IR IED 75

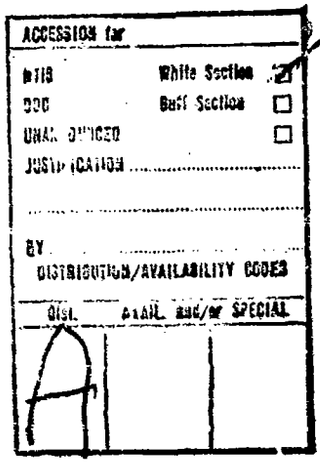
(12)

INDEPENDENT RESEARCH AND INDEPENDENT EXPLORATORY DEVELOPMENT

ANNUAL REPORT FY75

NAVAL ELECTRONICS LABORATORY CENTER
San Diego, California 92152
TECHNICAL DOCUMENT 448
1 SEPTEMBER 1975

See Form 1473



Approved for public release;
distribution is unlimited

REPORT CONTROL SYMBOL NAVMAT 3920-1

Foreword

The Independent Research and Independent Exploratory Development Programs for fiscal year 1975, described in this report, continued to support the Center's objectives by developing new capabilities in the technology base for the future and by improving present capabilities through extending range in sensitivity, frequency, or processing speed and through increased reliability, improved acquisition methods, and decreased vulnerability.

This year a portion of the Independent Exploratory Development funds was dedicated to the solution of Marine Corps problems. In each case there was a need for improvement in some specific sector of a major program — improvement that could be achieved with a small expenditure in funds and manpower but would result in a considerably enhanced capability.

Since 75 percent of the IR/IED projects were initiated in FY75, a larger proportion than usual continue into FY76. As a consequence of this, 85 percent of the funds are planned for continuing projects and there are only three new starts in each IR and IED. This meant that many excellent proposals had to be rejected because of lack of funds.

H. T. Mortimer, Head
Technology Program Management Office

Contents

Highlights of FY75

Solid-State Materials and Processes Characteristics: Reliability Improvement by Process Control and Surface Analysis

Independent Research
ZR011 02 (NELC Z195)

N. K. Wagner

Application of diagnostic techniques exposes such threats to reliability as high concentrations of surface impurities on "99.999% pure" aluminum pellets and interfacial oxides in thin deposited films. Measurement of spatial variation in electrical characteristics across CMOS test wafers reveals significant variations between batches and even between wafers within a batch.

Work performed during FY75 centered on the use of advanced analytical tools and techniques to achieve understanding of variations in reliability and performance of complementary metal-oxide-semiconductor (CMOS) silicon integrated circuits. The approach was twofold. First, semiconductor diagnostic techniques were used to study the effect of materials and processes on device characteristics. Second, the variation of key electrical parameters across CMOS/LSI wafers was measured in an attempt to determine the actual contributions of such diverse factors as materials defects, design criteria, and processing variables to the performance, yield, and reliability of finished integrated circuits.

DIAGNOSTIC TECHNIQUES

Work begun in FY74 involving the application of an Auger electron spectrometer to the analysis of 5 — 20-Å surface contamination layers was continued and expanded to include system modification for electron beam scanning to enable detection and spatial mapping of surface impurity sites as small as 5 micrometers in diameter.

Application of the advanced diagnostic techniques has resulted in direct benefits from both technological and scientific viewpoints. For example, aluminum pellets certified to 99.999% bulk purity by the manufacturer for use as aluminum metallization evaporation sources during electron beam deposition were found to contain high surface concentrations of impurities such as sodium. See figure 1. The detection of these impurities by Auger analysis was discussed with the wafer processing areas and the materials manufacturer to develop improved manufacturing methods. Also detected were interfacial oxides in thin deposited films, aluminum alloying areas formed during self-healing dielectric breakdown, and Schottky barrier diodes created in MOS capacitors by residual damage in the silicon surface.

Comprehensive test patterns — designed during FY74 — were fabricated in NELC's CMOS/LSI facility over a 9-month period involving five separate CMOS wafer batches. A testing technique was implemented by using a computerized tester and a large digital computer to measure and display the variation of critical parameters such as threshold voltage, breakdown voltage, sheet resistivity, saturation current, and aluminum-silicon contact resistance across the wafers.

The measurement was performed for a total of 22 wafers containing approximately 200 test patterns each. This information was displayed as a spatial variation pattern for each parameter and each test structure, showing the geometrical trend of the data as a three-dimensional surface. Consistent trends are recognizable in several parameters, however, significant variations were observed between batches and, occasionally, between wafers within a batch. The displays were found to be useful in correlations with physical parameters such as crystal defect density and surface state density measurements

in process control; as design guidance; and as a potential method for monitoring and acceptance-testing in crucial LSI device procurements.

PUBLICATIONS

Wagner, N. K., "Auger Electron Spectroscopy for the Analysis of Integrated Circuits," Proceedings of the National Electronics Symposium (NEC), p 107-111, October 1974

Wagner, N. K., "Analysis of Microelectronic Materials Using Auger Spectroscopy and Additional Advanced Analytical Techniques," Proceedings of the International Microelectronics Conference (IMC/NEPCON), February 1975

Wagner, N. K., "Semiconductor Reliability Improvement by Process Control," NELC Technical Note 2775, October 1974

Wagner, N. K., "Analysis of Microelectronic Materials Using Auger Spectroscopy and Additional Advanced Analytical Techniques," NELC Technical Note 2904, February 1975

Contact:
N. K. Wagner
NELC Code 4600
(714) 225-6591

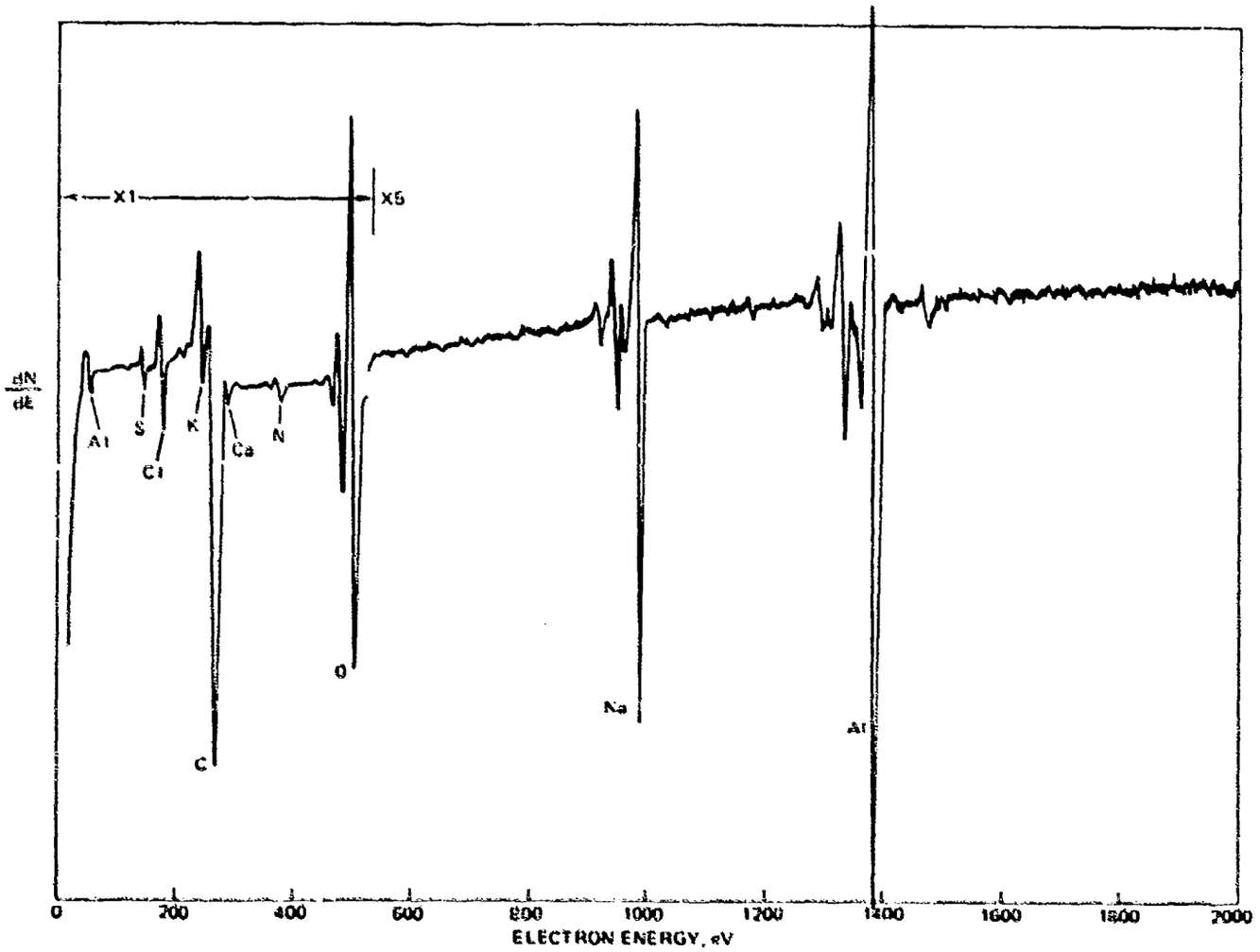


Figure 1. Auger electron analysis of dark area on surface of aluminum boule showing high sodium level.

Human Decision Making as a Function of Display Composition Variables

Independent Research
ZR042 09 (NELC Z109)

R. A. Fleming

In any command control system it is the display which makes needed information available to the decision maker to be used in the instant formulation of an effective response to a given situation. Before the display can be implemented, two basic questions must be resolved.

1. The display will of necessity be limited in capacity, whereas potentially useful information is almost infinite — which items shall be shown?

2. There are many forms in which the selected items may be made visible — in which forms will they be understood most quickly?

This project is specifically concerned with determining the information required for rapid-response tactical and task-force-level decision making, developing guidelines for the display of this information on the primary tactical display (a radar console or large-screen display), and outlining areas of research required for further optimization of the displays.

OVERALL ACCOMPLISHMENTS

The requirements analysis in FY75 indicated additional information which was required on the primary display. Alphanumerics and geometric symbology were the two major information coding candidates. A determination was made, where possible, as to which items of information would best be presented as alphanumerics and which as symbols or symbol modifiers. Literature reviews into information coding indicated substantial gaps in certain areas, and a series of research projects was proposed.

THE INTERACTIVE GRAPHICS PROGRAM

A significant accomplishment in FY75 was the development of an interactive graphics program for the creation of tactical symbology and high-quality simulated tactical scenarios.

The hardware for the graphics system consists of a memory scope and its associated hard-copy unit which can be purchased for less than $10 000 and a remote, time-shared computer. The graphics software makes the assumption that associated (required) software is available on the host computer.

A cost-effective interactive graphics program is developed for the creation of tactical symbology and high-quality simulated tactical scenarios. With suitable menus it can be adapted for use by other DoD and non-DoD agencies.

The program is based upon an earlier, simpler version of a drafting program used for the creation of flow charting and other drafting symbology. Modifications make it more suitable for the creation and production of classical Navy Tactical Data System (NTDS) symbology as well as for the creation of realistic static replicas of tactical scenarios as seen on a UYA-4 console. See figures 1 and 2.

The basic purpose of the program is the creation of menu items. After log-on procedures and initialization of the menu program, an X-Y grid is displayed as an aid in the layout of the symbol. Positioning of the cross hairs is used to specify beginning and end points of symbol lines. Special techniques are available for drawing arcs and curves. Once a symbol is completed and is of acceptable quality, it is filed on disc and assigned a unique three-digit identifier. Once filed, the symbol can be manipulated in a variety of ways. The angular orientation can be changed to any requirement, and symbols can readily be created which are 90° and 180° out of phase with the original symbol. A symbol can be recalled, rescaled in

size, rotated, and then added as a component of a new symbol. This embedding technique is very useful for creating complex symbols from a menu of relatively simple subcomponents. It is also helpful in adding symbol modifiers to basic symbols without the requirement of redrawing the original symbol. Also, a series of symbols can be added to a "blank" symbol and then filed. When the "blank" symbol is recalled, this single command will display a preselected and preformatted cluster of symbols in the specified location on the screen. These capabilities are illustrated in figure 3.

Tactical NTDS scenarios are created by use of a "put" (P) command. The cross hairs are positioned to a desired X-Y location on the screen and the letter "P" is typed by the operator. The computer requests the three-digit identifier of the symbol desired in that location. Once it has received the identifier, the computer will display the symbol in that location scaled to any size preselected by the operator. The current default condition is a size which produces on the hard-copy output (there is no 1:1 correspondence between scope size and hard-copy size) a symbol size identical to that on the UYA-4 console. Once the symbol has been displayed, the cross hairs reappear and can be positioned to the location for the next symbol. The cross hairs can also be left in the current position for the addition of modifiers to the latest symbol. Using combinations of these moves, the user can create a multi-symbol scenario which contains all the standard NTDS modifiers.

The primary advantage of the interactive graphics program is cost-effectiveness. Capital outlay for the initial procurement of the hardware is minimal. The terminal and its hard-copy unit can be purchased for a total under $10 000. The high-quality simulated tactical scenario displays can be produced at a fraction of the cost of producing similar displays on the NTDS.

The scenario displays are easily modified in terms of format, angular orientation, and size. If the program menu is changed from NTDS symbols to chairs, desks, consoles, etc, the program will function as a workspace layout program. If the menu items are knobs, dials, keysets, etc, it will function as a console design program. The "P" command described above would be used with the appropriate menu to create either workspace layouts or detail console design pictures.

The program is potentially useful to any agency concerned with the rapid display of a large volume of complex information. Possible users include other DoD agencies, the Federal Aviation Administration, and both military and nonmilitary human engineering research groups.

Stimulated by the interest aroused by the static scenarios, a new program is under development for another project which will enable animation (symbol movement) to be added to the scenario.

PUBLICATION

A document was written on this subject in FY75 by R. A. Fleming for publication as an NELC technical note. With the experimental data, this material will later be submitted to the *Human Factors Journal* for publication.

Contact
Dr. R. A. Fleming
NELC Code 3400
(714) 225-7372

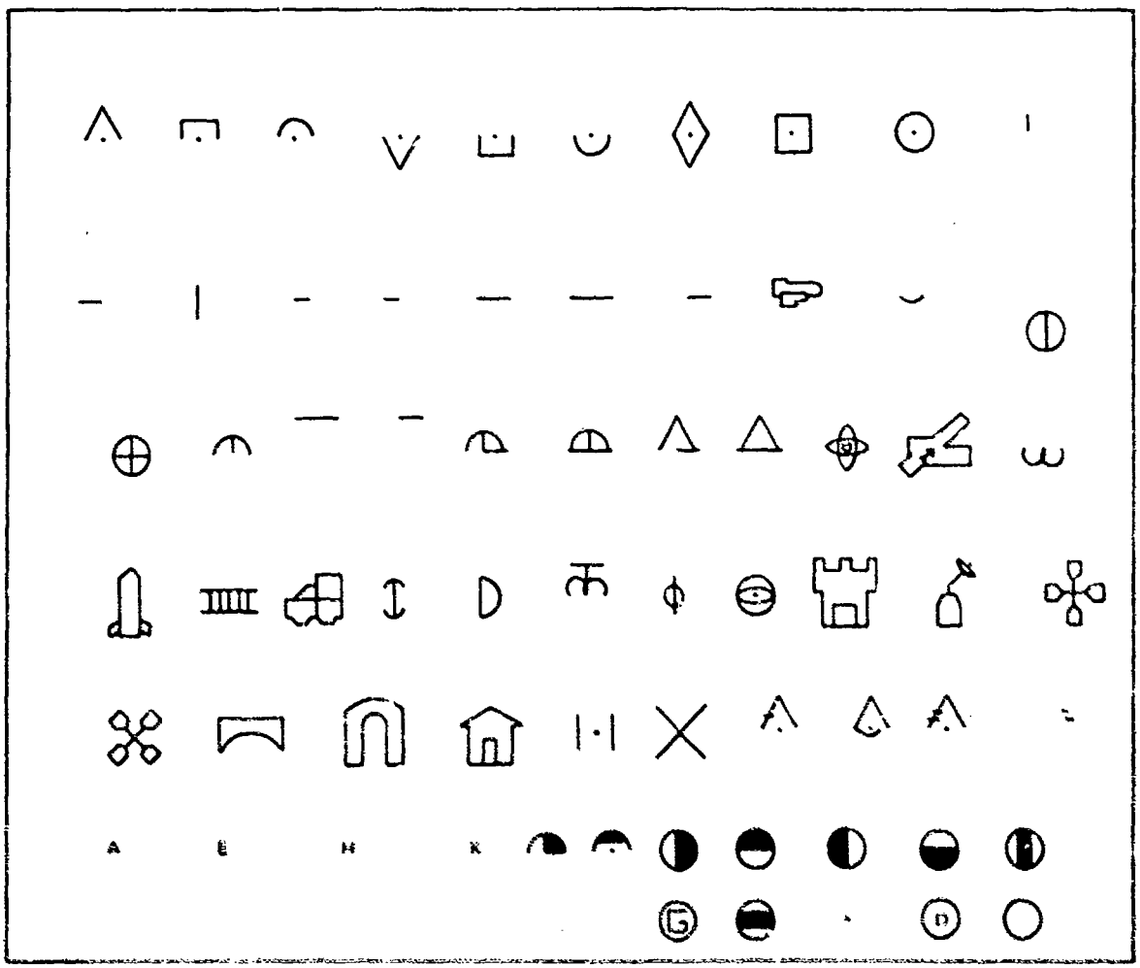


Figure 1. Current symbol menu.

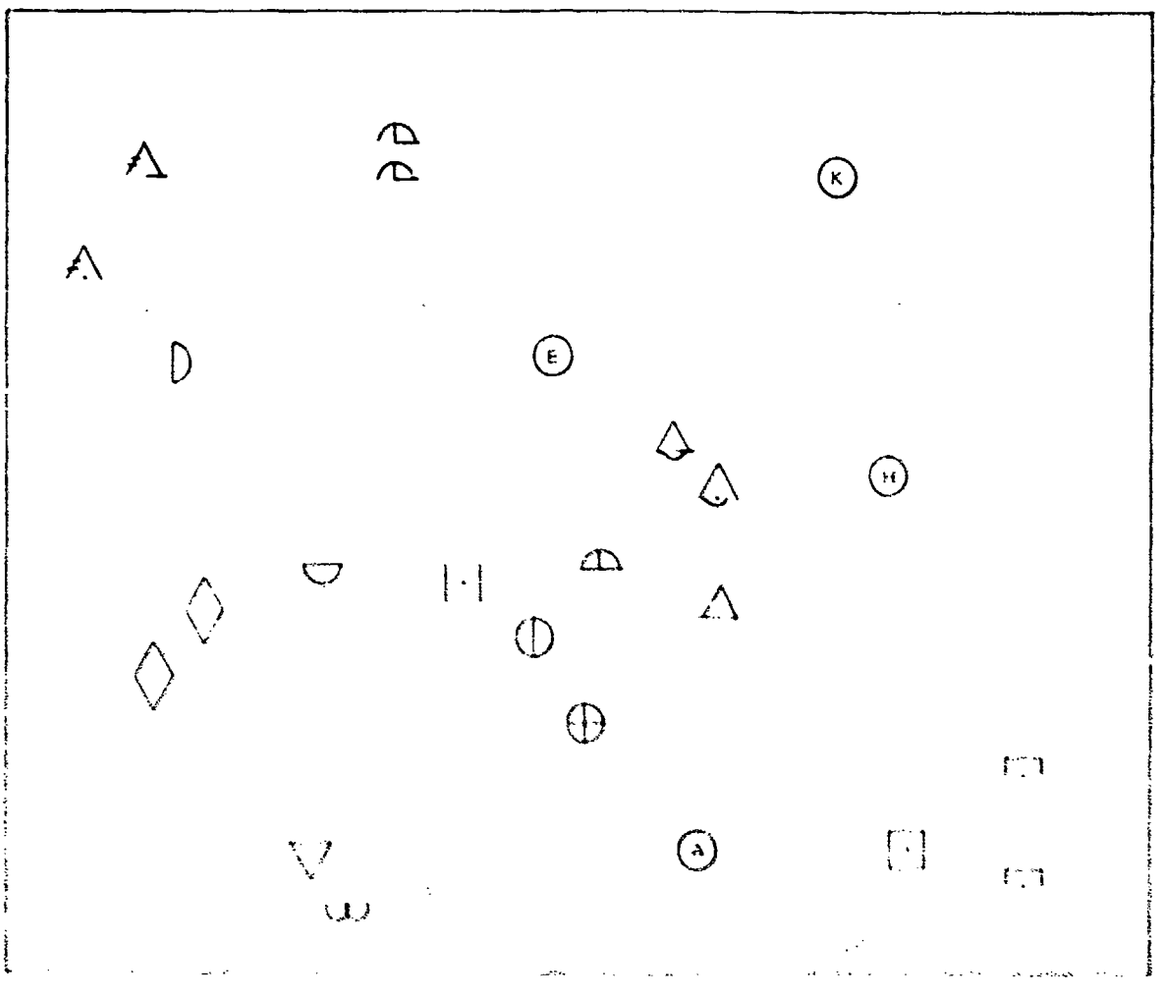


Figure 7. Hypothetical air and surface tactical scenario

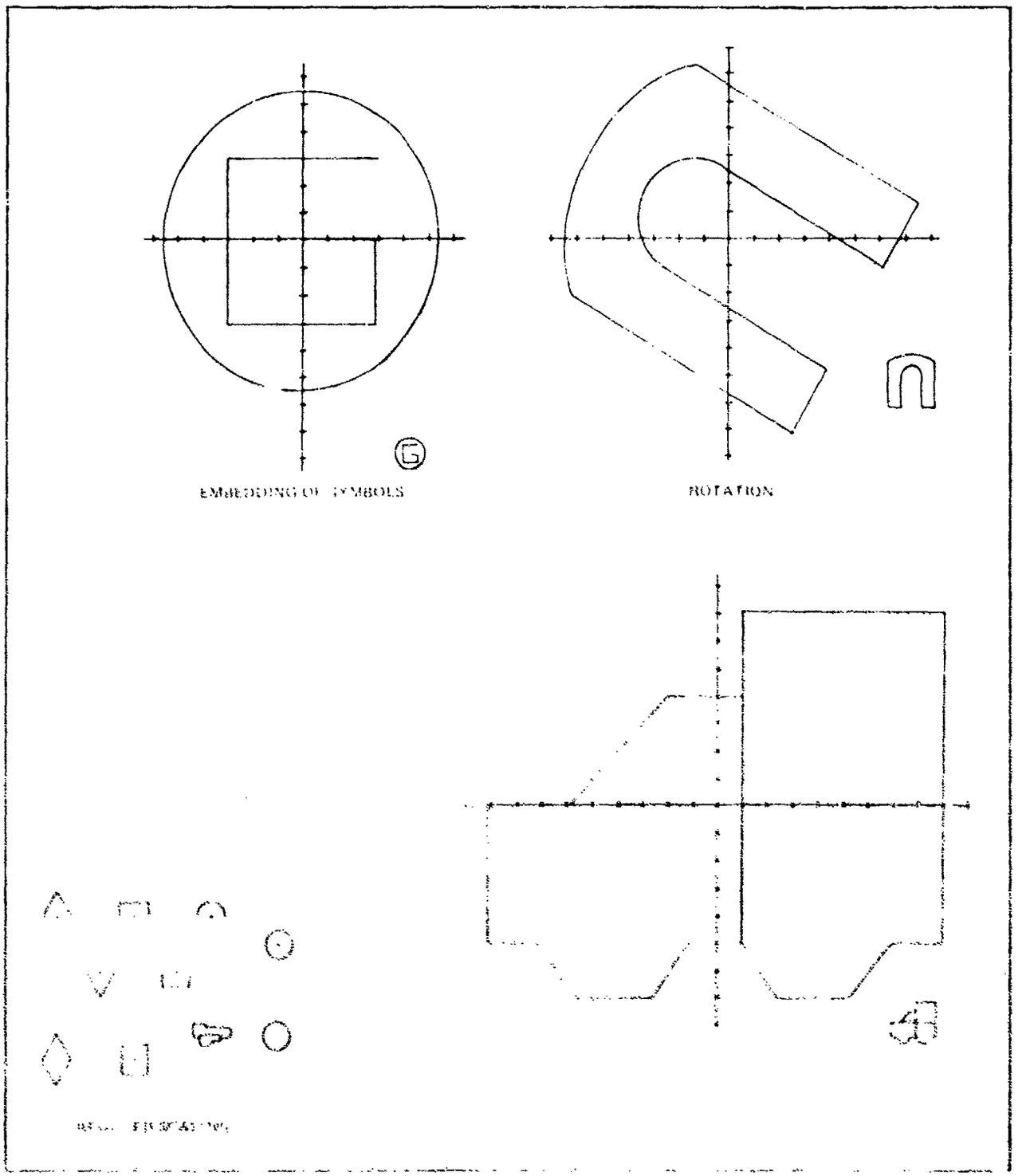


Figure 3. Samples of symbol construction

U.S. Marine Corps Tactical Time-Diversity hf Modem

Independent Exploratory Development
ZF61-212 (NELC Z279)

G. A. Clapp

Space in a 3-kHz hf radio channel not utilized for data is used for time-diversity error control. Error rate improvement effected by this technique exceeds a factor of 10. By taking maximum advantage of developments in digital technology, this austere and innovative development project — extending from modem design through construction and on-the-air testing to delivery of two operational units — was accomplished at a total expenditure of only $20k.

Most military hf circuits do not begin to fully utilize the available 3-kHz channel. Data rates in the channel that can support 2400-baud operation are frequently only 75 baud. If the channel space is not required for data, it should be used for error control. Significant error control can result from using any available diversity combining. Frequency diversity is available in some modems, but time diversity is not a currently available technique. Time diversity will be a significant asset to the hf user by providing protection against impulsive noise and fading.

The FY75 project effort consisted of the design and construction of time-diversity circuitry and testing over hf radio links, all accomplished at an expenditure of only $20k.

The simple, low-cost circuitry reflects current digital technology and incorporates a majority vote logic circuit recently developed at NELC (see fig 1). It provides up to eight orders of time diversity, and is designed to be used with existing multichannel frequency-shift-keying (FSK) modems. The tone circuitry of the in-service UCC-1 sixteen-tone hf modem was used to spare the time and expense of duplicating this capability for the first two feasibility units. Follow-on units will have their own tone package.

Prototype circuitry was completed in December 1974 and the 2-week-long hf test over a 500-mile path was completed in January 1975. Nondirective antennas were used and transmit powers were held to less than 1 kW in order to simulate tactical operating conditions. The testing permitted optimization of the number of orders of time diversity and the time delays of each diversity channel, and also indicated the improvement that could be expected from employing time-diversity techniques. Optimum configuration was five orders of time diversity spread equally over 2 seconds of time.

Significant bit error rate improvements were observed from applying time diversity to the 75-baud FSK signals. Error rate improvements generally exceeded a factor of 10 and on occasion a factor of 100.

As a direct result of enthusiasm at high levels in U.S. Marine Corps Development Center and the Naval Electronic Systems Command over the prospect of obtaining such a capability (less than 15 pounds, less than 0.5 cubic foot, and less than $500 per unit in production), NELC was requested to fabricate two units suitable for field demonstration and subsequent trial deployment to the Mediterranean with the 32nd Marine Amphibious Unit. The units were delivered and tested in July and will be on deployment from August 1975 through January 1976.

Concurrently, U.S. Marine Corps Development Center and NAVELEX tasked NELC to fabricate four feasibility models of a new Time Diversity Modem (XF21-222-015, NELC N466). These units will have their own tone package and thus not require that of the UCC-1. Additionally, they will have the capability of simultaneous voice and five-order time-diversity 75-baud data transmission over the same 3-kHz rf channel. These units will be delivered in November 1975. Finally, investi-

gations are planned for the provision of narrowband cryptographic voice protection with simultaneous time-diversity data transmission.

Time-diversity units have a large number of potential military applications. Any low-speed TTY circuit that has a 3-kHz channel assignment — selected ship-shore links, Antarctic-New Zealand, etc — can use the technique, which also has potential ASW air-ground application.

PUBLICATION

"Time Diversity for Use on Tactical HF Links" was written in FY75 by G. A. Clapp and will be published as an NELC technical note.

Contact:
G. A. Clapp
NELC Code 2100
(714) 225-7146
or
H. J. Feeney
NELC Code 1700
(714) 225-6764

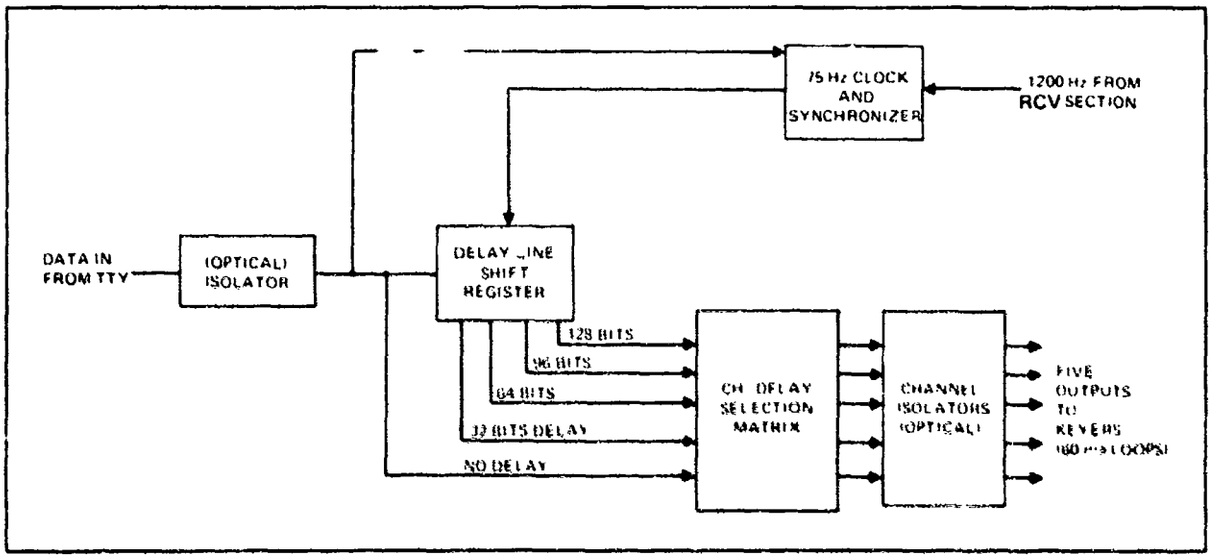


Figure 1. Transmit Section—Time Diversity Unit, block diagram. Receive section works in reverse—5 inputs, after suitable delay and bit-by-bit majority vote decision, drive a single TTY output circuit.

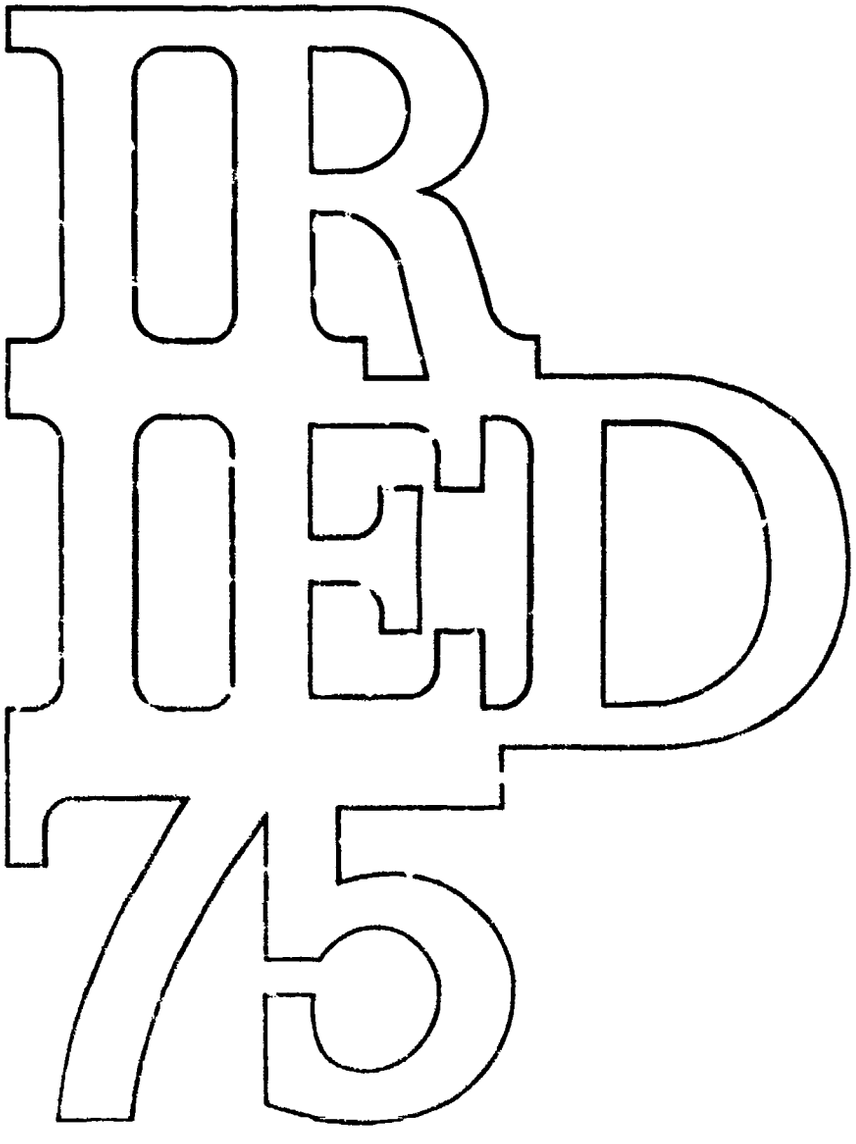
Sponsored Projects Based on IR/IED-Initiated Work

(Only projects not listed in earlier reports*)

Funding	NELC No.	Title	Based on
61153N RR04-120-01	S109	Automatic Processing of Echocardiograms	61152N ZR041-20 (NELC Z182)
61153N WR02-103-002	F303	Synthesis and Growth of Heteroepitaxial $InSb_xAs_{1-x}$ Epilayers and P-N Junction	61152N ZR021-02 (NELC Z102)
62712N XF12-151-003	G231	Millimeter Wave Downconverters	61152N ZR011-07 (NELC Z193)
62712N XF21-222 015	N466	USMC Tactical Time Diversity HF Modem	62766N ZF61-212 (NELC Z279)
62721N XF21-222-025 33401N X3259 & NRL NIF	N610	Electro-Optical Processing for Communications	62766N ZF61-212 (NELC Z274)
62762N XF54-545-011 & J22	R405	Low Cost Electronics	62766N ZF61-512 (NELC Z269)
62762N XF54-545-019	R224	Standard Electronic Modules/Standard Hardware Program (SEM/SHP) R&D Applications Program	62766N ZF61-512 (NELC Z240)
63713N S4636 & NSA	F234	Deep Submergence Rescue Vehicle Fiber Optic TV	62766N ZF61-212 (NELC Z246)
64518N S31X5	B193	Programmable HF Modem Suited for Link 11 Communications	62766N ZF61-212 (NELC Z277)
AF/NORAD	F236	Fiber Optic CONAD Interface Development	62766N ZF61-212 (NELC Z246)
NAD NIF	F235	Avionic Pressure Bulkhead Optical Connector	62766N ZF61-212 (NELC Z246)

*NELC TD 141, 1 Sep 1971, TD 194, 1 Sep 1972, TD 267, 1 Sep 1973, and TD 348, 1 Sep 1974

Independent Research



Integrated Optical Processing: Integrated Optics Devices

ZR011 12 (NELC Z104)

H. F. Taylor

"Integrated optics" is concerned with the development of thin-film dielectric waveguide components for carrying out a variety of operations (for example, modulation, switching, directional coupling) on guided light beams. Both theoretical and experimental investigations of integrated optics devices for information processing were carried out in FY75. New concepts in the areas of optical logic, A/D (analog to digital) conversion, addition of binary numbers, and fiber optics delay lines were developed, analyzed, and documented in journal articles, patent disclosures, and proposals. The analysis indicates that integrated optics could provide the capability to perform logic operations in 1 ns, A/D conversion at 500 MHz, and binary addition at 250 MHz; and to produce delay lines with time-bandwidth products in excess of 100 000. Significant improvements in the information-processing capabilities of radar systems and digital computers could result from the implementation of these new concepts.

A new class of devices combines optical and electronic techniques to achieve higher levels of performance in information processing. The FY75 effort ranged from analysis through experimentation to actual fabrication of devices.

Experimental work was directed towards demonstrating optical logic and A/D conversion. Under a contract supported by this program, the University of California, San Diego made measurements on the photoconductive properties of semiconducting II-VI compounds. Both bulk CdS and annealed polycrystalline CdS films demonstrated satisfactory photoconductive properties for use in logic elements.

Work on logic elements at NELC concentrated on the fabrication of devices by diffusion of Se into CdS. Techniques were perfected for polishing the substrates, compensating them by Cd diffusion, characterization of photoresist for mask patterns, obtaining ohmic electrode contact, and preparation of optical surfaces for coupling light into and out of the diffused waveguides. Excellent waveguide patterns have been obtained, and final device fabrication steps are in progress.

A bulk crystal of $LiTaO_3$ was used to modulate the intensity of light from a HeNe laser at 60 Hz in a demonstration of the feasibility of electro-optic A/D conversion. A maximum relative phase retardation of 8 π radians was obtained — equivalent to three bits of precision. The linearity was better than 1%, indicating that a precision of six bits or better is feasible.

PUBLICATIONS

Taylor, H. F., "An Electrooptic Technique for Analog-To-Digital Conversion," Proceedings of the IEEE, v 63, 1975 (in press)

Taylor, H. F., "An Electrooptic Technique for Adding Binary Numbers," *Electronics Letters*, v 11, 1975 (in press)

Contact:
Dr H F Taylor
NELC Code 2500
(714) 225-6641

Integrated Optical Processing: Silicon Detector

ZR011 12 (NELC Z104)

I. Lagnado

An infrared sensor, precharge circuit, and output amplifier integrated on a silicon substrate have been designed, fabricated, and tested. Capable of detecting a 10^4-electron signal, the device shows promise for fiber optics applications.

The FY75 effort in this program was devoted to the development of a technological base for the integration of a silicon photodetector and its accompanying amplifier. The integration of these two components alleviates some of the critical problems which limit the performance of presently designed optoelectronic systems with discrete parts. In the latter designs, stray capacitances and rf pickup are the main factors affecting speed and noise characteristics. The elimination or substantial reduction of these parasitic effects results in increased bandwidth and noise reduction in both fiber optics communication and optical processing applications by providing fast, active elements in compact form.

To demonstrate the feasibility and advantages of a "single" silicon substrate approach, an integrated sensor/precharge circuit/output amplifier was designed, fabricated, and tested at NELC. While PIN or other silicon avalanche diodes are usually used for optical detection, a simple metal-oxide-semiconductor (MOS) structure was selected for the silicon sensor, for compatibility with present integrated-circuit practice and ease of implementation. The fabrication of these optical sensor/amplifier devices uses the techniques of the n-channel, silicon gate technology for (1) its inherent higher-speed capability due to the combined effects of the higher electron mobility and elimination of Miller capacitances; (2) lower densities of fast interface states, hence lower I/f noise figure and smaller devices (gates), hence reduced RC thermal noise; and (3) relative transparency of the sensor polysilicon electrode to incoming optical signals, hence smaller losses. On the basis of an analysis of all noise sources in the sensor, a small metal-oxide-semiconductor field-effect transistor (MOSFET) is placed adjacent to the sensor to maintain a high signal-to-noise ratio to satisfy the requirements for high sensitivity. To reduce the effect of wiring capacitances and other parasites from peripheral electronics, this small MOSFET is "shielded" by one or two more stages which are designed to provide a high overall signal-to-noise ratio and larger bandwidth than a single amplifier stage.

The correlation between the design goals and the measured dynamic performance of the integrated functions of optical detection and signal amplification is seen from the data of table 1. Latest experimental results

	Transconductance, g_m (10^{-3} mho)		Turn-on time t_r (ns)		Bandwidth** (MHz)
	Calculated	Measured	Measured	t_{off}	Measured
First Stage	1	1	50 70	50 70	5
Second Stage	4.5	5	70 *50	100 *50	8
Third Stage	9.1	10	100	700	8

*Measured in source follower configuration

**At 3 dB attenuation and capacitive loading C_L = 100 160 pf

TABLE 1 STATIC AND DYNAMIC CHARACTERISTICS OF AMPLIFIER.

indicate that the circuit is capable of detecting a 10 000-electron signal at a 5-MHz repetition rate. This is equivalent to a light pulse energy 3×10^{-15} joule; ie, 10 to 30 nW at 5 MHz and a quantum efficiency which increases from 20% at $\lambda = 1\mu m$ to 70% at $\lambda = 0.8\ \mu m$. Operation up to 18 to 20 MHz was also demonstrated with similar sensitivity. An increase in sensitivity by a factor of 10 — ie, detection of 500 to 1000 electrons — is predicted when a floating gate replaces the floating diffusion employed in the experimental circuit. A model is being designed to demonstrate the high sensitivity of the device for the purpose of stimulating interest in the application of this device in fiber optics.

The practical uses of this demonstrated approach to fiber optics communications and optical information processing are mainly in operational missions requiring medium data rate (5 — 10 Mb/s), low-noise optical detection, and high signal-to-noise amplification.

Contact:
Dr. I. Lagnado
NELC Code 4800
(714) 225-6877

Solid-State Materials and Processes Characteristics

ZR011 02 (NELC Z195)

INTRODUCTION

H. H. Wieder

The five articles under NELC Z195 (one of them a highlight on page 5) describe work performed during FY75. The major thrust of this program is toward the research and development of advanced techniques and capabilities at NELC for the scientific analysis, understanding, and control of semiconductor materials and devices important for advanced Navy systems.

The program is cooperative in nature, involving several distinct groups in two NELC departments, industrial and academic concerns, and interaction with the Naval Research Laboratory.

Solid-State Materials and Processes Characteristics:

Metal-Oxide-Semiconductor Surface States

ZR011 02 (NELC Z195)

A. K. Nedoluha

Surface states critically affect the performance of MOS devices and represent one of the most serious problems of MOS process control in device fabrication. Improved control of surface states is expected to lead to higher device yield and reliability, beneficial to both Navy and industry. In FY75 the capability of measuring and characterizing surface states was established at NELC, and work to relate the surface state characteristics to processing parameters and device performance was begun. The test structures under investigation were silicon MOS capacitors fabricated at NELC.

NELC determines the energy distribution of surface states on MOS devices via surface photovoltage measurements and verifies the results by means of conventional capacitance and ac-conductance measurements. The ultimate goal is fabrication process control leading to higher yield and reliability.

Emphasis has been placed on developing surface photovoltage (SPV) measurements in the range of logarithmic light intensity dependence as a technique for quick, sensitive, and reliable determination of the spatial and energy distribution of surface states. To ascertain the practical usefulness of this method, experimental features such as wavelength dependence, illumination from front or back, ambient light, contact problems, chopper frequency, use of partially transparent chopper blades, and dependence on the capacitor area have been investigated. For capacitor diameters less than the minority carrier diffusion length, an empirical correction factor, linear in the capacitor diameter and dependent on the diffusion length, has been found.

To exemplify the role of surface state density with respect to processing parameters and device performance, SPV and flat-band voltages of an array of MOS capacitors distributed over a 2-inch wafer were measured and compared with the results of threshold voltage measurements on an array of MOS transistors over the same wafer. Correlations of surface state density, flat-band voltage, and threshold voltage as functions of position over the wafer have been shown.

To supplement the SPV technique, the capabilities of performing conventional and quasi-static capacitance measurements and bridge or lock-in ac-conductance measurements have been established. The ac-conductance method yields surface state cross sections in addition to density. To the limited extent that SPV and ac-conductance measurements have been compared, the resulting surface state densities are in agreement.

Contact:
Dr. A. K. Nedoluha
NELC Code 4600
(714) 225-6591

Solid-State Materials and Processes Characteristics:

Photovoltage Profiling

ZR011 02 (Z195)

D. L. Lile and N. M. Davis

In FY74 an optical beam scanning system was constructed for the profiling of semiconductor materials and circuits and for the determination of carrier lifetime by means of a photovoltage measurement. System operation was demonstrated by profiling samples of device grade silicon (fig 1).

In FY75 photovoltage profiling was compared with alternative, more standard, methods for determining lifetime; specifically, with measurement of photoconductive and photovoltaic pulse and frequency response, with measurements of capacitive decay, and with measurements of the photoelectromagnetic/photoconductive ratio, and with electron beam and optical beam scanned measurement. The results were encouraging. Photovoltage profiling compared very favorably with the National Bureau of Standards (NBS) method, photoconductive decay, and in fact NBS is reported to be considering the use of photovoltage measurement as an alternative lifetime measuring standard.

Photovoltage profiling may be used to detect defects in semiconductor materials and to provide data on carrier lifetime related to device performance. Applied early in the production cycle, it could increase the yield and reliability of semiconductor circuits.

Photovoltage profiling was also compared in FY75 with other methods of device and material evaluation. The equipment was modified and extended to allow for the probing of integrated circuits (ICs) and test pattern structures. Qualitative investigations and quantitative measurements of photovoltage and lifetime were conducted on a variety of structures, including commercial metal-oxide-semiconductor and field-effect-transistor devices as well as ICs and test pattern structures manufactured in house. Most recently a lifetime profile over the entire surface of a 2-inch-diameter test pattern array was obtained. The results of this measurement are currently being compared with other data obtained on the same sample.

The technique has also been applied in a cooperative effort with other concurrent programs to devices made of other materials. Samples of InAs, InSb, and n and π GaAs have been evaluated. The results indicate that photovoltage profiling, as expected, may have wide application in the testing of a variety of semiconductors.

PUBLICATIONS

Lile, D. L., and Davis, N. M., "Semiconductor Profiling Using an Optical Probe," Solid-State Electronics, Pergamon Press, v 18, p 699-704, 1975

Lile, D. L., and Davis, N. M., "Optical Techniques for Semiconductor Material and Circuit Inspection," Solid State Technology, July 1975

Contact:
Dr. D. L. Lile or N. M. Davis
NELC Code 2600
(714) 225-6591

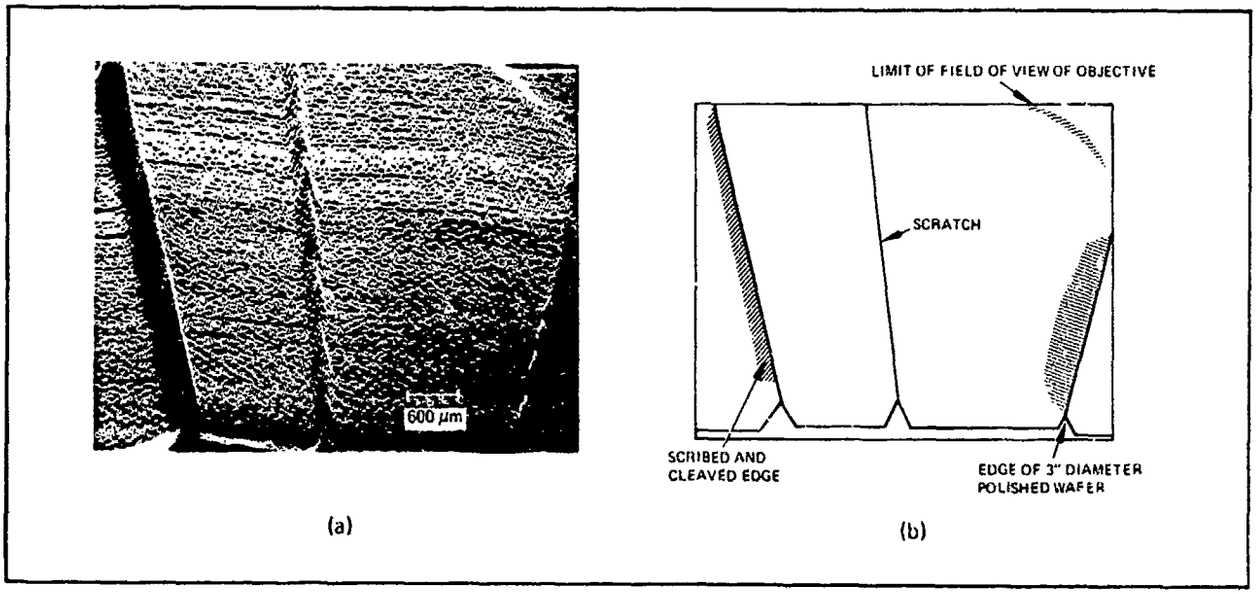


Figure 1. (a) Scanned photovoltage response of the polished front face of a piece of silicon immersed in Na_2SO_4 electrolyte which provides the (noncontaminating) electrical contact. The detail in the center of the slice is due to a fine scribe line drawn across the back of the sample. The sketch (b) defines detail in the photovoltage display.

Solid-State Materials and Processes Characteristics:

X-Ray Topography

ZR011 02 (NELC Z195)

A. R. Clawson

X-ray topography is used in the analysis of crystal defects and their effect on yield and reliability in metal-oxide-semiconductor device technology. It provides a Bragg reflection micrograph which images the defects in silicon wafers. These "x-ray topographs" allow identification of processing steps in the device production which introduce damage to the wafer. Furthermore, analysis of finished devices allows correlation of device performance and failure to the crystalline perfection of the wafer. Use of x-ray topography at NELC prior to the initiation of this task had been limited to a few topographs done by the courtesy of IBM, East Fishkill, New York.

In FY75 the procurement of x-ray topography apparatus for use at NELC was initiated on the basis of studies of the technique, including in-laboratory use of equipment at IBM. The equipment has been installed and good quality topographs are being obtained of 2-inch-diameter silicon wafers from the NELC microelectronics laboratory.

It is expected that x-ray topography will continue to be used as a tool in the evaluation of MOS/LSI device technology. It will also be used for evaluation of strain and defects in III-V semiconductor epitaxial layers in FY76 after purchase of a copper target x-ray tube for this purpose.

PUBLICATION

Clawson, A. R., "Dislocation Observation in MOS/LSI Silicon Wafers by X-Ray Topography," NELC Technical Note 3012, 29 July 1975

Contact:
A. R. Clawson
NELC Code 4600
(714) 225-6591

Solid-State Materials and Processes Characteristics:

Charge-Coupled Imaging Device Noise Measurements

ZR011 02 (NELC Z195)

C. R. Zeisse

The noise characteristics of a CCID were measured. Considerable improvement is needed before LLL imaging can be achieved through this technology.

The charge-coupled imaging device (CCID) is a recently developed solid-state imaging sensor which stores optical information in discrete packets of electronic charge ranging up to as many as a million electrons. It has been under consideration for use in Navy low-light-level (LLL) visible imaging systems. This application is a stringent one for *any* imaging sensor because of the dearth of photons available to begin with. In fact, optimistic calculations show that a CCID operating in typical television fashion would produce a maximum of 40 electrons in each photosensitive resolution element ("pixel"). This is a small signal. Therefore, CCID noise is very important in this application.

In FY74 a computer system was developed for making signal and noise measurements on CCIDs. In FY75 the system was refined, and the noise of a particular CCID was partially characterized at room temperature. The device was a 500-pixel, buried-channel, linear array, obtained by the Navy under contract and representative of current technology. The measurements were analyzed, and it was determined that a hypothetical 500-by-500 area array (similar to this 500-by-1 linear array) operating at room temperature in a television timing format would have the following noise contributions:

Dark current spikes	30 000 electrons
Number of spikes per line	3
Reset noise	100 electrons
Shot noise in the dark current	100 electrons
1/f noise in the output FET	50 electrons

It was concluded that:

1. Low-light-level imaging is not possible at room temperature with presently available CCIDs.
2. Dark current nonuniformities or spikes on the order of the dark current itself are the major limitation at room temperature.
3. Successful low-light-level imaging will require, in order of importance: removal of the dark current spikes, reduction of the reset noise, cooling to reduce the shot noise in the dark current, and reduction of the 1/f noise in the output field-effect transistor.

PUBLICATION

Zeisse, C. R., "Noise and Optical Measurement Techniques for CCIDs," NELC Technical Note 2831, 12 November 1974.

Contact
Dr. C. R. Zeisse
NELC Code 4600
(714) 225-6591

Indium Phosphide Diagnostics

ZR021 02 (NELC Z102)

H. H. Wieder and C. Wilmsen*

Microwave field-effect transistors (FETs) using indium phosphide epitaxial layers with metal (Schottky barrier) gate-electrodes have been produced successfully in the laboratory. The high electron mobility (4400 cm^2/V-sec) and large band gap (1.34 eV) of InP make this semiconductor a candidate for solid-state field-effect devices intended for use above 10 GHz. However, the reverse-bias leakage current of metal gate FETs is large; in consequence they are noisy and their power gain is greatly reduced. A metal-oxide-semiconductor field-effect transistor (MOSFET) structure (ref 1) offers an alternative device configuration which might circumvent these problems and also pave the way for an MOS InP integrated circuit technology for microwave logic and related device applications.

In order to fabricate a useful MOSFET, a thin dielectric film must be formed on this dielectric layer. The stoichiometry of the semiconductor surface must be preserved, and the surface state density within the semiconductor must be low enough so that the gate voltage can modulate the conductance of the MOSFET. In addition, the dielectric film should be relatively hard, electrically stable for long periods, and impervious to diffusion of impurities in order to preserve the integrity of the insulator-semiconductor interface. During this reporting period a number of metal-oxide-semiconductor (MOS) capacitors were formed on n-type InP wafers and epilayers. These had typical 300 °K electron densities and mobilities of 2×10^{16} cm^{-3} and 3100 cm^2/V-sec, respectively. Three types of dielectric films were formed on these InP specimens: anodized, sputtered SiO_2, and double layers made up of an anodized layer with a coating of sputtered SiO_2. The anodized films were formed electrochemically; a constant current density of 0.6 mA/cm^2 was applied between a platinum electrode and an InP specimen in a 0.1N KOH electrolyte in room light. The curves for voltage drop across the growing oxide vs time do not follow standard anodization theory (ref 2); the anodization of InP is complex, and the approximately 550-Å-thick oxide layers consist primarily of In_2O_3, as determined by Auger compositional analysis. The SiO_2 films were rf sputtered at an Ar pressure of 6 μm from a 4-inch-diameter quartz target. Half of the InP wafer was anodized and then the entire wafer was coated with the sputtered SiO_2, providing a direct comparison between the properties of the sputtered SiO_2 and the double-layer films.

The properties of the MOS capacitors with the three different types of dielectric layers are shown in fig 1 and 2. The surface of the anodized MOS capacitor changes from weak inversion at zero bias to accumulation at +0.7 volt. Thus, the surface potential can be modulated by an external voltage. However, the current through the oxide rises rapidly with voltage; while the anodic oxide-InP interface properties are excellent, the high leakage current through the oxide makes this type of dielectric unsuitable for MOSFET applications.

In this program concerned with the development of methods for the evaluation of material and device parameters, various MOS capacitors were formed on n-type InP wafers and epilayers, and three types of films were formed on the specimens. MOS capacitors formed by sputter-coating a SiO_2 layer on a previously grown anodic oxide on InP are found to have properties which may make this configuration useful in microwave logic devices needed for Navy data processing and digital time division multiplex communication systems.

*Professor Wilmsen, Department of Electrical Engineering, Colorado State University, Ft Collins; performed this work at NELC while on sabbatical leave in FY75.

The surface potential of the InP which had SiO_2 sputtered directly on the surface is pinned in accumulation: varying the gate voltage by ±15 volts did not change the surface potential of the InP. It is, therefore, not a suitable candidate for FET. On the other hand, the MOS capacitors formed by sputter-coating a SiO_2 layer on a previously grown anodic oxide on InP had low leakage current (as much as seven orders of magnitude lower than that of the capacitors formed of anodic oxide alone on InP), and the surface potential of the InP could be modulated appreciably with gate voltage as shown in figure 1. At zero bias the surface was still weakly inverted or depleted as with the anodic oxide alone. The zero-bias surface charge appears to be 6×10^{11} cm^{-2}, which is approximately the same as that of the anodized layer. Little or no charge is trapped at the interface between the two insulators, and the sputtering does not cause charge trapping damage. The SiO_2 not only reduces the current through the dielectric layer but also provides a hard coating for the relatively soft anodic oxide.

The surface state density of the MOS samples has been determined by the Terman method (ref 3 & 4). This requires calculation of theoretical C-V curve, surface potentials, and space charge capacitance, and measurement of the high-frequency C-V curve. Figure 3 shows the total number of occupied surface states per unit area for the anodized and also for the SiO_2-coated anodized InP samples. The shapes of these curves are quite similar, with the curve for the anodized samples shifted approximately a constant 10^{10} states cm^{-2} from the curve for the SiO_2-coated anodized samples. Differentiating these curves gives the surface state density per unit area per unit energy, which is of the order of 10^{11} surface states per cm^2 eV. These preliminary results indicate that two-layer oxides may be appropriate for use in InP MOSFETs. Further investigations are underway to demonstrate their applicability for elementary MOSFET device processing.

REFERENCES

1 Cardwell, M. J., and Peart, R. F., Electron Lett, 9, 88, 19[illegible]

2 Dell'Oca, C. J., Pulfrey, D. L., and Young, L., Physics of Thin Films, 6, Academic Press, New York, 1971

3 Terman, L. M., Solid State Electron, 5, 285, 1962

4 Zaininger, K. H., and Warfield, G., IEEE Trans Electron Devices, 12, 179, 1965

Contact:
H. H. Wieder
NELC Code 4600
(714) 225-6591

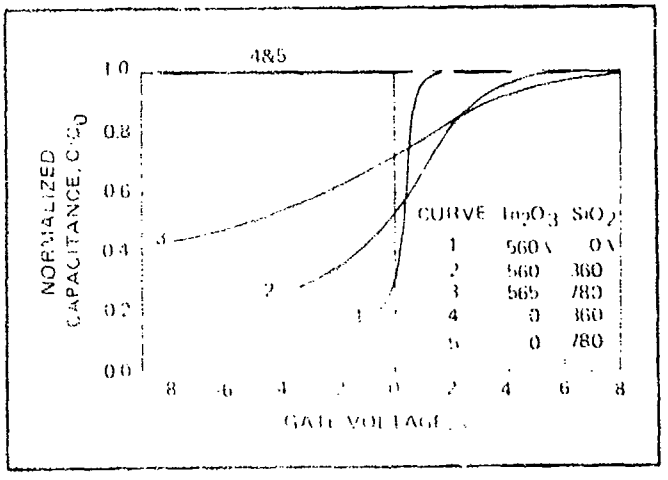


Figure 1. Normalized C-V curves at room temperature for InP MOS capacitor with insulators of anodic oxide, SiO_2 sputter-coated anodic oxide, and sputtered SiO_2.

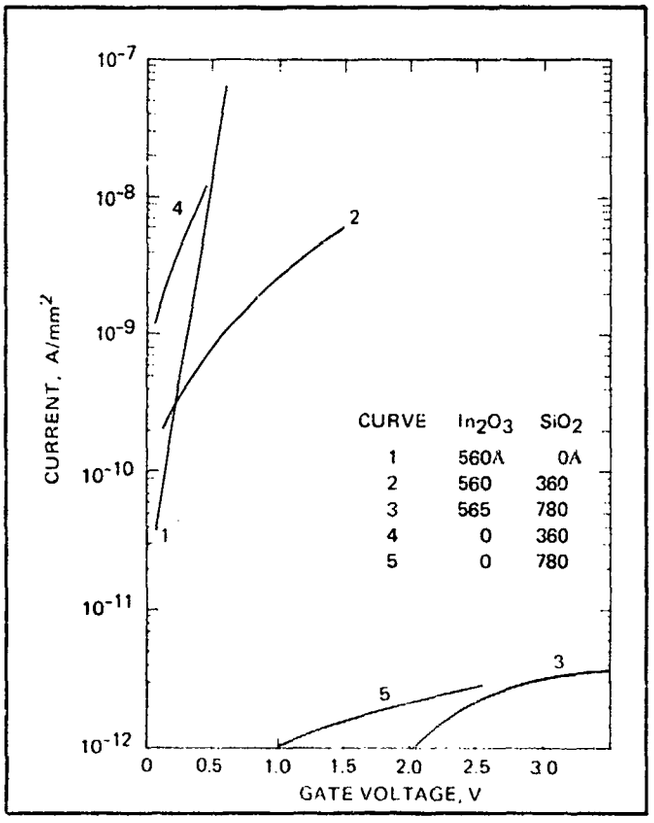


Figure 2. Current flow through the MOS insulator as a function of positive gate voltage for the five samples of figure 1.

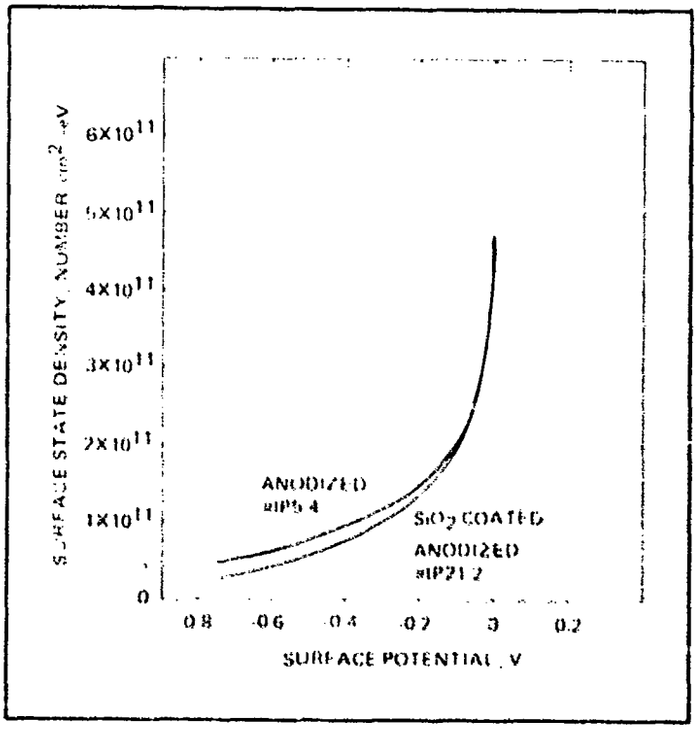


Figure 3. Comparison of the surface charge density of anodic oxide and SiO_2 sputter-coated anodic oxide InP MOS capacitors.

Signal Processing Imager Using Charge-Coupled Devices

ZR021 03 (NELC Z194)

I. Lagnado

During the past 2 years, the concept of combining detection (sensing) and processing of optical signals within a single photosensitive silicon charge-coupled device (CCD) was investigated. Various mathematical computations such as the Haar and Hadamard Transforms were efficiently performed with the recommended device organization (ref 1 and 2). The device was created by the application of NELC/Naval Undersea Center innovative design to an existing commercial product. The final result is another commercial product which fully satisfies the requirements of a key technology forecast item for components and devices to be available in the 1979-1981 era (ref 3). The technique to implement the more complex Discrete Fourier Transform (DFT) or Cosine Transform with the Chirp-Z Transform (CZT) algorithm (ref 4) with this linear imaging device constitutes the major innovation resulting from this study.

A method is provided for combining signal sensing, processing, and multiplication in a single chip using CCD, eliminating interface problems through the use of a single technology. Application is foreseen in the 1979-1981 era.

It was demonstrated experimentally in FY74 that the principle of simultaneously measuring an optically incident signal and performing a linear mathematical transformation upon it is feasible. The experimental verification of the novel concept is presented in the form of a convolution/correlation function as measured at the output of the device (ref 1 and 2).

The effort in FY75 extended the theory of the linear signal processor/imager to more complex transforms such as the DFT. For instance, as long as the function is real, the real R and imaginary I components of its Fourier or Cosine Transform can be computed with the linear device using the efficient CZT algorithm. The latter is extremely well suited to simple implementation with CCDs.

Thus, the present signal-processing sensor provides a viable alternative architecture for current signal processing and imaging tasks, and simplifies the computations and complexity of existing systems. As a general rule, these systems perform the following major tasks: image sensing, signal processing (convolution), and signal conditioning (multiplication). The integration within a single functional device of two out of three tasks achieves a first-generation improvement in system performance and hardware simplification. However, the specification that is usually attached to the operation of multiplication is technologically the limiting factor. In the search for a better approach that reduces or overcomes these limitations current to signal processing technology, the present investigations offer the solution of on-chip multiplication (ref 5) by means of the Dual CZT architecture. This result is obtained from the observation that the DFT is expressed by two equivalent formulations:

1. Multiplication followed by convolution followed by multiplication.
2. Convolution followed by multiplication followed by convolution.

The latter implementation, illustrated by the Dual CZT, provides the method for integrating all three tasks—sensing, processing, and conditioning—in a single functional device, thus eliminating interface problems through the use of a single technology.

The practical uses are related to current and projected operational requirements in motion compensation, facsimile, transmission by data bandwidth reduction, and remotely-

piloted vehicle, and in sensor requirements for bandwidth reduction. Application is foreseen in the 1979-1981 time frame (ref 3).

During FY76 it is planned to demonstrate the feasibility of a high-throughput, high-accuracy multichannel Discrete Fourier Transformer using the on-chip multiplication approach, in the design of a digital transversal filter whose finite impulse response can be adjusted for various signal-processing requirements.

REFERENCES

1 Lagnado, I., and Whitehouse, H. J., "Concept of a Signal Processing Imager Using CCD," NELC Technical Document 274, CCD Applications Conference Proceedings, 18-20 September 1973 (undated)

2 Lagnado, I., and Whitehouse, H. J., "Signal Processing Image Sensor Using CCDs," International Conference on Technology and Applications of Charge Coupled Devices, 25-27 September 1974, Edinburgh, Scotland (Edinburgh, Scotland: University Edinburgh 1974), p 198-205

3 IEEE Spectrum, April 1975, Technology Forecasting III, Components and Devices, p 50

4 Rabiner, L. R., et al, "The Chirp-Z Transform Algorithm," IEEE, Trans Audio and Electro Acoustics, AU 17, 86, 1969

5 Lagnado, I., and Means, R., Invention Disclosure entitled "High-Frequency Multiplier Using CCD Concept," Navy Case 59, 446

PUBLICATION

Lagnado, I., and Whitehouse, H. J., "Signal Processing Image Sensor Using CCDs," International Conference on Technology and Applications of Charge Coupled Devices, 25-27 September 1974, Edinburgh, Scotland (Edinburgh, Scotland: University Edinburgh 1974), p 198-205

Contact:
Dr. I. Lagnado
NELC Code 4800
(714) 225-6877

Advanced Integrated Material for Power Electronics Reliability

ZR021 03 (NELC Z103)

L. J. Johnson

All electronic functions can be subdivided into the processing of information and the processing of power. Information-processing technology (integrated circuits, medium-scale integration, charge-coupled devices, surface-wave devices) is so far in advance of power-processing technology that hardware reliability and system cost are disproportionately influenced by the relatively few power-handling components of the system.

Materials, processes, and circuits developed in the power electronics reliability program can be exploited in virtually every Navy electronic system with benefits including increased reliability, lower costs, and simpler interfaces with batch-processed integrated materials. This year's effort saw progress in implementation of the NELC-developed universal-input power supply circuit in the areas of dedicated packaging, standard electronic module application, and higher-power design.

Electronic power, before being filtered and regulated by the electronic power supply, is an extreme reliability hazard. Overvoltage stresses coming from line voltage transients which are permitted by military specifications allow overvoltages to occur on distribution lines to as much as twice normal voltage. Undervoltage conditions of large volt-time magnitudes (in some cases zero voltage) are also allowable. The electronic power supply is the link which must accept the distribution line power, condition the voltage so that it is steady and transient-free, and deliver reliable power to the electronic load. It is precisely in this critical area — between the power source and electronic systems such as computers, processors, range and fire control instrumentation, and surveillance electronics — that reliability has been low.

PROGRAM OBJECTIVE

The program objective is to upgrade the reliability of Navy electronic systems by improving materials and processes used in the fabrication of current hybrid integrated circuitry for power processing. A major concern of power processing is energy storage, and combined inductive and capacitive energy storage beyond the capacity of monolithic integrated circuit material systems is a major goal.

Results of the program will benefit virtually every Navy electronic system, providing increased reliability, lower costs, and simpler interfaces with batch-processed integrated materials.

The main thrust of the program is toward reducing new concepts to practice. An eventual integrated material approach is foreseen.

PROGRESS IN THREE AREAS

The FY75 effort saw progress in the implementation of the NELC-developed universal-input power supply circuit in three areas — dedicated packaging, standard electronic module application, and higher-power design.

Dedicated Packaging

One task was to develop a reliable packaging system for minimizing thermal weakness within a miniaturized universal-input, multiple-output electronic power supply. The task included thermal profiling within the circuit and the provision of low-loss thermal paths to an external heat sink. A thermal hot-spot temperature of 5 °C above the package surface temperature was desired. The first-cut design yielded an actual hot-spot temperature of 15 °C above surface temperature, and redesign was necessary. In the process of design analysis it was

found that the electronic circuit could be significantly improved with respect to electrical stability. The electronic circuit design changes were therefore incorporated and phased in with the package design change.

The end item of this task is represented by six packaged universal power supplies with performance and fabrication documentation.

Standard Electronic Module Application

The second task was to incorporate the universal-input circuit in a standard electronic module (SEM) configuration to increase military availability and usage of the high-reliability universal-input characteristic. The SEM configuration was implemented in cooperation with Naval Weapons Support Center, Crane, Indiana. Four fully reproducible SEMs were approximately 90% complete at the end of FY75. The circuit includes five separate output levels which are load interchangeable with a summed output of 6 watts. The standard output voltages are 15, 12, 9, and 5 volts of eithe. polarity.

Higher-Power Design

Under the third task, two 55-watt power supplies were constructed to fit super 2A configuration standard electronic hardware at NELC. The power supplies were constructed by means of a minimal modification of commercially produced power supplies. As modified, they have programmable semi-universal output and increased output isolation and overload protection. They provide a degree of adaptability often desirable in standard modules for universal application.

A 100-watt switching regulator circuit was also designed, fabricated, and breadboard tested.

Contact:
L. J. Johnson
NELC Code 4300
(714) 225-6859

Statistical Logic

ZR021 03 (NELC Z106)

W. L. Carper

New and theoretical logic techniques were investigated for applicability to Navy electronic system problems. A literature search was performed to determine possible logic candidates. Candidate logics were categorized and the promising categories were explored in more depth. Tradeoffs were made to determine whether any categories might be implemented to meet Navy needs.

Categories considered were majority logic, stochastic logic, multivalued logic, threshold logic, fuzzy logic, linear networks, and variable-valued logic. Of these categories the following were considered in greater depth: stochastic logic, fuzzy logic, linear networks, and variable-valued logic.

General conclusions concerning these logics are that the theories are well developed and do have applications related to Navy needs. However, hardware in general is crude compared to what is available for boolean operators via large-scale integration. Also, while exact applications are not well defined, they are characteristically complex and thus would require a large investment in hardware, even to show feasibility. Finally, designs using the newer logics will require substantially more academic rigor than is devoted to boolean designs, and this would further increase costs by increasing development time. It was therefore concluded that these newer logics are not attractive for near-term focusing of Navy interest.

Contact:
W. L. Carper
NELC Code 3500
(714) 225-6227

Frequency Shaping for Voice Communications

ZR021 03 (NELC Z108)

C. R. Allen

Linear filtering puts more of the available power into the speech frequencies which carry the most information. Two promising filters are tested, and one of them shows an advantage of 3 or 4 dB over systems with no filter.

In many Navy tactical situations noise impairs voice communication — either acoustic noise surrounding the listener or electrical noise introduced on a wired or radio link. Acoustic noise may drown out announcing systems or intercoms on helicopter decks, on carrier flight decks, and in engineering spaces; electrical noise limits the range of surface-to-air links.

Various kinds of electronic modification of the speech waveform can enhance intelligibility in noise. One of the simplest is linear filtering to shape the system frequency response in a way that puts more of the available power into the speech frequencies which carry the most information. The chief problem in designing a filter is that the optimum frequency response is not known. The speech literature documents several attempts to derive the optimum linear filter from different theoretical bases. One promising filter characteristic, due to J. D. Griffiths of the Air Force Cambridge Research Laboratory, was found analytically by maximizing the articulation index, a widely used physical predictor of intelligibility in noise. Another filter was derived empirically by I. B. Thomas at the University of Massachusetts, based upon data on the relative importance of different formants (vocal tract resonances) in supplying cues for consonant perception.

In this project the Griffiths and Thomas filters were compared with each other and with systems with no filter, with the peak speech power held constant to simulate the actual power constraint found in most communication systems. Intelligibility tests were conducted using noise of various intensities and spectral shapes. Preliminary results indicate that the Thomas filter shows a small advantage of about 1 or 2 dB over a conventional flat-response system. The Griffiths filter appears to be somewhat better, with an advantage of 3 or 4 dB over no filter.

More complete tests will be analyzed and presented in a journal article. The results should be useful in the design of new systems and the modification of existing ones.

Contact:
C. R. Allen
NELC Code 3400
(714) 225-7372

Intercept and Identification of Spread-Spectrum Signals

ZR021 05 (NELC Z105)

R. A. Dillard and D. H. Marx

This project developed from an earlier 2-year investigation of the detectability of spread-spectrum signals, sponsored by the Naval Electronic Systems Command. During that investigation (ref 1), which was concerned with designing covert systems, the need was seen to investigate techniques for identifying spread-spectrum signals and to coordinate the identification process with the detection process. The primary objective of the present project is to develop techniques for exploiting communication and radar signals in order to locate and track enemy forces. Although not a specified objective, a natural result will be design criteria for developing Navy anti-jam and low-probability-of-intercept systems resistant to signal intercept.

The FY75 effort has been directed at two goals. The first is a theoretical development of techniques for detecting and identifying spread-spectrum signals and their incorporation into an ideal total system. The second, scheduled for attainment in FY77, is development of an experimental prototype for testing system concepts under limitations of cost, time, and state of the art.

An initial concept formulation was made of an ideal system which would employ time-lag recording with the playback activated by an alarm from the detection stage, for signal analysis and pattern recognition. The detection and recognition stages would use appropriate combinations of data from a variety of receiver types and measurement devices. Feature-measuring methods considered for the ideal total system include narrowband and wideband filter-bank detection, compressive and conventional frequency-scanning, chip-rate and hop-rate detection, instantaneous frequency measurement, and spectrum-folded cross correlation. The accuracy and utility of possible signal parameter measurements attainable under ideal circumstances were determined for several receiver types and signal types. An examination was made of the applicability of various signal classification techniques.

System techniques are formulated for detecting and identifying spread-spectrum communication and radar signals in order to locate and track enemy forces.

An experimental prototype system concept was evolved and outlined in block diagram form. A redesigning of existing receiving and data-processing equipment originally built for other purposes has begun so that an early analysis of various received signals can be used in determining the best design for the processor. Because of cost limitations, few of the feature-measuring techniques proposed for the ideal system can be implemented in the experimental system. However, many of the decision and recognition procedures can be tested with this simple system.

Literature surveys were conducted to obtain information on spread-spectrum signals employed by possible adversaries, current U.S. capability against them, and work elsewhere related to this project. These equipment-related studies help to determine specifically the signal structures and receiver types that attention should be given to in the development of signal detection and recognition decision techniques. Also, these surveys are useful in establishing the feasibility of the possible measurements and providing indications of actual measurement accuracies.

REFERENCE

1 Dillard, R. A., "Detection of Covert Signals," NELC Technical Note 2722, 27 June 1974 (Part III of Naval Electronic Systems Command Covert Communications Notes (unnumbered, undated)

PUBLICATION

Dillard, R. A., "System Concepts for Detecting and Recognizing Spread-Spectrum Signals," NELC Technical Note 2988, 26 June 1975

Contact:
R. A. Dillard
NELC Code 3300
(714) 225-6257

Continuous Blood Pressure Monitoring

ZR041 01 (NELC Z107)

F. R. Borkat

The medical management of accident victims experiencing loss of blood and of patients suffering from acute heart disease and shock would be considerably improved if there were a noninvasive method to measure blood pressure. Biofeedback training to control high blood pressure, an area that has shown promise in research by others, would be greatly eased by the availability of a good continuous monitoring technique. The application of high-blood-pressure control techniques would be useful to the Navy wherever stress situations generally can lead to hypertensive crises. This project was initiated to identify or to develop a technique for meeting these requirements.

The technique of pressure capsule tonometry is developed. The output of the tonometer closely resembles the arterial pressure waveform. A computer program used in laboratory tests converts this output into a printout of average systolic and diastolic pressure values in real time.

During FY75, a review was made of the literature of blood pressure measurement technology in search of an appropriate technique. Commercial sources for blood pressure measurement equipment were also examined. No technique was found entirely adequate, but concepts from two methodologies appeared to be of value if they could be combined, and from these the technique of pressure capsule tonometry was developed.

A prototype measurement device was built and preliminary tests using a computer analysis scheme were performed. In pressure capsule tonometry, as developed here, a small tubular bladder filled with air is placed on the skin over the radial artery in the wrist. The bladder is covered by a hard plastic shell and is held in place by a partially inflated pediatric blood pressure measurement cuff (fig 1). The cuff only partially occludes blood flow to the hand. The pressure in the bladder is sensed by a solid-state pressure transducer on the wrist, amplified, and presented for measurement and display. A computer program samples the transducer output, searches for systolic and diastolic pressure values in each beat, averages the values for four beats, and prints the results. The computer program operates in real time and the averaged results are printed on line.

The output of the transducer is calibrated once during measurement by standard sphygmomanometry techniques.

Presently only systolic and diastolic pressure values are desired from the technique. However, the output from the pressure capsule tonometer resembles the arterial pressure waveform so closely that other pressure-related information about the health of the heart and circulatory system may be determined.

Blood pressure capsule tonometry with a single unit over the radial artery is sensitive to large motions, and there is some thermal drift. These problems can be minimized with further effort.

During FY76 improvements will be sought in the problem areas and clinical testing will be done.

Interest has been expressed by the Veterans Administration Prosthetics Center of New York for a noninvasive pressure monitor for telemetry from geriatric patients. The interest is based on the potential of this first year's work and the projected satisfactory conclusion of the clinical trials.

PUBLICATION

Borkat, F. R., Kataoka, R. W., and Silva, J., "Continuous Blood Pressure Monitoring," NELC Technical Note 3023, 30 July 1975

Contact:
Dr. J. Silva or Dr. F. R. Borkat
NELC Code 3400
(714) 225-6471/6542

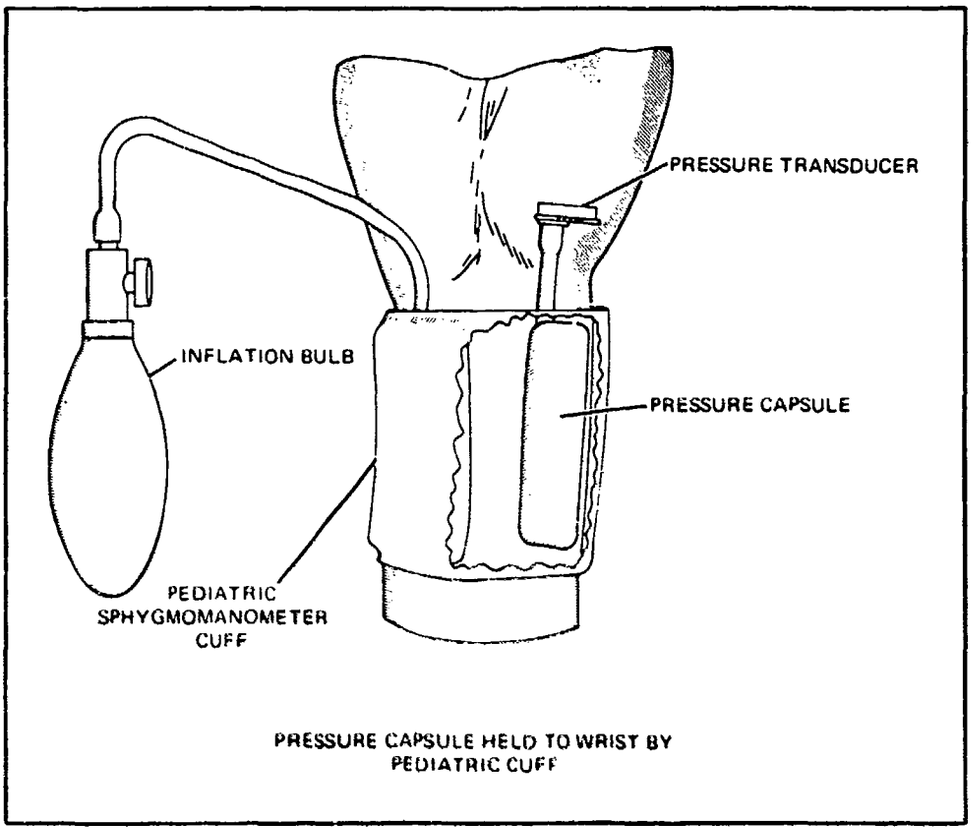
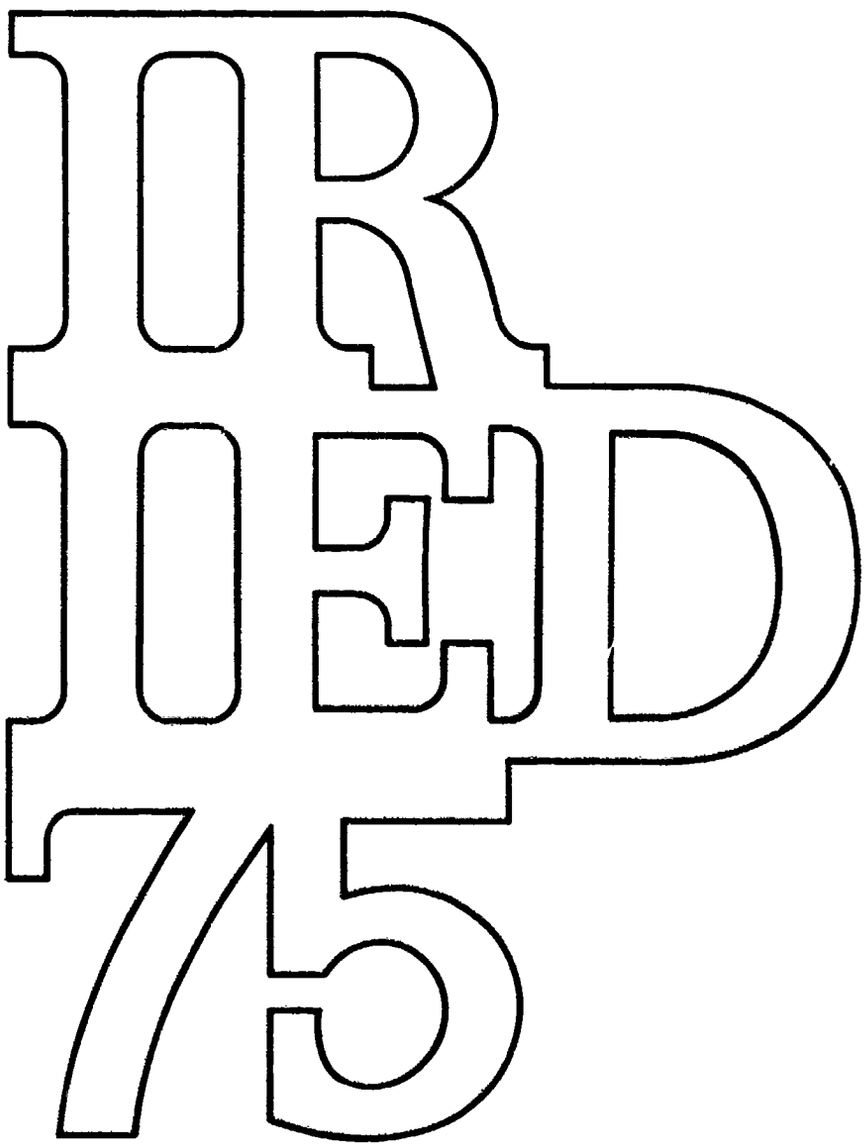


Figure 1. Pressure capsule held to wrist by pediatric cuff.

Independent Exploratory Development



U.S. Marine Corps Battlefield Surveillance Radar Modulation and Coding Study

ZF61-112 (NELC Z280)

L. H. Bossert

The need to determine the feasibility of the application to lightweight doppler radars of new techniques in microelectronics, filter, and filter control was recognized during Battlefield Surveillance Radar concept formulation. Surface acoustic wave technology—by means of which compact, lightweight devices analogous to the bulky multitapped delay line could be constructed, suitable for use as matched filters for complex coding—was considered especially attractive

Heretofore applicable only to complex radar systems too large and complex for portable use, digital phase coding pulse compression techniques were investigated to determine theoretical applicability to ultralight (less than 20 pounds), battery-powered (less than 28 Vdc) doppler moving-target-indicator radar systems. In addition, optimization of modulation, coding, signal format, and filtering forms selected was studied. The major thrust was directed toward maximizing signal processing gain (maximizing operating range for a given power output, or minimizing noise for a given range). Also, optimum wave form, coding, and modulation techniques were sought to maximize radar efficiency in each of the primary modes of operation—acquisition and tracking.

Although they are applicable to any doppler radar, the objective of the final phase of this study was to tailor the signal format and coding, filter design, and processor and power requirements to one specific doppler radar, the AN/PPS-[illegible], the U.S. Marine Corps sponsored effort to develop a 10-pound MTI radar, ongoing at NELC, offered an excellent test vehicle.

Size and weight economies achievable through surface acoustic wave technology make it possible to use coding techniques in lightweight doppler radars which considerably improve performance.

The optimum system defined by this study consists of a binary phase coded modulation waveform and all-range acquisition capability via a discrete variable-range acquire mode capable of step scanning through all ranges of interest.

The range sidelobe ambiguity problem that exists with all pulse compression type waveforms has been eliminated by the use of complementary codes—an elegantly simple solution.

The transition from acquisition to tracking mode operation is obtained by a logarithmic reduction scheme that requires $\log_2 N$ steps, where N is the ratio of track to acquisition bandwidth.

The net signal to clutter improvement is conservatively predicted to be 20+ dB, compared to currently deployed systems.

The continuing effort will address fabrication and testing of a signal processor as described above.

PUBLICATION

"USMC Intelligence Program Surveillance Radar Modulation and Coding Study" was written in FY75 by L. H. Bossert and will be published as an NELC technical note.

Contact
L. H. Bossert
NELC Code 2360
(714) 225-6560
or
H. J. Feeney
NELC Code 1700
(714) 225-6764

Optical Covert Communications Using Laser Transceivers (OCCULT)

ZF61-212 (NELC Z275)

G. C. Mooradian

Design and manufacturing problems occasion delay, but solutions are found. Sea tests originally scheduled for FY75 are rescheduled to optimize the probability of success. OCCULT project acquires new resources from being pursued cooperatively with an OPSATCOM program started at NELC in FY75 in conjunction with NRL.

The OCCULT project, which was started in 1971, was conceived to meet the Navy's need for a covert low-probability-of-intercept, antijam, wideband communication system for service ship-to-ship and ship-to-shore. An at-sea test was planned for FY75. The test was postponed for three reasons:

1. The pointing and tracking subsystem, utilizing a single mirror to remove both fine and coarse pointing errors, proved too slow to provide a high probability of success.

2. Certain design and fabrication errors were present in the OCCULT opto-mechanical packages as received from the manufacturer. This resulted in the destruction of both optical detectors and extremely time-consuming diagnostics to determine and quantify the problems — many of which had never been observed before and were therefore extremely difficult to detect.

3. The initial test plan involved USS KITTY HAWK in transit to the Hawaii area, with a possibility that the equipment would remain on board and operate during a Fleet exercise. The OCCULT equipment as designed (an exploratory development project) was never expected to operate in an unsupported shipboard environment for so long a period of time — extending in this case perhaps to 30 days. Spare parts were minimal, and installation of spare parts and optical alignment on board ship would have proved difficult. For these reasons, it was concluded that the probability of successful operation was less than optimum.

During FY75 work on a large Optical Satellite Communication (OPSATCOM) program was started at NELC in conjunction with the Naval Research Laboratory. To minimize duplication and make use of the expertise already developed on OCCULT, the two programs are being pursued cooperatively. This will optimize the probability of a successful sea test.

FY75 progress and current sea-test plans can be summarized as follows:

1. Coarse and fine pointing and tracking functions are being separated, and fine-angle tracking rates have been demonstrated beyond 200 Hz (approximately 10 times the projected requirement). Integration and testing plans for coarse and fine pointing and tracking have been developed.

2. The opto-mechanical packages were returned to the manufacturer for correction of design and fabrication errors and for inclusion of Stark Cell frequency stabilizers -- a modification funded by the OPSATCOM program to increase laser frequency stability. New detectors in vacuum Dewars were obtained. The revised optical system has been integrated with the NELC processing electronics and the entire system is operating. Duplex video transmission with fine tracking over a land link has been demonstrated.

3. Fabrication and testing are complete on OCCULT electronics developed at NELC to provide frequency stabilization, multiplexing/demultiplexing of radar and audio signals, interfaces to radars, accurate station keeping (distance between ships, relative bearing), receiver signal processing, etc.

4. To benefit from the comprehensive testing phase, the experience gained from operation of the equipment during the

OPSATCOM propagation tests, and the valuable propagation data obtained from the latter, the OCCULT sea tests will occur after the OPSATCOM propagation testing, which will continue through October 1975.

5. Ship services for sea tests are expected to be available during the third or fourth quarter of FY76.

Contact:
Dr. G. C. Mooradian
NELC Code 2500
(714) 225-7975

Real-Time Mask for Electro-Optical Processor

ZF61-212 (NELC Z274)

R. P. Bocker, M. A. Monahan, and K. Bromley

Within the past 3 years the feasibility of using light-emitting diodes, photographic film transparencies, scanning mirrors, and vidicon detectors for performing such mathematical operations as convolution, correlation (ref 1, 2), and matrix-vector multiplication (ref 3) has been demonstrated. More recently, solid-state charge transfer devices have been employed for detection (ref 4, 5).

The power of optical information processing and computing is due to the fact that optical systems, by their very nature, are capable of processing information in parallel at very high rates with relatively few components. The most recent exploratory development model of an electro-optical processor (fig 1) exploits some of this potential in performing a variety of higher-order linear mathematical transform operations. The mathematical transform kernel information is encoded on photographic film, however, a nonrecyclable medium. For the processing capability of the processor to be changed, the film must be changed. The processor is thus programmable, but only mechanically.

The objective of this project is to incorporate into this area-array charge-coupled-device processor under development at NELC an electro-optical mask which is programmable in real time. The target date is mid FY76.

The FY75 effort was mainly concerned with a search for the most promising recyclable materials and methods with which to update information on the mask.

Optical materials research is currently in a period of intense activity and rapid progress. Much work is being directed at the development of active materials and devices that could be utilized in optical computers, coherent optical processors, and display devices. Many new optical materials have demonstrated their potential as reusable recording media, but not without exhibiting limitations as well. This is attested to by the proliferation of articles appearing in print which address the need for active recording media.

FY75 investigation points to the electrode matrix addressed liquid crystal as the top candidate for a real-time programmable EO mask for the area-array CCD optical processor being developed at NELC.

A comparative evaluation of active recording media was conducted by NELC in FY75, involving a literature survey, personal contact with experts in industry and the academic community, and on-site review of work being performed in industry. Operating parameters of the active materials considered promising were determined, and the modes of addressing these materials for recording and erasing information were investigated.

It was determined that the most desirable mode for addressing an active optical medium, from the standpoint of compactness in system size and weight, would be the electrode matrix approach. The active optical medium currently best developed for this type of addressing is the liquid crystal. For example, flat-panel electrode matrix addressed liquid crystal devices have been developed (100 × 100) which typically can be recycled at 30 frames per second. Therefore, at the close of FY75, the electrode matrix addressed liquid crystal ranks as the top choice among real-time mask candidates for the area-array CCD optical processor being developed at NELC.

A mask will be procured in FY76 and incorporated in the processor.

This project parallels and complements a Naval Electronic Systems Command project (XF21-222-025) under which electro-optical signal processing techniques and

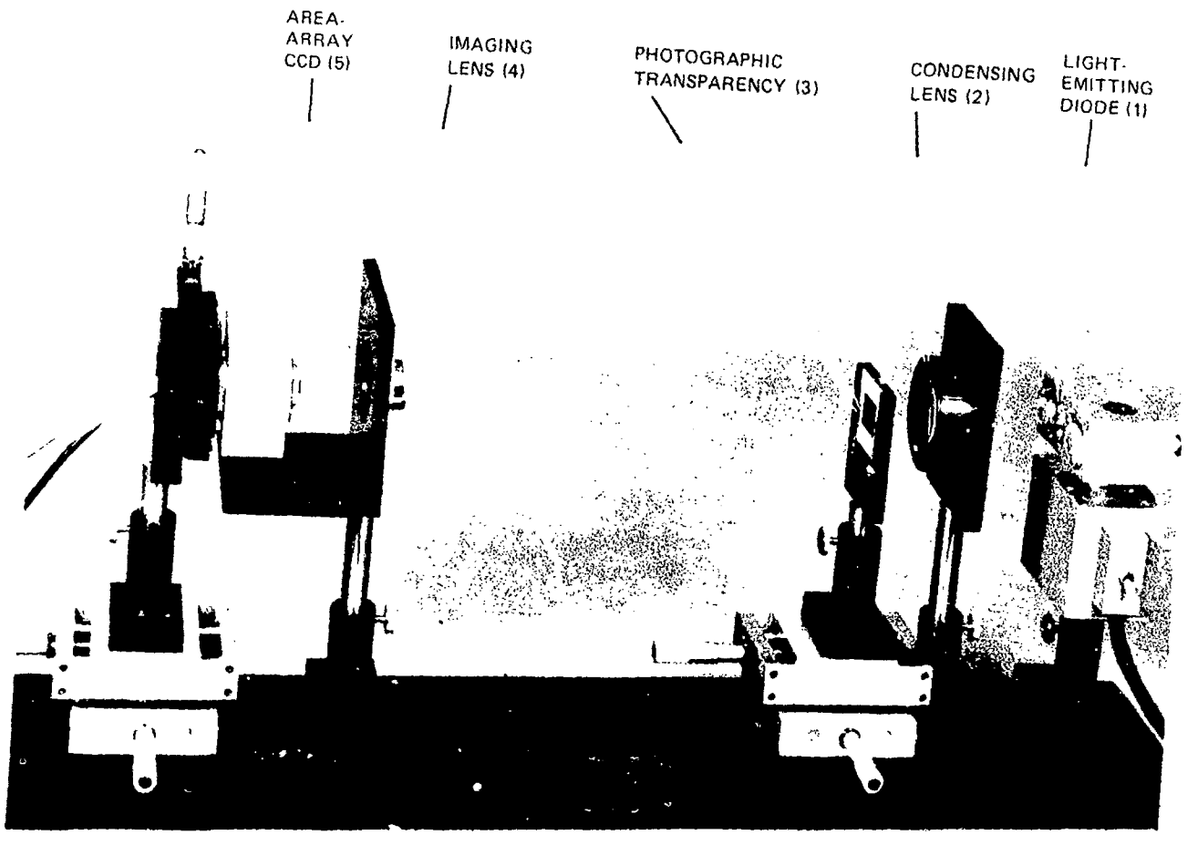


Figure 1. Most current implementation of the programmable electro-optical processor. The electrical input signal modulates the radiance of a light-emitting diode (1) as a function of time. The condensing lens (2) maximizes the light throughput in the system by imaging the light source into the entrance pupil of the imaging lens (4). Directly behind the condensing lens is placed a photographic transparency (3) in which is encoded the desired transform kernel. An image of the optical transparency is formed at the face of an area-array CCD (5) by the imaging lens. The CCD integrates the intensity-modulated image of the transparency, yielding the desired transform.

devices are being developed and applied to communications signal processing.

REFERENCES

1 Bromley, K., "An Optical Incoherent Correlator," Optica Acta, v 21, p 35-41, January 1974

2 Strand, T. C., and Persons, C. E., "Incoherent Optical Correlator for Active Sonar," NELC Technical Report 1887, 27 July 1973

3 Bocker, R. P., "Matrix Multiplication Using Incoherent Optical Techniques," Applied Optics, v 13, p 1670-1676, July 1974

4 Bocker, R. P., Bromley, K., and Monahan, M. A., "Optical Data Processing for Fleet Applications," Naval Research Reviews, v XXVII, p 44-48, May-June 1974

5 Monahan, M. A., Bocker, R. P., Bromley, K., and Louie, A., "Incoherent Electro-optical Processing with CCD's," International Optical Computing Conference Digest of Papers, p 25-33, April 1975

PUBLICATIONS

Bocker, R. P., and Marathay, A. S., "Photodichroic Crystals for Optical Processing," International Optical Computing Conference Digest of Papers, p 77-81, April 1975

Schneider, I., Lehmann, M., and Bocker, R. P., "Extinction Technique for Optical Storage Using Anisotropic Color Centers in Alkali Halides," Applied Physics Letters, v 25, p 77-79, July 1974

Stotts, L. B., Sussman, A., and Monahan, M. A., "Photoactivated Twisted Nematic Device," Applied Optics, v 13, p 1752-1753, August 1974

Contact:
Dr. R P. Bocker
NELC Code 2500
(714) 225-6641

Small Ship Command Control System (SSCCS)

ZF61-212 (NELC Z270)

D. G. Mudd

A computer architecture is defined for the DDG/TDS baseline system. A distributed processor testbed is designed and software developed for its use in a typical command control system application.

The Small Ship Command Control System project was established with the overall objective of applying advanced electronics technology to the various subsystems of a shipboard command control system with special emphasis on the growing fleet of smaller Navy ships including, for example, hydrofoils and surface effect ships. Implicit in this objective is the definition of low-cost alternatives to present system designs which have proved too costly for widespread implementation on even larger surface combatants. Analysis of various subsystems and available technologies indicated that the emerging large-scale-integration microprocessor and microprocessor-based computer networks provided such an alternative to present designs with potential payoffs including cost reductions for both system hardware and software. A computer architecture was accordingly defined to meet the processing requirements of the DDG/TDS (Guided Missile Destroyer/Tactical Data System) baseline system. The architecture essentially provided for a network of microprocessors each dedicated to a unique processing function and each communicating via an intercomputer data bus. This "distributed processor" architecture allows relatively low-capability individual microprocessors to be modularly configured to meet the overall requirements of the baseline command control system.

The principal accomplishments of this project during FY75 consisted of the design of a distributed processor testbed to allow technical evaluation of the architecture for command control applications. The functional and detailed design for the experimental system was completed and the hardware was in fabrication at the end of FY75 and scheduled for delivery in October 1975. The experimental system is built around a commercial processor operating with bus interface hardware to provide interprocessor communications. The bus interface has been designed to perform many of the typical executive software functions in an effort to reduce software costs. The experimental system will initially include two processors with bus interface electronics which will be utilized for testing of the data bus.

Progress has also been made on the utilization of the testbed in a typical command control system application. During FY75 application software was developed for performing selected AN/UYA-4 display, tracking, and data base management functions utilizing the distributed processor concept. Hardware to interface the display processor and the AN/UYA-4 display group was also designed and fabricated during FY75.

The SSCCS IED project was augmented with $100k from Naval Sea Systems Command (SEA 034) during FY75. Continued funding at this level is planned for FY76.

PUBLICATION

Bayless, T. H., "A Distributed Processing Concept for Small Ship Command Control: Expected Payoffs and Risks," NELC Technical Note 2776, 26 August 1974

Contact:
D. G. Mudd
NELC Code 3300
(714) 225-6258

Tactical Data Network

ZF61-212 (NELC Z277)

R. E. Kelly

During FY75 a working group of technical personnel from eight NELC divisions performed a tradeoff analysis on methods of improving tactical data network communications in the Navy. Priority was placed on attaining a low-cost communication network that could provide faster response times with jamming resistance and low probability of intercept. Consideration was given to advantages and disadvantages of the various communication frequencies from hf through optics. Existing data links and recommendations contained in the Naval Telecommunication System Architecture reports were reviewed.

Development has begun on a flexible microprocessor-controlled programmable data terminal set which will make possible the introduction of new techniques in future data networks as well as compatible improvements to the present Link 11 network.

The following alternative approaches were selected for more detailed investigation: (1) an hf antijam, anti-intercept (AJ/AI) system, (2) netting techniques, (3) algorithms for a programmable data terminal set, and (4) an m-ary, frequency-shift-keying, frequency-hopping hf AJ modem.

In February 1975 it was decided that development of a flexible microprocessor-controlled programmable data terminal set (PDTS) would result in both a near-time payoff in improved cost and performance and a flexible approach for long-term cost-effective improvement in tactical data networks.

Initially, the PDTS will be a Link 11 compatible plug-to-plug replacement for the AN/USQ-59 data terminal set. (Link 11 is a major Navy Tactical Data System hf digital data link used for the interchange of tactical data between ships on what is optimally a near-real-time basis.) Because of its programmability and modularity, the PDTS would allow for a method to change net control, coding, and modulation techniques for future data networks and also allow testing of compatible improvements to the present Link 11 network. Cost, size, weight, and power consumption would be significantly reduced versus both the present AN/USQ-59 and a planned AN/UYK-20 computer implementation of the DTS.

An approach has been selected to use a set of Standard Electronic Module cards including the Intel 8080 Microprocessor, random-access memory, and reprogrammable read-only memory to control Fourier transform logic used to convert time samples to the frequency domain. Approximately 80% of the required material has been ordered and design of additional required card types and system modeling has begun. System hardware for one demonstration model is scheduled for completion by April 1976, and software/firmware is scheduled for completion in June 1976. Compatibility testing with other Link 11 equipment will be completed in September 1976.

A related effort funded by Naval Electronic Systems Command in March 1975 is the implementation by NELC of a PDTS using the AN/UYK-20 computer. NAVELEX funding is expected to continue through FY76 for this related effort.

PUBLICATIONS

Pasahow, E. J., and Nuese, C., "Programmable Data Terminal Set Link 11 Algorithms," NELC Technical Note 2945, 9 May 1975 (Partially sponsored by NAVELEX under NELC B193, Programmable HF Modem Suited for Link 11 Communications)

"A Frequency Hopping AJ Modem" was written in FY75 by J. W. MacAfee, and "Low Cost NTDS RF Equipment Survey" by E. R. Crippa. Both will be published as NELC technical notes.

Contact:
R. E. Kelly
NELC Code 3200
(714) 225-6515

Telecommunications Equipment Low-Cost Acquisition Method (TELCAM)

ZF61-512 (NELC Z269)

L. J. Kinkel and J. H. Townsend

Progress is registered on a number of fronts in the effort to lower the cost of military electronics by using commercial devices wherever practicable.

Five specific tasks were carried out in FY75 under the TELCAM project.

1. TELCAM II, EVALUATION OF COMMERCIAL INTEGRATED CIRCUIT (IC) DEVICES

A research team from the NELC Microelectronics Division visited manufacturers, testing laboratories, and users of microelectronics to determine the feasibility of using commercial microcircuits in military electronics. An NELC technical report, TR 1957 (see PUBLICATIONS), is presently in final editing and will be distributed in September 1975. The overall conclusion of TR 1957 is that military electronics of nonvital and semivital classifications can utilize commercial ICs if the manufacturers' high-reliability lines (such as JAN-TX) are used or if testing laboratory screening is employed. A validation effort is planned in FY76 (see task 4.).

2. REVISION OF NELC'S "SUGGESTIONS FOR DESIGNERS OF NAVY ELECTRONIC EQUIPMENT"

Over the past 14 years NELC has published an engineering guide for Fleet electronic designers. The guide provides a list of important facts dealing with platform physical and environmental constraints, Fleet personnel considerations, and logistics support limitations which, if not considered in early design planning, will lead to operational reliability or support problems. The guide, published as NELC Technical Document 390, became available in August 1975.

3. EVALUATION AND FEASIBILITY TESTING OF THERMAL COOLING TECHNIQUES FOR SOLID-STATE CIRCUITS MOUNTED ON PRINTED CIRCUIT BOARDS

Increased density of solid-state devices on printed circuit boards has resulted in higher thermal temperatures which reduce circuit reliability. Although many techniques are available for heat transfer analysis, none are specifically directed to PC boards. A computer program for thermal analysis of PC boards was specifically designed. This work was carried out by instructors and students at the Naval Postgraduate School, Monterey, California. The program capabilities include variation in: card size, card material, and thickness; number of devices on the board; device location; device power dissipation; and physical parameters governing all modes of heat transfer. The program was tested under actual circuit conditions and was found to be accurate within 13% (worst case) in predicting individual device temperatures. A report titled "A Method to Predict the Thermal Performance of Printed Circuit Board Mounted Solid State Devices" is being published by the Naval Postgraduate School (NPS-59KK-75071A). If funds are provided in FY76, this task will be expanded

4. INITIATION OF A FLEET VALIDATION PROGRAM FOR THE TELCAM CONCEPT

During FY74 and FY75 the TELCAM concept of applying commercial off-the-shelf electronic equipment was developed by environmentally testing a few commercial equipments to environmental limits found in ship-

board electronics spaces. To validate the concept that commercial electronics are an alternative to militarized development, NELC has instituted a program with Commander Naval Surface Force Pacific (COMNAVSURFPAC) in selecting commercial equipment with attendant logistics support methodology tailored to ship requirements and constraints. Students from the Naval Postgraduate School assisted NELC in research of failure-free warranties and logistics strategies that could be employed in advanced procurement planning (see PUBLICATIONS). During FY76 this equipment and support methodology will be tested aboard COMNAVSURFPAC ships. Interim results will be published in a report at the end of FY76. This work is expected to move into advanced development in FY77.

5. START OF WRITING OF A TELCAM PROJECT MANAGER'S GUIDE

Drafting of a Project Manager's Guide was begun in FY75 to provide an overview document for managers on all important aspects of planning, taking into consideration alternative choices and the impact of these choices as development proceeds. Work on the Guide will continue in FY76 and the Guide will be available during the third quarter.

PUBLICATIONS

Leffler, R., "Telecommunications Equipment Low-Cost Acquisition Method (TELCAM)," NELC Technical Document 335, 15 July 1974

Allen, D. J., "Application of Reliability Improvement Warranty (RIW) to DOD Procurements," Naval Postgraduate School thesis T-165954, March 1975

Yatras, D. A., "A Generalized Approach for Evaluating Logistics Strategies during Advanced Procurement Planning," Naval Postgraduate School thesis T-165945, March 1975

"Suggestions for Designers of Navy Electronic Equipment," NELC Technical Document 390, 1975

West, C. A., and Dwyer, W. J., "Evaluation of Industrial Circuit Techniques for Application to Military Electronics," NELC Technical Report 1957, August 1957 (in press)

Contact:
J. H. Townsend
NELC Code 4400
(714) 225-7295

U.S. Marine Corps Tactical Communications Automatically Tuned vhf In-Line Filter

ZF61-512 (NELC Z278)

J. E. Kershaw

Filter provides 3% channel separation at the desired 40-dB rejection points for Marine Corps applications in which several vhf transceivers are used in close proximity.

This automatically tuned in-line filter is intended for the LVTC 7 Command Amphibious Tractor or any other Marine Corps application in which several vhf (30 to 76 MHz) transceivers are used in close proximity. The filter provides 3% channel separation at the desired 40-dB rejection points. It protects the receiver from overload by nearby transmitters and reduces transmitter to transmitter generated intermodulation distortion. Automatic tuning, upon the application of an in-band radio frequency, meets the operational requirement for fast frequency shifting.

The device is an equal-element, three-section, minimum-loss filter using high-Q capacitors integrated into a helical resonator. Input and output compensation networks provide uniform termination impedances across the band. A digital controller using an eight-bit microprocessor, random-access and read-only memories, and high-speed motor controllers is used to perform the automatic-tune function. The automatic-tune algorithm is identical to the manual-tune algorithm and consists of about 1000 words stored in read-only memory.

To date, the rf filter design, fabrication, and testing in the manual mode have been completed as scheduled. The digital controller has been designed, fabricated, and integrated with the rf filter. Initial testing reveals that automatic tuning is not possible with certain rf sources, and work is continuing to eliminate this restriction. Limited field testing with a manually tuned version of the in-line filter has demonstrated a significant improvement in performance.

A field evaluation of the completed unit is proposed for accomplishment under a separate program, and a detailed report will be written upon completion of that effort.

PUBLICATION

"Marine Corps Tactical Communications In-line Filter" was written in FY75 by J. E. Kershaw and will be published as an NELC technical note.

Contact:
J. E. Kershaw
NELC Code 2100
(714) 225-7701
or
H. J. Feeney
NELC Code 1700
(714) 225-6764

U.S. Marine Corps Message Entry Device

ZF61-512 (NELC Z281)

R. E. Kelly

Laboratory tests show that 5W deposited, transparent heater keeps liquid crystal display for Marine Corps message entry device operational at -40° C.

The purpose of this project was to determine a suitable heating technique for extending the temperature operating range of liquid crystal display devices. Two types of liquid crystal display devices were being developed on a Naval Electronic Systems Command sponsored project for use in a feasibility model of a hand-held message entry device for Marine Corps forward observers in the field. One was an electronic shutter matrix panel on which selected areas of dynamic scattering liquid crystal material would be made either transparent or opaque for printed material beneath the panel to be either visible or blocked from view. The other was a display using twisted nematic liquid crystal material to form 12 five-by-seven dot matrix alphanumeric characters.

The response time of liquid crystal material, whether dynamic scattering or field effect material, varies strongly with temperature; for example, from rise time of 0.1 second at 0 °C to rise time of several seconds at -10 °C. Although some improvement in response time can be attained by adjusting cell thickness, rating voltage, operating frequency, and doping level of the liquid crystal material, it is a fundamental property that the response time increases with a drop in temperature because of increasing viscosity and some form of heating will be required at lower temperatures.

The shutter matrix panel was too large for the effective utilization of body heat, so it was decided to apply heat directly to the panel, as the most efficient method of heating. Highly efficient heating was desired, since the unit was to be hand-held and battery operated (the liquid crystal panel without heat requires only approximately 0.02 watt of power). It was also important that a heating technique be selected which would not significantly degrade panel transparency.

Laboratory tests were conducted in a cold-temperature chamber at NELC on a full-size mounted panel mock-up to determine approximate power and heating time required. Response time of the liquid crystal material was considered satisfactory at a panel temperature of 0°C, marginal at -5°C, and unacceptable at -20°C. Heating would therefore be required whenever the temperature fell below 0°C in order for the panel to be instantaneously operational for tactical message entry.

The manufacturer of the shutter matrix liquid crystal panel then deposited a "transparent" heater of indium tin oxide on the bottom surface of the glass enclosing the liquid crystal. For the particular geometry of the panel, the heater impedance was 40 ohms, yielding 5 watts of power for a 14-volt battery. Decrease in light transmissivity due to this deposited heater was only 15%. To maintain the panel at 0°C would require a constant power of 5 watts at an outside ambient temperature of -40 °C, or 2 watts at an outside ambient temperature of -20 °C. The 5W transparent heater is therefore considered to be a satisfactory technique for extending the operating range of this liquid crystal display device to -40 °C ambient temperature.

Another technique worthy of consideration would be to use two liquid crystal materials, separated by glass, with different operating ranges. One would operate over a range of, say, 0 °C to 70 °C and the other over a range of, say, -25 °C to +5 °C. This technique could be used to increase the

temperature operating range without the use of heat, but heat would still be required below -25°C.

Contact:
R. E. Kelly
NELC Code 3200
(714) 225-6515
or
H. J. Feeney
NELC Code 1700
(714) 225-6764

Microprocessor Technology

ZF61-512 (NELC Z283)

R. Martinez

The expanding technology in large-scale and medium-scale integration has resulted in the availability of microprocessor chips at low cost for inclusion in electronic logic circuitry. Rapid improvements in metal-oxide-semiconductor and bipolar semiconductor LSI technology have enabled industry to produce these devices with good yields. Currently, 20 microprocessor or microcomputer device sets are available, and a dozen more are in the development stage.

This project was established to define and delineate the use of microprocessors as components in Navy systems, and to identify a common electrical interface which will allow them to replace hard-wired logic functions in such areas as decision and control, data acquisition, and data communications. The project has been directed toward quantifying the uses of microprocessors in Navy systems by determining requirements that currently exist.

The microcomputer is a set of LSI and MSI components including a microprocessor central processing unit, read-only and random access memories, and input/output control circuitry. It is designed to implement small-scale programmed functions stored as firmware in ROMs or RAMs. It combines elements of computer flexibility and hard-wired logic dedication. It can perform many functions in Navy electronic systems where compact electronic circuitry is desired — in weapon, antenna, and data systems, for example

This project was established to define and delineate the use of microprocessors as components in Navy systems, and to identify a common electrical interface which will allow them to replace hard-wired logic functions in such areas as decision and control, data acquisition, and data communications. The project has been directed toward quantifying the uses of microprocessors in Navy systems by determining requirements that currently exist. Progress has been made in the identification of classes of systems, such as message processing, signal processing, and data bus multiplexing. Preliminary surveys of the characteristics of available microprocessors that will meet specific system requirements are being completed. Work on developing a standard methodology for support software and hardware has been initiated. Benchmarks for comparison of these devices have been identified and are being analyzed for a common figure-of-merit definition.

Follow-on work funded by Naval Electronic Systems Command will allow the Navy to determine uses of microprocessors across classes of requirements for system developments and give a rational basis for specification of their characteristics for specific tasks.

Contact:
Dr. R. Martinez
NELC Code 4300
(714) 225-6859

Real-Time Multidimensional Fourier Transform System

ZF61-212 (NELC Z282)

K. Bromley (NELC) and J. M. Speiser (Naval Undersea Center)

Experiments with a modified electro-optical signal processor developed at NELC verify the feasibility of a high-speed, two-dimensional Fourier transform device with real-time input and output that would reduce equipment requirements and provide real-time capability in Navy sonar and acoustic imaging applications.

The use of large arrays of passive sonar detectors requires the processing of a vast volume of data. Specifically, the sonar array data must be Fourier transformed in both the space and time dimensions to provide the directionality and temporal power spectrum information required for detection, localization, and classification. This is called space-time (ω-k) processing. Realization of the full benefits of ω-k Fourier transform processing for passive sonar requires the implementation of a two-dimensional Fourier transform device with high capacity, high throughput rate, and real-time input and output. To perform the required transforms in real time without this prior input processing would exceed the capability of all but the largest electronic digital computers.

NELC and the Naval Undersea Center have been jointly pursuing an IED program to demonstrate the feasibility of a Real-Time Multidimensional Fourier Transform System analog transversal filter technology. A two-dimensional Fourier transform may be implemented as a horizontal (or row-by-row) Fourier transform followed by a high-speed vertical (or column-by-column) Fourier transform. Such an approach is block diagrammed in figure 1.

Either a multichannel optical correlator or a bank of identical transversal filter charge-coupled devices (CCDs) may be used to perform the horizontal discrete Fourier transform using the Chirp-Z transform (CZT) algorithm. An optical correlator configuration requires only a single area-array CCD rather than many transversal filter CCDs, but it also requires cylindrical optics and an array of light-emitting diodes (LEDs).

In order to avoid the need for a buffer memory, it is desirable that the vertical transform be capable of accepting its input data in parallel (a column at a time). Since a complete vertical transform must be completed in the time for a single horizontal data shift, a good speed match is provided by using CCDs in the horizontal transform and a surface acoustic wave (SAW) device in the vertical transform.

For its role in this joint project, NELC has examined the use of incoherent optical correlators and CCD transversal filters as the implementation of the horizontal transform of figure 1. NUC has examined transform architectures, types of complex arithmetic, and SAW technology for performing the required high-speed vertical transform.

PARALLEL HORIZONTAL TRANSFORMS (NELC)

A proposed electro-optical system for performing the horizontal CZT is shown schematically in figure 2. Each of the parallel analog inputs is first multiplied by a chirp waveform generated by a conventional digital read-only memory and a D/A converter. The resultant signals then intensity-modulate a linear array of LEDs. An optical system employing both spherical and cylindrical lenses then images the light from the LEDs through an optical transparency, containing a second chirp waveform, and onto an area-array CCD where multichannel convolutions are performed. The CCD output is then multiplied by the same chirp waveform used in the premultiplication, and the parallel horizontal CZT operation is complete.

There is a major tradeoff to consider in the selection of the CCD-to-SAW interface.

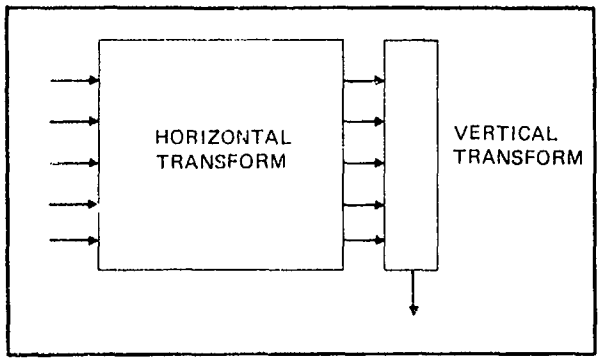


Figure 1. Two-dimensional Fourier transform implemented as a multichannel horizontal transform followed by a high-speed vertical transform.

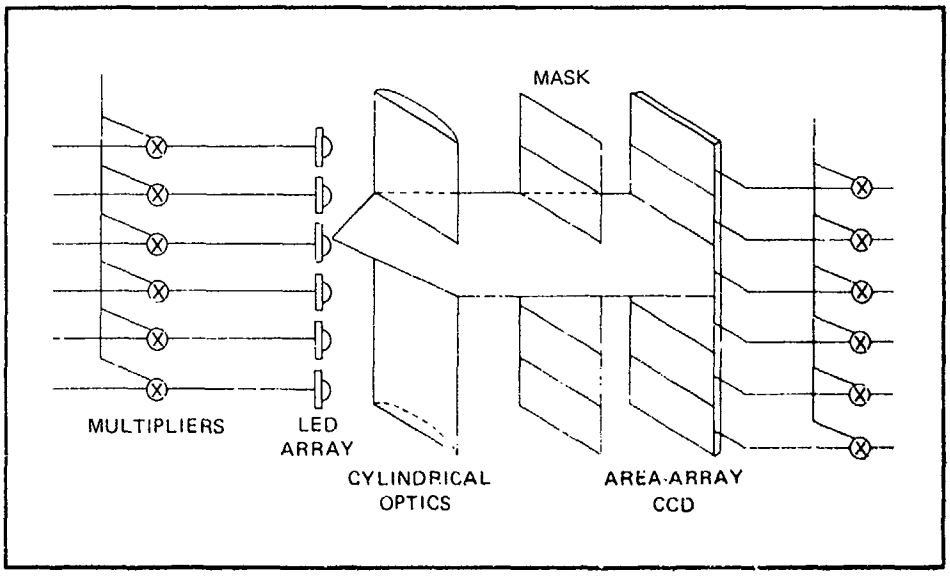


Figure 2. Multichannel electro-optical CZT device.

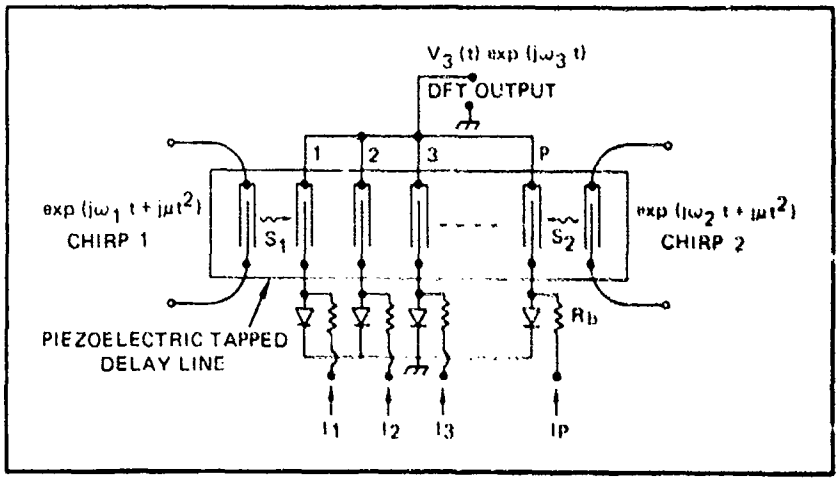


Figure 3. Programmable diode-convolver DFT module.

Figure 2 shows separate outputs from each CCD row. These would feed a parallel-in, serial-out SAW, and the 1-MHz throughput rate of 100 channels of the CCD would complement the potential 100-MHz rate of the SAW. However, this would require a custom CCD chip with separate output leads for each channel. On the other hand, using commercial CCDs, all of which have an on-chip parallel-to-serial converter, and a serial-in, serial-out SAW would eliminate the rather unwieldy separate output leads but would limit the system throughput rate to that of the on-chip parallel-to-serial converter, approximately 1 MHz. Consequently, the architecture selected must depend on the application requirements.

An experimental verification of the feasibility of this approach was conducted by modifying the electro-optical signal processor developed at NELC for matrix-vector multiplication operations in communications applications. Only a single channel (ie, one-dimensional CZT operation) was demonstrated. With a single LED source and the 50 × 100 CCD array in this device, the Tiemann method of complex convolution was selected and a 16-point CZT was performed.

HIGH-SPEED VERTICAL TRANSFORM (NUC)

In order to perform the vertical transform at high speeds, a parallel-input form of the CZT was developed. A programmable diode-convolver was used to test the parallel-input CZT, performing the multiplication of the data via a pair of propagating chirps and subsequent summation as shown in figure 3. An experimental diode-convolver was modified for NUC to provide separate bias inputs to the individual diodes, and was tested as a Fourier transform device giving a 32-point discrete Fourier transform in 1.2 microseconds. However, since the effective tap weight is a nonlinear function of the diode bias, a nonlinear compensator will be required for each tap to permit its use with input signals having wide dynamic range.

SUMMARY

The feasibility of space-time processing via hybrid electro-optical/surface-wave technology has been established. The high-speed computation of a two-dimensional Fourier transform was accomplished experimentally by performing an electro-optical multichannel horizontal chirp-z transform followed by a single high-speed surface wave vertical transform.

An alternative approach to the electro-optical horizontal transform portion has recently been developed. This new device is a 500-point CCD transversal filter chip. For many applications the number of horizontal transforms is sufficiently low that using a separate chip for each one is feasible; consequently, the new approach for the horizontal transform is considered to show somewhat more promise than the electro-optical approach, which would require the development of a new CCD chip. However, a surface acoustic wave device is still recommended for implementing the high-speed vertical transform.

PUBLICATIONS

Bocker, R. P., "Matrix Multiplication Using Incoherent Optical Techniques," Applied Optics, v 13, p 1670-1676, July 1974

Monahan, M. A., Bocker, R. P., Bromley, K., Louie, A., "Incoherent Electro-optical Processing with CCD's," International Optical Computing Conference Digest of Papers, p 25-33, April 1975

Powers, J. P., "Analysis of Multipurpose Electro-optical Signal Processor," Naval Postgraduate School Report NPS-52PO7411A

Contact:
K. Bromley
NELC Code 2500
(714) 225-6641

Publications and Presentations

External Publications

INDEPENDENT RESEARCH

Lagnado, I., and Whitehouse, H. J., "Signal Processing Image Sensor Using CCDs," International Conference on Technology and Applications of Charge Coupled Devices, 25-27 September 1974, Edinburgh, Scotland (Edinburgh, Scotland: University Edinburgh 1974), p 198-205

Lile, D. L., and Davis, N. M., "Semiconductor Profiling Using an Optical Probe," Solid-State Electronics, Pergamon Press, v 18, p 699-704, 1975

Lile, D. L., and Davis, N. M., "Optical Techniques for Semiconductor Material and Circuit Inspection," Solid State Technology, July 1975

Taylor, H. F., "An Electrooptic Technique for Analog-To-Digital Conversion," Proceedings of IEEE, v 63, 1975 (in press)

Taylor, H. F., "An Electrooptic Technique for Adding Binary Numbers," Electronics Letters, v 11, 1975 (in press)

Wagner, N. K., "Auger Electron Spectroscopy for the Analysis of Integrated Circuits," Proceedings of the National Electronics Symposium (NEC), p 107-111, October 1974

Wagner, N. K., "Analysis of Microelectronic Materials Using Auger Spectroscopy and Additional Advanced Analytical Techniques," Proceedings of the International Microelectronics Conference (IMC/NEPCON), February 1975

INDEPENDENT EXPLORATORY DEVELOPMENT

Allen, D. J., "Application of Reliability Improvement Warranty (RIW) to DOD Procurements," Naval Postgraduate School thesis T-165954, March 1975

Bocker, R. P., "Matrix Multiplication Using Incoherent Optical Techniques," Applied Optics, v 13, p 1670-1676, July 1974

Bocker, R. P., and Marathay, A. S., "Photodichroic Crystals for Optical Processing," International Optical Computing Conference Digest of Papers, p 77-81, April 1975

Monahan, M. A., Bocker, R. P., Bromley, K., and Louie, A., "Incoherent Electro-optical Processing with CCD's," International Optical Computing Conference Digest of Papers, p 25-33, April 1975

Powers, J. P., "Analysis of Multipurpose Electro-optical Signal Processor," Naval Postgraduate School Report NPS-52P07411A

Schneider, I., Lehmann, M., and Bocker, R. P., "Extinction Technique for Optical Storage Using Anisotropic Color Centers in Alkali Halides," Applied Physics Letters, v 25, p 77-79, July 1974

Stotts, L. B., Sussman, A., and Monahan, M. A., "Photoactivated Twisted Nematic Device," Applied Optics, v 13, p 1752-1753 August 1974

Yatras, D. A., "A Generalized Approach for Evaluating Logistics Strategies during Advanced Procurement Planning," Naval Postgraduate School thesis T-165945, March 1975

In-House Publications

INDEPENDENT RESEARCH

Borkat, F. R., Kataoka, R. W., and Silva, J., "Continuous Blood Pressure Monitoring," NELC Technical Note 3023, 30 July 1975

Clawson, A. R., "Dislocation Observation in MOS/LSI Silicon Wafers by X-Ray Topography," NELC Technical Note 3012, 29 July 1975

Dillard, R. A., "System Concepts for Detecting and Recognizing Spread-Spectrum Signals," NELC Technical Note 2988, 26 June 1975

Wagner, N. K., "Semiconductor Reliability Improvement by Process Control," NELC Technical Note 2775, October 1974

Wagner, N. K., "Analysis of Microelectronic Materials Using Auger Spectroscopy and Additional Advanced Analytical Techniques," NELC Technical Note 2904, February 1975

Zeisse, C. R., "Noise and Optical Measurement Techniques for CCIDs," NELC Technical Note 2831, 12 November 1974

NELC technical notes are informal publications intended for use within NELC.

INDEPENDENT EXPLORATORY DEVELOPMENT

Bayless, T. H., "A Distributed Processing Concept for Small Ship Command Control: Expected Pay-offs and Risks," NELC Technical Note 2776, 26 August 1974

Leffler, R., "Telecommunications Equipment Low-Cost Acquisition Method (TELCAM)," NELC Technical Document 335, 15 July 1974

Pasahow, E. J., and Nuese, C., "Programmable Data Terminal Set Link 11 Algorithms," NELC Technical Note 2945, 9 May 1975 (Partially sponsored by NAVELEX under NELC B193, Programmable HF Modem Suited for Link 11 Communications)

West, C. A., and Dwyer, W. J., "Evaluation of Industrial Circuit Techniques for Application to Military Electronics," NELC Technical Report 1957, August 1975 (in press)

"Suggestions for Designers of Navy Electronic Equipment," NELC Technical Document 390, 1975

Presentations to Professional Meetings

INDEPENDENT RESEARCH

Davis, N. M., "Photovoltage Profiling," SPIE meeting held in San Diego 19 August 1975

Dillard, R. A., and Marx, D. H., "Intercept and Identification of Spread-Spectrum Signals," NELC technical seminar sponsored by the Radio Technology Division, 4 March 1975

Kataoka, R. W., "Continuous Blood Pressure Monitoring," to be presented at the February 1976 meeting of the San Diego Biomedical Symposium

Taylor, H. F., "Integrated Optics," presented to the San Diego Chapter, Optical Society of America, June 1975.

Taylor, H. F., and Albares, D. J., "Integrated Optics Devices and Applications," presented at the American Vacuum Society Symposium, Los Angeles, June 1975.

Wagner, N. K., (1) "Auger Electron Spectroscopy for the Analysis of Integrated Circuits," National Electronics Conference (NEC), Chicago, Illinois, October 1974; (2) "Auger Electron Spectroscopy and Additional Diagnostic Techniques for the Analysis of Integrated Circuit Materials," University of Tennessee Space Institute Short Course, Tullahoma, Tennessee, November 1974; (3) "Analysis of Microelectronic Materials and Processes Using Auger Spectroscopy and Additional Advanced Analytical Techniques," International Microelectronics Conference (IMC/NEPCON), Anaheim, California, February 1975 (awarded best paper of session); (4) "Semiconductor Device and Process Analysis by Auger Electron Spectroscopy," Trends in the Application of Electron Spectroscopy to Materials Conference, Eden Prairie, Minnesota, April 1975 (paper invited and accepted, conference postponed); (5) "SEM and Auger Electron Spectroscopy Applications in Microelectronics Failure Analysis," Joint Meeting, North and South California Society for Electron Microscopy, San Diego, California, April 1975

Wilmsen, C. W. (Professor, Colorado State University, sabbatical year at NELC), "The MOS-InP Interface," 2nd ONR-ARO Conference on "The Physics of Semiconductor Interfaces," UCLA, February 1975. This paper will be published during the latter part of 1975 in the "Critical Reviews in Physics" Series of the CRC Publishing Company as part of the Conference Proceedings.

INDEPENDENT EXPLORATORY DEVELOPMENT

Bocker, R. P., and Marathay, A. S., "Photodichroic Crystals for Optical Processing," International Optical Computing Conference, 23-25 April 1975, Washington, D. C.

Monahan, M. A., Bocker, R. P., Bromley, K., and Louie, A., "Incoherent Electro-optical Processing with CCD's," International Optical Computing Conference, 23-25 April 1975, Washington, D. C.

Mooradian, G. C., papers at EO '74 Conference, March 1974, "A 10.6 μ Acousto-Optic Modulator"; N. Y. Academy of Sciences, April 1975, "Optical Communication for Naval Application"; and NSF Conference of Optical Communications, June 1975, "The Navy's Optical Communicating Programs."

Pasahow, E. J., "Simulation of a Real-Time Microprocessor Network," published and presented at Symposium on the Simulation of Computer Systems, Boulder, Colorado, 12-14 August 1975

Honors and Awards

Independent Research

Dr. Henry F. Taylor received The American Society of Naval Engineers' Solberg Award in May 1975 for his research contributions during 1972-1974. He was also selected to serve on the program committee of the International Microwave Symposium, held in Palo Alto, May 1975, and the OSA/IEEE Topical Meeting on Integrated Optics, to be held in Salt Lake City, January 1976.

Mr.Neil K. Wagner received the award for the Best Paper of the Failure Analysis Session of the International Microelectronics Conference (NEPCON '75 West), February 1975.

Mr. H. H. Wieder served as Foreign Examiner of a doctoral thesis submitted by R. Malyniak to the Electrical Engineering Department of the University of Western Australia on "The Interrelation between Structure-Sensitive Properties and Switching Behavior of Heterojunctions." He also was one of two U.S. representatives to the 3rd International Conference on Thin Films, Budapest, Hungary, and served on the Program Committee of the National Vacuum Metallurgy Conference, San Francisco, California, January 1975.

Independent Exploratory Development

Dr. G. C. Mooradian was chairman of the Institute for Graphic Communications Conference, "The Future of Optical Communications," Ipswich, Massachusetts, August 1974.

Patent Activity

Independent Research

PATENTS ISSUED

H. F. Taylor
Optical Switch

An electro-optic waveguide device for switching light from one channel to another. An optical switch comprises a substrate having a first refractive index and supporting electro-optic material having a second higher refractive index and defining waveguides which diverge into at least two spatially separated paths. A pair of electrodes is positioned proximate each of the spatially separated paths and when a source of electrical energy is applied to a selected pair of electrodes, an electric field is created across the associated spatially separated path which substantially lowers its refractive index and thereby diverts or switches optical energy from that path. This makes possible increased use of fiber optics in Naval communications and data transfer systems.

Patent 3,883,220 (Navy Case 55,084) Serial 423,624 Filed 10 December 1973 Issued 13 May 1975

H. E. Rast and H. H. Caspers
Dye Laser Transmitter-Resonant Fluorescent Detector System for Underwater Optical Communications

Dye laser transmitter-resonance fluorescent detector system for underwater optical communications. An optical carrier in the region of 4900Å is generated. The detector comprises an evacuated enclosure having an inner chamber and an outer chamber with means for evaporating a resonance detector material such as sodium. The signal is incident at right angles to the stream of molecules of the resonance detector material, and a photo detector or observer is mutually perpendicular to both signal and beam. Use of detector will improve covert underwater communications.

Patent 3,891,559 (Navy Case 56,265) Serial 494,102 Filed 2 August 1974 Issued 24 June 1975

R. E. Potter
Dual Mode CRT Screen

A dual phosphor screen consists of a mixture of a phosphor having a medium or long persistence emitting in the ultraviolet and a short persistent green phosphor. The system then provides for electronic switching from long persistence mode to short persistence mode and will make possible improved displays for Naval command control systems.

Patent 3,896,328 (Navy Case 56,482) Serial 473,987 Filed 28 May 1974 Issued 22 July 1975

PATENT APPLICATIONS FILED

I. Lagnado and H. J. Whitehouse
Signal Processing Imager Array Using Charge Transfer Concepts
A charge-coupled device (CCD) for combining the properties of signal processing and image measurement in a single charge transfer device to perform convolution and correlation. The integration of dissimilar functional operations in a single device reduces hardware duplication, simplifies system implementation, reduces maintainability costs, and improves performance and reliability (by the mere fact of reducing complexity). Reduces hardware duplication, improving performance and reliability for optical sensors in Navy applications.

Navy Case 56,691 Serial 508,472 Filed 23 September 1974

H. E. Rast and H. H. Caspers
Dual-Mode Display Device
An SiO_2 insulating layer is overlaid on a conducting glass substrate. The layer has a portion removed and this area is filled in with an electro-luminescent phosphor. The phosphor and SiO_2 insulator are overlaid with a thin transparent electrode. A liquid crystal is sandwiched between the above assembly and a conducting glass electrode. Under high ambient light conditions high contrast and visibility exist by means of the dynamic scattering from the liquid darkness. A switch is activated to place the AC potential across the phosphor and produce an illuminated background against which the liquid crystal alphanumeric character may be read in darkness or low ambient light. This may be used in improved displays for Naval command control systems.

Navy Case 57,008 Serial 592,705 Filed 2 July 1975

David L. Saul
Improved Millimeter Waveguide to Microstrip Transition
An improved means of transferring guided electromagnetic signals from dominant mode rectangular waveguide to microstrip transmission line at frequencies extending into the millimeter wave region. Wideband operation is a keynote feature, with high efficiency performance (as evidenced by low VSWR and low insertion loss) over at least a 3:2 band of frequencies, i.e., over at least a full standard waveguide frequency band. The initial development was done for the 26.5 to 40 GHz frequency band but the design can be scaled dimensionally to cover higher or lower bands. Allows size and weight reduction for aircraft and submarine applications.

Navy Case 57,530 Serial 586,113 Filed 11 June 1975

David L. Saul
Miniaturized Millimeter Wave Frequency Discriminator
A discriminator, in some suitable form, is a key part of an instantaneous frequency measuring (IFM) receiver. A receiver of the IFM type has the ability to monitor continuously all frequencies within a designated frequency band, a property very useful for certain types of surveillance operations. The IFM receiver's military and naval use has become widespread at microwave frequencies up to 18 GHz. Allows major size reduction in discriminators used in fleet.

Navy Case 57,604 Serial 546,367 Filed 3 February 1975

AUTHORIZED INVENTION DISCLOSURES

L. J. Johnson
Power Supply

An electronic power supply apparatus for use with a wide range of input voltages. A series switch type regulator is caused to regulate at two voltages (65 and 8 volts). This is done by sensing the regulated voltage and by means of gate circuits switching from one mode of regulating to the other without loss of efficiency.

Navy Case 56,508 Authorized for preparation of a patent application 17 January 1974

H. E. Rast and H. H. Caspers
Wide Aperture Optical Communications Detector

Provides a narrowband detection of optical signals over a large field of view. Most narrowband detectors are confined to a small aperture or field of view due to the necessity of using filters which require normal incidence and, hence, narrow field of view. This invention depends for its filtering action on an entirely different principle, thereby allowing large apertures.

Navy Case 56,110 Authorized for preparation of a patent application 21 April 1975

D. L. Lile and N. M. Davis
Optical Microprobe

The response of a semiconductor to optical stimulation may be used to detect inhomogeneities. An apparatus is described for the generation of a small spot of light which may be scanned in a raster pattern over the surface of the specimen. A noncontacting means of electrically coupling into the sample using an electrolyte is described.

Navy Case 58,669 Authorized for preparation of a patent application 20 May 1975

D. Rubin
Broadband Millimeter Wave Gunn Amplifier in Reduced Height Waveguide

A method is utilized for externally varying the gain and bandwidth of a millimeter wave Gunn amplifier. The Gunn diode is varied in position vertically between the broad walls of reduced height waveguide. The introduction of the relatively large cylindrical heat sink of the diode creates a discontinuity which acts to counter the parasitic reactance of the diode in its mount. The effect is a very pronounced broadening of the frequency range at which amplification takes place. Useful for surveillance receivers operating at millimeter wave frequencies.

Navy Case 58,774 Authorized for preparation of a patent application 16 June 1974

I. Lagnado and R. W. Means
High-Frequency Multiplier Using Charge Coupled Device Concept

A device for multiplying two signal voltages V_x and V_y utilizing CCD and MOSFET technologies. V_x and V_y are converted to first, second, and third charge packets Q_x, Q_y, and Q_{x+y}. These three packets are sensed by the separate floating gates each of which controls the drain-source current of a separate source-follower transistor. The potentials of the floating gates vary in proportion to the number of charges passing under them, which variation is translated by the source followers into output voltage changes. Two differential amplifiers combine these voltage changes to give the product KV_xV_y. Simplifies hardware interface and mechanization for signal processing systems.

Navy Case 59,466 Authorized for preparation of a patent application 29 July 1975

H. F. Taylor
An Electro Optic Binary Adder
An array of electro-optic modulators with a suitable electrode structure for performing fast parallel addition of binary numbers.

Navy Case 59,524 Authorized for preparation of a patent application 16 July 1975

INVENTION DISCLOSURES SUBMITTED

H. F. Taylor
Optical Waveguide Photoemissive Detector
A device for coupling an optical waveguide to a photoemissive film for sensitive, high-speed detection of light signals.

NELC 2264 Disclosure submitted to NELC Patent Counsel 24 January 1975

H. F. Taylor
Optical Analog/Digital Converter
Array of thin-film optical modulators for rapidly converting analog signals to a digital representation.

NELC 2267 Disclosure submitted to NELC Patent Counsel 13 February 1975

Independent Exploratory Development

PATENTS ISSUED

K. Bromley
Multi-Channel Optical Correlator System
An electro-optical device employing an LED, optical transparency, rotating mirror, and a vidicon detector can perform multi-channel simultaneous cross-correlations. It will be extremely useful in sonar, radar, and communications applications.

Patent 3,816,735 (Navy Case 53,286) Serial 234,749 Filed 15 March 1972 Issued 11 June 1974

P. L. Writer and M. L. Schiff
Surface Wave Narrow Bandpass Filter
In bandpass filter feedback loops, surface wave devices comprising aluminum fingers deposited on a piezoelectric substrate and employed to provide transmission characteristics which invert a transmission null into a bandpass. Bandpass filters are essential components of all communications systems.

Patent 3,846,723 (Navy Case 55,701) Serial 372,560 Filed 22 June 1973 Issued 5 November 1974

H. K. Landskov
Polypole Broadband Antenna Array
An effective, simple, and inexpensive broadband antenna array for small ships and light vehicles and comprising a plurality of like monopoles placed in either a triangle or quadrangle configuration with a monopole at each apex. Useful for light vehicles and small ships due to small size of array.

Patent 3,852,766 (Navy Case 55,647) Serial 423,339 Filed 10 December 1973 Issued 3 December 1974

Carlos Nuese
Block Coded Communication System
A noisy forward communication channel is employed to transfer data which have been symbolically coded and also to transfer correction instructions; a noiseless feedback channel is used to return each symbol as it is received to the sending station. The apparatus transfers binary digital data without excessive redundancy, delay, or complexity by correcting transmission errors by means of correction instructions as opposed to retransmitting the entire block of data. Affords solution to vital problem of error control in communications.

Patent 3,868,633 (Navy Case 54,665) Serial 425,580 Filed 17 December 1973 Issued 25 February 1975

R. L. Lebduska
Method and Apparatus for Detecting Individual Fiber Breakage in Multi-Fiber Optic Cables
A method of assessing the individual fiber breakage in a bundle of fiber glass fibers which consists of illuminating both of the terminated ends of said bundle of fiber glass fibers and viewing by a microscope over the ends of said bundle with the broken fibers appearing as black circular elements. Fiber optics is having increased use in Naval communication and data transfer systems. Examples are in the A-7E aircraft and undersea cables.

Patent 3,884,585 (Navy Case 56,533) Serial 445,406 Filed 25 February 1974 Issued 20 May 1975

CLAIMS ALLOWED, PENDING ISSUE

D. N. Williams
Fiber Optic to Electronic Interface
A fiber optic-to-electronic interface circuit which will improve Naval data and information transfer systems.

Navy Case 55,085 Serial 449,814 Filed 11 March 1974

R. L. Lebduska
Fiber Optic Cable Connector
A fiber optic cable connector of identical halves which press-fit together, with the terminals spring loaded to maintain the highly polished cable ends in close contact; a ferrule being provided to maintain the cable ends in perfect alignment and to act as a reservoir for the liquid inducing material that may be inserted between the cable ends to enhance optical transmission. Fiber optics will have increasing use in Naval communications and data transfer systems.

Navy Case 56,390 Serial 437,428 Filed 28 January 1974

L. B. Stotts
Improved Optical Coupler
A passive optical coupler employing the distinctive wavelength sensitivity and polarized directional responsivity of different cholesteric liquid crystal materials to selectively couple out optically transmitted data and information from a common optical bus. It will enable improved data and information transfer systems to be built.

Navy Case 56,703 Serial 465,962 Filed 1 May 1974

PATENT APPLICATIONS FILED

D. W. Doherty and E. J. Wells, Jr.
Universal Modularized Digital Controller
A miniaturized digital controller for use in a servomechanism system controlled by a signal from a computer or other digital data source. Useful for antenna tracking, gunfire control systems, and any analog powerdrive driven by digital command.

Navy Case 55,860 Serial 542,485 Filed 20 January 1975

A. Roth and G. M. Holma
Closest Point of Approach Calculator
A manually operative, programmed (dedicated) calculator that computes the Range, Bearing, and Time of Closest Point of Approach of any or all of five selected target ships, and also their course and speed. Can be used to avoid collision between ships.

Navy Case 56,072 Serial 537,971 Filed 2 January 1975

Richard Bocker, Keith Bromley, Mike Monahan, and Larry Stotts
Electro-Optical Spectrum Analyzer

An electro-optical device capable of performing a one-dimensional finite Fourier transform on temporal signals in real time. In addition to the Fourier transform capability, the device is also capable of performing matrix multiplication of a one-dimensional column vector by a two-dimensional matrix, yielding a one-dimensional column vector. This will make possible computation of large numbers of signals in real time.

Navy Case 56,834 Serial 542,524 Filed 20 January 1975

J. A. Cocci and M. L. Schiff
PCM Synchronization and Multiplexing System

The invention comprises apparatus for obtaining transmitter-receiver synchronization in an audio transceiver which employs pulse code modulation. The apparatus also provides demultiplexing of time multiplexed signals on the same data channel. The main advantage of the apparatus is that only one frame of data is lost for any one sync error. It can be implemented inexpensively by means of conventional digital integrated circuitry and will result in more accurate and less complicated data transfer systems.

Navy Case 56,908 Serial 530,794 Filed 9 December 1974

J. C. Lawrence and A. Roth
Variable-to-Block-With-Prefix Source Coding Technique

Provides data compression technique for use with general sources and comprising a direct generalization of run length coding. The technique is also operable with sources of time-varying and non-stationary statistics. Permits more efficient use of communication channels.

Navy Case 57,173 Serial 546,051 Filed 31 January 1975

AUTHORIZED INVENTION DISCLOSURES

J. E. Kershaw
Low Loss Tunable Filter

An especially designed low loss variable capacitor integrated with a helical resonator and housing results in a performance level not obtainable by any other known method. The capacitor tunes the helical resonator over greater than an octave range in the demonstration model, which can operate at power levels up to 250 watts, and which makes up one section of a three section filter. The filter is used as one channel of a multicoupler in one application and as an in-line automatically tuned filter in other applications.

Navy Case 59,309 Authorized for preparation of a patent application 16 July 1975

Active Projects for FY75

Independent Research

NELC Project	Title	Principal Investigator	NELC Mail Code	AUTOVON	Research Requirement	FY75 Funding	DDC Accession No.
Z194	Signal Processing Imager Using Charge Transfer Arrays	Dr. I. Lagnado	4800	933-6877	ZR021 03	$ 54.0k	DN 487535
Z195	Solid State Materials and Processes Characteristics	N. K. Wagner	4600	933-6591	ZR011 02	481.0	DN 487536
Z102	Indium Phosphide Diagnostics and Devices	H. H. Wieder	4600	933-6591	ZR021 02	83.0	DN 587501
Z103	Advanced Integrated Material for Power Electronics Reliability	L. J. Johnson	4300	933-6859	ZR021 03	101.5	DN 587502
Z104	Integrated Optical Processing	Dr. H. F. Taylor	2500	933-6641	ZR011 12	123.5	DN 587503
Z105	Intercept and Identification of Spread-Spectrum Signals	R. A. Dillard	3300	933-2395	ZR021 05	60.5	DN 587504
Z106	Statistical Logic	W. L. Carper	3500	933-6227	ZR021 03	36.0	DN 587505
Z107	Continuous Blood Pressure Monitoring	Dr. J. Silva	3400	933-6471	ZR041 01	58.0	DN 587506
Z108	Frequency Shaping for Voice Communications	C. R. Allen	3400	933-7372	ZR021 03	25.5	DN 587507
Z109	Human Decision Making as a Function of Display Composition Variables	Dr. R. A. Fleming	3400	933-7372	ZR042 09	50.0	DN 587508

Independent Exploratory Development

NELC Project	Title	Principal Investigator	NELC Mail Code	AUTOVON	ED Task Area	FY75 Funding	DDC Accession No.
Z269	Telecommunications Equipment Low Cost Acquisition Method (TELCAM)	L. J. Kinkel	4400	933-7136	ZF61-512	$345.0k	DN 587614
Z270	Small Ship Command Control System (SSCCS)	D. G. Mudd	3300	933-6257	ZF61-212	40.0	DN 587613
Z274	Real Time Mask for Electro-Optical Processor	R. P. Bocker	2500	933-6641	ZF61-212	101.5	DN 587613
Z275	Optical Covert Communications Using Laser Transceiver (OCCULT)	Dr. G. C. Mooradian	2500	933-7975	ZF61-212	75.0	DN 587613
Z276	QED Validation using VERDIN Receiving System	A. L. Heaberlin	2100	933-6856	ZF61-212	36.0	DN 587613
Z277	Tactical Data Network	R. E. Kelly	3200	933-6515	ZF61-212	328.5	DN 587613
Z278	USMC Tactical Communications Automatically Tuned VHF Inline Filter	J. E. Kershaw	2100	933-7701	ZF61-512	60.0	DN 587614
Z279	USMC Tactical Communications Program Tactical HF Modems	G. A. Clapp	2100	933-7146	ZF61-212	20.0	DN 587613
Z280	USMC Intelligence Program LWBSR Modulation and Coding	L. H. Bossert	2300	933-2626	ZF61-112	40.3	DN 587612
Z281	MC Tactical Communications - Message Entry Device	R. E. Kelly	3200	933-6515	ZF61-512	20.0	DN 587614
Z282	Real-Time Multi-Dimensional Fourier Transform System	K. Bromley	2500	933-6641	ZF61-212	45.0	DN 587613
Z283	Microprocessor Technology Task	Dr. R. Martinez	4300	933-6859	ZF61-512	43.7	DN 587614

Projects Terminated in FY75

Independent Research

NELC Project	Title	DDC Accession No.	Reason for Termination
Z106	Statistical Logic	DN 587 505	Hardware based on these logics would not be cost-effective for the Navy.
Z108	Frequency Shaping for Voice Communications	DN 587 507	Completed.
Z109	Human Decision Making as a Function of Display Composition	DN 587 508	One-year program completed; tests to be made under NAVSEA sponsorship.

Independent Exploratory Development

NELC Project	Title	DDC Accession No.	Reason for Termination
Z270	Small Ship Command Control System (SSCCS)	DN 587 613	Being continued with funding from Naval Sea Systems Command SF21-211-401 (NELC N718)
Z276	QED Validation using VERDIN Receiving System	DN 587 613	Completed; methodology applied to other comparisons of QED with conventional designs.
Z278	USMC Tactical Communications Automatically Tuned VHF In-line Filter	DN 587 614	Completed; field evaluation and follow-on development planned by USMC.
Z279	USMC Tactical Communications Program Tactical HF Modems	DN 587 613	Completed; deployed with 32nd Marine Amphibious Unit. Additional work under USMC as XF 21-222-016.
Z281	MC Tactical Communications - Message Entry Device	DN 587 614	Completed; selected features were used by USMC in specifications for procurement of new Digital Message Device (DMD).
Z282	Real Time Multi-Dimensional Fourier Transform System	DN 587 613	Awaiting technological developments in industry which will make approach cost-effective.
Z283	Microprocessor Technology Task	DN 587 614	Being continued with funding from Naval Electronic Systems Command XF 54 582 005 (NELC R279).

Multisponsored IR/IED Projects for FY75

Independent Exploratory Development

IR/IED PROJECT				OTHER FUNDING			
NELC Project	Title	Funding	Amount	NELC Project	Funding	Amount	DDC Accession No.
Z269	Telecommunications Equipment Low Cost Acquisition Method (TELCAM)	ZF61-512	$345.0k	R405*	XF54-545-002 XF54-545-011	$ 50k 10	DN 587581
Z270	Small Ship Command Control System (SSCCS)	ZF61 212	$ 40.0	N718*	SF21-211-701 XR02-105-001	$139 5	DN 587533
Z275	Real Time Mask for Electro-Optical Processor	ZF61-212	$101.5	N609*	RF21-242-002	$ 27	DN 487605
Z275	Optical Covert Communications Using Laser Transceiver (OCCULT)	ZF61-212	$ 75.0	Z275	NRL NIF	$ 25	DN 587613

*These projects are work closely related to the IED project and derived from it, but they are established as separate work units.

Projects for FY76

Independent Research

NELC Project	Title	Principal Investigator	NELC Mail Code	AUTOVON	Research Requirement	FY76 Funding	DDC Accession No.
Z194	All-Digital Signal Processing Functions Using Charge Coupled Devices	Dr. I. Lagnado	4800	933-6877	ZR021 03	$ 80.0k	DN 487535
Z195	Solid State Device Reliability and Vulnerability	Dr. A. Nedoluha	4600	933-6591	ZR011 02	250.0	DN 487536
Z102	III-V Semiconductor Device Technology	Dr. D. L. Lile	4600	933-6591	ZR021 02	205.0	DN 587501
Z103	Advanced Integrated Material for Power Electronics Reliability	L. J. Johnson	4300	933-6859	ZR021 03	95.0	DN 587502
Z104	Integrated Optical Processing	Dr. H. F. Taylor	2500	933-6841	ZR011 12	120.0	DN 587503
Z105	Intercept and Identification of Spread-Spectrum Signals	R. A. Dillard	3300	933-2395	ZR021 05	80.0	DN 587504
Z107	Blood Pressure Monitoring	Dr. J. Silva	3400	933-6471	ZR041 01	55.0	DN 587506
Z110	Communication Disturbance Prediction – Solar Flares	M. P. Bleiweiss	2200	933-7705	ZR021 01	48.0	DN 687514
Z111	Millimeter Wave Solid State Devices	D. Rubin	2300	933-7097	ZR021 03	100.0	DN 687515
Z112	Electronic Determination of Speech Intelligibility	E. Schiller	3400	933-7372	ZR021 03	50.0	DN 687516

Independent Exploratory Development

NELC Project	Title	Principal Investigator	NELC Mail Code	AUTOVON	ED Task Area	FY76 Funding	DDC Accession No
Z269	Low Cost Electronics	C. L. Ward	4400	933-7136	ZF61-512	$275.0k	DN 587614
Z274	Real Time Mask for Electro Optical Processor	Dr. R. P. Bocker	2500	933-6641	ZF61-212	85.0	DN 587613
Z275	Optical Covert Communications Using Laser Transceiver (OCCULT)	Dr. G.C. Mooradian	2600	933-7976	ZF61-212	260.0	DN 687613
Z277	Tactical Data Network Programmable Data Terminal Set	R.E. Kelly	3200	933-6515	ZF61-212	335.0	DN 587613
Z280	Signal Processing for MC LWBSR	L. H. Bossert	2300	933-2676	ZF61-112	70.0	DN 587612
Z284	Intelligence Analysis Automation	Dr. S. Z. Mikhail	230	933-7911	ZF61-112	52.0	DN 587612
Z285	VHF-FM Antenna, AJ Techniques	Dr. M. Kvegne	2100	933-7336	ZF61-212	75.0	DN 587613
Z266	Microprocessor Support System	Dr. R. Martinez	4300	933-6860	ZF61-512	68.0	DN 587614

EXTERNAL DISTRIBUTION

	Copies
Director of Navy Laboratories (MAT 03L)	3
Assistant Secretary of Navy for Research and Development	1
Assistant Secretary of Navy for Installations and Logistics (CDR J. M. McMorris)	1
Director of Defense Research & Engineering (Research and Advanced Technology)	1
Defense Advanced Research Projects Agency (Dr. G. H. Heilmeier)	1
Chief of Naval Material (MAT 03)	3
Chief of Naval Material (Dr. Norris Keeler, MAT 03T)	1
Chief of Naval Material (MAT 0352)	1
Chief of Naval Operations (OP 98)	1
Chief of Naval Personnel (CAPT N. D. Harding, PERS 445)	1
Chief of Naval Research (Code 401)	20
Commandant Marine Corps (MC-RD)	2
Naval Air Systems Command (AIR 3022A)	4
Naval Electronic Systems Command (ELEX 301)	4
Naval Electronic Systems Command (CAPT G. H. Smith, PME 107)	1
Naval Facilities Systems Command (FAC 03)	2
Naval Sea Systems Command (SEA 03)	5
Naval Medical Research & Development Com' and	1
Marine Corps Development & Education Command	2
Naval Air Development Center	1
Naval Coastal Systems Laboratory	1
Naval Missile Center	1
Naval Research Laboratory	1
Navy Personnel Research & Development Center	1
David W. Taylor Naval Ships Research & Development Center	1
Naval Ships Research and Development Center, Annapolis	1
Naval Surface Weapons Center, White Oak	1
Naval Surface Weapons Center, Dahlgren	1
Naval Undersea Center	1
Naval Underwater Systems Center, Newport	1
Naval Underwater Systems Center, New London	1
Naval Weapons Center	1
Naval Postgraduate School	2
US Naval Academy	1
Office of Naval Research Branch Office Boston	1
Office of Naval Research Branch Office Chicago	1
Office of Naval Research Branch Office Pasadena	2
Naval Research Advisory Committee Laboratory Advisory Board for Research	
Dr. Victor C. Anderson	1
Dr. Bruno W. Augenstein	1
Dr. William R. Bennett, Jr.	1
Dr. Eugene P. Cronkite	1
Dr. Burton I. Edelson	1
Prof. Peter Franken	1
Dr. N. Bruce Hannay	1
VADM John T. Hayward, USN (Ret)	1
Dr. H. Janet Healer	1
Mr. Brian T. Howard	1
Dr. Harry D. Huskey	1
RADM F. L. Pinney, USN (Ret)	1
Dr. Augustus B. Kinzel	1
Dr. David Middleton	1
Dr. David Z. Robinson	1
RAND Corporation (Dr. R. D. Shaver III)	1

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NELC Technical Document 448 (TD 448)	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): ANNUAL REPORT FY75 INDEPENDENT RESEARCH AND INDEPENDENT EXPLORATORY DEVELOPMENT	5. TYPE OF REPORT & PERIOD COVERED: ANNUAL - FY75
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Electronics Laboratory Center, San Diego, California 92152	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Z1, Z2
11. CONTROLLING OFFICE NAME AND ADDRESS: Director of Navy Laboratories	12. REPORT DATE: 1 September 1975
	13. NUMBER OF PAGES: 74
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited.

fiscal year 1973.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Decision making - Command and control
Diversity reception - Radio reception
Independent exploratory development
Independent research
Inspection - Optical techniques
Process control - Surface defects

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document is an overview of the NELC IR and IED programs. It summarizes the accomplishments achieved within each project in FY75. Longer articles are presented on three of the most significant projects - (1) Reliability Improvement by Process Control and Surface Analysis, (2) Human Decision Making as a Function of Display Composition Variables, and (3) US Marine Corps Tactical Time-Diversity hf Modem.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

403