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COMPUTER FACILITIES FOR HIGH-SPEED DATA ACQUISITION
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DEPT OF ELECTRICAL AND COMPUTER E... N M BILGUTAY

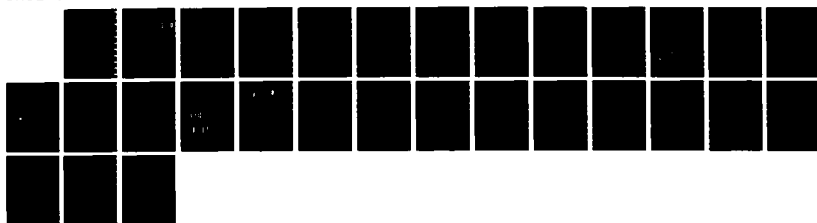
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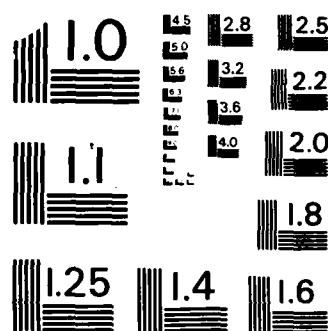
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Final Scientific Report on Equipment

Grant No. AFOSR-85-0056:

"Computer Facilities for High-Speed Data
Acquisition, Signal Processing and Large Scale
System Simulation"

Submitted by:

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ABSTRACT Cont'd:

which were developed or enhanced as a result of this grant. A list of projects currently utilizing or having access to these facilities is also provided to indicate the scope and success of this project.

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Introduction:

In accordance with the AFOSR provisions, the following is the Final Scientific Report on Grant No. AFOSR-85-0056. This Equipment Grant was issued under the Department of Defense (DOD) - University Research Instrumentation Program (FY 1984/FY 1985) for the purpose of upgrading the research instrumentation at Drexel University, Electrical and Computer Engineering Department, in order to improve the existing facilities to better support present and future research having relevance to the National Defense goals.

In accordance with the guidelines of the grant the funds have been expended to fulfill the stated goals of the grant. The following report describes the equipment acquired under the grant and outlines the status of the research facilities which were developed or enhanced as a result of this grant. A list of projects currently utilizing or have access to these facilities is also provided to indicate the scope and success of this project.

Objectives of the Project:

The main objective of the project was to expand the existing facilities at the Electrical and Computer Engineering (ECE) Department and the Biomedical Engineering and Science Institute at Drexel University to better meet the growing research needs in high frequency data acquisition, signal processing and data display facilities. Many of the current and pending research projects at Drexel, which require such equipment, involve DOD projects or are relevant to the National Defense goals in areas such as: ultrasonic non-destructive testing, materials and tissue characterization, ultrasonic grain size estimation, modeling of ultrasonic bonding systems, linear and nonlinear analysis of dispersion phenomena, and clutter reduction in radar. In addition, one of the objectives was to complement the existing facilities to allow development of new research areas requiring high-speed data acquisition and more comprehensive signal processing capabilities.

These objectives have been accomplished through the purchase of some key state-of-the-art equipment* as described in the following section. In addition, the equipment has been interfaced with the Masscomp workstation, which is directly linked to the ECE Vax 11/780 computer through Ethernet as well as other workstations in the ECE Department. This allows direct access to the equipment and facilities by a large number of researchers in the Department.

*(i.e. Masscomp workstation with color graphics subsystem, high speed digital scope, waveform analyzer, ultrasonic scanning equipment, etc.)

List of Equipment Acquired:

The following is a list of equipment acquired under the AFOSR grant and the information pertaining to the manufacturer and cost of the equipment.

1. Masscomp 168 Mb Disk with controller and colorgraphics Subsystem
\$31,312
2. Hewlett-Packard HP3562A Dual Channel Dynamic Signal and FFT Analyzer
\$21,032
3. LeCroy Model 9400 Digital Oscilloscope
\$11,890
4. Fujitsu 2322, 165 Mb Winchester Disk Drive with Controller and enclosure.
\$6,470
5. Masscomp ME-510 1Mb memory and port expansion (multiplexer) to facilitate installation.
\$5,525
6. Modullynx Motor controller system for the ultrasonic scanner: (system controller card, 3-axis-system, micro-stepper indexer card, driver card, power supplies) and Superior Electric stepper motors.
\$4,594
7. Wavetek 116 50 MHz Pulse/Function Generator
\$2,495
8. Apple Macintosh (512K) personal computer with external disk drive and Imagewriter Printer.
\$2,240
9. Masscomp CPU Board
\$1,107
10. 20Mb hard disk drive for Apple Macintosh
\$1,100
11. ILS Software Package (1/8th contribution)
\$1,000
12. Ethernet and IEEE-488 cabling for Masscomp computer
\$595
13. Cem Programmers Toolkit
\$500
14. Masscomp Unix System Software Handler
\$500
15. Tektronix Graphics Device Filter
\$450

Total Cost: \$90,810

The AFOSR grant covers \$78,000 of the above total and the remaining amount is covered by Drexel cost sharing.

The following items were on the approved equipment list but were not acquired under the AFOSR grant either because they were purchased through other grants or found to be less critical to current research needs:

- 1) Ultrasonic Pulser
- 2) Programmable Filter
- 3) Laser Printer
- 4) Multimeter
- 5) Amplifier/Trigger Generator

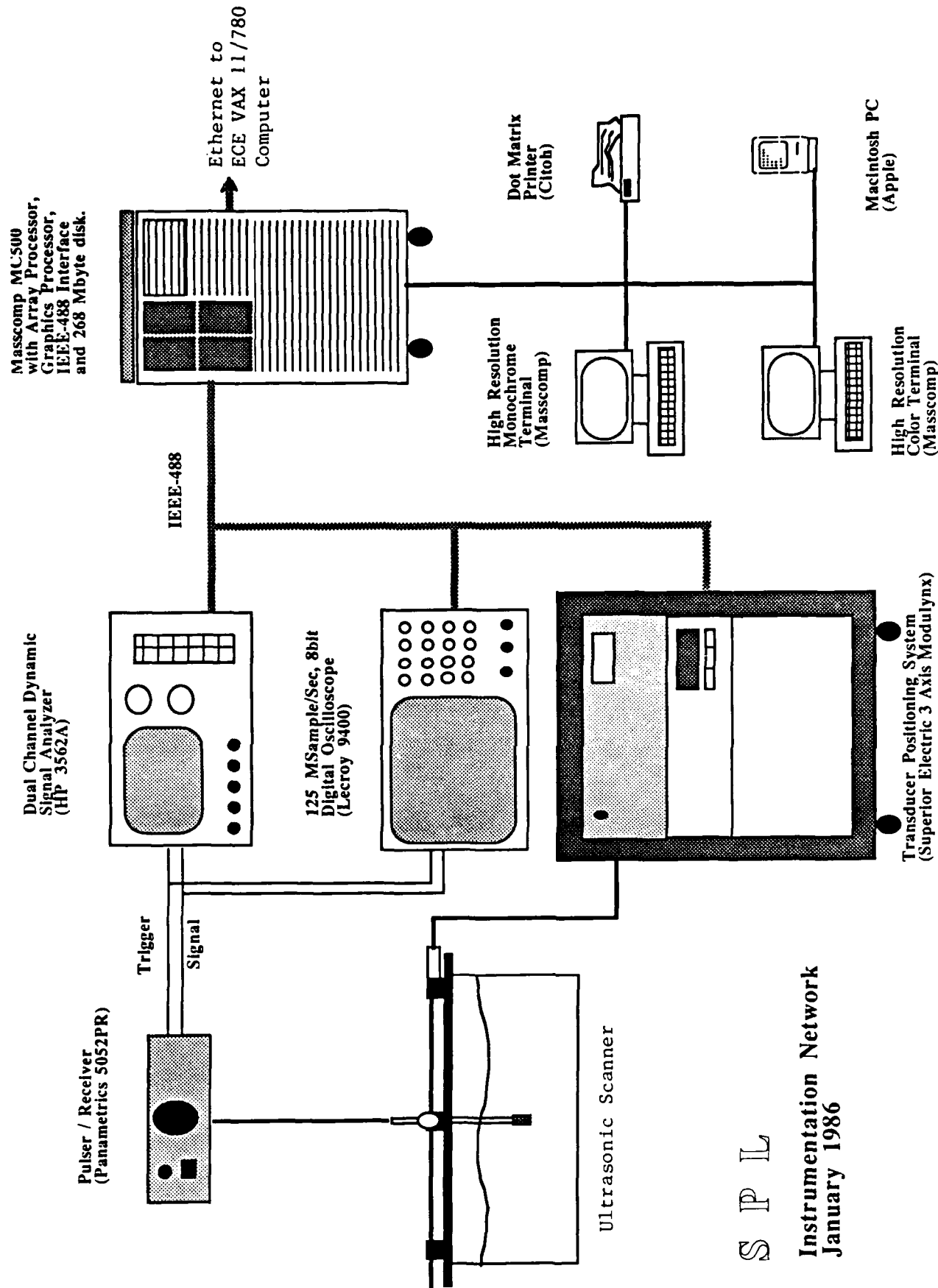
Current Facilities:

The equipment acquired through the AFOSR Grant has been crucial in the development of the Signal Processing Laboratory (SPL) shown in Fig. 1. In addition, two NSF Equipment Grants (ECS-8305154 and ECS-8405793) have also been utilized to complement the AFOSR funds to develop an excellent state-of-the-art facility which is suitable for performing research in a wide range of topics including digital signal processing, ultrasonic non-destructive testing and imaging.

The SPL facility shown in Fig. 1 has the following major equipment:

1) 32-bit Masscomp MC 5500 workstation consisting of:

- 1 Array Processor
- 1 Floating Processor
- 1 68010 based CPU board
- 1 Ethernet Interface board
- 1 IEEE 488 Interface board
- 3 Mb RAM
- 1 Xylogics 450 Disk Controller board
- 1 Data Systems 412 Multi-Function Controller board
- 1 2 - plane Graphics Terminal Interface
- 1 6 - plane Graphics Terminal Interface
- 1 8 - port RS232 Expansion Card
- 2 Micropolis 50 Mb Winchester Disk Drives
- 1 TEAC 5.25" Floppy Disk Drive, 1,183 Mb Formatted Capacity
- 1 Archive .25" Streaming Tape Drive, 45 Mb Capacity
- 1 Fujitsu M2322 165 Mb Winchester Disk Drive



S P L
Instrumentation Network
January 1986

Figure 1: Signal Processing Laboratory

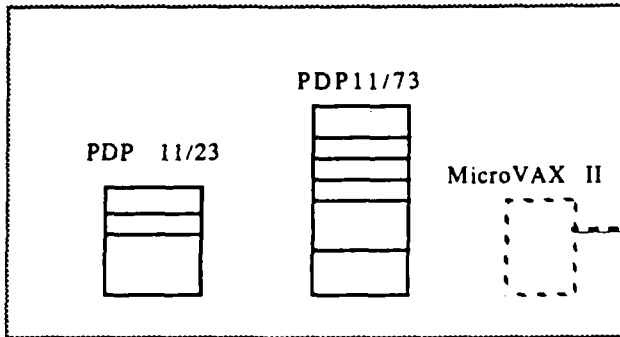
The system runs on real time Unix and supports the Fortran and C languages. Also included in the system is an AP-501 High performance Array Processor, which significantly enhances the performance of vector and array calculations. The system serves as the central unit for controlling data acquisition and performing signal processing. The major equipment in the laboratory is interfaced with the Masscomp workstation through RS-232 or IEEE-488 as shown in Fig. 1. In addition, through Ethernet it links the SPL to the main Departmental computer facility (VAX-11/780) and the other smaller computers in the Departmental Computer Network (ECE net) as shown in Fig. 2. This allows interactive communication with various facilities in the Department, thus both providing Departmental access to and from SPL.

The high resolution color graphics subsystem with color independent graphics processor and a 19" color monitor provides high quality images essential in many imaging applications.

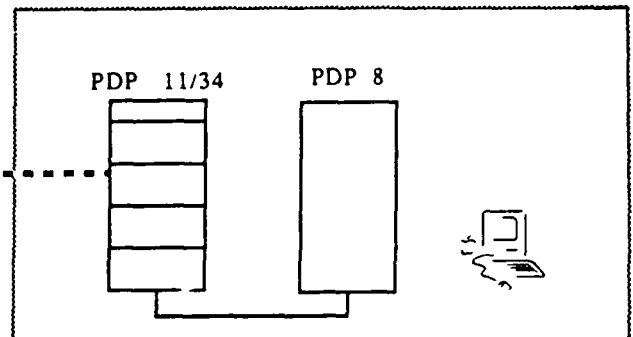
ECEnet

Electrical & Computer Engineering Department

Bio-medical Ultrasound Research Laboratory

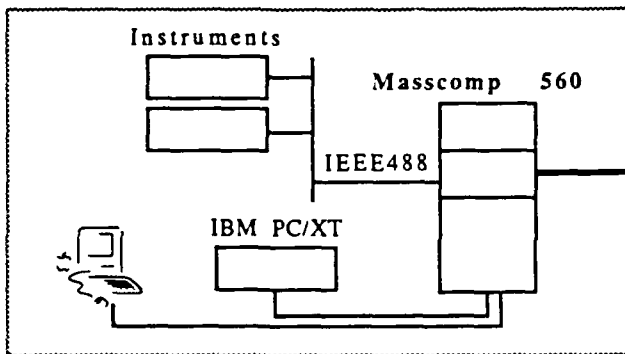


Bio-medical EEG Research Laboratory



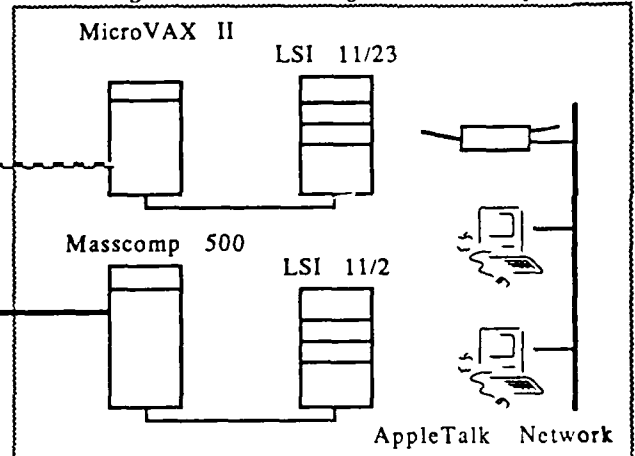
BERL

Bio-medical Electrode Research Laboratory

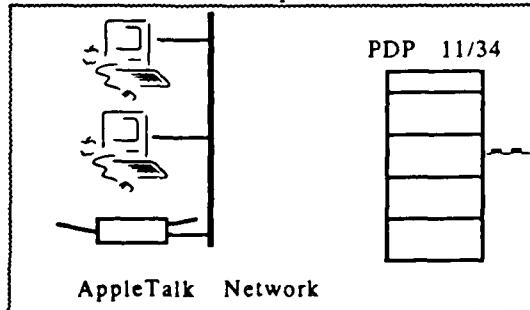


SPL

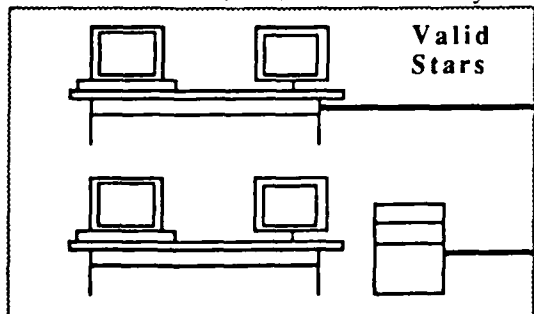
Signal Processing Laboratory



Microwave-Electrooptics Laboratory



Microelectronics Laboratory



LAMIR

Laboratory for Applied Machine Intelligence and Robotics

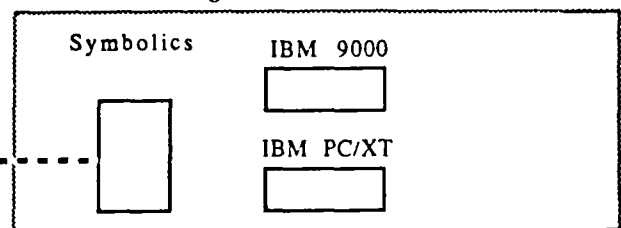
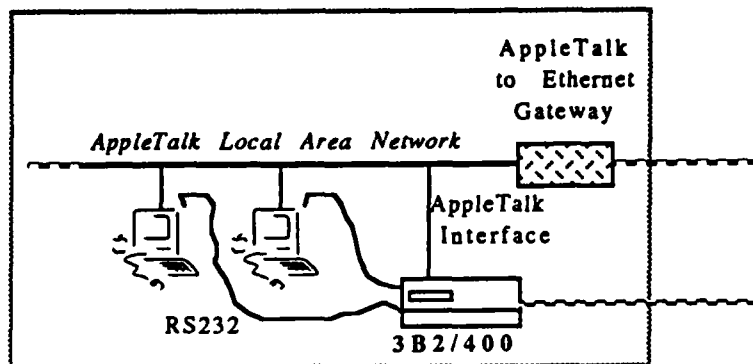
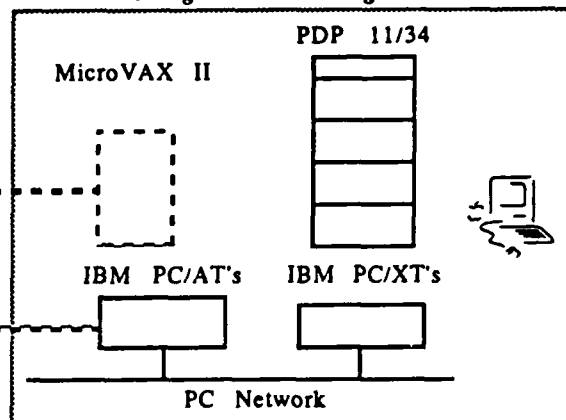


Figure 2: Computer Network at Electrical&Computer Engineering Department

AT&T Foundation - Macintosh/3B2 Project

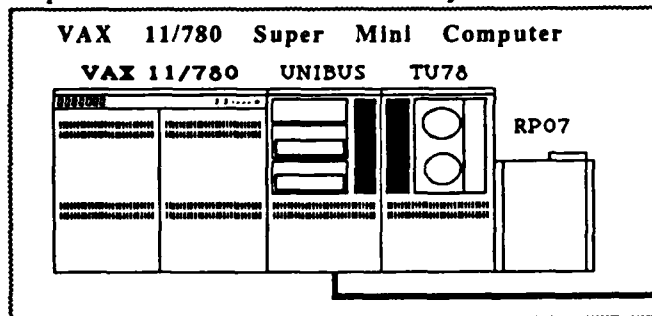


IPC Image Processing Center



CBIS

Computer Based Interactive Systems Laboratory



Ethernet Local Area Network

TCP/IP Protocol
10 MegaBits / Second
Coax Cable

CAD/CAE Classroom

Computer Aided Design / Computer Aided Engineering

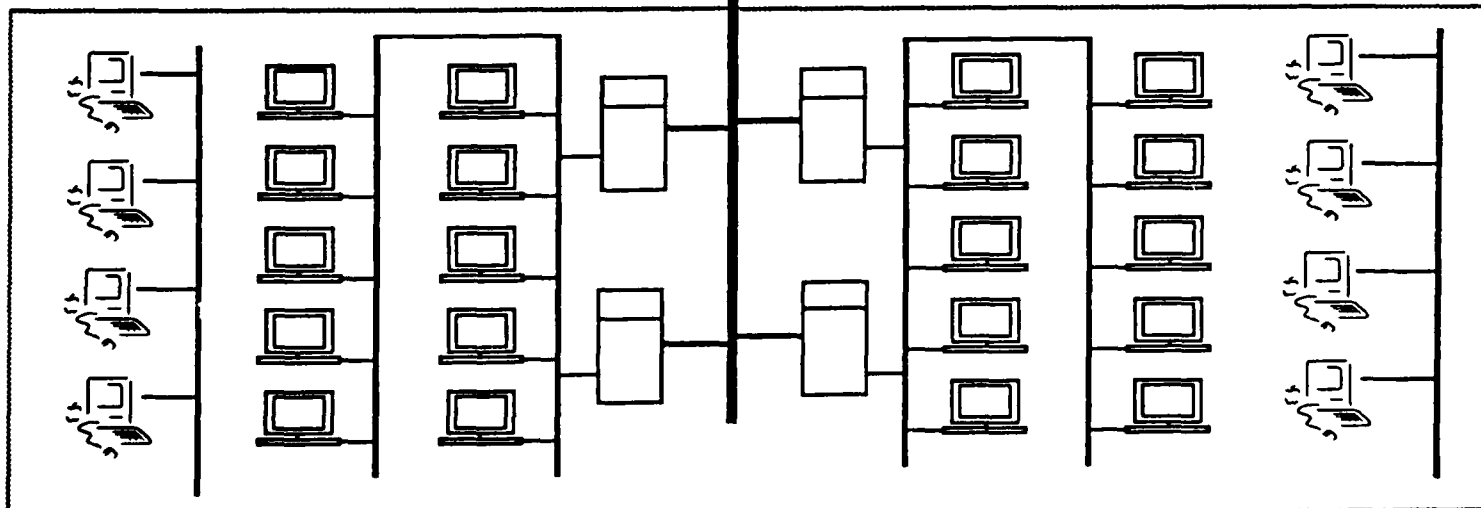


Fig. 2-cont.

2) A Hewlett-Packard HP 3562A Dual-Channel Signal Analyzer with frequency range of 64 μ Hz to 100KHz. This is a Fast Fourier Transform (FFT) based network, spectrum, and waveform analyzer which provides analysis capabilities in both the time and frequency domains. The system has DC-to-100KHz frequency range, 150 dB measurement range and 80dB dynamic range. The system may be used as a spectrum analyzer, transient recorder (AD converter) and waveform analyzer with zoom and storage capabilities. Other features include a full range of data analysis capabilities such as vector averaging, block-operation waveform Math, a 40-pole/40-zero Curve Fitter and Frequency Response Synthesis.

3) A 125 MHz Dual-Channel Le-Croy 9400 Digital Oscilloscope. The system is capable of recording high frequency signals at a rate of 100MHz with 8-bit accuracy. Two 32 K waveform memories and 128 K of storage memory is available. The system includes WPO1 waveform Processing Package which provides signal averaging and arithmetic processing, including integration and differentiation. The system is fully programmable and has computer, plotter-printer interfacing via IEEE-488 and two RS232-C ports.

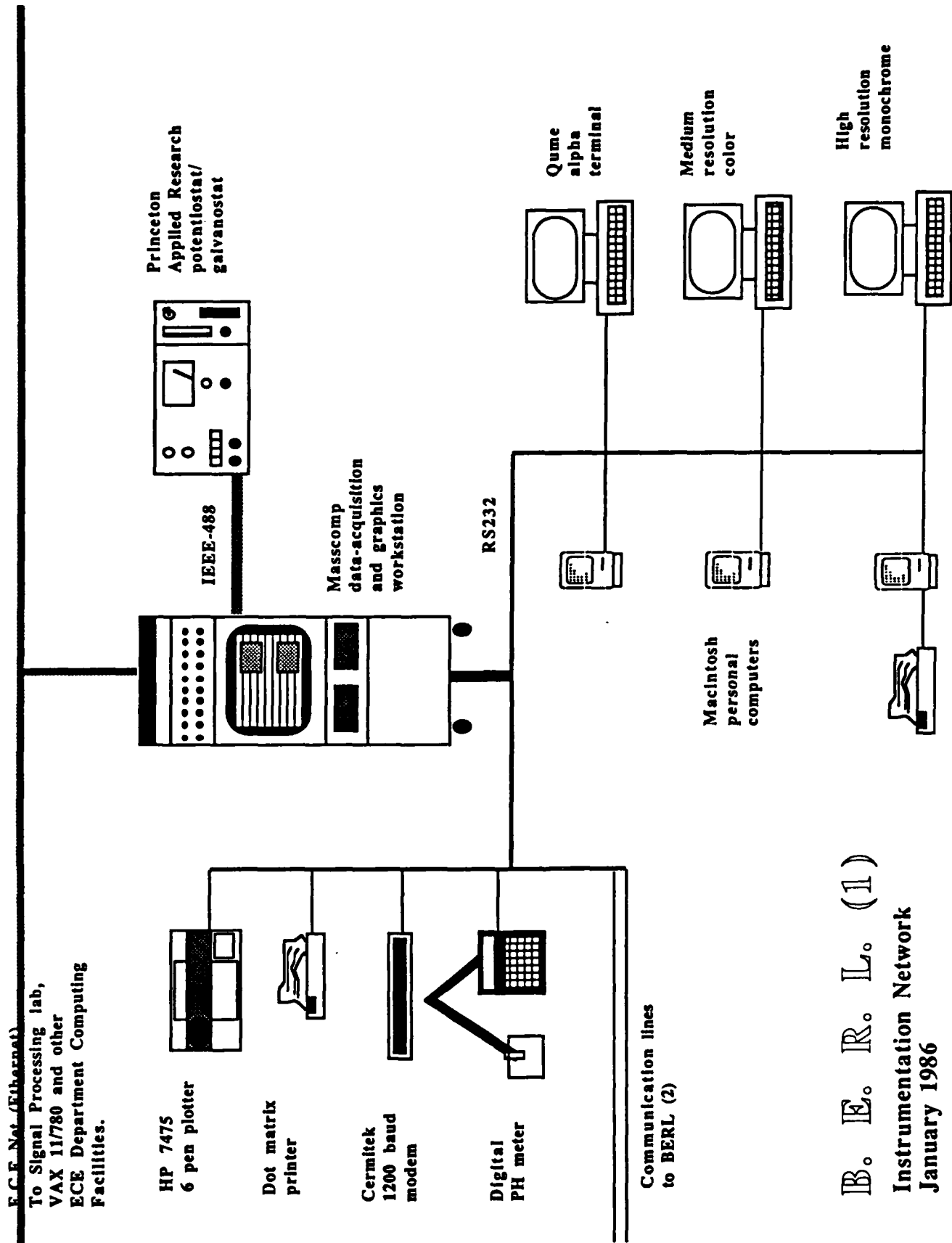
4) The transducer Positioning System is an automated system powered by stepping motors capable of 10 μ m steps. The scanner is controlled by the Masscomp Workstation using Superior Electric Motor Controller System consisting of:

- 1 IOD010 Modulynx System Controller Card w/ IEEE 488 interface
 - i. control programs can be stored permanently in EEPROM for autonomous motion
 - ii. can be controlled using IEEE 488 interface or joystick
 - iii. capable of controlling up to 6 axis simultaneously
 - iv. acceleration and velocity profiles are fully programmable

- 2 IMD128A Modulynx Microstep Indexer Cards
 - i. produces the stepping sequence needed by the DRD003 Driver Cards to move the motors the desired distance
 - ii. capable of generating movements as small as 0.0141°
 - iii. all functions can be accessed by IOD010 System Controller
 - 2 DRD003A Modulynx Driver Cards
 - i. converts the step sequence generated by the IMD128A Microstep Indexer Card into the voltages necessary to drive the motors
 - ii. can be fully controlled by the IOD010 System Controller
 - Stepper motors, power supplies and SKD113 Modulynx 3 - Axis System Crate
- 5) 512-K Apple Macintosh Personal Computer, 400K external disk drive, and Imagewriter printer.
 - 6) Apple Laser Writer printer.
 - 7) General Instrumentation (i.e. oscilloscope, signal generator, multimeter, power supplies, ultrasonic pulser, etc.)
 - 8) HP 7475-A 6 pen plotter.

As indicated in Fig. 2, SPL facilities are linked to various computer facilities in the ECE Department through the ECE net. This allows interaction with a large number of researchers in the ECE Department. A particularly close research interaction and facility sharing has been developed between the Signal Processing Laboratory (SPL) under the direction of Dr. Bilgutay and the Biomedical Electrode Research Laboratory (BERL) under the direction of Drs. Onaral, Sun and Beard (see Fig. 3), and the Speech Analysis Laboratory under the direction of Dr. Paarmann.

These three facilities support approximately 15 graduate and numerous undergraduate students. The projects related to these laboratories are listed in the following section.



B. E. R. L. (1)
Instrumentation Network
January 1986

Figure 3: Bio-Electrode Research Laboratory

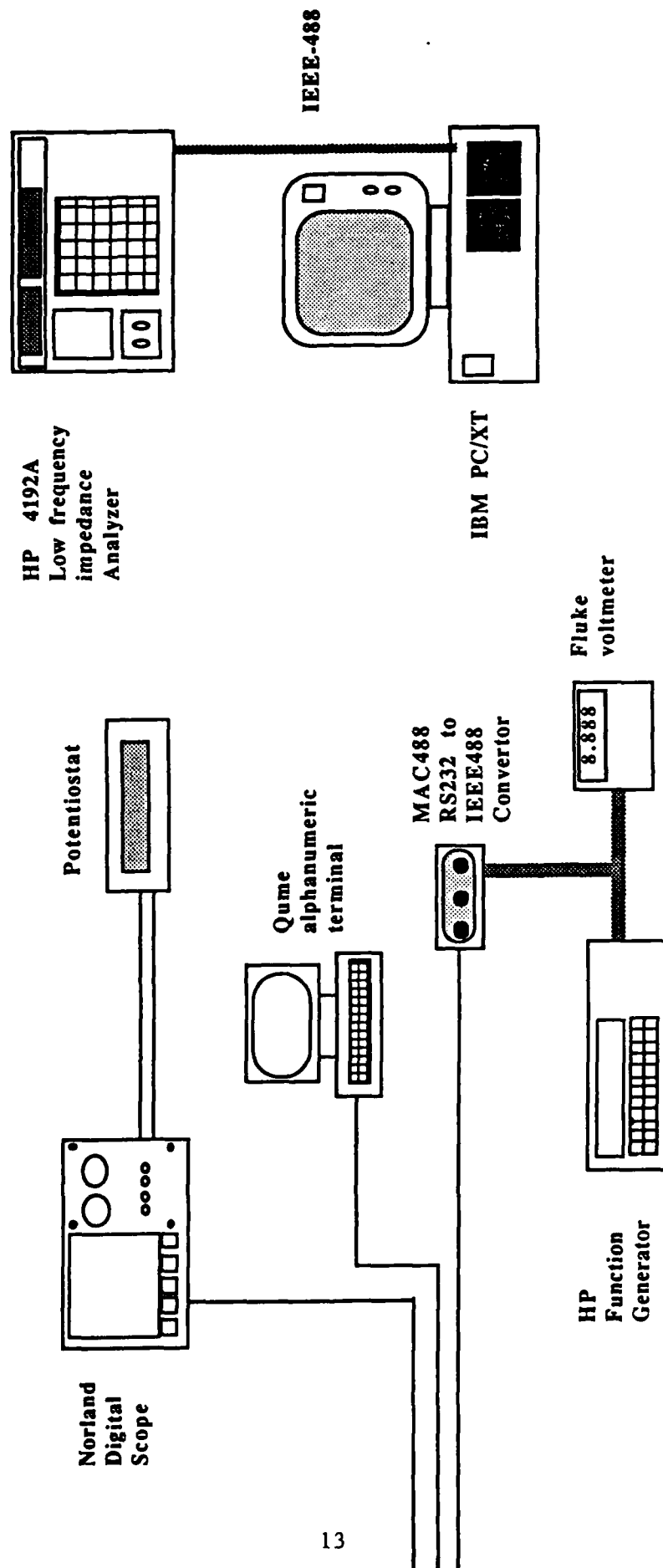


Fig. 3-cont.

B. E. R. L. (2)

Conclusions:

The facilities developed have met the projected goals and timetable of the grant. In addition, the new facilities have provided the impetus for furthering current research work and the means for pursuing proposed new concepts which are relevant to the DOD goals. All the major equipment has been interfaced with the Masscomp workstation through standard automation bus protocols. In addition, the Masscomp workstation has been integrated with the ECE Computer Network, thus providing authorized persons direct access to the facilities.

Current/Pending Projects:

The following list summarizes the projects which are of interest to the DOD for which the acquired equipment has been or will be used:

A Proposed Signal Processing Scheme for Target Extraction
and Automatic Clutter Rejection in Radar

Principal Investigators: Nihat Bilgutay and Jafar Sanie*

* Illinois Institute of Technology

Funded Project: SDI, ONR 4/1/86 - 12/31/88

When a large number of small and randomly distributed scatterers are present in the target range cell, the resulting interference pattern can severely deteriorate the image quality to the point of concealing the desired target. Although the terminology may vary, a similar problem exists in nearly all imaging and detection applications such as radar (clutter), non-destructive testing (grain echoes) and clinical imaging (speckle). This fundamental problem cannot be eliminated by conventional noise reduction techniques such as time averaging or filtering, since clutter generally consists of stationary (coherent), unresolved and randomly distributed reflectors.

A signal processing scheme has been developed in ultrasonic NDT applications which significantly improves the signal-to-clutter ratio in large grained materials. In this scheme a technique called split-spectrum processing was introduced, which obtains decorrelated grain boundary echoes (i.e. clutter signals) from a wideband echo signal by digital filtering and processes them using a novel technique referred to as the minimization algorithm. Split-spectrum technique was shown to have superior clutter reduction capabilities compared to the conventional frequency agile radar detection schemes such as square law detection followed by n-pulse integration. Theoretical and conceptual similarities between ultrasonic and radar detection suggest that the adoption of the split-spectrum processing technique to frequency diverse or spread-spectrum radar systems can significantly enhance target detection in clutter environment. In the proposed work the feasibility of split-spectrum processing and minimization algorithm for target detection and clutter rejection will be investigated for radar. The study will consist of theoretical analysis, simulation and experimental verification of the proposed radar techniques.

The proposed research is relevant to the SDIO Program since it deals with a potentially superior radar detection technique, which may be critical to strategic defence surveillance, target tracking and data acquisition where clutter interference (i.e. correlated noise) is the primary limiting factor. In addition, since the technique is based on spread spectrum type signalling it will be far less susceptible to jamming. Furthermore, the minimization processing has other potential applications such as sonar detection in sea clutter and remote optical imaging for target recognition in clutter.

Diagram 1 shows one of the proposed real-time split-spectrum radar systems using minimum detection scheme. Here the transmitted signals can be generated using either the frequency agility or chirp principles. The objective is to obtain a signal set $r_i(t)$ corresponding to different frequency bands (i.e. consisting of decorrelated clutter echoes). In order to obtain $r_i(t)$, the received signal $s_R(t)$ is passed through a pulse compression filter and the resulting broadband signal is passed through a set of band-pass filters. The band-pass signals $r_i(t)$ are full wave rectified prior to selecting the minimum magnitude values at each time instant. Since clutter type reflectors are much smaller in size than the target, the clutter interference pattern will be far more sensitive to the variation in the frequency contents of the band-pass signals. Therefore, the minimum detection scheme will suppress the clutter echoes to a much greater extent than the target echo, resulting in signal-to-clutter ratio enhancement.

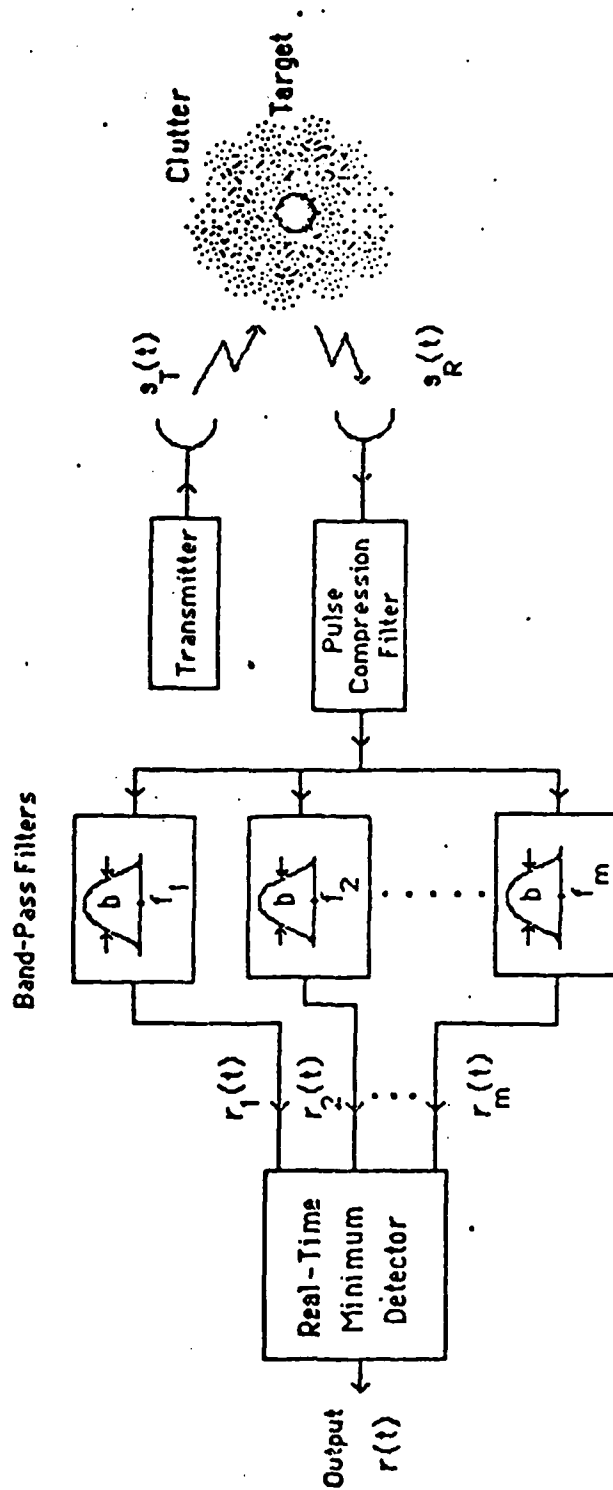
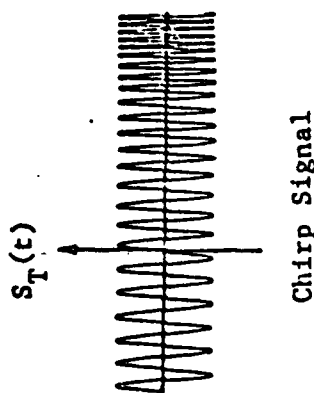
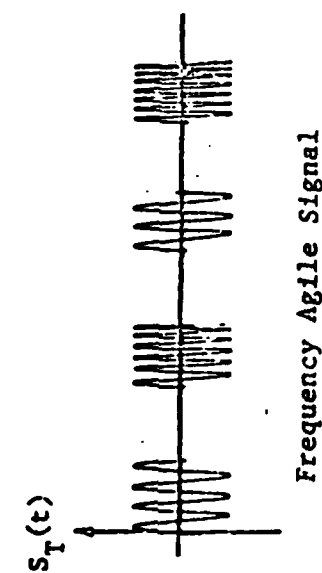


Diagram 1 - A Proposed Real-Time Minimum Detector Radar System Using Frequency Agility or Chirp Principle.

Detection of High G Blackout Based on Digital Signal
Processing of the EEG

Principal Investigators: Banu Onaral and Bruce Eisenstein
Funded Project: ONR N00014-83-K0559, 7/1/84-6/31/85

The physiological stresses on the human body exposed to several times the normal gravitational force present severe problems for military pilots when making evasive maneuvers in jet aircraft. The high G_z opposes the blood flow to the brain causing blackout if sustained too long. Some measures are taken to increase the pilot's threshold for G_z exposure, however, many test pilots exceed their G_z threshold and lose consciousness. Under test conditions, a reliable means of monitoring the pilot's physiological state is necessary. The purpose of this research is to investigate a physiologically and behaviorally noninvasive, objective, reproducible and reliable method of detecting high G_z induced blackout under experimental conditions. Work done in this area has led to the use of vision loss as an end-point in acceleration research. Monitoring of the eye-brain channel is accomplished by extracting a visually evoked response (VER) of the pilot to a Barker coded strobed light stimulus. The VEP is buried within the electroencephalogram (EEG) which is measured around the visual cortex of the brain. Monitoring is accomplished by matched filtering the EEG to make a yes/no decision as to the pilots visual functioning. The matched filter is custom designed for each subject based on preliminary EEG recordings under normal G_z . Experiments were performed at the Naval Air Development Center in which volunteer's were exposed to high G_z , using a dynamic flight simulator, while the eye-brain channel was stimulated with a strobed light source. Results show that the matched filter successfully detects blackout in most cases but the power of the test statistic is poor. This leads to the occurrence of false alarm. Ensemble averaging prior to the matched filtering reduces the amount of false alarm. Attempts to characterize the noise power of the EEG were not successful in improving the results. Analysis of the dynamic data show the non-stationary nature of the EEG during acceleration. This indicates that noise normalization using static noise will not help in the detection of blackout. Updating of the matched filter on the acceleration ramp, however, was ineffective due to the transient nature of the evoked responses.

Modelling of Ultrasonic Bonders for Quality Monitoring

Principal Investigator: Nihat Bilgutay

Funded Project: K&S and ATC/SEP 9/1/85 - 8/31/86

One of the goals of the proposed study is to formulate and evaluate the relationships between boundary conditions due to loading at the bond-tool interface and the measured parameters such as the ultrasonic frequency and the impedance variations during the bonding process. It is believed that improved process monitoring techniques can be developed based on the functional dependence between the ultrasonic frequency and impedance variations and the boundary conditions at the interface.

To date, mathematical models have been developed and analyzed for the bonding tool using two representations: single cantiliver, and dual cantiliver joined at the driven end. Simulation programs were developed to study the behavior of the system for both the free and the loaded (i.e. during bonding) cases. For the single extension model, the interdependence between gain, beam length and impedance were evaluated for the free case. In addition, the boundary conditions and impedance variations with load were analyzed for the loaded case. For the double extension model, the optimal beam lengths and clamping heights vs. impedance and gain plots were obtained for the free case. In addition, the relationship between resonant frequency and clamping height was obtained. The dual extension model was also analyzed for the loaded case.

Both experimental and simulation results indicate that a strong dependence exists between load, resonant frequency, and input impedance in an ultrasonic bonder. Resonant frequency was observed to increase as loading on the bond surface increases. The analysis also showed that resonant frequency is strongly dependent on load velocity but independent of shear force. The input impedance was found to be a function of increasing load and strongly dependent on both the load velocity and shear force.

As an extension of the current research we plan to continue the analysis of the physical model of the bonder for the loaded case. Experimental verification of simulation and theory will continue using the facilities at K&S and Drexel. In addition, improvements will be made in the mathematical model to include the variation in the tool geometry and the frictional losses, to consider the effects due to other components of the bonder (driver, coupler, horn), and to re-examine the boundary conditions for possible improvements. Finally, experimental data obtained from the bonding tools under various bonding conditions will be examined to evaluate possible in-process monitoring techniques based on the improved theoretical models.

Recent developments also indicate that using a voltage source in bonders results in an adaptive property which makes it more suitable for optimal bonding, while using a current source provides conditions convenient for monitoring the bonding process. Therefore, it is suggested that the feasibility of using two source bonders be examined (i.e. voltage source during bonding, current source for subsequent monitoring). This approach should improve monitoring capabilities while maintaining high bond quality levels.

Linear and Non-Linear Analysis of Bio-electrode Polarization

Principal Investigators: Banu Onaral, Hun Sun and Richard Beard

Funded Project: NSF ECS - 8408294, 2/1/85-6/31/87

The project has progressed according to the proposed research objectives and time table. We have continued our work on systematic characterization of the electrical properties of metal electrode-electrolyte interfaces both in the linear and nonlinear range. We have further developed the unifying analytical approach introduced by our group to conveniently model the electrical properties of polarized interfaces in general, and the metal electrode-electrolyte interface in particular, using methods of linear and nonlinear system theory.

One objective of this research effort has been to validate the proposed analytical methodology by extensive measurements of the metal electrode interface under a broad range of experimental factors. In order to streamline these experiments, we have developed a number of automated measurement schemes based on an extension of the transfer function analysis performed by digital correlation.

Our preliminary results both on the platinum and palladium electrodes indicate that our approach to characterization serves well to monitor the interfacial electrochemical behavior in a wide dynamic range, both in terms of amplitude and frequency content. Also, through interaction with other studies in the general area of polarizable lossy media characterized by multiple relaxation/dispersion behavior over broad frequency and amplitude spectra, we have been able to substantiate our speculation concerning the potential applicability of our methods to a wide class of interfacial, dielectric and mechanical relaxation processes. During the remainder of the project, we will attempt to fine-tune our analysis procedures and, if successful, offer it as an analytical tool for the study of processes which bear phenomenological resemblance to the interfacial polarization at the electrode-electrolyte boundary. During this past funding period, we have finalized analysis techniques for the linear dynamics of the interface and we have investigated a variety of options to explore nonlinear dynamics. Our results indicate that describing function analysis is limited to gain compression/expansion and other nonlinear distortion criteria, such as harmonic distortion and intermodulation which can not be quantitated. We are currently investigating other nonlinear transfer function analysis techniques based on the Volterra-Wiener approach, namely frequency mix and noise response approaches. In conjunction with this work we have recently initiated phase-plane analysis of nonlinear bio-electrode dynamics.

The extension of linear and nonlinear dynamic analysis in the presence of interfacial DC bias will be initiated during the next funding period in preparation for a systematic analysis of the bias dependence of the linear and nonlinear dynamics of electrochemical interfaces; we will attempt to delineate specific distortion criteria to facilitate the detection of regions of thermodynamic nonequilibrium. The target application, though beyond the scope of this project, is the enhancement of Pourbaix maps used to monitor corrosion stages of metals and alloys. The behavior of metals in physiological saline, in particular those typically used as implanted electrodes is of interest to us considering that a main objective of this work is to develop operational rules for the design and evaluation of metal electrode-electrolyte interfaces for acute and chronic bioelectric sensing and stimulation applications.

Development and Analysis of an Ultrasonic Imaging System
for Clutter Reduction

Principal Investigator: Nihat Bilgutay

Funded Project: NSF ECS-8505 153 7/1/85 - 12/31/87

When a large number of small and randomly distributed scatterers are insonified, the resulting backscattered echoes can severely deteriorate the image quality. This fundamental problem known as clutter exists in nearly all imaging and detection applications and cannot be eliminated by conventional noise reduction techniques such as time averaging or filtering. However, a non-linear minimization algorithm utilizing a frequency decorrelation technique, which achieves significant clutter suppression in one-dimensional (A-scan) ultrasonic applications, was recently developed.

The objectives of the proposed research are three-fold:

- 1) To develop a two-dimensional (B-scan) ultrasonic imaging system utilizing the non-linear clutter rejection concepts used in A-scan applications.
- 2) To develop and refine the theory for the two-dimensional minimization algorithm and split-spectrum processing.
- 3) To experimentally verify the theory and evaluate the imaging system in both clinical and materials applications.

Since improved imaging in clutter has significant ramifications in both materials and medical imaging, the successful completion of the proposed research can have significant impact on the solution of a fundamental problem in ultrasonic imaging.

Analysis/Synthesis: Non-Linear Spectrum Compression of Speech Signals

Principal Investigator: Larry Paarmann

Funded Project: NSF ECS-8404 629 10/1/84 - 9/30/86

The overall objective of this research project is the non-linear spectrum compression of speech signals as an aid to the profoundly hearing impaired. This involves the identification of model parameters for the speech signal, determining the model poles, warping the poles non-linearly, and synthesizing non-linearly spectrum compressed speech to match the residual auditory function of the hearing impaired.

The objective of the initial sub-project is to accurately model speech signals such that the model parameters can be accurately and efficiently identified. Specifically, the goal of this research is the development of an innovative systems identification algorithm for quasi-periodic signals that is computationally efficient and insures accurate pole identification, without involving explicit pitch extraction.

The approach is to analyze the identification process whereby the autoregressive parameters of quasi-periodic speech are determined in a least-squares sense, noting the improvements gained by processing pitch-synchronously. Since it is assumed that significant improvements will be gained by pitch-synchronous processing, the next step is to develop an innovative system identification algorithm that accurately identifies the model poles without explicit pitch extraction. No such algorithm presently exists in the literature.

Approaches we are investigating include pitch-synchronization feedback within the algorithm, homomorphic deconvolution prior to identification, utilization of a modified ARMAX model, and considering the identification process as an application of constrained optimization.

Speckle Reduction in High Resolution Ultrasonic Imaging

Principal Investigators: Nihat Bilgutay & Mohana Shankar
Proposal Submitted to NSF March, 1986

Speckle is a major source of image degradation in ultrasonic imaging. The present methods of speckle reduction consist of frequency diversity or spatial diversity, which involve generating multiple uncorrelated images and combining them. In a typical spatial diversity compounding technique, the image is viewed from different transducer orientations to create independent images. The improvement in image contrast is proportional to $\sqrt{N}$, where N is the number of images. N can be increased only by decreasing the transducer aperture, which leads to worsening of the lateral resolution. Lateral resolution may be improved by making the transducer aperture large; which in turn leads to overlapped transducer locations for a given N . This results in correlation between images, leading to contrast value less than $\sqrt{N}$. On the other hand, a statistical decorrelation technique described here can be employed to create uncorrelated images from N correlated images. A new processor can then be derived for spatial compounding, whose output corresponds to weighted averaging. The weighted averaging restores the contrast to $\sqrt{N}$ with improved spatial resolution. The above technique can also be used in a similar fashion in frequency diversity compounding when the frequency bands overlap.

Quantitative Grain Size Evaluation Techniques Using Time and Frequency Domain Analyses

Principal Investigator: Nihat Bilgutay
Proposal in preparation

Grain size estimation in polycrystalline materials using ultrasonic backscattered echoes has significant practical implications in evaluating the integrity of materials during their manufacture and use. In addition, it has been shown that certain material characteristics can be evaluated based on grain size analysis. Therefore, reliable methods for nondestructively evaluating the microstructure of materials is highly desirable in industrial applications. However, the complexity of backscattered signals, which consist of interfering multiple echoes with random amplitudes makes accurate grain size evaluation difficult. Despite the complexities involved, our preliminary work has shown that conventional ultrasonic methods combined with proper signal processing techniques can facilitate ultrasonic grain size evaluation. The purpose of the proposed project is to further the development and analysis of these techniques.

In the work to date, various signal processing techniques were utilized, both to obtain attenuation measurements from the backscattered random echoes, and to quantify their statistical parameters. Application of these techniques to stainless steel samples indicate that the processed data can be used to evaluate the grain size. In addition to the time and frequency domain techniques, a homomorphic signal processing technique was also utilized to determine the relative size of grains in stainless steel samples. A satisfactory agreement has been found between the various experimental methods and the micrographic grain size measurements.

Dispersion Analysis of Ultrasound Propagation in Tissue

H.H. Sun, B. Onaral, R.B. Beard, N.M. Bilgutay

Accurate determination of parameters characterizing the transmission and reflection of ultrasound in tissue has important implications in the noninvasive monitoring of tissue types and states. The mechanical relaxation processes elicited by the propagation of diagnostic dose ultrasound manifest in the form of linear dispersion phenomena characterized by a fractional power function dependence on frequency akin to dielectric and interfacial polarization. A method to fully and precisely represent such dispersion systems over extended frequency ranges has been developed by the investigators. The method has been implemented by an interactive computer program which extracts automatically the ultrasonic tissue model parameters solely based on the attenuation characteristic and produces the corresponding phase velocity profile which is not readily measurable due to the subtle velocity dispersion of tissue. The development of the method as a noninvasive diagnostic tool necessitates high frequency measurements and extensive data analysis afforded by the proposed system.

Compensation of Blood Pressure Waveforms

Principle Investigator: Larry D. Paarmann

The objective of this research is to develop a digital signal processing algorithm that will adaptively compensate for the distortion introduced by the catheter in a conventional blood pressure monitoring instrumentation system. In such conventional instrumentation, as used in the intensive care unit and in the cardiac catheterization laboratory, the fluid-filled catheter acts as the connective link between the pressure monitoring instrumentation and the point in the cardiovascular system where the blood pressure waveform is desired. Due to inadequate frequency response, and the tendency of the catheter to oscillate, the measured blood pressure waveform is distorted by the catheter. The characteristics of this distortion are time-varying.

Compensation techniques have been previously attempted, with varying degrees of success, but to date no satisfactory solution has been achieved for the clinical setting. For critical measurements, costly, fragile, and difficult to calibrate catheter-tip pressure transducers are presently used.

This research applies modern systems and signal processing concepts to the problem. The approach is to identify and compensate for the catheter distortion from parameters of the measured blood pressure signal only. It is an on-line technique that will adapt to catheter changes as they occur.

This approach should significantly improve the fidelity of the displayed blood pressure waveform and thereby improve decision making regarding candidacy of the patient for heart surgery. It could significantly reduce, or obviate, the need for catheter-tip pressure transducers.

EEG Signal Analysis

Principle Investigators: Larry D. Paarmann and Banu Onaral

This research project is concerned with detecting the onset of blackout in pilots subjected to high-G forces by analyzing the pilot's EEG waveforms. Raw data have been obtained from pilots in the human centrifuge facility at the Naval Air Development Center, Warminster, Pennsylvania. Previous work on this project conducted at Drexel involved data compression of EEG data, time-averaging the EEG signal across blocks of data and using matched filters for detection of the onset of blackout. The present work involves the modeling of the EEG signal as a pure autoregressive process.

The technique is to extract the autoregressive model parameters from the EEG signal using an identification program; a standard sequential least-squares algorithm appears to be the most promising. The model parameters may then be processed directly for the detection of the onset of blackout, or the corresponding frequency spectrum based on the autoregressive parameters may be so processed.

Direct processing of the autoregressive parameters will involve rooting routines to determine the poles of the equivalent model transfer function or working directly with the autoregressive parameters themselves, establishing decision boundaries in the z plane for the model poles or decision boundaries in the space of autoregressive parameters, and monitoring the poles/parameters to detect the crossing of decision boundaries that indicate the onset of blackout.

Processing the frequency spectrum for the detection of the onset of blackout is based on the assumption (which in turn is based on experimental observation) that the EEG spectrum changes significantly as blackout is entered. This processing will require monitoring the spectrum at several key points and determining decision criteria upon which to indicate the onset of blackout.

These detection schemes are presently under investigation, and will be compared among themselves and with the previous matched-filter schemes to establish the technique that can yield the earliest onset of blackout decision.

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