

BROADBAND USW PROCESSING WORKING GROUP

1ST MEETING RESULTS, COMMENTS & RECOMMENDATIONS

Randy K. Young
Leader, Broadband USW
Processing
Working Group

The Pennsylvania State University
Applied Research Laboratory
PO Box 30
State College, PA 16804
(814) 863-4499 rky1@psu.edu

Nancy Harned
ONR 321US Sponsor

Program Manager: Active USW
Processing
800 North Quincy Street
Arlington, VA 22217
(703) 696-4758
harnedn@onrhq.onr.navy.mil

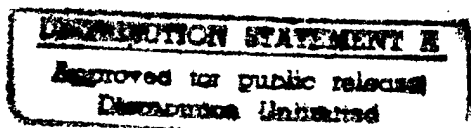
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Applied Research Laboratory

The Pennsylvania State University

State College, PA



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Meeting Minutes from the Broadband USW Processing Working Group

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SUMMARY

On June 12-13, 1996, ONR's Broadband Undersea Warfare Processing Working Group convened its first meeting at The Pennsylvania State University's Applied Research Laboratory. Approximately 30 attendees interacted, discussing the value, status and issues associated with broadband processing for USW. The SYSCOMM, sponsor, laboratory and academic communities were all represented. Discussions ranged from existing operational systems to abstract theory. The attached minutes and results are a product of the entire group and represent the group's initial recommendations.

The focus of the working group was to identify the *potential payoffs of broadband sensing/processing/modeling*, quantify the value-added (or potential value added) by each broadband payoff, determine the status of realizing each payoff, the references associated with its realization, and the issues that must be resolved for practical Fleet utility. The primary documented result of this initial meeting is this list of payoffs and the information associated with each payoff. This list is included as 14 "slides". The intent of these spacious slides is to have reviewers/attendees amend/supplement these slides with their ideas, comments and feedback.

Obviously, other non-documented products of the working group included the interactions between the diverse group members and a new "awareness" between these diverse communities. The stated ONR objectives of the working group (listed in the attached ONR321US presentation) were satisfied. The resulting list of payoffs are in prioritized order (relative to the opinions of our working group only!) and the status of each of these payoffs will help focus future efforts. Due to these successes, the working group will continue to exist and will likely expand its membership and its association with related working groups (a wide consensus of the working group was the requirement to incorporate broadband environmental and sensor information into the broadband processing concepts).

Coordination with related working groups is on-going, attendees continue to interact and provide references and other information, new members have been recommended, and broadband sensing, processing and modeling concepts continue toward Fleet utility. The next Broadband USW Processing Working Group meeting will likely convene prior to the end of 1996 due to the heightened interest and demand for broadband processing. For further information on the Broadband USW Processing Working Group, please contact one of the authors.

ONR 32's Broadband USW Processing Working Group

June 12 & 13 at

The Applied Research Laboratory (PSU/ARL)
The Pennsylvania State University, University Park, PA

Motivations/Deficiencies: Broadband processing is beginning to be more intensely researched by a diverse USW S&T community. Previous broadband processing research efforts were often limited by the immense processing required for its implementation. As computing capabilities have soared and narrowband processing has approached its theoretical limits, broadband processing has become a primary direction for further USW processing gains. By leveraging the basic research in broadband processing common to USW and other diverse applications, a Broadband USW Processing Working Group can efficiently and rapidly educate the USW community and focus/prioritize the broadband processing issues unique to USW. Coordinating these diverse efforts and fusing them with current USW needs and requirements will create a more consistent and rapid understanding of broadband processing concepts, issues, and current status, benefiting the entire USW S&T community.

Approach: The Processing Working Group would hold several technical meetings throughout the year to discuss issues spanning broadband processing: theories, definitions, fundamental processing limitations (environmental/target/sensor effects included), simulations, implementations, etc. These meetings will emphasize the *generally applicable, abstract broadband processing concepts* that are common to the diverse applications and concentrate their applicability to USW problems. Culmination of these interactions would result in multiple joint reports and papers.

USW Broadband Processing Working Group Membership (Target initial group size is 20):
ONR, PEO-USW and related Navy sponsors with on-going or proposed broadband processing programs will provide a program representative(s). To reduce the management overhead and maintain focus on the underlying, abstract, common features of broadband *processing* (not associated issues), the *initial* membership in the working group will consist of researchers currently under contract to perform broadband *processing* research and/or implementation (as well as their Navy sponsors). Additional, "adjunct," members that perform broadband processing outside of the USW application may be consulted and invited to speak to the group as appropriate, such as spread spectrum experts, etc. Obviously, it is intended to grow the membership in this working group in the future. Potentially subgroups will be created for environmental/target/sensor effects (beyond processing).

POC: Nancy Harned, ONR 321US, Program Manager of Active USW Processing....

Applied Research Laboratory
The Pennsylvania State University

ONR's
WIDEBAND USW PROCESSING WORKING GROUP
June 12-13, 1996
ARL's New Building Auditorium

June 12, 1996

8:30	WELCOME & ORIENTATION	Dr. Randy Young
8:45 - 9:15	ARL/PSU OVERVIEW	Dr. Edward G. Liszka
9:15 - 9:30	WORKING GROUP'S CHARGE	Nancy Harned, ONR 321US
9:30 - 12:00 (break included)	BROADBAND DETECTION - 1	Motivation/Payoffs/Ultime Goals Current Status/References Issues - Specific & Quantified
1:00 - 2:00	BROADBAND DETECTION - 2	Prioritization New Term Goals/Approach
2:00 - 5:00 (break included)	BROADBAND CLASSIFICATION	Motivation/Payoffs/Ultime Goals Current Status/References Issues - Specific & Quantified Motivation/Payoffs/Ultime Goals Current Status/References Issues - Specific & Quantified

June 13, 1996

8:30 - 8:45	COMMENTS & FEEDBACK	Nancy Harned, Randy Young
8:45 - 11:30 (break included)	BROADBAND LOCALIZATION	Motivation/Payoffs/Ultime Goals Current Status/References Issues - Specific & Quantified Motivation/Payoffs/Ultime Goals Current Status/References Issues - Specific & Quantified
1:00 - 3:00	DISCUSSION, CONCLUSION, FEEDBACK & PLANNING Other issues, such as Environmental & Target Modeling & Characterization	
3:00	CHARGE TO WORKING GROUP	Nancy Harned, ONR 321US

Wideband Processing Working Group Attendees

Last Name	First Name	Registered	Company Name	Work Phone	Fax Number	Email/Address
Altes	Richard	Yes	CHIRP Corp	(619) 453-4406	(619) 453-4406	
Barton	Bob	Yes	NUWC	(860) 440-5253		barton@vsdec.nl.nuwc.navy.mil
Campbell	Rick	Yes	PEO-USW	(703) 604-6013	(703) 604-6056	campbell-richard@hq.navsea.navy.mil
Chang	Weita	Yes	NUWC	(860) 440-5946	(860) 440-6571	chang@vsdec.nl.nuwc.navy.mil
Dial	Kenneth	Yes	ONR	(703) 696-0806		dialk@onrhq.onr.navy.mil
Harned	Nancy	Yes	ONR	(703) 696-4758		harnedn@onrhq.onr.navy.mil
Hillsley	Ken	Yes	ARL/PSU	(814) 863-4379		kih@sparcy.art.psu.edu
Jackson	Pam	Yes	NRL/Stennis	(601) 688-4782	(601) 688-5341	pmjackson@nrlssc.navy.mil
Jacobi	Les	Yes	ONR	(703) 696-7021	(703) 696-8423	jacobil@onrhq.onr.navy.mil
Milklovic	Don	Yes	AETC	(619) 450-1211	(619) 450-1794	dmilklovic@aol.com
Novik	Arnie	Yes	PEO-USW	(703) 604-6011	(703) 604-6056	missionsci@aol.com
Pitt	Pat	Yes	ARL:UT	(512) 835-3513		pitt@arlut.utexas.edu
Polcari	John (CDR)	Yes	PEO-USW	(703) 604-6011	(703) 604-6056	
Sands	Scott	Yes	NUWC	(860) 440-6849	(860) 440-6571	sands@vsdec.nl.nuwc.navy.mil
Sibul	Leon	Yes	ARL/PSU	(814) 863-0312		lhs2@psu.edu
Smigel	John	Yes	Lockheed-Martin	(315) 456-1425	(315) 456-1430	johns@spcf.syr.ge.com
Smith	George	Yes	NRL/Stennis	(601) 688-5892		george.smith@nrlssc.navy.mil
Symons	Frank	Yes	ARL/PSU	(814) 865-7505	(814) 865-7097	fws2@psu.edu
Tattersall	Matt	Yes	NUWC	(860) 440-5771		tatter@twizzle.nl.nuwc.navy.mil
Titlebaum	Ed	Yes	Univ. of Rochester	(716) 725-4061	(716) 275-2073	tbaum@ee.rochester.edu
Young	Randy	Yes	ARL/PSU	(814) 863-4499		rky@enterprise.art.psu.edu



BROADBAND SYSTEMS: THE FUTURE OF NAVY ASW OPS

- **Operation in harsh littoral environments requires more robust systems**
- **Smaller, quieter, slower targets are difficult to detect using conventional narrowband processing**
- **Broadband source technologies are maturing**
- **Near-future Navy Broadband systems**
 - LBVDS
 - EER/IEER
 - LELFAS



BROADBAND PROCESSING WORKING GROUP OBJECTIVES

- **Discuss broadband processing issues for applications to future Navy systems**
- **Focus & prioritize issues for further research**
- **Provide opportunity for coordination and cooperation**
- **Form the foundation for future working group meetings (semi-annual)**



BROADBAND PROCESSING WORKING GROUP ORGANIZATIONS REPRESENTED

- **ONR**
- **PEO-USW (ASTO)**
- **LBVDS program**
- **ONR-sponsored 6.2 Active Signal Processing projects**
- **Other interested signal processing experts**



BROADBAND PROCESSING WORKING GROUP GROUND RULES

- **Open forum to facilitate exchange of ideas**
- **No funding decisions are on the line**
- **No formal presentations**
- **Randy Young - moderator (not lecturer)**

BROADBAND/WIDEBAND PROCESSING

- What are wideband signals? Wideband processing?
Wideband systems?
- Why are they used, needed or even considered?
- Why consider them now?
- What are their payoffs?
- What can we do? What can't we do? Status
- What do we need to do?

WIDEBAND SIGNALS/SYSTEMS

- “Large” bandwidths. Relative to what? center freq, tone,...
- Coherent -vs- noncoherent broadband
- Impulsive -vs- coded signals
- Spread spectrum signals
- Images, speech, noise, ... examples
- Time-varying systems - create broadband signals (tone inputs)
- Create new frequencies (nonlinear) - typically more freqs
- Change freq content - time scaling (compression/dilation)
- Processing that operates on broadband signal/systems or models
broadband signals/systems are considered “wideband proc.”

BROADBAND PROCESSING EXAMPLES

- IMPULSIVE:

 - Ultrasound

 - Biomedical

 - Material imaging

 - Radar (impulse versions)

 - Communications (impulse)

- COHERENT BROADBAND

 - Spread spectrum communications

Wideband USW

Processing

Motivation

Payoffs

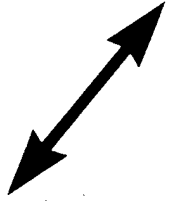
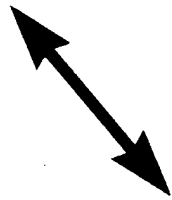
Algorithms

Quantifications

External Requirements



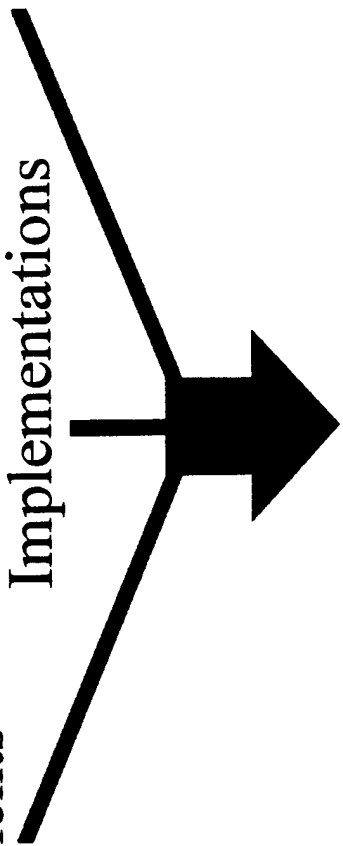
Under "ideal" conditions, what is the processing that we would do and how would it help?



Broadband
Environmental
Models/Experiments

Broadband
Target/False Target
Models/Experiments

Efficient
Implementations



Fleet USW Systems

12 June 1996, New Building Auditorium

Action Items for the Broadband Undersea Processing Working Group

1. Mutual interference, which is associated with broadband processing, is a critical issue that must be examined.
2. Build balanced surface active sonar systems for surface ships. In the next decade, the focus will be on quieting surface ships cheaply by using technologies from the submarine community. LPI (low probability of intercept) is an essential issue.
3. The future of broadband sources lies in the spreading out of the spatial distribution of sources and in multiple sources.
4. Broadband capabilities are still unproven, so more research is needed to define the technical potential.
5. Two approaches support target categorization. The first, which was developed by Dave Nelson in the area of hydrodynamics, establishes a series of point targets. The second focuses on the dispersive effects of submarines through a frequency analysis. In this approach, frequency sweeps and dispersive effects are clearly seen and provide strong evidence.

Performance Quantification

6. Compare our techniques against EER as a baseline.
7. Generate measures of effectiveness.
8. Enunciate the requirements for broadband modeling.

Questions from Commander John Polcari (USN)

1. How do we maximize the 'S' in SNR?
2. How do we minimize the 'N' in SNR?
3. How do we suppress the tails of the 'N' distribution?
4. What's the "right" transmitted waveform?
5. What's the "right" approach to spatial source/receiver diversity?
6. How do we properly address target motion?
7. How do we properly address source/receiver motion?
8. How do we properly address motion of the medium?
9. What approaches for fade/glint resistance?
10. What environmental parameters must be known to "stabilize" the target return?
11. How do we get a handle on these parameters?
12. What multipulse strategies?
13. What strategies can be used to maximize the data rate?
14. What is the "right" approach to spatial aspects of the processing problem, particularly for receivers?
15. In the broadband problem, what is the level of interaction between the spatial aspects and the processing?

Detection — Broadband Enhancement Classification and Localization

Motivation/Goal

1. Low Doppler target
2. Resolution gains – target frequency response/target reconstruction/overresolution/narrower beams
3. Fading resistance – "Brush" filter multipath

Payoffs

Quantified/baseline

1. Reverberation reduction

- Interoperability
- Sparse array (fewer sensors)
- High–rate probing/multi-ping
- Resolution gains for environmental robustness
- Doppler beam sharpening
- Energy gains—time bandwidth
- Covert/LPI active
- Environmental characterization utility of broadband

Approach/Status

- Cite signal processing techniques
- References [Communication theory textbook – Dick Altes needs to provide reference]
- [Leon Sibul will provide specific references on using broadband in conjunction with spatial processing]
- [Cite reference on optimum 'S' –D. Ricker]
- [Don Miklovic can provide references on the nonadaptive beamformer]
- [Don Miklovic noted that Lockheed Martin has data sets – who will provide?]
- [Don Miklovic will provide SACLANT Center data, and he said a journal article was based on this data set]
- [Matt Tattersall mentioned the NUWC data set, but said nothing's ever been done with it]
- [Don Miklovic will provide a set of 100 charts]
- [LLDS data should be made available]

Issues

1. How do we maximize the 'S' in SNR?

The working group discussed how to optimize 'S'. As explained by Dr. Ricker, one technique is to optimize the receiver, but keep the transmitter the same. By focusing on the receiver's design (where power is the only constraint), the signal is optimized. But Dr. Young noted that many assumptions about optimal situations exist. Commander Polcari asked if a broadband receiver were built, which arrays should be chosen.

At this point of the meeting, our emphasis is shifting to broadband processing payoffs and the issues associated with realizing these payoffs.

General Broadband Processing Issues for Each Payoff

- Medium broadband coherences/losses
- Target response structure
- Processing requirements
- Source coherence
- Target response at all bandwidths
- Theory v. practice
- Coherent v. incoherent broadband noise
- Broadband-"anything" definitions
- Payoff v. cost
- Can you substitute bandwidth for spatial aperture?
- Sufficiency of data
- Mismatch between the assumptions and reality
- Over what regions are these assumptions valid?

Reverberation Reductions (Highest Priority)

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • Pulse compression (resolution) 		<ul style="list-style-type: none"> • Realize?? 	<ul style="list-style-type: none"> • Graduate students under: <ul style="list-style-type: none"> —Dick Altes —Ed Titlebaum —Leon Sibul —Dennis Ricker 	<ol style="list-style-type: none"> 1. Does resolving the reverb. field hurt or help? And when?
<ul style="list-style-type: none"> • Incoherent reduced Variance — Diversity 	<ul style="list-style-type: none"> • Environmental Detection 		<ul style="list-style-type: none"> • Broadband 53C —Ed Titlebaum 	<ol style="list-style-type: none"> 2. Coherent pulse compression (high time bandwidth) —channel coherence support
<ul style="list-style-type: none"> • Min $[S^{1*} A_{sig}]$ Reverb —WSSUS —Specular 	<ul style="list-style-type: none"> • Signal design and environmental estimation —Deconvolve 			<ol style="list-style-type: none"> 3. Target coherence 4. Source coherence —Array response 5. WSSUS —invalid

Reverberation Reductions (Highest Priority) Cont.

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • Spatial Diversity (Broadband) 	<ul style="list-style-type: none"> • Multiple sensors • Spatial correlation • Ambiguity function 	?	ARL/UW — Spatial Correlation	

Low-Doppler Target Detection

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • Reverb reduction • Range / cross-range • Resolution / motion 	<ul style="list-style-type: none"> • SNR gain • (Mis) Matched filtering • Signal design • Biologically (BASS algorithm) • Twin processor • Operator's audio quality 		<p><i>Newhall waveform</i> <i>(grating lobes in Doppler</i> <i>traded off for ϕ-Doppler</i> <i>resolution)</i></p>	<ol style="list-style-type: none"> 1. Coherence 2. Motion compensation 3. Environmental spreading — multipaths 4. Glint 5. Transmit signals 6. Audio quality — issue unknown

Resolution Gains (Target Reconstruction)

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • Coherent / noncoherent gains (variance reduction) 	<ul style="list-style-type: none"> • Wavelet estimator-correlator 	$ST(x, x^1)??$	<ul style="list-style-type: none"> • L. Sibul 	<ol style="list-style-type: none"> 1. Characterizing structure <ul style="list-style-type: none"> —Spatially —Frequency response of highlights 2. Decouple from environmental response
	<ul style="list-style-type: none"> • Knowing target scattering function 			
	<ul style="list-style-type: none"> • Sequential imaging and RAKE 			
	<ul style="list-style-type: none"> • Temporal target highlight classifier (NUSC) 		<ul style="list-style-type: none"> • Scott Sands provided a reference from NUWC 	

Resolution Gains (Target Highlight Structure)

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • Resolution gains • Pulse compression 	<ul style="list-style-type: none"> • Twin processors (reduce sidelobes) • SCAT (Spectrogram Correlation and Translations) 		<ul style="list-style-type: none"> • Jim Simmons' article 	<ol style="list-style-type: none"> 1. Medium 2. Ping-to-ping consistency
<ul style="list-style-type: none"> • BASS • Broadband monopulse • C^espstrum 			<ul style="list-style-type: none"> • Terry Anderson's work (funded by ASDO) • D. Ricker • Weiner/Turin (ask Dick Altes) 	<ol style="list-style-type: none"> 3. Target/medium/coherence 4. Nonlinear effects 5. SCAT has a problem with ghosts (ref. Jim Simmons)

Resolution Gains (Target's Frequency Response)

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • Acoustic 	<ul style="list-style-type: none"> • Spectral classification 		<ul style="list-style-type: none"> • Don Miklovic 	<ol style="list-style-type: none"> 1. Knowing target frequency response v.: <ul style="list-style-type: none"> — False targets — Environment — CMs
			<ul style="list-style-type: none"> • Pat Pitt 	<ol style="list-style-type: none"> 2. Effect of spatial view (aspect)/depth
	<ul style="list-style-type: none"> • Highlight type classification 		<ul style="list-style-type: none"> • Larry Riddle/ Patrick Flawber ref. (given by George Smith) • (George Smith will provide ref.) 	<ol style="list-style-type: none"> 3. Motion effects — target and sensors
				<ol style="list-style-type: none"> 4. Validity of TAP model (ref. Harry Cox of Orincon — given by Don Miklovic)
				<ol style="list-style-type: none"> 5. Search/adapt stationarity and variability

~~AGABORN~~

Resolution Gains (Target's Frequency Response) Cont.

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
				6. Validity of the geometric theory of different ^V action model (five categories of different test scatters)
				7. Validity of scaled model responses v. full-scale

Reduce Fading and Glint

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • Reduced constructive / destructive interferences 	<ul style="list-style-type: none"> • BRUSH 	<ul style="list-style-type: none"> • L. Sibul 	<ul style="list-style-type: none"> • ref. Dick Altes 	<ul style="list-style-type: none"> 1. Variability / stationarity robustness in estimating multipaths
<ul style="list-style-type: none"> • RAKE 	<ul style="list-style-type: none"> • Diversity <ul style="list-style-type: none"> —Spatial —Frequency —Time 	<ul style="list-style-type: none"> • "Noise Propagation in SW" [Ed Titlebaum read] 	<ul style="list-style-type: none"> • Dennis Ricker 	
<ul style="list-style-type: none"> • Waveform design 		<ul style="list-style-type: none"> • Ben Jones of TRACOR (ref. given by Scott Sands of NUWC) 		
<ul style="list-style-type: none"> • Multipath compensation 				

Enhanced Beamformers *Space time processing*

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> Grating lobe reduction 	<ul style="list-style-type: none"> Don — nonuniform arrays General ambiguity functions <p><i>Adaptive proc.</i> <i>High resolution</i></p>	<ul style="list-style-type: none"> Time delay v. phase 		<ol style="list-style-type: none"> Array design Sensitivities — Spacing, frequency... Position errors Variability Baffle effects Coherent v. incoherent Susceptibility to NB interference

Covert / LPI Operations

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • Spread spectrum signals • Agility • Biological 			<ul style="list-style-type: none"> • Many textbooks describe spread spectrum. (Ed Titlebaum) 	<ol style="list-style-type: none"> 1. How good? 2. The signals are still useful. —Spreading/motion 3. Propagation loss (one-way)

Better Environmental Characterization

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> Excite more modes Probe pulses 				<ol style="list-style-type: none"> Utility of same waveforms and processing for environmental characterization and target DCL
<ul style="list-style-type: none"> Exploit dispersiveness (exploit channel for pulse compression) 	<ul style="list-style-type: none"> CDC Program 	<ul style="list-style-type: none"> Frequency propagation loss —Sustained charges 	<ul style="list-style-type: none"> Bob Barton 	<ol style="list-style-type: none"> Can you substitute bandwidth for spatial aperture?
<ul style="list-style-type: none"> Use propagation structure 	<ul style="list-style-type: none"> Deconvolutions/twin receiver 		<ul style="list-style-type: none"> Bruce Williams of NRAD 	<ol style="list-style-type: none"> Spanning multiple frequency regions — validity of the models?
<ul style="list-style-type: none"> Noncoherent 	<ul style="list-style-type: none"> UPF 		<ul style="list-style-type: none"> Steve Wolf (NORELL) [given by George Smith] 	<ol style="list-style-type: none"> Sensitivity of deconvolution and other approaches
<ul style="list-style-type: none"> Frequency responses —Reverberation —False targets (fish) —Targets 	<ul style="list-style-type: none"> Mode excitation Wideband/wavelet/space-time-varying spreading function 	<ul style="list-style-type: none"> Modal compression analysis of the target and environmental research 	<ul style="list-style-type: none"> Scott Sands provided a reference 	<ol style="list-style-type: none"> Trying to solve inverse problems Stochastic v. deterministic

Interoperability Gains

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • Reduction of sidelobes (Don Miklovic/Dick Altes) • Reduce mutual interference • Sensor reuse • Bistatic motion 	<ul style="list-style-type: none"> • Multistatics • Beam patterns • Coded signals • Band overlap • Spatial diversity/multiple sensors 			<p><i>All of the general issues apply in a bistatic sense.</i></p> <ol style="list-style-type: none"> 1. Structure of reverberation 2. Implementation/cost 3. Sensor reuse 4. Interference 5. Operational constraints <ul style="list-style-type: none"> —Configuration —Signal type

Smaller / Cheaper / Sparse Arrays

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • Sensor reuse • Cost 	<ul style="list-style-type: none"> • Band overlap • Broadband beamforming • Monopulse 		<ul style="list-style-type: none"> • Henderson [given by Pat Pitt] 	<ol style="list-style-type: none"> 1. Efficiencies 2. Theory v. practical 3. Transducer v. system level 4. Reverberation statistics 5. Array design/ aperture stability

High-Rate Probing / Sensing

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • Continuous view 	<ul style="list-style-type: none"> • Multi-ping 			1. Self-interference
<ul style="list-style-type: none"> • Frequency diversity 	<ul style="list-style-type: none"> • Frequency diversity 			2. Stability/ variability
<ul style="list-style-type: none"> • Code diversity 	<ul style="list-style-type: none"> • Code diversity 			3. Motion effects
<ul style="list-style-type: none"> • UPF 	<ul style="list-style-type: none"> • UPF 			4. Reverberation
<ul style="list-style-type: none"> • Continuous wave FM (CWFM) 	<ul style="list-style-type: none"> • Continuous wave FM (CWFM) 		<ul style="list-style-type: none"> • Newhall? 	5. Source —Power —Duty cycle
<ul style="list-style-type: none"> • Sweeping ambiguity region 	<ul style="list-style-type: none"> • Sweeping ambiguity region 		<ul style="list-style-type: none"> • Matt Tattersall gave ref. 	

Energy Gains

Why?	How? (BW ↑)	Quantified NB Comparison	References (Status)	Issues
<ul style="list-style-type: none"> • High time bandwidth • Maintain range resolution (more energy) 		<ul style="list-style-type: none"> • Time bandwidth 		<ol style="list-style-type: none"> 1. Implementation 2. Cavitation

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