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ASAP PROGRESS and EXPENDITURE REPORT for the month of December 1-31, 1995

Joint UK/US Radar Program

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ASAP PROGRESS and EXPENDITURE REPORT
for the Month of December 1-31, 1995

Organization: LLNL
Project: P.LLN.10 Airborne RAR/SAR
Principal Investigator: Mark G. Miller

Long Term Objectives:
The RAR/SAR is a high-priority radar system for the joint US/UK Program. Based on previous experiment results and coordination with the UK, specifications needed for future radar experiments were identified as follows: dual polarimetric (HH and VV) with medium to high resolution in SAR mode. Secondary airborne installation requirements included; high power (circa 10kw) and SLAR capability to emulate Tupelev-134 type system; initially x-band but easily extendible to other frequencies.

In FY 96 we intend to enhance the radar system's capabilities by providing a second polarization (VV), spotlight imaging mode, extended frequency of operation to include S-band, increase power, and interface to an existing infrared sensor.

Short Term Objectives:
- Continue to evaluate and characterize the radar system.
- Upgrade navigation and real-time processing capability to refine motion compensation.
- Upgrade to dual polarimetry (add VV).
- Develop a "spot-light" mode capability.

Accomplishments THIS reporting period:
Design specifications for the SAR system polarimetric upgrade are complete. The upgrade is ready to begin the procurement cycle when funds become available.

System characterization is one of the highest priority tasks for the SAR. Although the radar is dedicated for our use, Hughes is waiting for contract funding before allowing us access to the hardware.

Other Issues or Concerns: (None)

Project Budget Estimate (FY), Monthly Actual and YTD expenditures for WUA number P.LLN.1010:

	DIRECT LABOR						ODC		TOTAL
	Management		Technical		Support		Procurement	Travel	
	M/M	Cost	M/M	Cost	M/M	Cost			
Project Budget	0	0	TBD	TBD	0	0	TBD	TBD	TBD
Actual	0	0	1.2	18.1	0	0	7.4	0.0	25.5
YTD	0	0	6.6	88.8	0	0	63.3	0.8	152.9

Organization: LLNL

Program: P.LLN.1020 Radar Data Processor

Principal Investigator: James M. Brase

Long Term Objectives:
The objectives of the Radar Data Processor development for the airborne RAR/SAR are:

- Provide real-time SAR image formation for immediate feedback on experiment operations.
- Provide a full-resolution SAR mode for off-line processing in the field.
- Provide limited image enhancement and analysis for field experiments.

The principal task in FY96 is to implement a new version of the RDP for the UK Experimental Surveillance Radar (ESR).

Short Term Objectives:

- Complete software upgrades to keep current with ground-based SAR processor.
- Prepare for and give design review for ESR RDP in January.
- Completion of COPE processing in January.
- Complete and test interface to RAID storage system.

Accomplishments THIS reporting period:

- Design work on UK implementation is continuing; the next milestone is a review to be held in conjunction with the UK/US program meeting in January.
- Reconstruction of imagery from the COPE experiment is continuing. Many high contrast surface features have been identified. Comparison with in-water measurements will be necessary to understand their origin.

Other Issues or Concerns: None

Project Budget Estimate (FY), Monthly Actual and YTD expenditures for WUA number P.LLN.1020:

	DIRECT LABOR						ODC		TOTAL
	Management		Technical		Support		Procure-ment	Travel	
	M/M	Cost	M/M	Cost	M/M	Cost			
Project Budget	0	0	TBD	TBD	0	0	TBD	TBD	TBD
Actual	0	0	0.6	10.6	0	0	0.0	0.0	10.6
YTD	0	0	2.7	43.4	0	0	(29.9)	0.0	13.5

Organization: LLNL
Program: P.LLN.1030 Ground-based SAR Signal Processing Workstation
Principal Investigator: James M. Brase

Long Term Objectives:
The ground-based signal processing workstation provides four classes of signal processing capabilities:

- Tools for real-aperture radar (RAR) image formation and data management.
- SAR image formation: our standard dark SAR processor and our new Precision SAR processor (PSAR).
- Doppler filtering, local normalization, and matched filter codes for LGA imagery.
- Image enhancement, feature extraction, and detection codes for SAR imagery.

Our FY96 objectives are to extend the LGA software tools to incorporate locally optimal (LO) detectors and to complete development of PSAR, particularly its motion and Doppler processing compensation capabilities.

Short Term Objectives:

- Finish reconstruction of AUTEC imagery from Overview I trial using dark SAR processor including target and sensor location maps.
- Completion of motion compensation software for PSAR.
- Resolve "ghosting" artifact in Loch Linnhe 94 LGA data.
- Develop locally optimal detector software.

Accomplishments THIS reporting period:
An estimation technique for parameters of a class-A clutter model has been developed and tested.

Processing of AUTEC 95 (Overview I) imagery is continuing. Priority images will be completed in March. The "ghosting" problem in LL94 data was resolved successfully. A brief report is being written and new data sets will be distributed in January.

Other Issues or Concerns: None

Project Budget Estimate (FY), Monthly Actual and YTD expenditures for WUA number P.LLN.1030:

	DIRECT LABOR						ODC		TOTAL
	Management		Technical		Support		Procure-ment	Travel	
	M/M	Cost	M/M	Cost	M/M	Cost			
Project Budget	0	0	TBD	TBD	0	0	TBD	TBD	TBD
Actual	0	0	0.0	0.0	0	0	0.0	0.0	0.0
YTD	0	0	0.3	4.3	0	0	(0.2)	0.0	4.1

Organization: LLNL
Program: P.LLN.1040 Static Airborne Radar
Principal Investigator: Michael J. Newman and Mark L. Vigars

Long Term Objectives:

- Maintenance, and storage of aerostats and related systems.
- Engineering modifications and support as needed for two aerostat mooring systems (mobile land based and East coast ship based).
- Development of a stabilized platform and high resolution radar system for deployment by the aerostat.
- Utilization of these systems in field experiments in the UK/US program.

Short Term Objectives:

- Complete ground support operation shelters.
- Start engineering modification to land-based mooring platform.

Accomplishments THIS reporting period:
Refurbishment and reconfiguration of the four ground stations continued during the month of December. The installation of the State of Health Shelter #1 hardware, cabling, integration and testing is complete. The four shelters are completed with the major hardware infrastructure, but need specific hardware integrated per experiment.

A new task of Aerostat inventory at Sharpe Depot will be followed by transfer of ISSO hardware to LLNL and relocation. Contract with Sharpe Depot warehouse will be terminated by February 15th.

Other Issues or Concerns: None

Project Budget Estimate (FY), Monthly Actual and YTD expenditures for WUA number P.LLN.1040:

	DIRECT LABOR						ODC		TOTAL
	Management		Technical		Support		Procure-ment	Travel	
	M/M	Cost	M/M	Cost	M/M	Cost			
Project Budget	0	0	TBD	TBD	0	0	TBD	TBD	TBD
Actual	0	0	1.8	29.5	0	0	17.7	0.0	47.2
YTD	0	0	6.9	110.6	0	0	47.1	0.0	157.7

Organization: LLNL
Program: P.LLN.1060 Radar Field Experiments
Principal Investigator: David Mantrom

Long Term Objectives:
Continue planning for FY96 field experiments, including possible LLNL participation in Auspoly Experiment and West Coast Clutter Flights.

Short Term Objectives:

- Finalized Plan for West Coast Clutter Flights
- Briefing on Project Overview at Joint UK/US ROI Program Review Meeting 25 January at LLNL
- Meeting with UK Collaborators at LLNL re: FY96 Field Experiments

Accomplishments THIS reporting period:
Revised Project Auspoly AETB Plan (Second Draft)
We have sent a second draft plan document (classified) for data collection with the LLNL/Hughes AETB for Trial Auspoly to DRA Farnborough (via ASAP Program Office), AUTEC, and included an information copy to the ASAP Program Office. [Subsequently, a decision was made that LLNL would not participate in Auspoly so this plan has become moot.]
We have continued looking at sites for a possible FY96 MTF experiment involving imaging ambient IW's with the AETB and with in-water instrumentation. We will likely discuss options with our UK collaborators on 26 January.
A document describing the plan for West Coast Clutter flights over five NDBC meteorological buoys off the coast of Southern California has been drafted and is being reviewed internally.
We have determined that our participation in the Navy's Emerald II experiment with the AETB SAR is feasible and we have developed a data collection concept. We will discuss this and issues we have identified with Emerald people off line at the 25 January ROI Program Review.
We have not yet received the COPE environmental data formally requested in writing from ETL via the ASAP Program Office in October.

Other Issues or Concerns:
COPE environmental data request approval by ASAP Program Manager.

Project Budget Estimate (FY), Monthly Actual and YTD expenditures for WUA number P.LLN.1060:

	DIRECT LABOR						ODC		TOTAL
	Management		Technical		Support		Procure-ment	Travel	
	M/M	Cost	M/M	Cost	M/M	Cost			
Project Budget	0	0	TBD	TBD	0	0	TBD	TBD	TBD
Actual	0	0	0.9	21.8	0	0	1.9	0.0	23.7
YTD	0	0	2.7	67.2	0	0	77.6	0.0	144.8

Organization: LLNL
Program: P.LLN.1070 Data Analysis and Detection Theory
Principal Investigator: James M. Brase

Long Term Objectives:
The overall goal is to develop a model for the detectability of internal wave wakes in radar images. Our detection models have four parts:

- A signal model describing the amplitude and shape of the image model as a function of target, environmental, and radar system parameters.
- A clutter model which describes the amplitude distribution and correlation structure of the ambient image clutter.
- Detection algorithms which prescribe the method for making detection decisions.
- A performance analysis methodology.

Our FY96 objectives concentrate on extending our signal and clutter models and on using the models to define optimal detection on algorithms for non-Gaussian clutter.

Short Term Objectives:

- Complete summary report on wake detection in database.
- Complete report on MTF analysis through LL94.
- Develop locally optimal detection methodology and characterize performance.
- Characterize clutter distributions in Overview I SAR imagery.

Accomplishments THIS reporting period:
Signal analysis for initial AUTEC imagery was completed. A report is in preparation. Work on the database summary reports and MTF reports are continuing.

Other Issues or Concerns: None

Project Budget Estimate (FY), Monthly Actual and YTD expenditures for WUA number P.LLN.1070:

	DIRECT LABOR						ODC		TOTAL
	Management		Technical		Support		Procure-ment	Travel	
	M/M	Cost	M/M	Cost	M/M	Cost			
Project Budget	0	0	TBD	TBD	0	0	TBD	TBD	TBD
Actual	0	0	3.3	53.3	0	0	22.1	0.8	76.2
YTD	0	0	9.9	164.4	0	0	119.9	1.3	285.6

Organization: LLNL
Program: P.LLN.1080 Management
Principal Investigator: Richard E. Twogood

Long Term Objectives:
Provide ongoing management oversight and support for the Joint UK/US Radar Program in addition to other consultant and management services (Wells, Manasse, etc.). All administrative support for UK/US program included (clerical, administrator, facilities).

Short Term Objectives:
- Execute all administrative and management actions required to keep the UK/US Program functioning smoothly. For FY96 Q1, this includes dealing with all short-term issues arising from the continuing resolution(s).
- Prepare for UK/US Radar Program meeting tentatively scheduled at LLNL for 1/24-25/96.

Accomplishments THIS reporting period:
All management functions for the UK/US Radar Program, plus the related functions and contract management, were successfully performed. We are working closely with the contractors involved to minimize the impact during this part of the shut-down.

Tony Wells continued his efforts coordinating the AIRMS system issues with ASAP, ARPA, and other DoD organizations.

Other Issues or Concerns:
A financial crisis within the UK/US Program is having clear impacts on milestones for late in FY96. These are being documented separately due to their extent. FY95 levels of effort averaged $825K per month for the UK/US Radar Program. Under the continuing resolution, we have stopped all major procurements and stop-work orders were issued to most contractors to comply with regulations. A MIPR for $980K was sent from ISSO to DOE on 12/18/95, bringing total FY96 funding to only $1.33M through Q1 FY96. Once received, that funding pays costs only through November (total costs for Oct./Nov. were $1264K as reported herein and in last month's report).

Project Budget Estimate (FY), Monthly Actual and YTD expenditures for WUA number P.LLN.1080:

	DIRECT LABOR						ODC		TOTAL
	Management		Technical		Support		Procurement	Travel	
	M/M	Cost	M/M	Cost	M/M	Cost			
Project Budget	TBD	TBD	0	0	TBD	TBD	TBD	TBD	TBD
Actual	1.1	26.8	0	0	1.1	9.1	128.7	4.3	168.9
YTD	3.6	102.6	0	0	1.2	10.7	618.0	21.1	752.4

Organization: LLNL

Program: P.LLN.1110 Modeling and Analysis (LLNL)

Principal Investigator: David Chambers

Long Term Objectives:
This task involves the updating and utilization of computer codes and models in support of data analysis, system design, and experiment planning. The principle tasks are:

- Run 2D+time codes to support data analysis and experiment planning.
- Upgrade 2D+time codes to include turbulent wake generation of internal waves.
- Compare internal wave generation codes and models with laboratory data, upgrade models as required.
- Upgrade and refine source models for turbulent wake generation of internal waves.
- Run wind-wave relaxation code to update radar modulation model.
- Update clutter models for detection applications.
- Assess performance of new model-based processing approach to enhance wake images.
- Collect codes together into a single end-to-end simulator.

Short Term Objectives:

• Complete preliminary analysis of model-based processing scheme applied to radar images	March 96
• Complete internal wave model upgrades	March 96
• Complete comparison with lab data	April 96

Accomplishments this reporting period:
Continued reevaluation of time-dependent models of internal wave generation by turbulent wakes. For application to a normally operating submarine, these models must be applicable for momentumless turbulent wakes. In particular, the speed of the large scale wake eddies must be determined. As an aid to determining this, turbulent wake theory was evaluated to calculate the mean velocity profile for an axisymmetric momentumless wake.

Continued learning the software package needed to evaluate the performance of model-based image processing schemes. Due to other responsibilities and Christmas vacation, learning process did not proceed as rapidly as planned. Thus the short term objective of preliminary analysis of model-based processing scheme was revised to March.

Ran 2D+time codes using AUTEC 1995 (Project Overview) environmental data in support of radar data analysis.

Other Issues or Concerns:
Due to budget delay the restart of the wind-wave generation effort has been delayed.

This report is based on the first draft of the Work Unit Assignment, which was in effect during November. Subsequent reports will reflect the revised Work Unit Assignment sent in December when the revised WUAs are formally approved.

Project Budget Estimate (FY), Monthly Actual and YTD expenditures for WUA number P.LLN.1110:

	DIRECT LABOR						ODC		TOTAL
	Management		Technical		Support		Procure-ment	Travel	
	M/M	Cost	M/M	Cost	M/M	Cost			
Project Budget	0	0	TBD	TBD	0	0	TBD	TBD	TBD
Actual	0	0	0.6	9.7	0	0	1.4	0.6	11.7
YTD	0	0	2.4	39.8	0	0	27.8	0.6	68.2

Organization: LLNL
Program: P.LLN.1410 UCSB Wave Tank
Principal Investigator: James M. Brase

Long Term Objectives:
The UCSB Wave tank provides a capability for controlled test and evaluation of radar scattering models, image formation models, and modulation mechanisms, with realistic modulated ocean wave spectra. Three radar systems can be deployed at the wave tank: an LLNL radar covering 1.5 to 4 GHz, a UCSB radar covering 4-8 GHz, and TRW radar covering 9-10 GHz.

In FY96 our objectives are to complete initial experiments on scattering from breaking and near-breaking waves (set A), to extend the experiments to full wind-wave spectra (set B), and modulated by a surface current. (set C)

Short Term Objectives:
- Complete characterization of wind wave spectra.
- Run preliminary Set B experiments with UCSB radar.
- Complete Set A experiments with LLNL radar upgraded to dual-polarization.
- Integrate high speed framing camera into surface truth diagnostics and synchronize with radars.

Accomplishments THIS reporting period:
- Calibration of the OEL 6 radar has been simulated with geometric optics based technique. This may provide a means to gain physical insight into scattering mechanisms. Comparisons are currently being made to full EM scattering calculations.
- A paper on the UCSB radar was completed and is attached.
- Preliminary planning for an upgrade of the OEL 6 radar to 18 GHz has started.
- We have acquired and tested a finite difference time domain EM simulation which will be used to model the LLNL impulse radar experiments.

Other Issues or Concerns:
As has been discussed with the ASAP program management, costs/liens accrue on our UCSB work over periods of several months. In December, the $400K charge that accrued covers work planned roughly for the first 2 quarters of FY96.

Project Budget Estimate (FY), Monthly Actual and YTD expenditures for WUA number P.LLN.1410:

	DIRECT LABOR						ODC		TOTAL
	Management		Technical		Support		Procure-ment	Travel	
	M/M	Cost	M/M	Cost	M/M	Cost			
Project Budget	0	0	TBD	TBD	0	0	TBD	TBD	TBD
Actual	0	0	0.1	0.0	0	0	397.9	0.0	399.8
YTD	0	0	0.1	0.0	0	0	367.7	0.0	369.6

Organization : LLNL

Program: P.LLN.1420 Stratified Wave Tank

Principal Investigator: Harry Robey

Long Term Objectives:
To study the generation of internal waves by moving submerged bodies and their wakes in a controlled laboratory tank. The experimental results will be used to improve numerical models.

Short Term Objectives:
(1) finish and submit papers documenting experiments on internal wave generation by a towed sphere and its wake, and (2) evaluate feasibility of using liquid crystals to visualize IW patterns in a horizontal plane vs. time.

Accomplishments THIS reporting period:
A draft of a paper describing the experiments and numerical simulation of IW generation by a towed sphere is nearly complete. What originally was going to be 2 papers (1 on IWs generated by the body and 1 dealing with the wake) has now been combined into one full paper. This will be submitted to ASAP in January, prior to submission to Physics of Fluids.

The series of experiments on IW generation by a 10:1 ellipsoid has been extended to very high towing speeds with very good results. We are currently testing a method of visualizing the spatial IW patterns using liquid crystal visualization. This is essential for understanding the non-stationary wake-generated IWs and their implication for SAR imaging.

An 8:1 self-propelled ellipsoid has been designed and is in fabrication for upcoming experiments.

Other Issues or Concerns: None

Project Budget Estimate (FY), Monthly Actual and YTD expenditures for WUA number P.LLN.1420:

	DIRECT LABOR						ODC		TOTAL
	Management		Technical		Support		Procure-ment	Travel	
	M/M	Cost	M/M	Cost	M/M	Cost			
Project Budget	0	0	TBD	TBD	0	0	TBD	TBD	TBD
Actual	0	0	1.7	28.0	0	0	4.0	0.0	32.9
YTD	0	0	6.0	97.6	0	0	13.3	0.0	111.8

Organization : LLNL

Program: P.LLN.1430 Institute of Applied Physics, Russia

Principal Investigators: Harry Robey

Long Term Objectives:
Continue experiments in the large thermo-stratified tank. Work will emphasize generation of internal waves in a stratified environment with shear.

Short Term Objectives:
No new work will be done until the new contract is in place. The contract is currently at DOE for final approval. Contract is expected to be in place by beginning of February.

Accomplishments THIS reporting period:
The first draft of a joint paper by IAP and LLNL describing internal wave generation experiments with a towed sphere was received from IAP. It will now be combined with LLNL results.

Other Issues or Concerns:
IAP was never paid for the last phase of their work in FY95 (documented in report # 7) due to internal (IAP) budget problems (the work extended past the original schedule). They requested a no-cost extension of the duration of the contract to 3/31/96 so that they can be paid. This has been done.

Project Budget Estimate (FY), Monthly Actual and YTD expenditures for WUA number P.LLN.1430:

	DIRECT LABOR						ODC		TOTAL
	Management		Technical		Support		Procure-ment	Travel	
	M/M	Cost	M/M	Cost	M/M	Cost			
Project Budget	0	0	TBD	TBD	0	0	TBD	TBD	TBD
Actual	0	0	0	0.0	0	0	0.0	0.0	0.0
YTD	0	0	0	0.0	0	0	0.0	0.0	0.0

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Simple Techniques to Correct for VCO Nonlinearities in Short Range FMCW Radars

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Abstract — Standard hardware techniques for the linearization of the frequency sweep in FMCW radars are difficult to implement and often offer only moderate improvement in linearity. A simple software-based linearization technique is introduced for short-range FMCW radars, and compared with a simple hardware linearization scheme. These techniques have been verified in an existing C-band FMCW scatterometer, and results in a dramatic focusing of the point return. The resulting range resolution (measured) approaches the theoretical limit, with a >20dB reduction in sidelobes.

1. Introduction

One of the main problems with obtaining a sharp point spread function with a FMCW radar system (focused return of a point target) is the nonlinearity of the FM sweep signal. Two commonly used lineariation methods are hardware phase-locked loop circuitry and digital synthesis of a corrected VCO tuning curve. The software resampling method introduced in this paper is ideal for short range FMCW scatterometers. It is very easy to implement, uses a dynamic rather than a static calibration of the VCO and results in a well focused point spread function. We will describe our C-band FMCW system, configured for scatterometry measurements in UCSB's Ocean Engineering wave tank (fig. 1), and a combination of a simple hardware linearization technique and the software resampling scheme. The efficiency of both methods will be compared using a delay line and a more realistic measurement of a metal calibration sphere suspended above the wave tank.

2. FMCW Radar Design

The configuration of the FMCW radar is essentially of textbook topology [1] with some modifications to customize it for our application (fig. 2). The sweep oscillator is a packaged GaAs MMIC design from Avantek (HTO-4000), covering the range 4-8 GHz with a hyperabrupt varactor tuning element. Separate antennas for transmit and receive were used to reduce transmit-to-receive leakage. The 3 foot diameter parabolic dishes are fed by Tecom dual polarized horns, which provides separate horizontal and vertical polarization. An FM sweep rate of 1 msec was used with a 2GHz bandwidth, alternately switching the transmitter polarization between horizontal and vertical polarization, giving and effective PRF of 500 Hz. With zero range chosen to be at the antennas, quadrature detection was not required for unambiguous range and Doppler information. Two identical homodyne receiver channels based on a triple-balanced mixer were employed for simultaneous measurement of the co- and cross-polarization return. Background clutter associated with short range returns near the radar set and distant scatterers beyond the viewing range were reduced with a bandpass filter in the preamplifier. The filtered signals are digitized with 12-bit A/D converters, with a sampling rate of 2MHz per channel, which is equivalent to a transfer rate 8.2 Mbytes per second to a hard disk array.

3. VCO Linearization

The software linearization scheme uses a simple measurement of transmission through a coaxial delay line in place of the antennas, with a length equivalent to a point target at the center of the radar footprint in the wavetank (10 meters range). Phase information of the measured time-domain signal is obtained by a Hilbert transform [2]. For a TEM delay line, the phase should be a linear function of time if the VCO sweep is linear; this gives a direct measurement of VCO linearity. Figure 4 (top) shows a measurement of the phase deviation from linearity for the real VCO. The measured curve of time versus unfolded phase is interpolated and resampled at equidistant phase increments to obtain the new sampling points in time for a linear sweep. Focusing the radar then amounts to resampling the measured time domain waveform at these new sampling points by a linear interpolation. It should be mentioned that an additional simple calibration step was required to remove the mixer's frequency dependent DC offset from the delay line return; this was done by subtracting the mixer signal measured with a terminated RF input.

A simple hardware linearization was also explored for comparison, using a programmable waveform generator to correct the VCO tuning curve. This is possible here because we are using a varactor tuned oscillator with a tuning port bandwidth well above the radar PRF. The DC tuning voltage versus RF frequency calibration curve of the VCO was characterized with a spectrum analyzer/frequency counter, at 50 points over the full 4 to 8 GHz range (figure 3). The interpolated voltages at equidistant frequency increments were digitized and downloaded to an HP 33120A programmable waveform generator (12-bit direct digital synthesis of the waveform) to generate the VCO sweep.

4. Measured Results

The scatterometer was designed for wave scattering experiments at the Ocean engineering lab of UCSB. The wind-wave tank is 175 feet long and 12 feet wide. Figure 1 shows the experimental setup at the lab. For the experiments presented here the antennas were positioned for six degrees grazing angle, the footprint was centered at 10 meters from the antennas, and the 3dB beamwidth was 1 meter wide at 10 meters range. The 2GHz bandwidth (4-6GHz) yields a theoretical range resolution of 7.5 cm. With 1024 samples per burst the maximum unambiguous range is roughly 35 meters. The sampling frequency is three time higher than necessary to allow the the unfolding of the signal phase needed for the resampling technique.

Fig 5a shows the measured return versus range using the delay line (point target at 10 meters) with a linear VCO sweep voltage; that is, an uncorrected sweep. The resulting spread in range at 20dB below the peak is 70 range cells wide. In figure 5b the same measurement is shown with the hardware linearized ramp. The peak is higher and sharper, with the spread at 20 dB below the peak of 50 range cells wide. This technique could possibly be further improved with more accurate measurement of the VCO tuning curve. Figure 5c shows the same measurement using the software focusing technique, and shows a dramatic improvement in the point spread. The width at 20dB below the peak is 3 rangecells. Fig. 4 (bottom) shows the corrected phased deviation of the VCO sweep using a combination of the two methods.

More realistic measurements were made to test the technique with a small metal calibration sphere suspended *in situ* above the wave tank. Here the measurement is complicated by close-in clutter (associated with imperfect transmit-reciver isolation and reflections from the "beach" end of the tank) and scattering from the wind tunnel beyond the target range (see fig. 1). These unwanted signals are removed by subtracting a measured response with no target in a still tank; this approach fails at distant range due to oscillator phase noise, but is fine for the range of interest. Figure 6a shows the sphere with a hardware linearized ramp and Figure 6b shows the same dataset with the software resampling. The focusing effect again observed. This resampling technique pushes the real range resolution of the radar close to the theoretical prediction.

5. Acknowledgements

The authors wish to acknowledge the help of Dr. Dean Mensa, formerly of the Pt. Mugu Pacific Missle Test Center. This work was supported by Lawrence Livermore National Laboratories.

6. References

[1] M.I. Skolnik, ed. *Radar Handbook*, McGraw-Hill: New York, 1970

[2] D.L. Mensa, *High Resolution Radar Cross-Section Imaging*, Artech House: Boston, 1991.

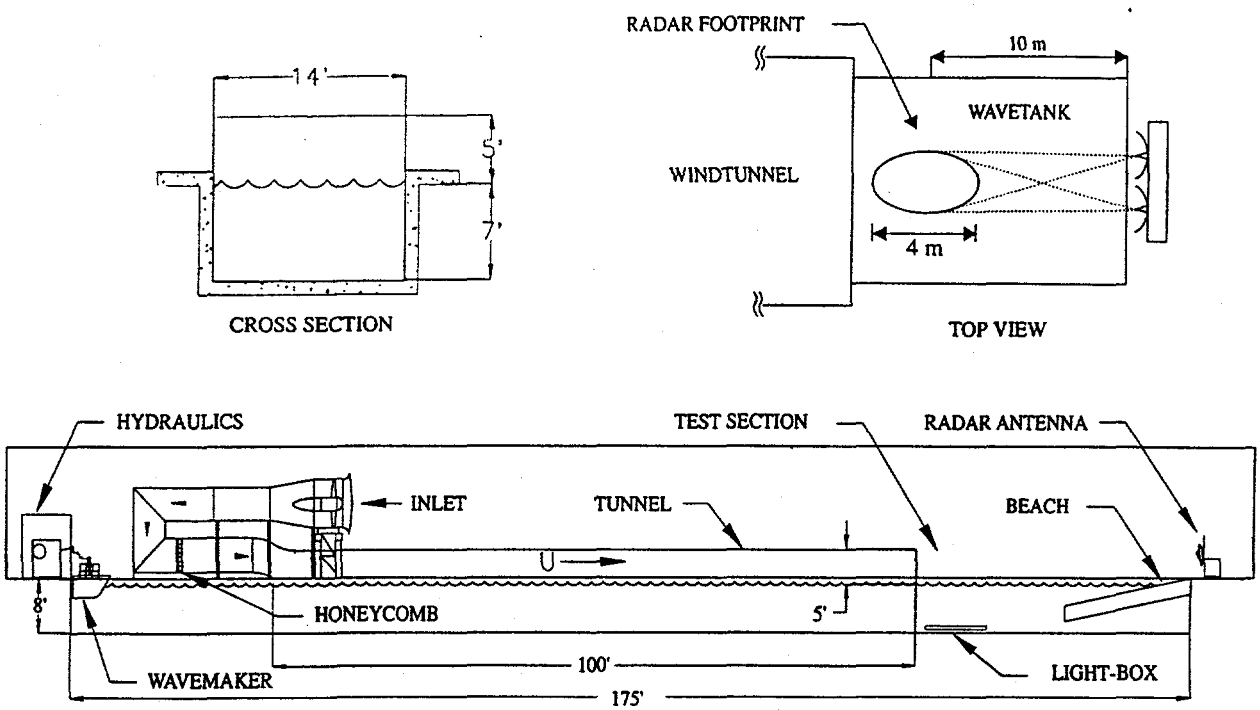

Figure 1- Experimental setup at the Large Wind-Wave Facility (LW^2F) of UCSB

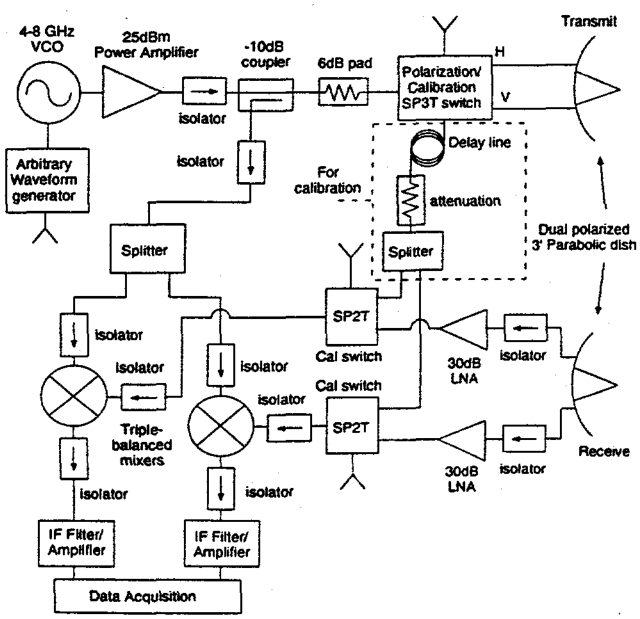

Figure 2 - C-band FMCW radar configuration. Dashed box encloses hardware used in software linearization of the VCO.

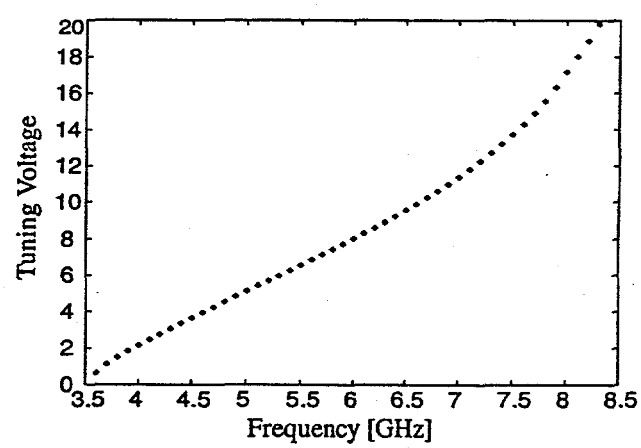

Figure 3 - VCO tuning curve

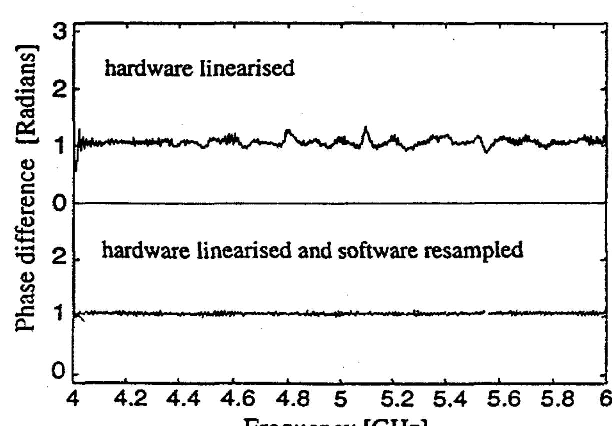

Figure 4 - Delay line, phase differences between samples

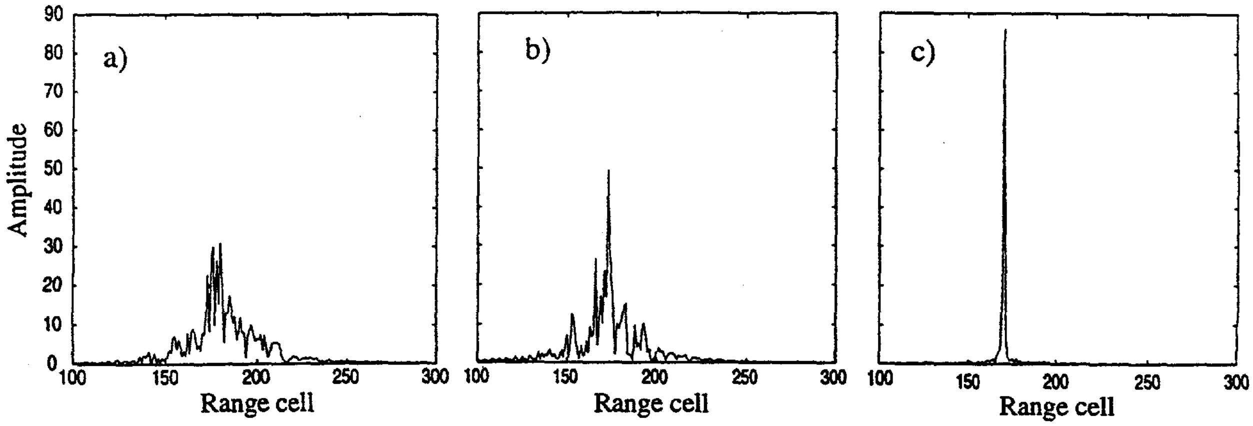

Figure 5 a,b,c - Range profile of the delay line. The VCO was fed with a linear tuning voltage in Figure 5a. Hardware linearisation of the frequency sweep shows some improvement in the point spread in 5b. In Figure 5c the hardware linearised return signal of 5b was further compressed with the software resampling technique.

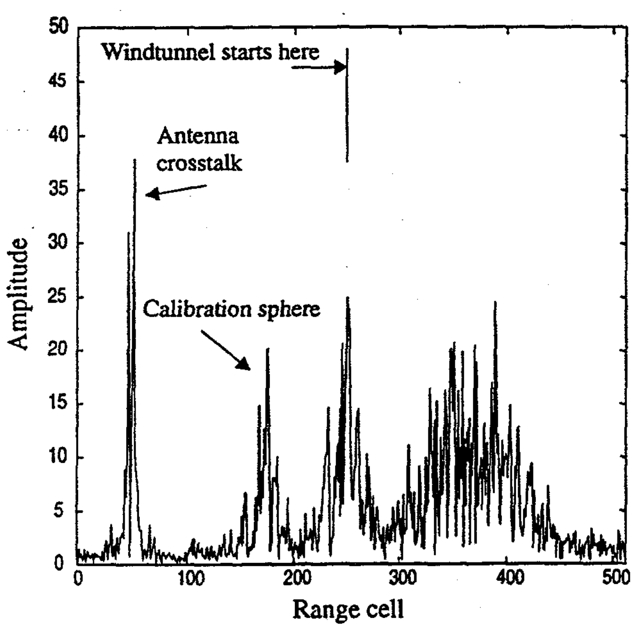

Figure 6- Range profile of the wavetank with a calibration sphere suspended above the water surface at 10 meter range. The RF sweep is hardware linearised. This plot incudes the static background. Compare the profile of the sphere to 5b.

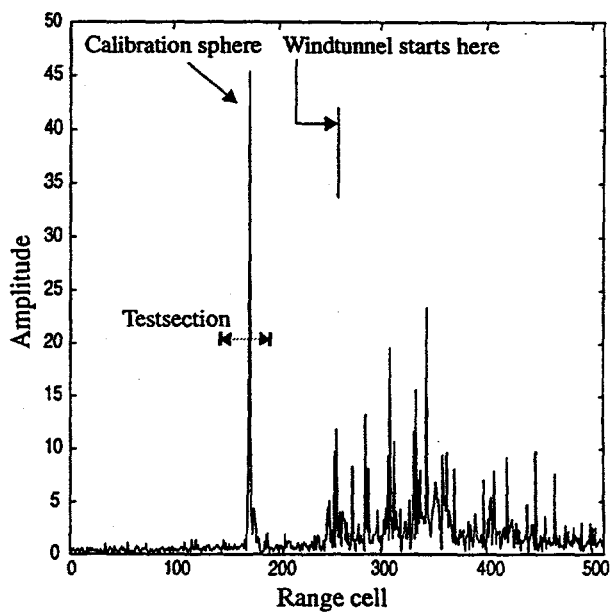

Figure 7 - The data set of Figure 6 software resampled.The static background is subtracted.Phase noise of the VCO prevents the background removal at long ranges.

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