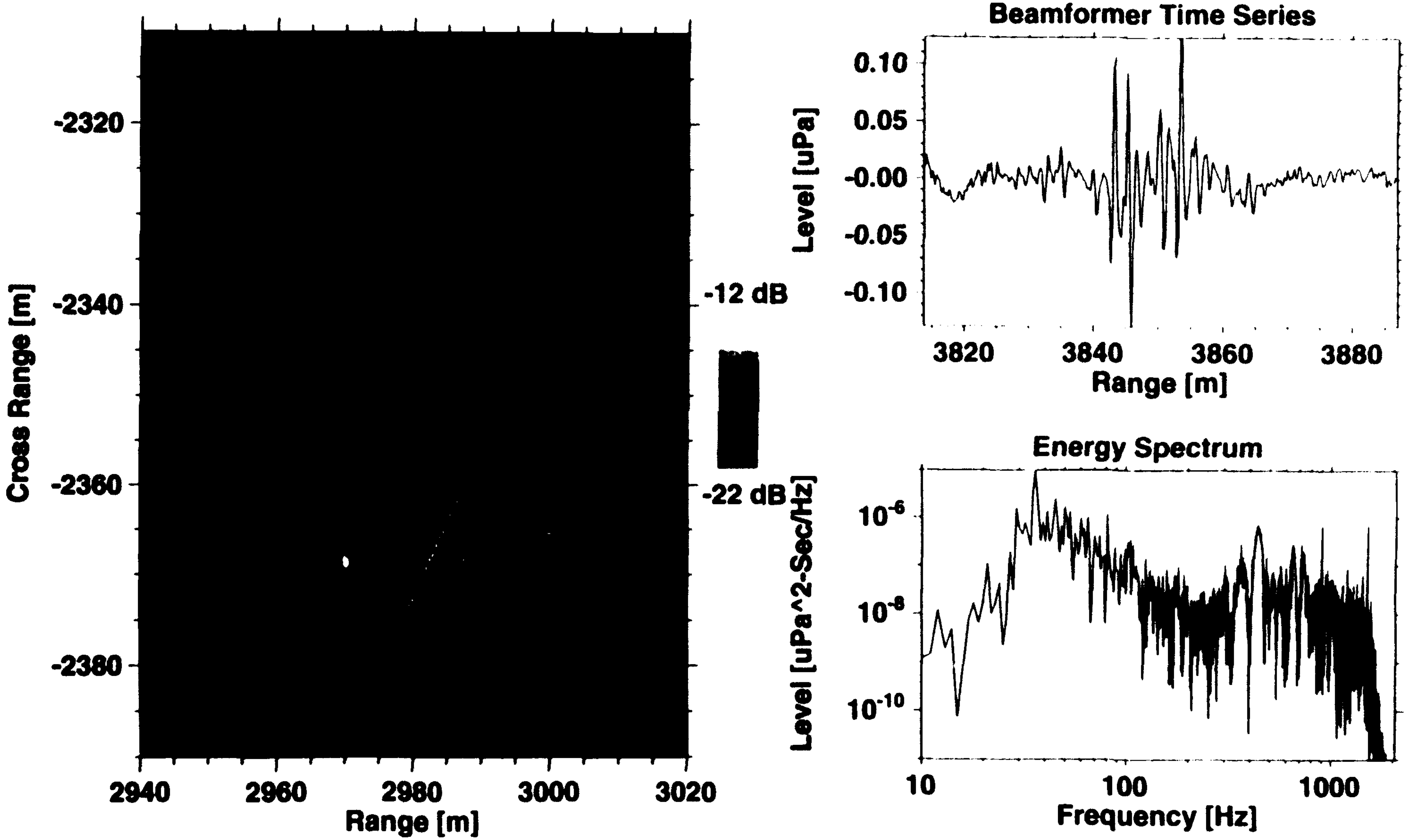


Left-Right Resolution of Clutter Event at 26 km

□ peak intensity for 7 monostatic shots

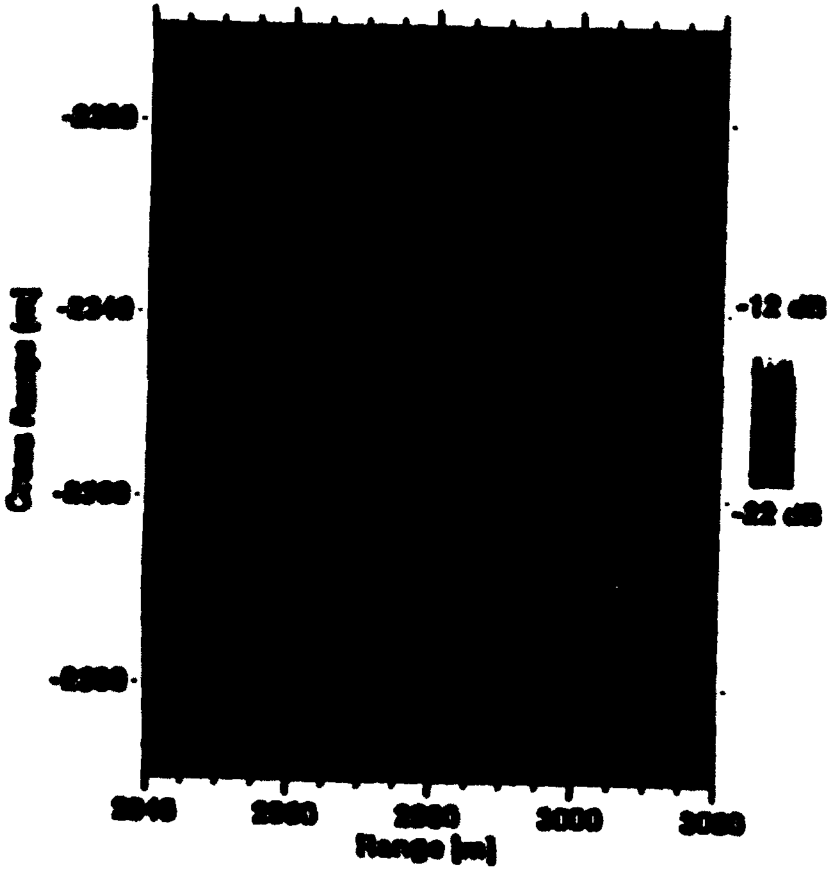


Volume Feature and Associated Multipaths From CST7

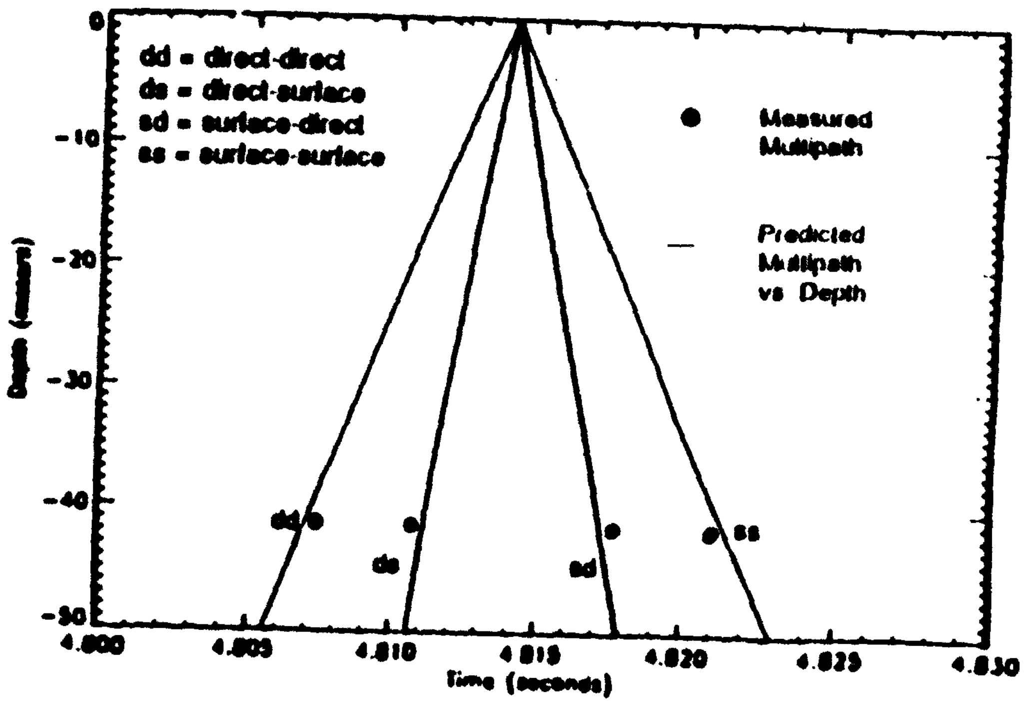


EXAMPLE OF DEPTH CLASSIFICATION BROADBAND LFA

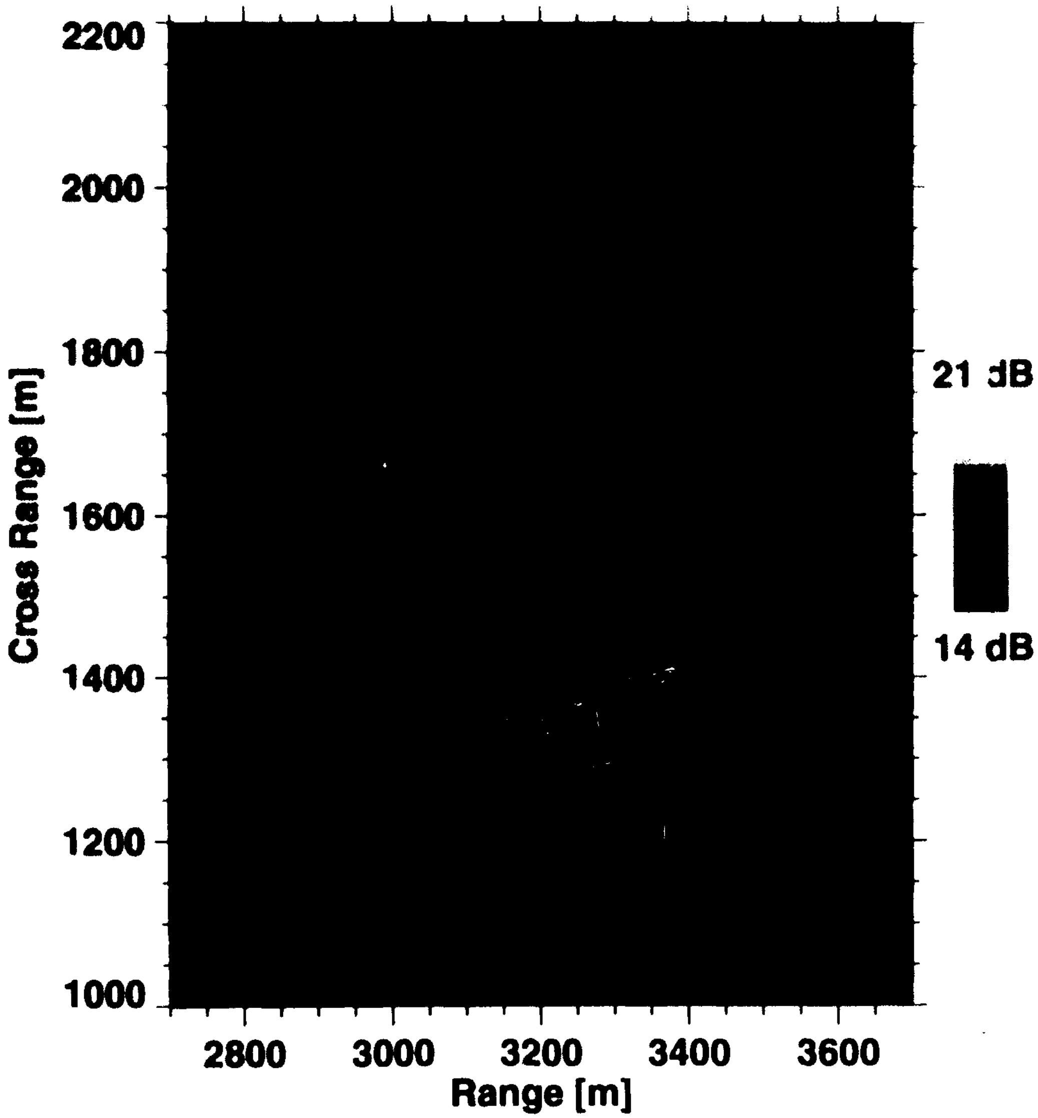
MULTIPATH RESPONSE

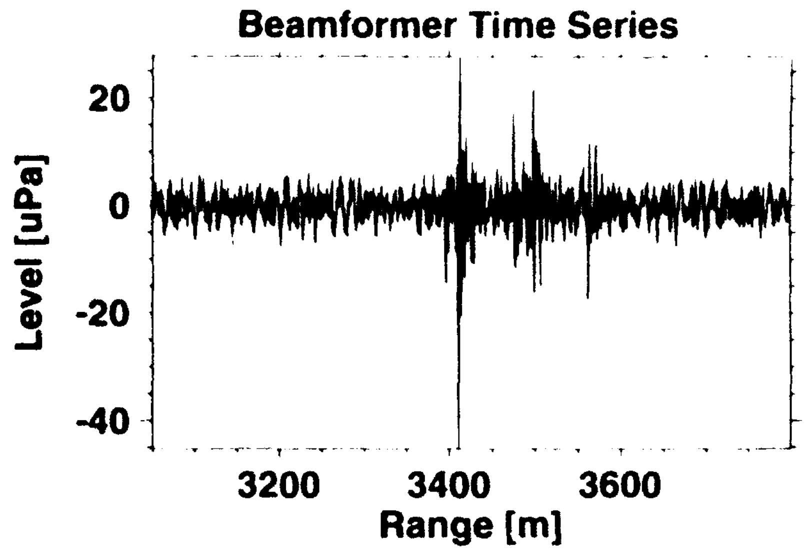


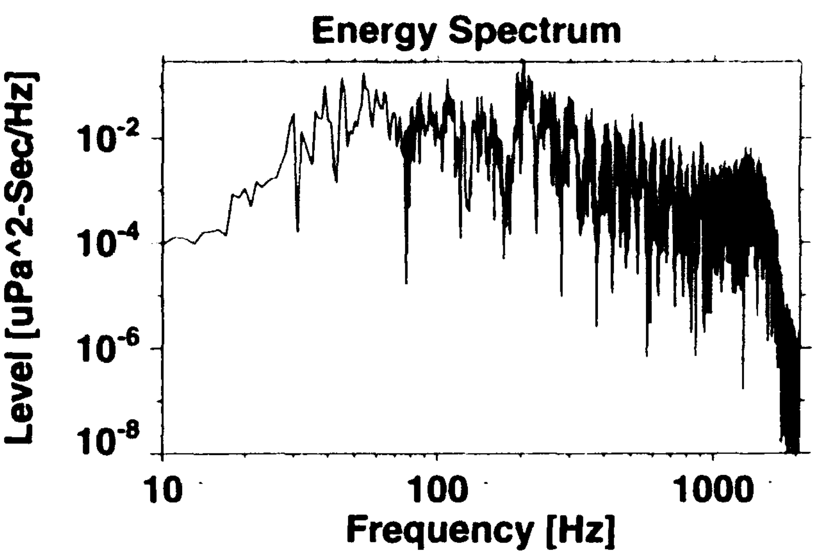
DEPTH LOCALIZATION



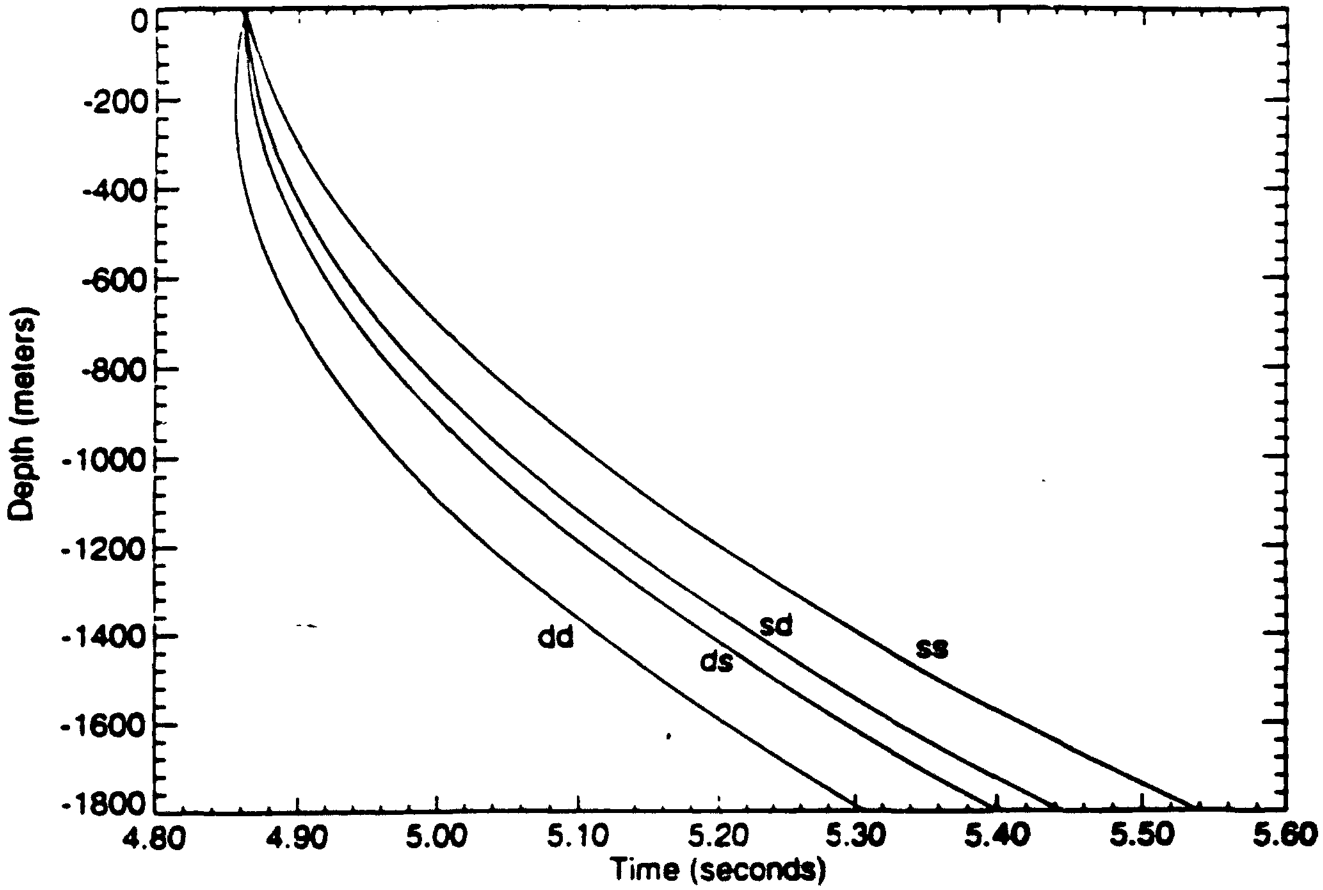
Bottom Feature and Associated Multipaths From CST5



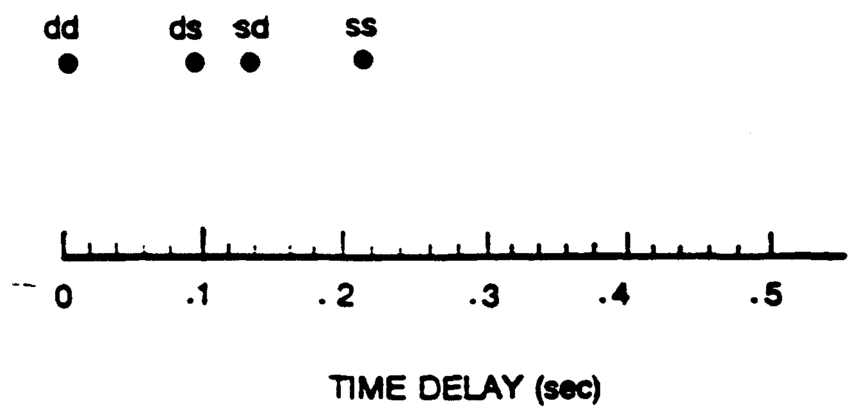




PREDICTED MULTIPATH FOR A CONTACT AT (3050m, 1450m), CST 5



MEASURED MULTIPATH FOR A CONTACT AT (3050m, 1450m), CST 5



CURRENT AND PENDING ARETÉ DATA BASES

Current Data Base

Experiment	Sponsor	Location	Water Depths (m)	Frequencies (Hz)	Comments	Sensor
CST-5	ONR/AEAS	Mediterranean Sea	1000-2000	100-1500	Bottom Features	Horizontal towed array
CST-7	ONR/AEAS	Gulf of Alaska	5000	100-1500	Suface and volume features	Horizontal towed array
CST-7	DARPA	Washington Coast	150-500	100-1500	Bottom Features	Horizontal towed array
Broadband Transmission	Martin Marietta	Santa Cruz Range	300-800	500-5500	Bottom and surface reflection	Vertical array
Dolphin Target	ONR, Martin Marietta	San Diego Coast	100-3800	100-6000	Bottom loss, backscattering and features	vertical array
ACT-1	DARPA	Gulf of Mexico	50-400	50-2000	Long-range bottom interaction	Bottom horizontal and vertical arrays

Pending Data Base

Experiment	Sponsor	Location	Water Depths (m)	Frequencies (Hz)	Comments	Sensor
CST-7	DARPA	Washington Coast	150-2000	100-1500		SQR-19 towed array