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(Continued on inside back cover)

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1989 OFFSHORE TECHNOLOGY CONFERENCE

Attendance was just over 26,000, approximately the same as last year, at the 1989 Offshore Technology Conference (OTC) held May 1-4 at the Astrohall in Houston, Texas.

Topics of major interest included the Conoco Tension Leg Well Platform currently being installed in the Gulf of Mexico, Shell Bullwinkle, the world's tallest offshore structure, results of one year of operation of the Placid Floating Production System, and an overview of the Tommelitten subsea installation in the Norwegian North Sea. Brazilian technology highlighted the strong foreign content of this year's conference.

Technical sessions sponsored by IEEE — OES covered subsea control technologies; offshore control and monitoring, including remote operation of unmanned offshore platforms; and, new developments in ROV technology such as higher powered vehicles with unique capabilities, and new concepts in underwater camera and viewing systems.

THE GLOBAL OCEAN TO BE ADDRESSED AT OCEANS '89

"There is a growing awareness of how critical the ocean is to the survival of our planet," states Robert C. Spindel, chairman of OCEANS '89, an international conference addressing the global ocean. Co-sponsored by the Marine Technology Society and the Oceanic Engineering Society of the Institute of Electrical and Electronics Engineers, OCEANS '89 will be held in Seattle, Washington, USA, September 18-21, 1989, at the Washington State Convention and Trade Center.

"OCEANS '89, with more than 400 technical presentations and panel discussions, will help launch an extraordinary era of ocean exploration and exploitation, where the waters of the world are viewed as one ocean," continues Spindel. Conference speakers and participants will include ocean engineers, ocean scientists, marine technologists and policy makers from around the world.

A major emphasis of the conference will be on marine environmental quality, with more than 100 papers in 23 sessions scheduled. This represents one of the largest concentrations of ocean-pollution papers ever to be presented at a U.S. conference. There will also be 14 sessions devoted to global ocean studies and oceanographic studies, 18 sessions on ocean engineering and technology, 14 sessions on underwater vehicles and exploration, and 13 sessions on acoustics.

OCEANS '89 will host an extensive exhibit of marine products and services available from an international array of firms, institutions and agencies. Eleven tutorial sessions, which will provide participants with in-depth instruction in key areas of emerging fields of ocean technology and policy, will be offered the first day of the conference, Monday, September 18.

For further information about OCEANS '89, please contact Nancy Penrose, Program Coordinator, at the Applied Physics Laboratory, University of Washington, HN-10, 1013 NE 40th Street, Seattle, Washington, 98105, USA; by telephone (206) 543-3445; or via OMNET electronic mail at OCEANS.89 or ARPANET electronic mail at oceans 89@slug.apl.washington.edu.

(Reprinted from *OCEANS '88 Conference Proceedings*)

APPLICATION OF THE POLARIMETRIC MATCHED IMAGE FILTER (PMIF) TECHNIQUE TO CLUTTER REMOVAL IN POL-SAR IMAGES OF THE OCEAN ENVIRONMENT

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ABSTRACT

We focus on image contrast optimization between two rough surface classes, which is based strictly on polarimetric filtering and, therefore, no digital image processing techniques are employed. The approach is tested on a complete polarimetric synthetic aperture radar image of the San Francisco Bay area (NASA/JPL CV-990 L-band POL-SAR data). Optimal transmitted polarizations are found for each image pixel and the results are analyzed statistically via a set of joint 2D histograms. This is done for both of the rough surface classes. The image response to the "optimal" incident polarization is then simulated digitally by adjusting the receiver polarization according to the modes of the histograms. The corresponding images are computed and displayed with significant image contrast improvement.

I. INTRODUCTION

This paper addresses the problem of coherent image contrast optimization between two rough surface classes. We focus on such contrast which is due to the differences in polarimetric scattering from one rough surface to another. The novelty of this problem is due to the combination of coherent imaging and polarimetric scattering. The former introduces speckle reduction as a major issue while the latter provides the full scattering matrix (i.e., complete polarization information) per image pixel. The second and equally important task of this work is to develop efficient statistical tools for polarimetric image data analysis and speckle reduction techniques.

Speckle has long been recognized as the main problem of coherent imaging (1) and many processing techniques have been advanced to overcome it. The vast majority of these techniques, however, are of a scalar nature simply because vector/matrix imaging data are so sparse and have become available only very recently. Such data, taken with the NASA/JPL CV-990 dual-polarization L-band (1.225 GHZ) SAR (Synthetic Aperture Radar) system, have been made available to us. Here, we investigate the potential of a strictly polarimetric image filtering which takes full advantage of the matrix data provided on a pixel by pixel basis, and complements the existing scalar contrast optimization and speckle reduction techniques. We wish to stress from the outset that our goal is contrast optimization (with the corresponding speckle reduction) **without** the help of incoherent averaging over pixels or "looks", because of the corresponding loss of spatial or temporal resolution. At first glance, speckle reduction is impossible without incoherent averaging but further consideration shows that it is so only for **scalar** data. Indeed, taking "projections" onto the receiver direction in the polarization space decreases amplitude fluctuations and an image appears less speckled. The goal of this paper is to find such a choice of the polarization projection which makes a given rough surface class least speckled and, by doing so, to improve the image contrast between two given classes.

The paper is structured as follows: a brief description of basic polarimetric definitions is provided in Section II, while in Section III the image data are described and the precise problem formulation is given. In Section IV, our three-stage polarimetric optimization procedure is outlined and implemented for each image pixel. In Section V, we make the transition from the single pixel result to a combined description. A statistical analysis of the results is given, and the images are displayed and discussed. The operation of the polarimetric matched filter is summarized in Section VI. Section VII contains concluding remarks.

II. ESSENTIAL POLARIMETRIC DEFINITIONS

Following (2), we define the origin of the coordinate system at the receiving antenna terminals with the $+\hat{z}$-axis directed toward the target (pixel) as shown in Fig. 1. Note that in SAR applications the receiver and transmitter are co-located but may be different antennas so that the situation is slightly bistatic. The reflected $\underline{E}_R$ and the transmitted $\underline{E}_T$ waves, together with the antenna "height" $\underline{h}$ (polarization of the receiving antenna when used as transmitter (2)), can all be written as plane waves

$$[1a] \quad \vec{E}_T = (E_{T_1}^2 + E_{T_2}^2)^{1/2}[\cos\gamma_T\hat{x} + \sin\gamma_T\, e^{j\phi_T}\hat{y}] \cdot \exp\{j(\omega t - kz + \alpha_T)\}$$

$$[1b] \quad \vec{E}_R = (E_{R_x}^2 + E_{R_y}^2)^{1/2}[\cos\gamma_R\hat{x} + \sin\gamma_R\, e^{j\phi_R}\hat{y}] \cdot \exp\{j(\omega t + kz + \alpha_R)\}$$

$$[1c] \quad \vec{h} = (h_x^2 + h_y^2)^{1/2}[\cos\gamma_h\hat{x} + \sin\gamma_h\, e^{j\phi_h}\hat{y}] \cdot \exp\{j(\omega t - kz + \alpha_h)\}$$

where in all equations $\gamma \equiv \tan^{-1}(E_y/E_x)$, and ϕ and α are the relative and absolute phases, respectively (2). From here on, we will operate with the expressions in square brackets, written as complex normalized 2D vectors (also known as Jones vectors (3) in optics and spinors in quantum mechanics (4)), e.g.,

$$\underline{E}_T = \begin{bmatrix} \cos\gamma_T \\ \sin\gamma_T\, e^{j\phi_T} \end{bmatrix} \equiv \begin{bmatrix} E_H \\ E_V \end{bmatrix}_T .$$

When usual assumptions about a linear passive medium are employed, the input-output polarization ellipse characteristics of a target (image pixel) are given by its scattering matrix defined as

$$[2] \quad \underline{E}_R = [S]\underline{E}_T$$

where [S] is a 2 x 2 complex matrix, and α_T is set to zero by the choice of the time origin (2). Finally, the voltage at the receiving antenna terminals as a function of transmitter and receiver polarizations is given by

$$[3] \quad V = \underline{h}^T\underline{E}_R = \underline{h}^T[S]\underline{E}_T$$

where superscript T denotes the transpose (as opposed to hermitian conjugate - see (2, pp. 1471-1473), and (5) for details). For reference, we also include the transformation properties of [S] and V from one polarization basis to another using, a similarity transformation for [S] to [S] as discussed in (2, pp. 1471-1473),

$$[4a] \quad [S]' = [U]^{-1}[S][U]$$

$$[4b] \quad V' = V = \underline{h}'^T[U]^T[U]\underline{E}_R' = \underline{h}^T\underline{E}_R$$

where [U] is the unitary change-of-basis matrix and primes indicate quantities in the new basis. With these definitions we now proceed to describe the polarimetric SAR image data and to formulate the problem more precisely.

III. IMAGE DATA DESCRIPTION AND PROBLEM FORMULATION

The 4096 x 1024 SAR image of the San Francisco Bay area (6,7) is shown in Fig. 2a for horizontal transmitter and receiver polarizations (HH). The brightness of each pixel is assigned according to the total received energy in the horizontal channel. The data was taken with a dual-polarized antenna and a four-channel receiver system so that a complete scattering matrix was measured for each image pixel. The radar wavelength was 24.5 cm and the resolution (size of each pixel size) was about 10m x 10m (see (6) for more details). The image texture can be roughly classified into three main categories:

man-made structures (ships, the bridge, urban area, etc.), vegetated area (park), and the ocean region. All three classes can be considered rough at 24.5 cm according to the Rayleigh criterion (1). This surface roughness leads to a random modulation of phase of the reflected wave which, in turn, produces image speckle (1).

Any kind of averaging is likely to smoothen the image and reduce speckle. As an example of averaging in polarization space, the span of [S] image (sum of the magnitudes of all four scattering matrix elements) is shown on Fig. 2b. The image is essentially an incoherent superposition of the four separate polarization images obtained per pixel and, therefore, a noticable speckle reduction (relative to the HH image) is not surprising (8). As was mentioned above, this paper focuses on contrast optimization without incoherent averaging of any kind.

Since a complete scattering matrix is available for every pixel of each of the three categories, one can simulate the response of the area to any transmitted polarization $\underline{E}_T$ by calculating $\underline{E}_R$ via [2]. Furthermore, the response of the image can also be simulated for an arbitrary receiver polarization $\underline{h}$ via [3]. Both equations must be implemented for each pixel of the entire image. The brightness is then assigned to each pixel according to $P \equiv V^*V = (\underline{h}^T\underline{E}_R)^*(\underline{h}^T\underline{E}_R)$ (* stands for complex conjugate). Such numerical simulations were recently carried out by the JPL group (6,7), demonstrating the ability of polarimetric adjustment to substantially improve image contrast. Our goal here is to develop an algorithm for the search of optimal image contrast via the combination of our recently developed Three-Stage-Procedure (TSP) which is described in the following section, and a subsequent statistical analysis of the set of polarization eigenvectors computed with the TSP for each pixel. Again, we emphasize that our algorithm must not include any incoherent averaging and/or smoothing procedures because of the corresponding loss of information, e.g., temporal (phase) or spatial resolution. In this paper we focus on finding such transmitter and receiver polarizations that allow significant ocean clutter removal for better contrast with the urban area and ship/man-made structure identification. The method and implementation of the optimal polarization search for a single pixel are briefly described in the next section, after which we proceed to the statistical analysis of the results.

IV. THE THREE-STAGE PROCEDURE

The TSP addresses the following problem (see (2,5) for more details): For a given pixel (i.e., known scattering matrix), find such transmitting and receiving polarizations, for which the received power is maximal (minimal). In mathematical terms this means: find $\underline{E}_T$ and $\underline{h}$ such that $P = V^*V = |\underline{h}^T[S]\underline{E}_T|^2$ is optimal for a given [S], subject to the constraints $||\underline{h}|| = ||\underline{E}_T|| = 1$.

The TSP accomplishes this in three separate stages (2):

Stage 1) The energy density in the reflected wave (before it has reached the receiver) is optimized as a function of transmitted polarizations via the following eigenvalue problem

[5] $$\{[G] - \lambda[I]\}\underline{E}_{T,opt} = 0$$

where $[G] \equiv [S]^+[S]$ is by construction a hermitian matrix for any [S] (+ stands for hermitian conjugate), [I] is the identity matrix, and $\underline{E}_{T,opt}$ is the eigenvector corresponding to the largest (smallest) eigenvalue λ_{max} (λ_{min}) giving the largest (smallest) energy density. The eigenvalues are always real (they correspond to the measured values of energy density in the reflected wave) and the eigenvectors are orthogonal because [G] is hermitian (9).

Stage 2) At this stage, the polarization state of the reflected wave is computed using the known $\underline{E}_{T,opt}$

[6] $$\underline{E}_{R,opt} = [S]\underline{E}_{T,opt}.$$

Stage 3) Finally, the receiver polarization is adjusted to ensure that all of the power contained in $\underline{E}_{R,opt}$ (reflected wave) is either absorbed or rejected, depending on the application. The former is accomplished with the choice

[7a] $$\underline{h} = \underline{E}^*_R$$

while the latter requires that

[7b] $$V = \underline{h}^T\underline{E}_R = 0.$$

In terms of imaging applications, one expects a given pixel to look relatively "bright" when $\underline{E}_T$ corresponds to the largest eigenvalue (maximal energy density) and h is adjusted according to [7a], while the adjustment [7b] ensures that the pixel looks "dark", especially when supplemented with the choice of minimal $\underline{E}_{T,opt}$. These observations, together with the statistical considerations, constitute the basis of pixel-by-pixel polarimetric image filtering.

V. STATISTICAL ANALYSIS OF OPTIMAL POLARIZATIONS AND IMAGING

Even within a single rough surface class (e.g., ocean), there is a considerable variability in polarization properties of pixels in any given patch and we, therefore, must introduce a statistical description at this stage. We assume that the two terrain classes are sufficiently different in their polarimetric responses so that their statistics do not "overlap" significantly. Then, with proper statistical tools, a "threshold" can be found such that the TSP can be used to "darken" not just one pixel but a majority of pixels in a given class.

In order to gain insight into the polarimetric response of various terrain and ocean categories, we have performed Stage 1 of the TSP for each pixel of two chosen segments of ocean and urban areas. Let us consider the ocean vs. city contrast enhancement as a specific application. In order to minimize the ocean return or to maximize the city return, the minimum energy eigenvector is computed for each pixel of the ocean patch and the maximum energy eigenvector is computed for the city patch. The eigenvectors corresponding to λ_{min}, λ_{max} are computed according to [5] for each pixel and expressed in the form (2, p. 1400)

[8a] $$\underline{E}_{T,opt} = \frac{1}{\sqrt{(1 + \rho\rho^*)}} \begin{bmatrix} 1 \\ \rho \end{bmatrix}, \qquad \rho = E_Y/E_X$$

where ρ is the complex polarization ratio (3). After the eigenvectors are computed, we express them in terms of the more convenient ellipticity ε and tilt τ coordinates which describe, respectively, the "fatness" and the inclination of the polarization ellipse. They are defined (3, p. 35) as

[8b] $$\varepsilon = 1/2 \arcsin\{2\mathrm{Im}(\rho)/(1-\rho\rho^*)\}$$

[8c] $$\tau = 1/2 \arctan\{2\mathrm{Re}(\rho)/(1-\rho\rho^*)\}.$$

Thus, an optimal polarization state which makes a given pixel darkest (brightest) is characterized by two numbers, ε and τ. Naturally, one would like to choose the incident polarization in such a way as to make most ocean pixels dark if our goal is to contrast urban area against ocean or to enhance visibility of ships at sea. To this end, we present in Figs. 3a-b joint 2D histograms (ε and τ) for the two surface categories of interest: statistics of minimal eigenvectors are presented for the ocean, and maximal eigenvectors for the urban area. Each patch contains 40,000 (200 X 200) pixels so that the statistics are quite good. Both histogram modes are near the linear vertical ($\varepsilon \approx 0°$, $\tau \approx 90°$) polarization. Thus, if the transmitter is adjusted to produce vertically polarized waves (relative to the direction of propagation), the majority of the ocean pixels will have relatively low scattered energy, while the majority of city pixels will reflect strongly. Once the optimal transmitted field is chosen and the scattered field is computed, one can use a similar procedure for the receiver adjustment. In Figs. 4a-b, we present the ε-τ histograms for the scattered fields of the two regions. These histograms were constructed by letting the incident wave be vertically polarized and by computing the scattered field of each pixel via Eq. 6. Again, the two histograms peak around the same vertical polarization state and the ocean distribution is more pronounced. In fact, the ocean incident and scattered field histograms are quite similar which leads one to conclude that most of the scattering matrices of the ocean region are "flat plate-like" identity matrices. This behaviour is consistent with Bragg scattering assumed to be the dominant physical mechanism of the ocean scattering (6). The urban area histograms, on the other hand, differ because the scattered field does not have a peak at horizontal polarization. The fact that this peak vanishes seems to disagree with the assumption of dihedral corner reflectors (6) as the basic scattering elements of the urban area. Indeed, in such a case, the scattering matrix (having entries ± 1 along the diagonal and 0 along the off-diagonal) would produce a mild peak at horizontal polarizations which would not disappear.

If the receiver is adjusted to horizontal polarization, most of the energy of ocean pixels will be rejected because the receiver is perpendicular to the sharp histogram mode at vertical polarization. The urban area will not be affected as much because of the much larger spread. When the brightness is assigned according to $P = V^{*}V$ (V is computed from Eq. 3), the image in Fig. 5a results. Compared with the original HH image, this near HV image has better contrast: the average brightness ratio between the urban and the ocean areas increases; but, because of the fact that the two modes are not separated in the polarization space, the urban area has lost some structure. Note, however, that most of the ocean speckle has been "filtered out" with the proper choice of polarization, yet, without significant effect on the man-made structures.

The image of Fig. 5b was computed for the vertical polarization of the receiver (near VV image). The ocean area is quite a bit more speckled than on Fig. 5a and the contrast with the urban area is lower. On the other hand, there is a better contrast between park/vegetated area and the urban region. Thus, the results of the JPL group (6) as well as our experiments clearly show that a much improved contrast can be achieved between man-made, vegetated and ocean areas with the proper choice of polarization. Of course, when the rough surface is such that the scattering is polarimetrically isotropic (i.e., there is no spatial polarization dependence), this technique cannot work (one such example is a random sea surface). Fortunately, such cases are rather unlikely and all of the data available to us indicate that real terrestrial rough surfaces exibit a very strong polarization dependence. Even an ocean surface is often modulated by well-defined internal wave patterns which show up clearly in POL-SAR images.

A sequence of one-dimensional image brightness distributions in Fig.6 illustrates the effect of various steps of the above procedure on the ocean and city patches, separately. One notices a gradual improvement in contrast between the two categories as indicated by the decreasing overlap area and better peak separation. This suggests that the $\underline{h}$-adjustment is responsible for most of the clutter removal, as can also be seen on the actual images of Figs. 5a and 5b. Note that identical uniform grey scale assignments have been used for all images so that the effects are entirely polarimetric.

VI. SUMMARY OF THE POLARIMETRIC MATCHED FILTER STRATEGY

In this section, we summarize and quantify the approach outlined in the previous paper in a series of well-defined steps. Again, consider the suppression of ocean clutter for optimal contrast with man-made structures such as ships, etc. We perform the first two steps of the TSP, and display the "typical" statistics of the ocean and urban area patches in a form of joint bivariate histograms of transmitted $\underline{E}_T$ and received $\underline{E}_R$ fields as is shown in Figs. 3a,b and 4a,b. We then identify the modes of the two distributions $\underline{E}_T$ and $\underline{E}_R$ and adjust $\underline{h}$ so that the "majority" (i.e., histogram peak) of the "unwanted" patch pixels "darken". For instance, if $\underline{h}$ is adjusted in such a way that the peak in the ocean distribution $\underline{E}_R$ satisfies

$$[9] \qquad V_{peak} = \underline{h}^T \underline{E}_{R,peak} = 0,$$

it is ensured that the majority of the ocean pixels will appear "black" on the actual image.

The following procedure (see Fig. 7), which is a statistical extension of the TSP, constitutes the **polarimetric matched filter for coherent imaging:**

1a) the energy density of each pixel is maximized (minimized) as a function of the transmitted polarization. The corresponding eigenvectors, $\underline{E}_T$, are found from Eq. 5 as in Stage 1 of TSP;

1b) the joint bivariate histograms of $\underline{E}_T$ (ε and τ) are constructed for all rough surface classes of interest;

1c) the transmitted field $\underline{E}_T$ is adjusted to either the peak of the minimal eigenvector pdf of the unwanted region (e.g., to reject ocean clutter) or to the peak of the maximal eigenvector pdf of the region of interest (e.g., bridge, urban area, etc.). The choice depends on the relative sharpness of the modes;

2a) the scattered field $\underline{E}_R$ is computed for each pixel for the $\underline{E}_T$ chosen in Step 1c, see Eq. 6 in Stage 2 of TSP;

2b) as in Step 1b, the joint (ε and τ) histograms of the scattered field $\underline{E}_R$ are constructed. The histogram mode is identified.

3a) the receiver polarization $\underline{h}$ is adjusted via Eqns. 7a or 7b to either match or mismatch the polarization of the histogram mode found in Step 2b;

3b) $P = V^*V$ (received power) is computed for each pixel as $P = (\underline{h}^T\underline{E}_R)^*(\underline{h}^T\underline{E}_R) = (\underline{h}^T[S]\underline{E}_T)^*(\underline{h}^T[S]\underline{E}_T)$, and the resulting image is displayed.

VII. CONCLUDING REMARKS

The potential of complete polarimetric methods for radar imaging has already been convincingly demonstrated by the JPL group (6,7). In this paper, we have attempted to quantify and organize a search for optimal image contrast into a systematic polarimetric filtering method. In addition, no incoherent pixel/look or spatial averaging was allowed. We have accomplished this by combining the TSP search for optimal polarizations on a pixel-by-pixel basis with a subsequent statistical analysis of polarization eigenvectors (versus surface category), and the digital adjustment of the polarimetric variables $\underline{E}_T$ and $\underline{h}$. We find the preliminary results (Figs. 3-7) promising.

The effectiveness of our strategy depends sensitively on the sharpness of the relevant histogram peaks because such a sharpness reflects similarity of the polarimetric scattering behaviour of all the pixels within a given class. Therefore, other image processing techniques, when used in conjunction with the polarimetric enhancement, should be directed towards the increase in peak sharpness of the relevant field distributions (e.g., N X N block averaging, discretization, and quantization, etc.). Here, however, we concentrate strictly on polarimetric enhancement methods. Furthermore, the polarimetric image contrast improves with the separation of the histograms in the polarization space (two "spikes" with no overlap would correspond to a "black and white" image with an ideal contrast). In this respect, the TSP was not successfull because the scattered field histograms of ocean and the urban area (Figs. 4a and 4b) are approximately at the same ε and τ. Another approach would be to choose the transmitting field in such a way as to maximize the peak separation of the scattered field histograms. This approach is currently under investigation in our laboratory and preliminary results based on Monte-Carlo simulation of structures in Rayleigh noise indicate better contrast (relative to TSP) but less efficient speckle reduction.

We wish to state here that an immediate objective of the research is to establish a "tool-kit" of matrix image processing techniques, designed specifically for the handling of polarimetric scattering matrix data on a pixel-by-pixel basis. Consequently, we did not emphasize either the modeling or an interpretation of polarimetric scattering patterns beyond some very basic physical arguments based on flat plates, corner reflectors, Bragg scattering, etc.

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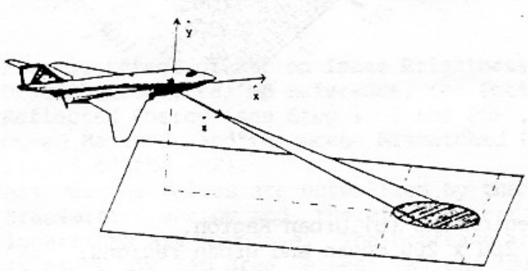
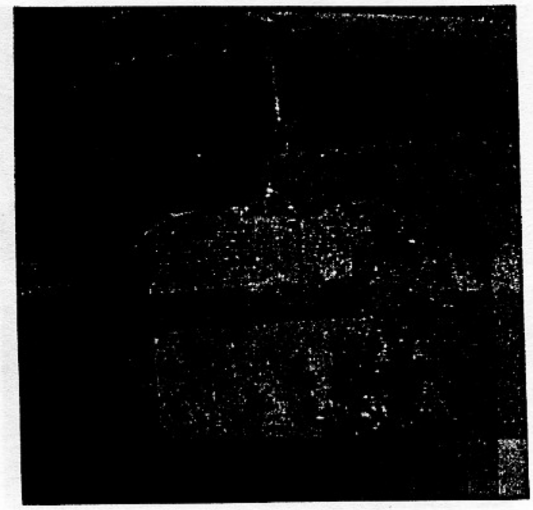
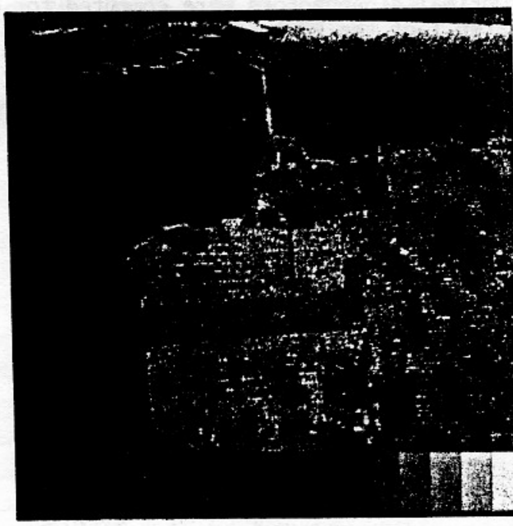


Fig. 1. Arrangement of Coordinate System for Polarimetric SAR.



(a)



(b)

Fig. 2. Synthesized Images: (a) HH Element of [S] and (b) Span of [S].
Speckle in these coherent images is due to random phase modulation associated with surface roughness. The span image (b) has less speckle than the HH image (a) because

$$\text{span}\ [S] = |S_{HH}|^2 + |S_{HV}|^2 + |S_{VH}|^2 + |S_{VV}|^2$$

is an incoherent average of four images. Sixteen uniformly spaced gray scale levels have been used to cover the voltage values in the range $[10^{-3.5}, 10^{-1.5}]$ on a logarithmic scale.

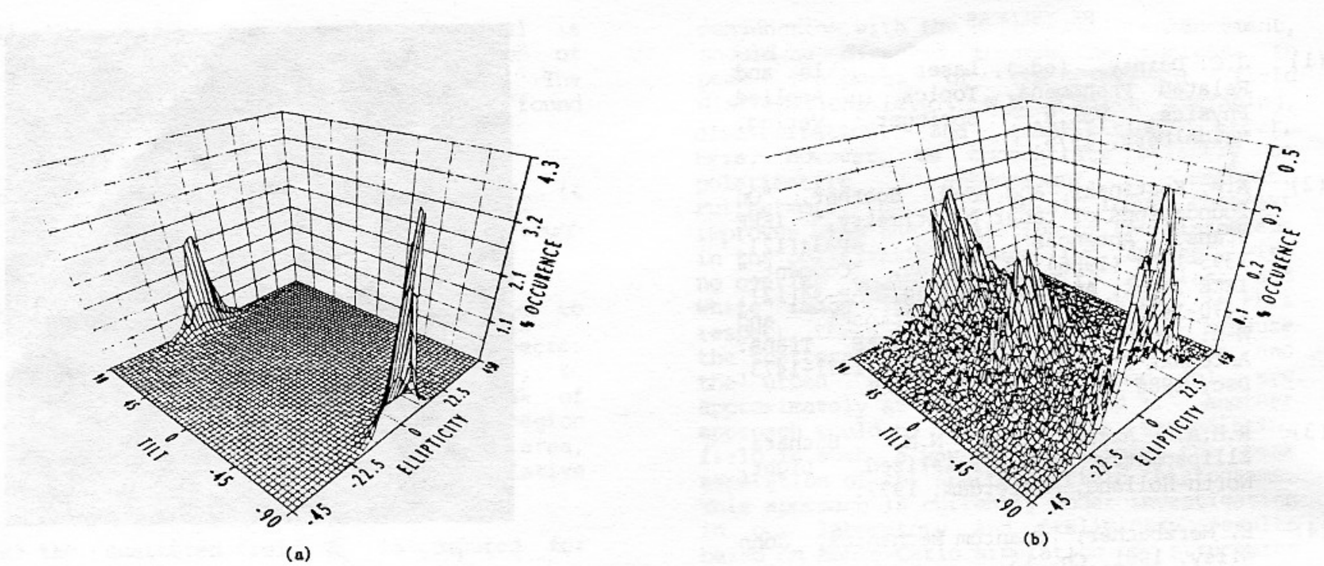


Fig. 3. Histogram of Optimal Transmitted Polarizations: (a) Ocean Region and (b) Urban Region. Optimal eigenvectors were computed for each pixel of the 200 x 200 ocean and urban regions (see Step 1 of the PMF). These eigenvectors were histogrammed in ellipticity ε and tilt τ coordinates (see Eq. [8]). Minimum energy eigenvectors were found for ocean pixels and maximum for urban pixels. The mode (peak of histogram) location indicates that at $\underline{E}_T$ of $\varepsilon = 0°$ and $\tau = 90°$ (vertically polarized), a majority of ocean pixels will respond weakly. Fortunately, the modes of (a) and (b) are the same and, therefore, the majority of city pixels will respond strongly to the same polarization.

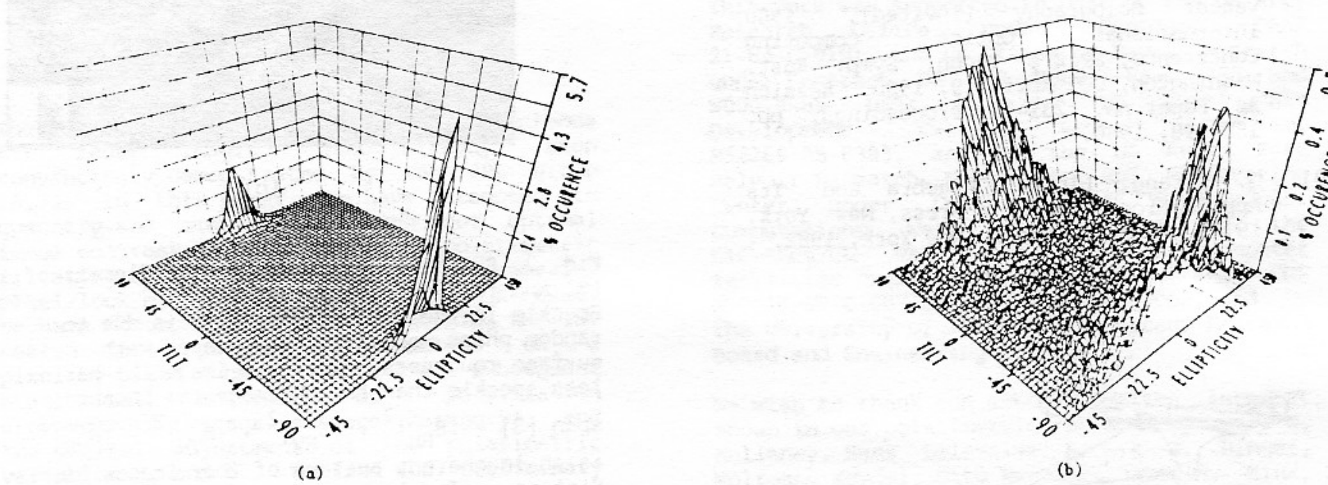
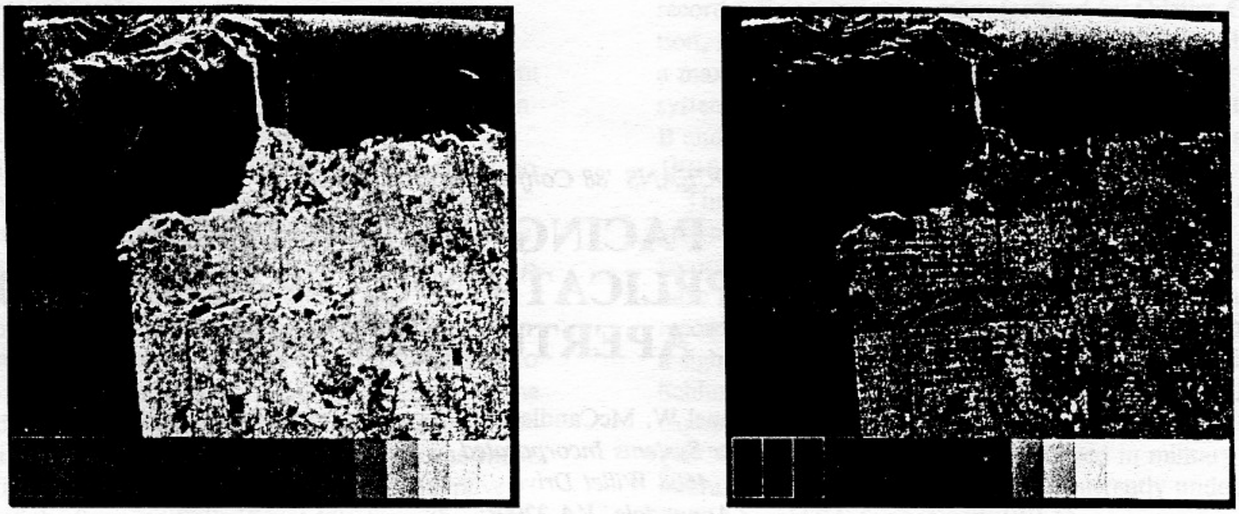


Fig. 4. Histogram of Scattered Polarizations: (a) Ocean Region and (b) Urban Region. The scattered field $\underline{E}_R$ was computed for each pixel of the 200 x 200 ocean and urban regions; the transmitted polarization was chosen in accord with Fig. 3. These scattered polarizations were histogrammed in ellipticity ε and tilt τ coordinates (see Step 2 of the PMF). The ocean mode at $\varepsilon = 0°$ and $\tau = 90°$ indicates that a majority of ocean pixels are mismatched by adjusting $\underline{h}$ to $\varepsilon = 0°$ and $t = 0°$. Because the two modes coincide, an appreciable portion of the urban region will also be mismatched. However, the large spread of the urban histogram still leads to significant contrast improvement.



(a) (b)

Fig. 5. Synthesized Images: (a) Ocean Polarization Mismatched and (b) Ocean Polarization Matched.
In (a), the ocean was mismatched by adjusting E_T to the peak of Fig. 3a ($\varepsilon = 0°$, $\tau = 90°$) and by adjusting $\underline{h}$ orthogonal to the peak of Fig. 4a ($\varepsilon = 0°$, $\tau = 0°$). In (b), the ocean was matched by adjusting E_T as before, while adjusting $\underline{h}$ to the peak of Fig. 4a ($\varepsilon = 0°$, $\tau = 90°$). Note that the ocean vs. urban contrast is much higher in (a) than in (b). Sixteen uniformly spaced gray scale levels have been used to cover the voltage values in the range $[10^{-3.5}, 10^{-1.5}]$ on a logarithmic scale.

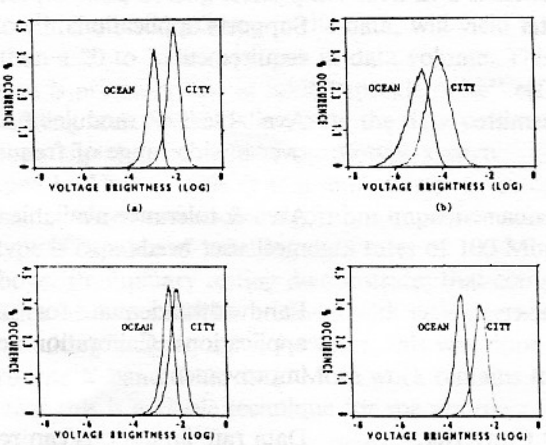


Fig. 6. Effect of PMF on Image Brightness Distributions: (a) HH Reference, (b) Optimal Reflected Energy (see Step 1 of the PMF), (c) Ocean Matched, and (d) Ocean Mismatched (see Step 3 of the PMF).
All voltage values are normalized by the transmitted energy and, therefore, their logarithms are negative. The decrease in relative overlap area between (a) and (d) indicates contrast enhancement. Also, note that the decrease in variance of the ocean distribution between (a) and (d) signifies speckle reduction.

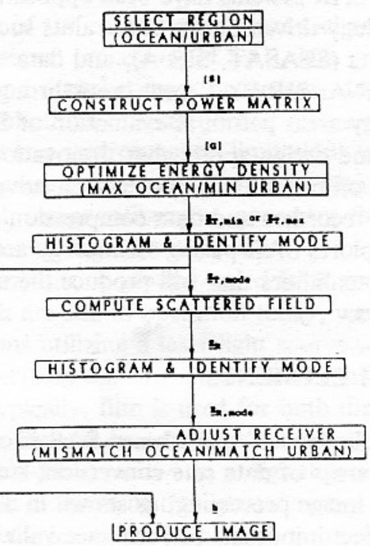


Fig. 7. PMF Flow Chart with Applications to Ocean vs. Urban Contrast Enhancement.

(Reprinted from OCEANS '88 Conference Proceedings)

THE INFLUENCE OF PACING TECHNOLOGIES ON ENVIRONMENTAL APPLICATION OF SPACE-BASED SYNTHETIC APERTURE RADAR

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ABSTRACT

Space-based synthetic aperture radar (SAR) sensing of ocean and polar regions began with the NASA SEASAT system in 1978. Since then, ocean applications have continued with space shuttle flights and free-flyer satellites. Each of these SAR systems have been applications limited due to technology driven design constraints such as on-board recording (SEASAT, SIR-A), and data collection rate limits (SIR-A, SIR-B). Recent breakthroughs in relevant technology areas permit re-evaluation of SAR system architectures and design approaches. Innovations include optical/digital on-board image processors, advanced magnetic tape recorders and data compression algorithms. This paper explores SAR pacing technology areas in terms of projected capabilities that will produce the most benefits for ocean users.

SAR SYSTEM ELEMENTS

Oceanic application of space-based SAR is currently limited in the areas of data rate conversion, storage, downlink and image processing, as shown in Table 1. This barrier can affect important performance values such as swathwidth, dynamic range, range spatial resolution, sensitivity and real time application.

Several of the SAR subsystems can be eliminated from consideration as pacing technologies. For most historic, planned and projected designs the portions of the SAR from the radar transmitter through the radar receiver can be eliminated as pacing technologies.

The basic pacing technologies for space-based SAR are:

- Analog to digital (A/D) conversion
- On-board image processing
- On-board data recording
- Data transmission to the ground

TABLE 1
SPACE-BASED SAR
PACING TECHNOLOGY ASSESSMENT

ELEMENT	STATUS
Exciter	Supports applications requirements.
Transmitter	Available T/R modules & tubes over a wide range of frequencies.
Antenna	Area & tolerance available to meet user needs.
Receiver	Bandwidth adequate for applications. Calibration needs improvement.
A/D Converter, Data Recorder, Downlink	Data rate limitations can reduce swathwidth, coverage, dynamic range and range resolution.
Image Processing	Does not support real time application. Processing choice and location (space or ground) can limit dynamic range, calibration sensitivity, range resolution, etc.

These subsystems can be arranged in a variety of ways. Regardless of how the steps are performed, each can impose significant limits on SAR application. Image signal processing can be performed on-board (preceding the recording and downlink steps) or on the ground. Both options will be discussed.

A/D CONVERSION

If the data is to be processed digitally, as is the current U.S. preference, it must be sampled and converted from analog to digital form, as shown in Figure 1.

Following the analog-to-digital conversion of the video signal produced by the SAR receiver, the digital data stream is typically time expansion buffered to reduce the instantaneous data rate to a lower sustained rate which is continuous over the interpulse period.

For most SAR applications that require high precision estimation of the echo power, an 8 bit ADC is needed to prevent significant saturation or quantization noise in the sampled data. A 300 MHz/8 bit ADC manufactured by Tetronix is currently operationally used in airborne radar systems. Techniques have been developed for adaptive selection of the four most significant bits from the 8 bit ADC output to reduce the effective data rate. A threshold level (or exponent) is calculated to accompany a block of data based on the average power in that block. This technique, referred to as Block Adaptive Quantization (BAQ), can reduce the data rate by a factor of 2. The BAQ technique is being used by the NASA-JPL Magellan Venus Radar Mapper and the Shuttle Imaging Radar SIR-C, both scheduled for early 90s operation.

A large amount of work has been devoted to another data reduction technique identified as pre-image data compression. However, this area is much less promising. Using noiseless (lossless) coding techniques, such as a Huffman code to eliminate redundancy in the data, will yield no more than a 20 to 30% reduction in data volume. This limitation is primarily due to SAR "speckle noise" effects. Lossy coding techniques for reducing the data volume/rate of the raw signal data, include a prototype system developed by Unisys. This system implements a vector quantization fixed code-book algorithm implementation. A prototype is capable of handling data rates of 100 Mbps and above. Preliminary testing demonstrates that compression ratios of 4 to 1 can be achieved with little degradation in the resulting image quality, however, this was done only for airborne X-band SAR data. More work remains to prove that this is a viable technique for spaceborne applications.

Following the buffering/coding stage to reduce the peak data rate (typically by a factor of 4) the data stream passes into a data steering network. This network routes the signal to any of three destinations: 1) On-board high rate recorder system; 2) SAR signal processor for image formation; or 3) Downlink transmitter system for relay to a ground station.

HIGH RATE RECORDER

The high rate recorder system must be capable of recording at data rates of 50 Mbps and above with a recording capacity of at least 8 Gbytes (about 20 minutes of operation) to handle even the simplest SAR system (e.g., single channel, 50 km swath). For the multiple channel, wide swath, multi-polarization SAR required to meet future observation requirements, an order of magnitude better performance is needed. To date, the most advanced recorder flown in space, manufactured by Odetics Corporation, is capable of a maximum record rate of 60 Mbps with a maximum capacity of 8 Gbytes and a BER of 10^{-7}. This system has been flown on SPOT, on the Shuttle with SIR-B and is planned on upcoming SAR satellites such as JERS-1.

The recording technique used in the Odetics and most ground recorders (e.g., Honeywell HD-96) is called linear recording, where as many as 42 parallel longitudinal tracks have been packed onto a one inch wide tape. The helical recording format can realize 600 tracks per inch producing a significant increase in packing density. The helical format Schlumberger Industries model PV6410 (MIL STP 2179) is capable of 240 Mbps, a capacity of 50 Gbytes at a BER of $<10^{-10}$ [1]. This machine is being utilized in military combat aircraft, helicopters, and ships. It is currently undergoing testing by NASA for use with SIR-C.

Although high rate recording systems are still a factor of 2 less than what is required for projected SAR systems, the compact size (1.3 $ft.^3$), low power (0.3 KW) and light weight (66 lbs.) of high rate recorders permit multiple systems to be flown on a single platform. It appears that over the next decade these systems will increase in performance even above current specifications and that the recording technology will not be a significant limitation in future spaceborne SAR systems.

OPTICAL IMAGE SIGNAL PROCESSING

An analysis of the current and future technology as it relates to the signal processing of SAR data must consider both optical and digital computing systems. In addition to the historic limitations of spaceborne processors, such as weight, power and environmental limitations (radiation shielding, outgassing), consideration must also be given to system control, image calibration, processor flexibility and reliability (graceful degradation) issues.

The early versions of ground-based SAR processors, some of which are still in operation today, were analog (optical) systems utilizing a laser light source with a series of lenses to perform the two-dimensional convolution processing. Typically, film is used for both the input and output media. Optical processing systems feature high throughput (real-time) relative to a digital processor, but are constrained in terms of the dynamic range of the film, limitations of the lenses for high resolution imaging and swath width limitations.

Recent technology advances in the field of electro-optics have resulted in improvements in state-of-the-art optical computing. A functional block diagram of an optical SAR processor is shown in Figure 2. Specific advances include: available semiconductor light sources (LEDs, laser diodes) that are more reliable than previous light sources, acousto-optic devices (AOD) that have improved for input spatial light modulation use and semiconductor detector arrays (charge coupled devices — CCDs) that replace the film [2]. With today's technology it is feasible to construct a real-time, compact, power efficient optical computer to perform on-board processing of SAR imagery. However, improvements must still be made in the area of performance, flexibility and reliability.

The performance in terms of the image pixel resolution will be limited by factors such as aberrations in the optics, mechanical/electronic stability and light source coherence. Resolutions on the order of SEASAT SAR (25m) are achievable with today's technology, but an order of magnitude better resolution is not currently feasible. Additional problems exist with the light source. Since the duration of the light source pulse must be shorter than the inverse BW of the signal to avoid range smearing, extremely short pulses (in the 10 nanosecond range) must be used. This presents a problem with coherence and gain transients that effectively degrade the resolution. This problem could be overcome if a pulsed gas laser were used, but this is only currently feasible for a ground processing system. The other major area of technology improvement is in the CCD array technology. Currently CCD chips are limited in width to 1000 elements. This limitation can be overcome by interfacing a number of chips to realize a wide range swath, however, the time bandwidth product of the AOD may then become a constraint on the swath width. Another severe limitation of existing CCD arrays is the dynamic range. Without special cooling to reduce the dark current, a reliable dynamic range of only 30dB can be achieved which is too small for high precision, calibrated SAR image processing.

Although tremendous strides have been made in electro-optical computing over the last decade, major technological advances are still required before these systems can compete with digital computers in terms of image quality and performance. However, the potential advantages of optical systems for on-board SAR processing are tremendous. Specifically, the high speed ADC and buffers shown in Figure 1 can be eliminated from the SAR system and the signal can be routed directly to the optical processor which in turn generates the image nearly instantaneously. This image is captured on a digital CCD and routed to the downlink processor for transmission to a ground receiver before the satellite has passed from reception range.

Considering the size of the engineering community working in optical computing today, it is reasonable to assume that a high performance spaceborne SAR processor will become technically feasible within the next decade.

DIGITAL IMAGE SIGNAL PROCESSING

The tradeoff in digital versus optical processing is typically performance for throughput. Digital signal processing is not theoretically limited in terms of the dynamic range, swathwidth, or resolution that the processor can achieve but rather by the quality of input signal data and the ancillary data such as platform ephemeris, attitude and sensor calibration data. It is fair to say that the processing algorithms/techniques are sufficiently mature today such that they contribute little or no degradation to the resultant image quality. The major issue in implementing an on-board digital processor is in achieving the necessary computational power within the size weight and power limitations of the platform.

Recent gains in semiconductor technology using VHSIC Gallium Arsenide (GaAs) circuitry and advanced Complementary Metal Oxide Silicone (CMOS) devices produced with Silicon On-Insulator (AOI) architecture, bode well for major performance gains in the near future. Looming on the horizon is the potential of superconductivity revolutionizing the microelectronics industry. Superconductor research is on-going to greatly increase the cycle time through improved junctions.

The state-of-the-art in terms of currently available or near operational technology primarily utilizes CMOS circuitry which exhibits excellent speed/power characteristics [3]. For spaceborne systems, a 64K radiation hardened RAM and a 16 bit radiation hardened microprocessor (80C86RH) are to be used in the Mars Observer satellite. One of the most advanced processor candidates for space use is the IBM Common Signal Processor (CPS) developed for the Advanced Tactical Fighter (ATF) program and used in conjunction with the Westinghouse Ultra Reliable Radar (URR) [4]. The architecture consists of a number of processing elements each rated at 125 MFLOPS contained in a module with 32 Mbytes memory. The system can be configured with a number of modules each interfacing into a common data network achieving a maximum performance of 1.8 achieving a maximum performance of 1.8 GFLOPS. The CSP uses CMOS technology, does not require special cooling and is currently constructed with 6 x 9 in. boards (2 $ft.^3$ volume). Considering that this system is within a factor of 4 of what is required for SEASAT real-time processing, it is highly probable that the technology will soon exist for spaceborne high resolution real-time SAR processing.

An alternative approach for the SAR signal processor architecture is to develop a custom chip taking advantage of the highly repetitve nature of the SAR processing algorithm. The range processing could be performed with an analog device (such as a SAW filter) before digitization as shown in Figure 3. Following the ADC, a azimuth correlator chip could be designed that does not require a corner turn of the data from a range file to an azimuth file. The most efficient algorithm for this type of implementation is the time-domain approach where the azimuth correlation is a convolution operation [5]. A custom chip is required that performs resampling for the range migration correction followed by a complex multiplier for the reference function weighting and an accumulator (complex adder with memory for one range line). This chip would be replicated for each element in the synthetic aperture followed by a multiplexer to recombine the data. This approach does not appear to represent any significant technology drivers, although this chip has never been fabricated.

The signal processor should also be followed by a compression subsystem which performs spatial compression of the SAR imagery. Studies have shown that compression ratios of 20:1 are achievable with little degradation in the image quality. This would significantly reduce the requirements on the digital downlink and the ground data handling systems.

DIGITAL DOWNLINK

With recent technology advancements in digital telecommunication systems, wide bandwidth digital links have become commonplace. The NASA Tracking and Data Relay Satellite (TDRS) has two 150 Mbps communication channels for a total capacity of 300 Mbps. To increase the link capacity or equivalently the system bandwidth requires an increase in power to offset the commensurate increase in noise.

Considering the potential of on-board data processing and compression the next generation of direct downlink systems and data relay satellites should be able to handle data rates on the order of 0.5 to 1.0 Gbits/sec, which even after error correction coding is equivalent to instantaneous rates of 8 Gbits/sec coming from the SAR ADC [6]. As previously reviewed, the recorder technology to capture such a data stream is currently available. A number of recorders, each with a 240 Mbps capacity could be interfaced in parallel to achieve the desired capacity.

GROUND DATA SYSTEM

It is reasonable to conclude that existing IC technology and data networks (using fiber optics) make the question of feasibility of real-time ground processing mute. The pertinent question is not the feasibility of such a system, but rather what is the optimal architecture and what systems exist or are under development? A number of organizations have already built custom signal processors with GFLOP computation capabilities. Specifically, the Advanced Digital SAR Processor (ADSP) designed and built by NASA/JPL to support the Magellan Venus Radar Mapper and the Shuttle Imaging Radar (SIR-C) has been demonstrated to be capable of 6 GFLOPS.

An architecture with dedicated pipeline processing modules, custom designed to perform a specific function will reduce system reliability, since a failure will typically halt all processing. This architecture is used in the ADSP. It is capable of extremely high computational rates when the pipeline is full, but relies on every module to be functioning for the system to be operational (i.e., no graceful degradation).

The IBM CSP represents an alternative approach using multiple identical boards for each type of processing (e.g., FFT, memory, complex interpolators) and routes the data using a high speed switch to each board as required in the processing algorithm. One drawback to this architecture is the extremely high data rates at the data transfer node. However, this system does feature graceful degradation at the computational board level.

A third potential architecture is the concurrent processing system such as the Massively Parallel Processor (MPP) developed by Goodyear for the NASA Goddard Space Flight Center (GSFC) or the Hypercube developed by Caltech/JPL. These systems consist of a large number of identical microprocessors each with local memory. The microprocessors are interconnected to each other with different configurations for each application. For example, the MPP is a planar array with each microprocessor communicating with its nearest neighbor. The Hypercube permits multiple interconnection schemes such that any processor can communicate with any other. As the microprocessor technology improves, this type of architecture becomes more desirable due to its high redundancy, system reliability and flexibility.

SUMMARY

The current state-of-the-art and expected future developments in data handling and on-board signal processing were presented at a functional module level. The analysis indicates that the primary technology driver is in the spaceborne image signal processor. Optical, digital or combination hybrid designs can be considered for space-based implementations.

If an on-board processor is implemented, this system could be followed by a data compression system that would reduce both the data rate and volume by a factor of at least 20. This would alleviate any issues regarding the capacity of available high rate recorders and downlink systems.

The only area of lingering concern is the control of the processor and the data calibration. The requirement that the SAR must be capable of discerning small changes in the radar cross section is an extremely difficult specification to meet in the laboratory, not to mention in space. A rule of thumb is that the calibration accuracy is inversely proportional to the resolution. Thus, the higher the resolution, the poorer the calibration performance. Typical specifications for planned spaceborne systems (e.g., SIR-C) are on the order of 0.5 to 1.0 dB for the relative calibration (stability) of the system. It is difficult to make a measurement to better than 0.1 dB.

A more achievable specification for the calibration within the next ten years is 0.2 to 0.3 dB. This will require internal calibration signals to characterize the amplitude and phase characteristics of the system (including the antenna) over the entire signal bandwidth. This information must then be input to the processor to modify the appropriate processing parameters in near-real-time.

High precision GPS and attitude determination are also required for estimation of the Doppler parameters and the antenna boresight. All of these elements are technically feasible but have yet to be incorporated into an operational system.

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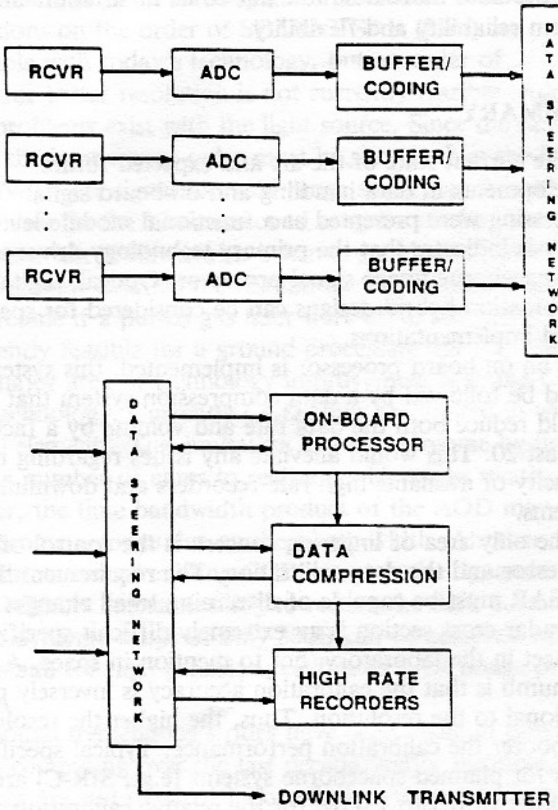
6. Pritchard, W., "Satellite Communications - An Overview of the Problems and Progress", Proc. of the IEEE, Vol. 65, No. 3, pp. 294-307.

FIGURE 1 FUNCTIONAL BLOCK DIAGRAM OF MULTI-CHANNEL SPACEBORNE RADAR SYSTEM WITH ONBOARD PROCESSOR



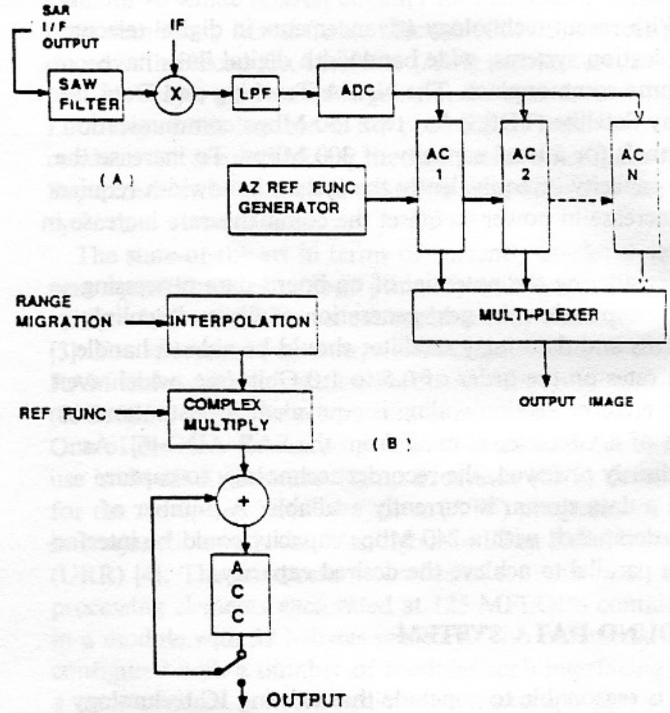


FIG 3 ARCHITECTURE FOR:
A) HYBRID ANALOG/ DIGITAL TIME DOMAIN SAR CORRELATOR
B) AZIMUTH CORRELATOR (AC) CHIP

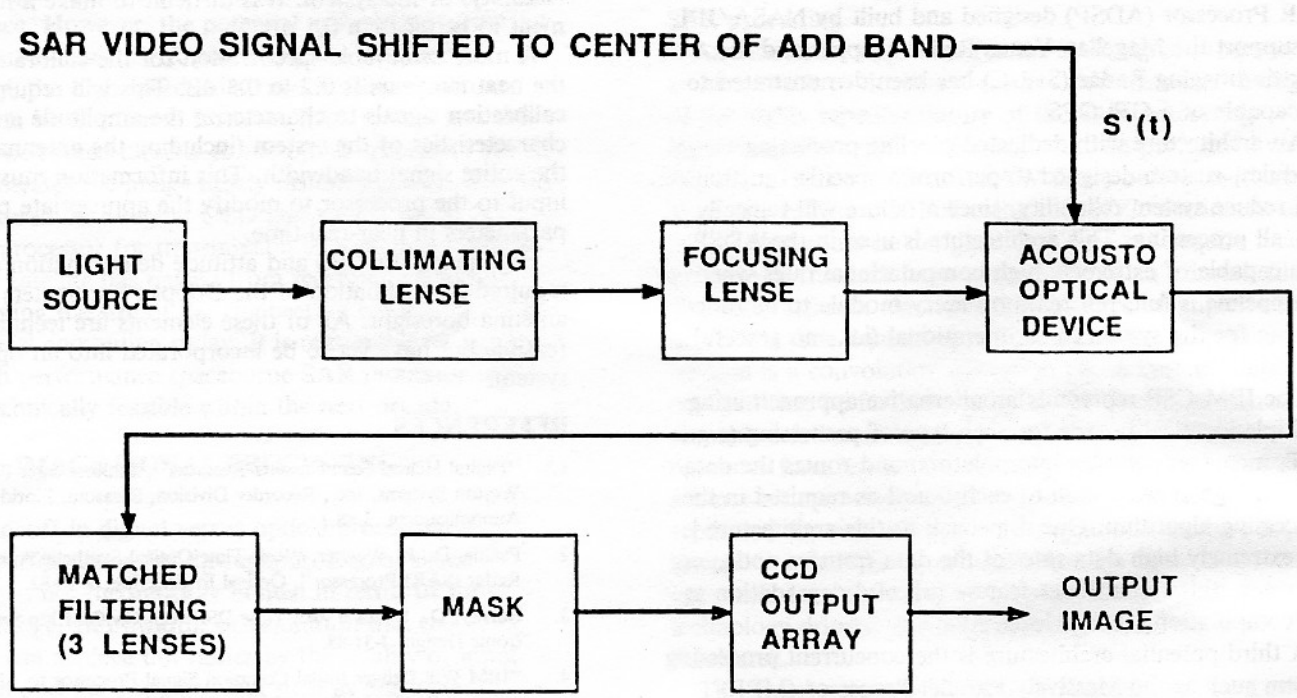


FIG 2 FUNCTIONAL BLOCK DIAGRAM OF OPTICAL SAR PROCESSOR

'TIS A PUZZLEMENT

LAST QUARTER'S PUZZLE — 3D

Last quarter's puzzle was to determine a set of equations for rotating a three dimensional object into any orientation and then displaying it in two dimensions, such as on a computer display.

Set up a coordinate system where the one axis is towards you, the second axis is to the right and the third axis is up. Let the coordinates of a specific point in this coordinate system be (A, B, C) so that:

Out (1)	= A
Right (1)	= B
Up (1)	= C

Rotation of this point into any orientation can be broken down into two steps. The first step consists of rotating the point clockwise about the Up axis by θ degrees. This results in the following coordinates for the point:

Out (2)	$= r \cos(a-\theta)$
Right (2)	$= r \sin(a-\theta)$
Up (2)	= C

$$r = \sqrt{A^2 + B^2}$$

$$a = \tan^{-1}(B/A)$$

The second step consists of rotating the point counterclockwise about the Right axis by $90 - \phi$ degrees. This is equivalent to tipping the point forward $90 - \phi$ degrees. This results in the final coordinates for the point:

Out (3)	$= d \cos[b - (90 - \phi)]$
Right (3)	$= r \sin(a-\theta)$
Up (3)	$= d \sin[b - (90 - \phi)]$

$$d = \sqrt{C^2 + [r \cos(a-\theta)]^2}$$

$$b = \tan^{-1}(C/r \cos(a-\theta))$$

For two dimensional display, the x coordinate for the display is equal to the value of Right (3), and the y coordinate for the display is equal to the value of Up (3). The Out (3) coordinate is in / out of the screen and therefore cannot be displayed.

Thanks to Chris McMahon of Indianapolis for providing the idea for this puzzle and its solution.

THIS QUARTER'S PUZZLE — MOONLIGHTING

You may have noticed that when there is a quarter moon, the dark side of the moon is not completely dark. It appears very slightly lighter than the background of space. Is this real or just an optical illusion caused by your mind completing the incomplete circle? If it is real, then what is the explanation for this effect? Can you estimate the ratio of the illumination of the dark side to the bright side?

Useful Data:

Radius		
	Earth	6.4×10^6 meters
	Moon	1.7×10^6 meters
Distances		
	Sun to Earth	1.5×10^{11} meters
	Sun to Moon	1.5×10^{11} meters
	Earth to Moon	3.8×10^8 meters
Power Output Sun (est)		3.9×10^{26} watts
Reflectance of Earth		0.35
Reflectance of Moon (est)		0.70

Send solutions and ideas for puzzles to:

Dave Hollinberger
Puzzlement Editor
5264 East 77th St.
Indianapolis, IN 46250

ANNOUNCEMENTS AND CALLS FOR PAPERS

IEEE TRANSACTIONS ON NEURAL NETWORKS

On February 15, 1989, the IEEE Publications Committee voted to initiate the IEEE Transactions on Neural Networks which will start as a quarterly publication next year with 320 pages in 1990. The Transactions will cost $10 per year for IEEE members who belong to societies that participate in the IEEE Neural Networks Committee and cost $15 per year for other IEEE members. You can sign-up for the IEEE Transactions on Neural Networks on your IEEE dues bill which comes out in September.

Over the last several years interest has been growing in the use of artificial neural networks as an alternative to conventional computation. Some have envisioned neural networks as an alternative to artificial intelligence (AI) as a way to attack problems that AI has been unable to solve. Neural networks can be considered as massively parallel distributed processing systems with the potential for ever improving performance through adaptive learning. There have been significant demonstrations of neural network applications in fields such as vision, speech, signal processing, pattern recognition, robotics and combinatorics. Now there is a centralized IEEE publication in artificial neural networks where you can learn about what is happening in this exciting field.

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Joseph A. Edminister, Editor—Catherine S. McGowan, Associate Editor

Consumer Electronics—Approximately 60 representatives of industry, academia and government addressed a national initiative to revitalize the U.S. electronics industries at a workshop sponsored by the IEEE-USA Committee on Communications and Information Policy in February.

The workshop participants reached a basic consensus on several points:
• the survival of the U.S. industrial base in vital electronics sectors is at stake;
• industry-led consortia with government cooperation and support are necessary to address the problem; and
• dual-use technologies that meet both civilian and military needs should be developed in cooperation with the Defense Advanced Research Projects Agency (DARPA) and the Department of Commerce's National Institute for Science and Technology.

According to a statement released by the workshop sponsors, DARPA's initiative in high-resolution systems recognizes that future low-cost military technology is related to the overall health of U.S. design and full-scale manufacturing capability in consumer electronics. The Committee recommended that high-resolution systems technology and world-class manufacturing are key areas for action. "Displays and dynamic random access memories (DRAMs) are most critical to this process."

Further, the sponsors wrote that the Federal government should help facilitate an economically attractive environment for industry-led consortia by adopting measures for the provision of government financial support for such consortia; recognizing the importance of an hospitable antitrust environment to attracting private U.S. capital; and equalizing capital costs for U.S. participants relative to foreign competitors.

For more information about the workshop, contact the IEEE-USA Office in Washington, D.C.

New Positions—The United States Activities Board approved three new Entity Position statements at its first 1989 meeting, held in Washington, D.C. on February 22:
• **U.S. Supercomputer Vulnerability** recommends that the new administration recognize the critical importance of supercomputing capabilities. Leadership in a variety of other high-technology product areas is dependent on such capabilities. IEEE-USA also recommends that the Office of Science and Technology Policy assign a high priority to developing a program that will foster continuing U.S. leadership in the supercomputer industry.
• **USAB Policies on Graduate Enrollment in Electrical and Computer Engineering Education** proposes that Federal and state governments, foundations, industry, and professional societies cooperate in increasing the numbers and support levels of fellowships. The position also recommends that industry increase its research sponsorship at universities and sponsor and encourage employees to undertake full-time graduate studies; and that foreign students should be required to pay a fair share of the cost of their graduate education in the United States.
• **USAB Policies on University-Industry Cooperation in Advanced Technology** recommends that the U.S. government increase tax incentives to encourage companies and individuals to donate up-to-date resources for teaching and research; that industry be encouraged to provide speakers to universities and provide summer jobs with meaningful experience for students; that Federal grants and contracts stipulate or encourage university participation in a way that's analogous to the small business set-asides currently existing in some contracts; and that a high-level government-academia-industry board be set up to address these and other urgent issues and provide policy and oversee specific actions.

Copies of these positions are available from the IEEE-USA Office in Washington, D.C.

Technology Policy—Approximately 175 leaders from government, industry, academia, the media and IEEE were on hand for the 1989 IEEE Conference on U.S. Technology Policy, held in Washington, D.C., on February 21. This year's Conference addressed "Policy Imperatives for Commercialization of U.S. Technology," stressing technological innovation, engineering education, international competitiveness, and effective utilization of science and technology.

The Conference was sponsored by the IEEE United States Activities and Technical Activities Boards' U.S. Technology Policy Committee. Among the distinguished speakers were Dr. Harold Liebowitz, Dean of Engineering and Applied Science at George Washington University; Dr. James H. Babcock, Chief Engineer for The Mitre Corporation; Dr. William G. Howard, Senior Fellow of the National Academy of Engineering; and Dr. Robert N. Noyce, Chief Executive Officer of SEMATECH. Dr. Ernest Ambler, Acting Under Secretary for Technology at the U.S. Department of Commerce, gave a keynote address during the luncheon.

A Conference Digest will be available from the IEEE-USA Office in Washington, D.C.

Careers Conference—The sixth biennial IEEE-USA Careers Conference has been schedules for November 1–3, 1989 at the Tradewinds Hotel in St. Petersburg, Florida. Sponsored by the IEEE-USA Career Maintenance and Development Committee, this year's Conference will address "Engineers and Engineering Managers: Career Challenges for the 1990s."

If you register before September 5, 1989, the cost for the two and a half-day event is $175 (member) and $250 (nonmember). After September 5, the cost will be $225 (member) and $300 (nonmember). The cost includes a reception, breakfasts, lunches, breaks and a Conference Record, which will be available at the Conference.

For more information or to register, please call the IEEE-USA Office in Washington, D.C.

USAB telephone hotline recording: (202) 785-2180

IEEE USAB HOT LINES

HDTV—Alan K. McAdams, member of IEEE-USA's Committee on Communications and Information Policy, presented testimony on establishing a competitive edge in advanced television systems before the House Committee on Science, Space and Technology on March 22. He said the U.S. electronics technology base is in a crisis situation with respect to commercial and defense applications. To address the crisis, IEEE-USA's Technology Activities Council proposes a "National Initiative to Revitalize the U.S. Electronics Industries."

He said the advent of high-definition television provides an opportunity and a challenge for this country to recover its posture in electronics. He pointed out steps recommended by the Technology Activities Council to revitalize the U.S. electronics industry base:

- Create three industry-led consortia—one on HDTV, one on dynamic random access memory circuits (DRAMs), and one on high-resolution systems;
- Provide an antitrust environment that will attract private U.S. capital;
- Equalize capital costs for U.S. participants in global markets;
- Counter the bias in the world electronics market structure until U.S.-owned firms achieve world-class quality and costs for their products.

Copies of Mr. McAdams' testimony are available from the IEEE-USA Office in Washington, D.C.

Standards and Technology—IEEE Past President Russell C. Drew appeared before the House Subcommittee on Science, Research and Technology on March 22 on behalf of IEEE-USA's Engineering Research and Development Committee to comment on the proposed FY 1990 budget for the National Institute of Standards and Technology (NIST, formerly the National Bureau of Standards).

Dr. Drew said that NIST has been historically underfunded, receiving insufficient resources for continually expanded missions. The 1988 budget increase to $159 million was in line with IEEE-USA's 1987 recommendation that the budget be increased to $200 million over three to five years. With the 1988 increase, however, came the transformation of the Bureau to NIST, which included a major expansion in mission.

This year's decrease to $156 million "is another step toward the brink of disaster," he said. "There can be little doubt why the international competitive position of the United States continues to decline when the Federal government does not adequately support its own standards role which, under the law, can belong to no other organization."

Copies of Dr. Drew's testimony are available from the IEEE-USA Office in Washington, D.C.

W.I.S.E.—IEEE will sponsor two electrical engineering students again this year to participate in the Washington Internship for Students of Engineering program. On May 30, Steven Durham, from the United States Military Academy at West Point, and Ann Salcido, of New Mexico State University, will join more than a dozen students from around the nation who are sponsored by various technical and professional societies and by industry. They will study U.S. government operations during the 10-week program and will complete projects and reports, for which they will receive credit from their respective colleges and universities.

R&D—IEEE-USA's Aerospace, Defense, and Engineering Research and Development Committees sponsored a briefing on Federal Research and Development Funding for FY 1990 on March 8 in Washington, D.C. This year's briefing was held in conjunction with the Engineering Societies Government Affairs Conference.

Speakers from the U.S. Departments of Defense and Energy, the National Aeronautics and Space Administration, the National Science Foundation, and the National Institute of Standards and Technology presented highlights of their agencies' budgets before approximately 60 IEEE and government leaders and media.

IEEE-USA has published a report on "Electrotechnology in the FY 1990 Research and Development Budget," which covers proposed 1990 R&D budgets for electrical and electronics technology used in the agencies represented at the Briefing. Copies of the report are available from the IEEE-USA Office in Washington, D.C.

Precollege Education—"A Passport to Opportunity," IEEE-USA's new videotape presentation dealing with solutions to the nation's precollege education crisis, was shown for the first time on March 13 at a conference on precollege education that was convened in Washington, D.C., under the leadership of the American Medical Association.

The presentation, developed by IEEE-USA Precollege Education Committee member Lawrence P. Grayson in cooperation with cable television's The Learning Channel, points out that solving the serious problems in the U.S. education system will require an effort by everyone. It presents four major points—that quality education is important for the nation and for all individuals; that American education compares poorly in relation to education in other nations and in absolute terms of what American students are learning; that there is reason for hope, since many successful activities have been implemented to help right the situation; and that much more needs to be done to improve American education and there's a role for everyone in the effort.

The Learning Channel aired the show on its national cable television network on March 19 and will repeat the show periodically during the coming months. Copies of the videotape will be available from the IEEE-USA Office in Washington, D.C., and from Regional PACE Coordinators. The Precollege Education Committee urges IEEE members to show "A Passport to Opportunity" at Section meetings and to local civic groups, PTAs and school administrators.

USAB telephone hotline recording: (202) 785-2180

IEEE USAB HOT LINES

Fusion Research—IEEE-USA's Energy Committee submitted a statement in April on the Federal magnetic fusion research program to the House Subcommittee on Energy Research and Development. "IEEE supports a strong, stable, government funded fusion research program," the Committee wrote. The United States must develop a consistent energy policy that includes the timely assessment of fusion energy as an alternate source of electric power production with a virtually inexhaustible supply of fuel and attractive environmental properties.

The Committee recommended that the fusion program include "both a strong domestic program and an international component for otherwise prohibitively demanding projects," in order to achieve feasibility and timeliness. The program plan should be adequately stable to permit timely completion of construction projects, efficient execution of research programs, encouragement and exploitation of innovation, and development and retention of technical staff.

Copies of the Committee's statement are available from the IEEE-USA Office in Washington, D.C.

NASA Testimony—IEEE-USA Aerospace R&D Committee Chairman Theodore R. Simpson and Committee member Richard G. Gould appeared before the House Subcommittee on Space Science and Applications on April 4 to comment on the proposed FY 1990 budget for the National Aeronautics and Space Administration (NASA). Since the shuttle *Challenger* accident, NASA has received substantial annual budget increases. "We have and continue to support these increases because they are necessary to maintain U.S. leadership in aeronautics and space," Mr. Simpson said. "[IEEE-USA] also likes the overall distribution of funding within the proposed FY 1990 budget."

Simpson and Gould called particular attention to the need for a long-term goal for manned space flight; increased funding for space technology; and continuing the Advanced Communications Technology Satellite (ACTS) program.

Copies of their testimony are available from the IEEE-USA Office in Washington, D.C.

Photovoltaics—In a statement to the House Subcommittee on Energy Research and Development, the IEEE-USA Energy Committee urged restoration of the FY 1989 budget for U.S. Department of Energy photovoltaic (PV) R&D. The Committee said the DoE-U.S. industry partnership in PV R&D has been successful in the past year. However, the proposed 30-percent decrease in Federal funding to $25 million in FY 1990 would "essentially destroy the partnership."

According to the Committee, the $10 million decrease would either shut down the vital PV program at the Solar Energy Research Institute or Sandia National Laboratories or it would cut U.S. industry funding to well below the level required to complete existing contracts.

The Energy Committee added that while the United States is proposing drastic cuts in America's PV program, European countries and Japan have government programs that approach or exceed those of the United States. Germany and Japan have more than twice the funding of the proposed DoE budget. "This budget cut could delay economic PV for central power generation well into the next century and leave the vast, developing world market to European and Japanese industries."

Copies of the Committee's statement are available from the IEEE-USA Office in Washington, D.C.

Age Discrimination—On behalf of IEEE-USA's Age Discrimination Committee, USAB Chairman Edward C. Bertnolli sent letters to the chairmen of the House Select Committee on Aging and the Senate Subcommittee on Labor to express IEEE-USA's support of legislation that limits unsupervised waivers of rights under ADEA to instances where a specific claim of age discrimination against an employer has been settled. These letters will be included in the House and Senate Committee hearing *Records.*

"Since technology moves at such a rapid pace, older engineers are often victims of the stereotype that their knowledge is outdated and their experience is not relevant to state-of-the-art research," Dr. Bertnolli wrote. They are often given only a few days to make decisions that will affect the rest of their lives and "must waive rights for an offer of increased benefits at a time when they have little or no idea what those rights might be."

The Age Discrimination Committee requested cooperative efforts between IEEE-USA, other concerned organizations and Congress to press for an end to the use of age as a criterion in making employment decisions or in matters of compensation or benefits.

Supercomputers—United States Activities Board Chairman Edward C. Bertnolli sent a letter to Secretary of Commerce Robert A. Mosbacher recently to call attention to two announcements that he called "further evidence that U.S. leadership in high-performance computing is in danger."

Dr. Bertnolli, who sent the letter on behalf of IEEE-USA's Committee on Communications and Information Policy, referred to an announcement that Control Data Corporation closed ETA Systems, Inc., its subsidiary responsible for manufacturing supercomputers, because it couldn't achieve profitability. He also called attention to Japan's announcement that it has released a new supercomputer that is advertised as being several times more powerful than any currently available from an American manufacturer.

"Although press reports indicate that the machine has been developed by a U.S.-Japanese joint venture, to the best of our knowledge the entire technology base for the machine comes from Japan and the U.S. company does marketing and market analysis for the supercomputer," he said. He forwarded a copy of CCIP's Scientific Supercomputer Subcommittee report on "U.S. Supercomputer Vulnerability," asking that the statements and recommendations presented in the paper be considered when policies affecting science and technology are being discussed.

IEEE-USA telephone hotline recording: (202) 785-2180

Vol. 5, No. 5 ✦ May 1989

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OFFICIAL ABSTRACT SUBMISSION FORM FOR PAPER PROPOSALS

MAY 7–10, 1990
HOUSTON, TEXAS

DEADLINE FOR SUBMISSION—SEPT. 15, 1989

AN ANNUAL CONFERENCE ON OFFSHORE RESOURCES AND ENVIRONMENT JOINTLY SPONSORED BY:

American Institute of Mining, Metallurgical, and Petroleum Engineers—Society for Mining, Metallurgy, and Exploration—The Minerals, Metals, and Materials Society—Society of Petroleum Engineers • **American Association of Petroleum Geologists** • **American Institute of Chemical Engineers** • **American Society of Civil Engineers** **American Society of Mechanical Engineers**—Petroleum Div. • **Marine Technology Society** • **Institute of Electrical and Electronics Engineers**—Oceanic Engineering Society • **Society of Exploration Geophysicists** • **Society of Naval Architects and Marine Engineers**

1990 OFFSHORE TECHNOLOGY CONFERENCE ABSTRACT SUBMISSION FORM
Deadline for Receipt—Sept. 15, 1989

Note: All information requested on this abstract submission form must be included in order to be considered by the OTC Program Committee. Specific details regarding the nature of the work will be given priority consideration by the Program Committee.

GUIDELINES FOR AUTHORS

All Sponsoring Societies of the Offshore Technology Conference will participate in developing the technical program for the 1990 Conference. The Program Chairman for the 1990 Conference is W.C. (Bill) Kazokas. Individuals interested in submitting an abstract for consideration by the 1990 Conference Program Committee should review carefully the material included in this document. Specifically, potential authors should note that a **manuscript will be required for inclusion in the *Proceedings* volume for each paper accepted for the 1990 Conference Program.**

The OTC Program Committee will evaluate papers solely on the basis of information supplied on this form. Authors **must** provide specific information on the paper proposal in **each** of the areas of the abstract section.

OTC provides complimentary registration **only** for presenting authors who register on special author registration cards. OTC assumes no obligation for any other expenses incurred by authors for travel, lodging, food, or other incidental expenses.

INSTRUCTIONS FOR ABSTRACT COMPLETION

Please type and limit abstract to this page only

Solicitation of technical papers for the 1990 Conference will be made primarily with this Abstract Submission Form. The form contains space for the abstract that must be included for all proposed papers. This system permits the selection of papers for the program before manuscripts are written. Additional copies of this form will be supplied by the OTC Headquarters on request.

ABSTRACT: An abstract, containing 200 to 300 words, must be provided. Develop the abstract by separately addressing the four parts in the space provided on the form. The individual parts are described below.

Description of the Paper: Summarize the scope and nature of the work upon which the paper will be based. Note the relative emphasis of components such as field data, laboratory data, design, analysis, field operations, research, or system development. Note differences from other past or current related work being done in this area. If the paper is a review paper, carefully state the extent of the coverage.

Application: Describe the possible application of knowledge provided in this paper to a particular area of offshore resource development and recovery. If the paper is a review paper, carefully state the extent of the coverage.

Results, Observations, Conclusions: Describe results to be presented in the paper and state specific conclusions of work. Describe how these differ from results or conclusions of previous work in the same or similar subject. If the paper describes hardware, operation of a system, or an event, state specific new information revealed. Also state whether results of field data, laboratory test data, or calculated computer work will be included in the paper.

Significance of Subject Matter: Briefly state the most significant aspect of the subject matter.

Subject categories are listed below. Please indicate by number the most appropriate Primary Category designation on the abstract form where indicated. A secondary category is optional.

1. Marine Geology & Geochemistry
2. Exploration & Production Geology
3. Geophysical Interpretation
4. Geophysical Data Gathering & Data Processing
5. Seafloor Surveying & Mapping
6. Foundations & Soil Structure Interaction
7. Oceanography & Meteorology
8. Wind, Wave, & Current Forces
9. Response to Wind, Waves, & Currents
10. Offshore Platform Concepts
11. Design & Analysis of Bottom Founded Structures
12. Design & Analysis of Mobile & Floating Structures
13. Platform Construction & Installation
14. Drilling Technology & Equipment
15. Well Completion Technology & Equipment
16. Field Development System Evaluation & Selection
17. Production Facilities & Process Technology
18. Subsea Production Facilities
19. Marine Riser Systems
20. Offshore Pipelines
21. Marine Terminals & Ocean Transportation
22. Ocean Minerals & Mining
23. Ocean Energy Technology
24. Arctic Technology
25. Mobile Offshore Drilling Units
26. Construction, Support, & Service Vessels
27. Manned & Unmanned Submersible Systems
28. Diving, Salvage, & Repair Operations
29. Position Control & Station Keeping of Vessels
30. Navigation & Telemetry Systems
31. Instrumentation & Control
32. Mooring & Anchoring
33. Safety & Fire Prevention
34. Environmental Quality Considerations
35. Engineering Materials for Offshore Applications
36. Corrosion & Corrosion Control
37. Welding & Fatigue

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EVALUATION OF ABSTRACTS BY THE 1990 PROGRAM COMMITTEE

The following criteria will be observed by the Offshore Technology Conference Program Committee in selecting papers for the 1990 Conference.

1. The paper must not have had prior extensive publication or circulation. Publication in trade periodicals or other professional and technical journals will be considered extensive publication.

2. The paper should contain new knowledge or experience in some field of offshore resource and environment.

3. The paper must be technically correct and should be of interest to a reasonable number of people working in the field of offshore resources and environment. It may be theoretical or may present the results of laboratory studies, and it may state or analyze a problem. The paper may also be a review-type paper, but must be of significant value to the technical field.

4. The paper may present information about equipment and tools to be used in offshore technology. Such papers must show the definite applications and limitations of such equipment and should avoid undue commercialism and the extensive use of trade names.

5. **The abstract should have necessary clearance before submittal to OTC Headquarters. Prospective authors should provide information on any clearance problems when the abstract is submitted.**

Although theoretical papers will be selected in various fields, application papers presenting solutions to problems are also desired. Program time is limited, so the Program Committee will emphasize the quality of the contribution and its value in the field of offshore technology.

A WORD ABOUT COMMERCIALISM . . .

The OTC Program Committee has a stated policy against use of commercial trade names, company names, or language that is **commercial** in tone in paper titles, figures, and slides and these should be avoided in the text. Use of such terms will result in **careful scrutiny** by the Program Committee in evaluating abstracts, and the presence of **commercialism** in the text of papers submitted for the *Proceedings* volume is cause for removal of the paper from the program.

COPYRIGHT

In accordance with U.S. Copyright Law, the Offshore Technology Conference must receive and maintain on file a copy of the Transfer of Copyright Form, signed by all authors of papers to be presented at the OTC.

PREPARATION OF MANUSCRIPTS OF ACCEPTED PAPERS

Authors of papers selected for the 1990 OTC program will be notified by mail in Dec. 1989.

Authors offering papers for the program should fully understand that a manuscript will be required for each technical paper selected for the 1990 Conference. If selected, the manuscript will be printed in the *Proceedings* volume to be sold at the Conference. The maximum desirable length for any paper is about 7,000 words.

Complete instructions on preparation of manuscripts and slides will be sent to authors of accepted papers.

Final manuscripts are due **Feb. 10, 1990**, where author types the final copy of his/her manuscript on special forms provided by the OTC office, then sends typed forms and loose illustrations to OTC Headquarters. The OTC staff completes the layout and printing of the paper.

ABSTRACT DEADLINE: SEPT. 15, 1989

READ ATTACHED INSTRUCTIONS CAREFULLY

PAPER TITLE: ____

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CORRESPONDING AUTHOR: ______________________ TELEX: ______________
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Subject Categories are listed on attached sheet. Please indicate number of subject heading that most directly applies to your proposal in Primary and Secondary (if appropriate) boxes.

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Note to Authors: The OTC Program Committee will evaluate papers solely on the basis of information supplied on this form. Preference will be given to authors giving specific information in each of the areas outlined in the section entitled "Instructions for Abstract Completion."

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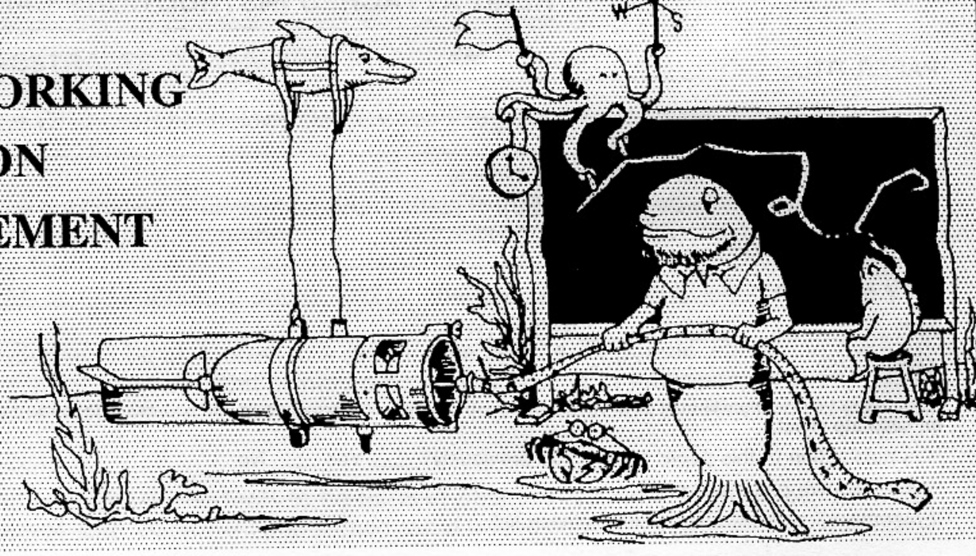

APRIL 3-5, 1990

to be held in the Washington, D.C. area

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CALL FOR PAPERS !

Papers are invited from interested authors on all aspects of current measurement technology. Abstracts should be submitted by October 1, 1989.
Major topics are:

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3. Acoustic Doppler & related technologies (Correlation, scintillation, etc.)

Authors of papers chosen for presentation and publication in the Conference Proceedings will be notified by January 1, 1990. Select authors will be invited to prepare manuscripts for a special edition of the IEEE Journal of Oceanic Engineering.

Abstracts should be sent to:

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