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SCIENCES AND SYSTEMS DIVISION SIMULATION MODELS CATALOG.(U)

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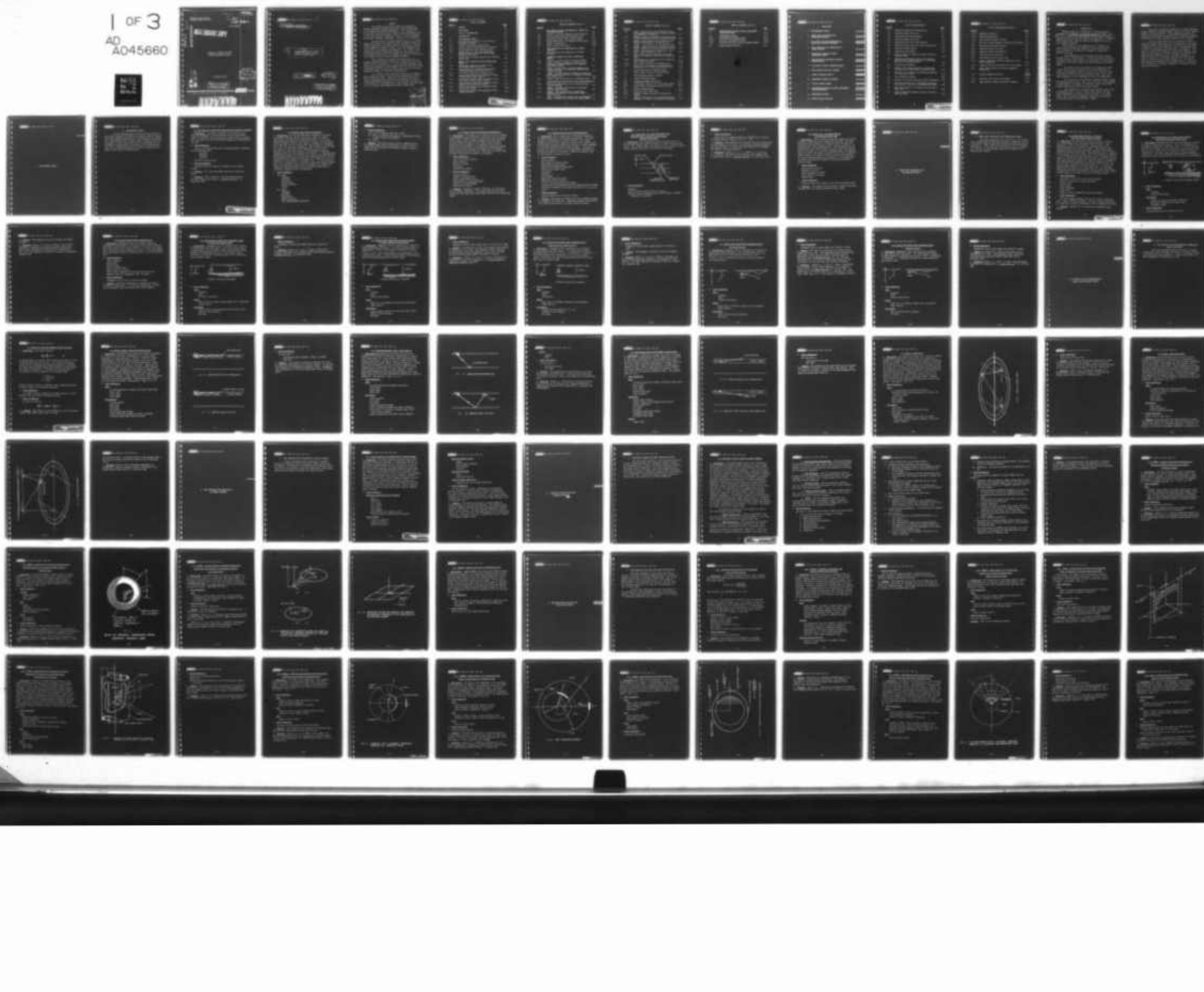

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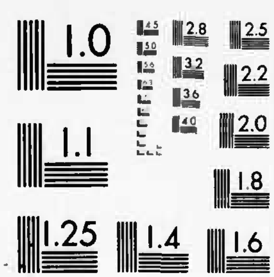

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SCIENCES & SYSTEMS DIVISION

SIMULATION MODELS CATALOG

5 February 1969

TRACOR
6500 Tracor Lane, Austin, Texas 78721, AC 512/926-2800

This Catalog of Simulat [redacted]

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

TRACOR Project 002 951
Document Number 69-210-U

SCIENCES SYSTEMS DIVISION SIMULATION MODELS CATALOG

5 Feb[redacted]69

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

PREFACE

This catalog of simulation models was prepared by TRACOR's Hydrospace Programs Department, with the assistance of the Systems and Research Departments. The collection in its entirety represents years of work in model development, and is the result of many thousands of hours of effort by TRACOR's scientists, engineers, programmers, analysts, and technicians.

The collection of models presented here is by no means static--new models are continually under development within the TRACOR laboratories, and older models are improved or replaced as new demands are imposed on them, or as new knowledge is obtained about the processes they represent. As a result of this continuing program of model development and improvement, many of the models described in this catalog are the most advanced for their purpose of any that are available, anywhere.

This document was prepared for TRACOR staff use, to acquaint TRACOR personnel in the various laboratories with the models that are available, and to aid in program planning. When copies are distributed outside TRACOR, they are provided with the understanding that the data contained herein are not to be disseminated outside the recipient's organization.

It is expected that additional models will be added to this catalog from time to time, and that modifications may be made to existing models. Holders of this catalog who wish to receive supplemental material as it is issued may be placed on the mailing list by providing their name, address, and copy number to A. N. Glennon, 6500 TRACOR Lane, Austin, Texas 78721.

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INTRODUCTION

This document is a compendium of simulation models developed in the Sciences and Systems Division of TRACOR, Inc., for use in a wide variety of research and development projects. Although the models were developed for implementation on TRACOR's UNIVAC 1108 digital computer, they can be adapted for use on other digital computers.

The purpose of this compilation is to acquaint the reader with the functional capability of each of the models, and to explain how the models are employed in simulating a physical system.

The documentation here represents the first of three planned levels of documentation. A brief functional description is given for each model along with a discussion of the parametric generality of the model, input and output variables, and output format.

The second level will present the mathematical details of each model so that a prospective user will understand the model on a fundamental basis, and will be able to use the model intelligently for his particular simulation task. This level can be referred to as an "engineering" level of documentation.

The third level will consist of computer program listings and operating instructions. This level will assist the programmer or data analyst in obtaining the numerical results or possible program modifications which the analyst desires.

The complexity of the models described here varies from a fundamental level, such as a model which produces the beam pattern generated by an array of point sources, to a complex level, such as a tactical engagement model which uses several of the basic models in generating its output.

The utility of digital simulation is further emphasized through examples of modeling complex systems by "wiring" together several of the basic models. These examples demonstrate the "building block" concept through which both individual component performance and overall system performance can be evaluated.

The first few sections of the compilation present relatively simple models which can be described in a few pages. In these sections, an introduction discusses the general types of models in the section, and their uses. Following the introduction, the individual models are described separately. The latter sections of the compilation present more complex models, which are not amenable to quick, individual description. In these sections, the introduction discusses the model in more detail, and covers much the same material that is covered in the individual descriptions of the simpler models. Following this introduction, individual components of the model are described very briefly.

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1. ENVIRONMENTAL MODELS

1. ENVIRONMENTAL MODELS

The environmental models relieve the sonar analyst of the burden of manually calculating the effects caused by variations, both temporal and spatial, in the medium and its boundaries. These models permit a broader scope of analysis than would be possible by manual calculation, both by permitting the consideration of a wide range of variations in a relatively short time, and by allowing the analyst to study the effects over a region, rather than at isolated points.

1.1 Sea Noise as a Function of Sea State and Frequency (Knudsen)

1. Description: Sea noise is computed as a function of sea state and frequency by a two-dimensional linear interpolation. Values for "Knudsen" type curves were extracted from the reference. Five sea States (0.5→7.0) and nineteen frequencies (200.0→20000.0) are used.

2. Input Parameters:

This is a subroutine with three calling parameters, appearing in the following order:

Sea State
Frequency
Sea Noise

The first two are inputs.

3. Output Parameters:

Sea Noise (from list above) is returned to the calling program.

4. Comments: This subroutine SEAN requires the subroutine XYINT.

5. Reference: Wenz, Gordon M., "Acoustic Ambient Noise in the Ocean: Spectra and Sources," J. Acoust. Soc. Am., 34, 1936-1956, 1962.

1.2 Ambient Ocean Noise (Directional)

1. Description: For any specified depth, frequency, sea state, bottom loss, velocity profile, and $\sigma G(\theta_S)$, where σ = surface noise density and $G(\theta_S, \phi_S)$ = normalized intensity of the noise radiated surface element in the direction (θ_S, ϕ_S); the directional noise field $N(\theta)$ in the vertical plane is calculated in increments of 1° from -89° (directly overhead) to +89° (toward the sea bottom). The results of this noise field computation are then used to calculate the total noise intensity by performing a numerical integration over all solid angles at the receiver. If experimentally measured data of $N(\theta)$ is read into the program, along with pertinent environmental and velocity profile data, the program will solve for $\sigma G(\theta_s)$ and give the results at increments of 1°. If the directional noise over a frequency band is desired, rather than single frequency data, the directional noise field is calculated for frequency increments of specified length, and the resultant noise field is obtained by integrating over the bandwidth.

2. Input Parameters:

(a) Depth
Frequency
Sea State
Bottom loss
Velocity profile
$\sigma G(\theta_S)$

(b) Depth
Frequency
Sea State
Bottom loss
Velocity profile
$N(\theta)$ (experimentally measured)

3. Output Parameters:

For θ in 1° increments from -89° to +89°:

(a) $N(\theta)$; by numerical integration of experimental values of $N(\theta)$ over all solid angles.

(b) $\sigma G(\theta_s)$

4. Comments: The model has been used in a TRACOR study of the AN/BQS-13(MOD) system (Document No. 67-677-C) and in a technical note dealing with the AN/BQR-7 (DIMUS), Document Number 68-364-C.

1.3 Coherent Surface Scattering and Reflection

1. Description: The pressure as a function of time is computed for an arbitrary sonar pulse after interaction with the moving ocean surface. Care is taken to preserve the phase structure so that correlation losses due to Doppler-shift and phase distortion may be predicted. The scattered sound field is derived by an application of the Kirchhoff scattering integral and the moving ocean surface is generated with the Neumann-Pierson spectral density function. Simulation of various types of signal processors is included in the program.

2. Input Parameters:

   Input pulse form and level
   Source position
   Receiver position
   Wind speed
   Transmit beam pattern

3. Output Parameters:

   Pressure function
   Energy in returned pulse
   Peak crosscorrelator output
   Average power in crosscorrelogram
   Energy in crosscorrelogram
   Peak detector output

4. Comments: Program is limited to 100 msec, 3.0 kHz pulses due to storage limitations. The program calculates the two-dimensional scattered sound field rather than the three-dimensional field.

1.4 Bottom Reflection and Scattering Model

1. Description: Given a source and its directivity pattern, an insonified portion of the bottom is determined. The bottom roughness is described by a Cos-Cos function, and a single frequency pulse of finite duration is used as the incident sound. The Rayleigh reflection coefficient provides for finite impedance of the single deterministically rough boundary. A receiver is placed at the specular point, and an approximate expression of Kirchhoff's equation is utilized to compute the pressure field at that point as a function of time.

2. Input parameters:

    Source strength
    Wave length of incident sound
    Depression (grazing) angle
    Vertical and horizontal beam width
    Velocity of incident sound
    Water depth
    Frequency
    Pulse length
    Sampling interval for pulse
    Amplitude of bottom function
    X- and Y-direction bottom wave lengths
    Dimensions of infinitesimal areas into which bottom is divided
    Acoustical parameters of the water and bottom (i.e., ρ_2/ρ_1 and c_1/c_2)

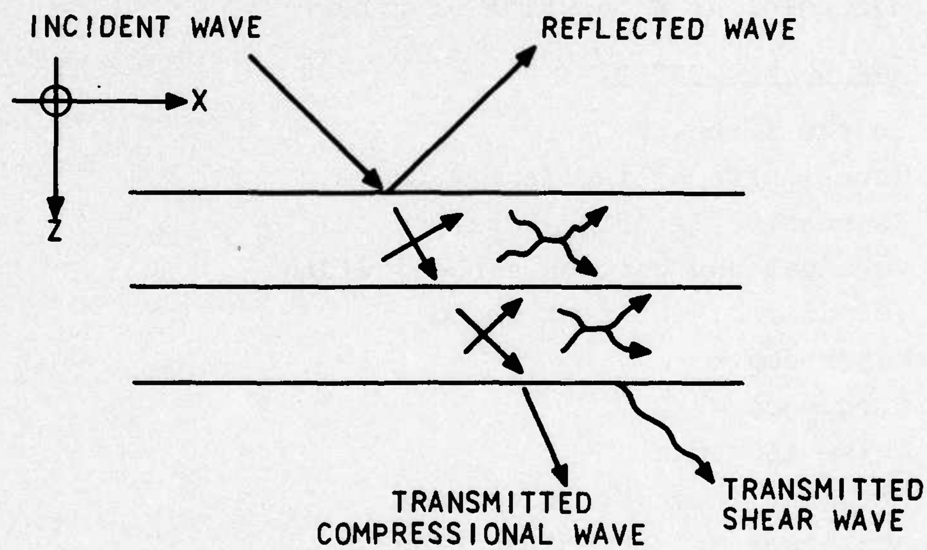
3. Output Parameters:

    Specular pressure as a function of time.

4. Comments: The program can handle only small beamwidths because of a computer time limitation. Additional programs are available to do limited processing of the output pressure function.

1.5 Bottom Loss of a Plane Sinusoidal Wave Reflecting From a Layered, Visco-elastic Sediment Ocean Floor

1. Description: This program calculates the bottom loss of a plane single frequency sonar wave when it reflects from the ocean bottom. The sediment layers are modeled as up to 9 layers of visco-elastic material lying over a visco-elastic half-space.



2. Input Parameters:

Frequency
Water constants (sound velocity, density)
Sediment constants (compressional sound velocity, rigidity, attenuation, thickness)

3. Output Parameters:

Bottom loss and complex reflection coefficient as a function of grazing angle for angles 1°, 2°, 3°, ...90°.

4. Comments: This program can be used for bottom loss calculations at any frequency up to 20 kHz. Good agreement between calculated and observed values of bottom loss were obtained for the FASOR I and FASOR II deep water stations.

5. References: Bucker, H. P., J. A. Whitney, G. S. Yee, and R. R. Gardner, "Reflection of Low Frequency Sonar Signals from a Smooth Ocean Bottom," J. Acoust. Soc. Am., 37, 1037-1051, 1965.

1.6 Bottom Loss, Processing Methods For Explosive Source Data

1. Description: Bottom reflected explosive signals and various systems for processing these signals are simulated. The basic processing system consists of a bandpass filter followed by a rectifier and a time averaging device. The peak outputs of the bandpass filter and time averager are used to compute different bottom loss values as a function of grazing angle. The computed values of bottom loss cannot be interpreted in terms of absolute levels; however, the relative values of bottom loss associated with each processing method are considered to be representative of results which would be obtained from analog processing of actual sea data.

2. Input Parameters:

   Bottom return structure
   Bandwidth of filter
   Center frequency of filter
   Step response of averager
   Grazing angle

3. Output Parameters:

   Relative bottom loss values at each specified grazing angle

4. Comments: This program has been used to evaluate processing methods used by the Marine Geophysical Survey (MGS).

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2. NORMAL MODE PROPAGATION AND REVERBERATION MODELS

2. NORMAL MODE PROPAGATION AND REVERBERATION MODELS

The models presented in this section are, for the most part, special purpose models for determining propagation loss as a function of range for specified velocity profiles, using normal mode theory. In one model, the reverberation level is computed as a function of time, assuming normal mode propagation in a shallow water channel.

2.1 Normal Mode Solution in a Medium With Curvilinear Velocity Profile

1. Description: The solution of the wave equation is obtained for a fluid medium with curvilinear velocity profile. The reciprocal of the velocity squared is represented by an N^{th} degree polynomial as a function of depth. This leads to depth-dependent special functions numerically evaluated from recurrence relations by digital subroutines. The general solution is expressed as an integral in the wave number space. The integrand is analytic in the cut complex wave number plane except at a countably infinite number of poles which characterize the normal modes of propagation. The residue theorem transforms the integral expression to an infinite series, the normal modes contribution, plus a branch line integral which vanishes in the long range limit. In the short range limit the branch line integral leads to a wave diminishing in amplitude as the inverse square of the range and having a phase velocity equal to the speed of sound in the ocean's bottom.

2. Input Parameters:

   Polynomial of best fit to the velocity profile
   Speed of sound at the surface and bottom
   Density ratio
   Source depth
   Source frequency
   Water depth
   Ranges at which transmission losses are desired

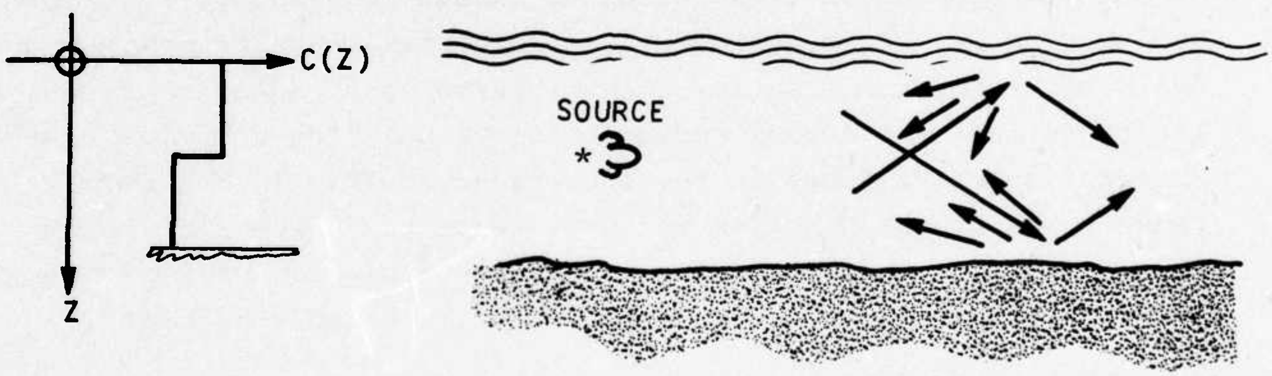
3. Output Parameters:

   The first program calculates the first n poles or characteristic numbers (real and complex). The second program calculates the transmission losses corresponding to the n characteristic modes.

4. Comments: Checked out for shallow and intermediate water depths.

2.2 Reverberation in a Shallow Water Channel Calculated Using Normal Mode Theory

1. Description: Reverberation levels are calculated as a function of time in a shallow water channel. The sound propagates down the channel according to normal mode theory. At the surface and bottom of the channel, part of the sound is scattered back toward the source as a function of the surface and bottom scattering coefficients. This back-scattered energy propagates according to normal mode theory and arrives back at the source as reverberation.



(LAYERED VISCO-ELASTIC SEDIMENT BOTTOM)

2. Input Parameters:

Sonar

frequency
vertical beam pattern

Environment

surface and bottom scattering coefficients
parameters required by the normal mode propagation model

3. Output Parameters:

Reverberation level as a function of time

4. Comments: This program is written in Fortran 63 computer language.

5. Reference: Bucker, H. P. and H. E. Morris, "Use of Bottom Parameters in Calculation of Bottom Reflection Coefficients, Shallow Water Propagation and Shallow Water Reverberation," Proc. 24th. Navy Symposium on Underwater Acoustics, Philadelphia, November 1966.

2.3 Bi-linear Normal Mode Propagation Loss

1. Description: Propagation losses of underwater sound are calculated by normal mode for a bi-linear sound velocity gradient. The source and/or receiver may be either in, or below, the surface duct. The surface loss is assumed to be zero. It is also assumed that sound does not arrive via bottom bounce or via the convergence zone.

2. Input Parameters:

   Signal frequency
   Source depth
   Receiver depth
   Depth of surface duct
   Speed of sound at surface
   Sound velocity gradients in and below the surface duct
   Ranges at which the propagation loss is desired

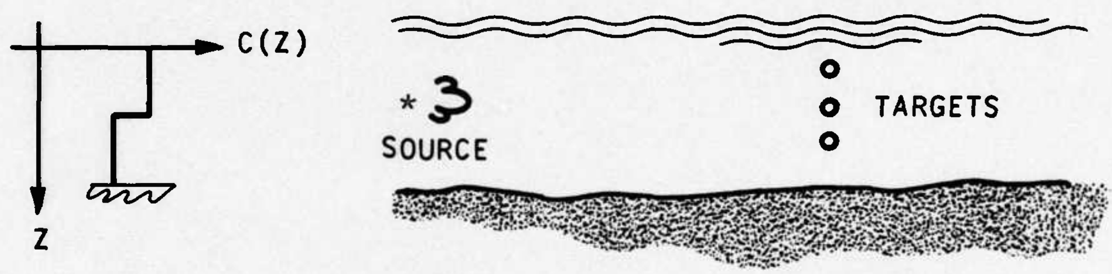
3. Output Parameters:

   Propagation loss in dB as a function of range

4. Comments: Particularly applicable to propagation losses in and below a surface duct. It is limited to deep water, and the velocity gradient below the surface duct must be negative.

2.4 Shallow Water Normal Mode Propagation Model (2 Isovelocity Water Layers)

1. Description: Propagation loss is calculated as a function of range using normal mode theory. The velocity-depth profile is approximated by two isovelocity water layers and the bottom sediments are represented by up to 9 visco-elastic layers. Corrections are made for volume attenuation of the sound waves and for surface losses.



(LAYERED VISCO-ELASTIC SEDIMENT)

2. Input Parameters:

Sonar
- frequency
- depth
- vertical beam pattern

Target
- depth (up to 6 different target depths can be specified)
- range interval

Environment
- sound velocity and thickness of the two water layers
- sediment layer constants
- sea state

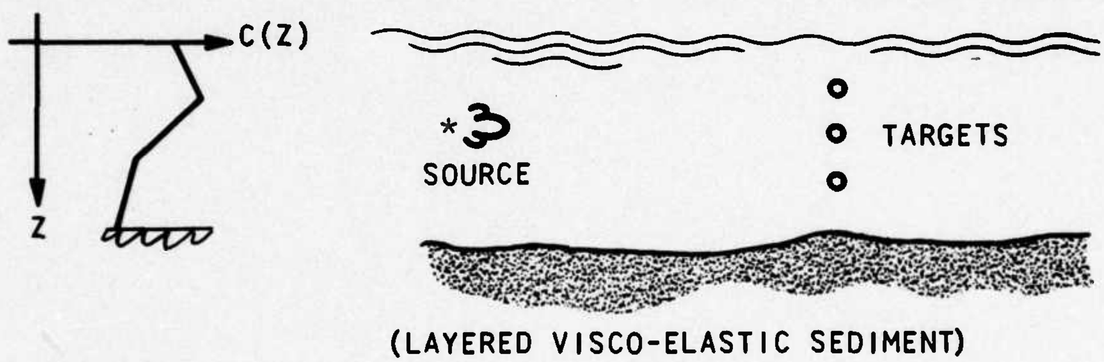
3. Output Parameters:

Propagation loss for each target depth as a function of range.

4. Reference: Bucker, H. P. and H. E. Morris, "Normal Mode Intensity Calculations for a Constant Depth Shallow-Water Channel," J. Acoust. Soc. Am., 38, 1010-1017, 1965.

2.5 Shallow Water Normal Mode Propagation Model (3 "Linear Gradient" Water Layers)

1. Description: Propagation loss is calculated as a function of range using normal mode theory. The velocity-depth profile is approximated by three "linear gradient" profiles of the form $C^{-2}(Z) = A + BZ$. The bottom sediments are represented by up to 9 visco-elastic layers. Corrections are made for volume attenuation of the sound energy and for surface losses.



2. Input Parameters:

Sonar

- frequency
- depth
- vertical beam pattern

Target

- depth (up to 6 different targets can be specified)
- range interval

Environment

- sound velocity profiles for the three water layers
- sediment layer constants
- sea state

3. Output Parameters:

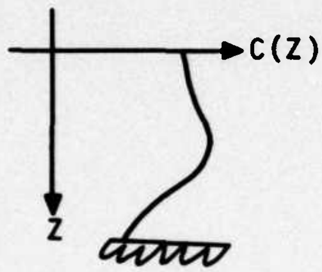
Propagation loss for each target depth as a function of range.

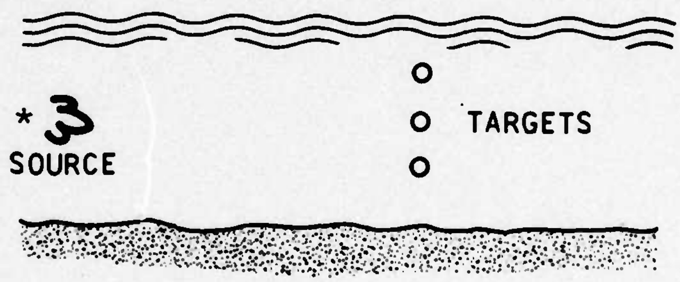
4. Comments: The model can be used for any shallow water channel at frequencies up to 5 kHz. Good agreement between calculated and experimental values of propagation loss has been obtained for all the shallow water FASOR I and FASOR II stations.

5. References: Bucker, H. P. and H. E. Morris, "New Models for Shallow Water Normal Mode Propagation," U. S. Navy Journal of Underwater Acoustics, July 1968.

2.6 Shallow Water Normal Mode Propagation Model (Epstein Velocity-Depth Profile)

1. Description: Propagation loss is calculated as a function of range using normal mode theory. The velocity-depth profile is approximated by the curve $C^{-2}(Z) = A\ \mathrm{sech}^2(Z/H) + B \tanh(Z/H) + D$. The bottom sediments are represented by up to 9 visco-elastic layers. Corrections are made for volume attenuation of the sound waves and for surface losses.





(LAYERED VISCO-ELASTIC SEDIMENT)

2. Input Parameters:

Sonar

- frequency
- depth
- beam pattern

Target

- depth (up to 6 different targets can be specified)
- range interval

Environment

- constants of the profile (A, B, D, H)
- sediments layer constants
- sea state

3. Output Parameters:

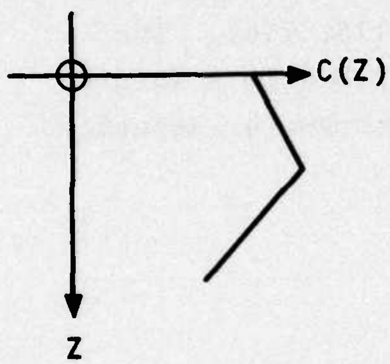
Propagation loss for each target depth as a function of range

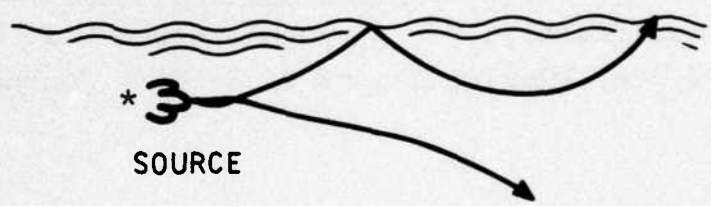
4. Comments: This program is written in Fortran 63 computer language.

5. Reference: Bucker, H. P. and H. E. Morris, "New Models for Shallow Water Normal Mode Propagation with Examples for Fasor Stations," 25th Navy Symposium on Underwater Acoustics, Orlando, Fla., November 1967.

2.7 Surface Duct Normal Mode Propagation Model (Bi-linear Profile)

1. Description: Propagation loss is calculated as a function of range using normal mode theory. The velocity-depth profile is approximated by two "linear gradient" profiles of form $C^{-2}(Z) = A + BZ$. Corrections are made for volume attenuation and surface losses.





2. Input Parameters:

Sonar

- frequency
- depth
- vertical beam pattern

Target

- depth (up to 6 different targets can be specified)
- range interval

Environment

- sound velocity profile constants
- sea state

3. Output Parameters:

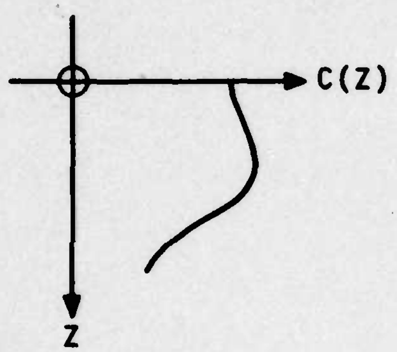
Propagation loss for each target as a function of range

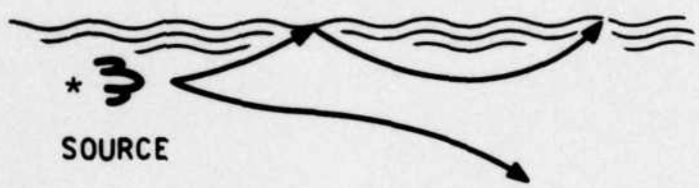
4. Comments: This model can be used for any surface duct at frequencies up to 5 kHz. Good agreement between calculated and experimental results has been shown in NEL tests off the California coast (J. Acoust. Soc. Am., 37, 105, 1965) and calculations for a duct with a rough surface agree well with tests made by the Key West Test and Evaluation Detachment.

5. Reference: Pedersen, M. A. and D. F. Gordon, "Normal Mode Theory Applied to Short Range Propagation in an Underwater Acoustic Duct," J. Acoust. Soc. Am., 37, 105-118, 1965. The modification for a rough surface will be published in a future (~Jan. 1969) issue of U. S. Navy Journal of Underwater Acoustics.

2.8 Surface Duct Normal Mode Propagation Model (Epstein Profile)

1. **Description**: Propagation loss is calculated as a function of range using normal mode theory. The velocity-depth profile is approximated by the Epstein curve of form $C^{-2}(Z) = A\ \mathrm{sech}^2(Z/H) + B \tanh(Z/H) + D$. Corrections are made for volume attenuation and surface losses.





2. **Input Parameters**:

Sonar

- frequency
- depth
- vertical beam pattern

Target

- depth (up to 6 different targets can be specified)
- range interval

Environment

- sound velocity profile constants
- sea state

3. Output Parameters:

Propagation loss for each target as a function of range.

4. Comments: The model can be used for any surface duct at frequencies up to 5 kHz. Good agreement between calculated and experimental values were found in NEL tests off the California coast.

5. References: Bucker, H. P. and H. E. Morris, "Epstein Normal-Mode Model of a Surface Duct," J. Acoust. Soc. Am., 41, 1475-1478, 1967.

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3. RAY THEORY AND AMOS REVERBERATION RUMBLE AND PROPAGATION MODELS

3. RAY THEORY AND AMOS REVERBERATION, RUMBLE AND PROPAGATION MODELS

The models presented here use ray theory to compute reverberation level and target echo level as a function of time for various specified geometries. In some of the models, the AMOS propagation loss equations are used.

3.1 Solution of Eikonal Equation of Ray Acoustics

1. Description: The Eikonal equation,

$$\frac{d}{ds}\left(n \frac{d\vec{r}}{ds}\right) = \vec{\nabla} n \ , \qquad (1)$$

is solved, where s is the arc length along the ray path, $\vec{r} = \vec{r}(s)$ is the position vector of the ray. In a cartesian coordinate system (x,y,z), performing the indicated operations on equation (1) yields three ordinary differential equations of second order. The index of refraction n is a function of the temperature T, the salinity S, and the pressure p of the medium, with

$$T = T(x,y,z) \ ,$$
$$S = S(x,y,z) \ ,$$
$$p = p(z) \ .$$

Wilson's formula is used to calculate n and a Runge-Kutta method is used to solve the differential equations.

2. Input Parameters:

Arc length increment, maximum arc length, initial x,y, and z position, and four initial differential values.

3. Output Parameters:

For each arc length s,

$$\left(\frac{dx}{ds}\right)\text{S-X}, \ \left(\frac{dy}{ds}\right)\text{S-Y}, \ \left(\frac{dz}{ds}\right)\text{S-Z} \ .$$

4. Comments: The program is called DRIKUT and uses sub-routines RUNKUT, FUNC, SPEED, TEMP, SALIN, and PRESS.

3.2 Surface Channel Reverberation/Echo Level

1. Description: Reverberation and target echo levels are computed as a function of time after transmission for an active sonar operating in an isothermal layer. Account is taken of surface reverberation, volume reverberation (either in or out of the surface channel), and first order bottom reverberation. Target echo levels are based on a target in the layer. Spreading loss is determined from ray theory using a velocity profile composed of linear segments. Propagation in the channel is assumed to be by numerous RSR (Refracted-Surface-Reflected) rays, each of which may experience numerous surface reflections (and, consequently, numerous surface losses). Output levels are for a point immediately following the receiving beamformer. Beam patterns must be read into the program from tapes. (See Sketches - Figs. 3-1, 3-2.)

2. Input Parameters:

Sonar

- 3-D beam patterns for transmit and receive (from tape)
- source level
- source depth
- pulse length

Environmental

- velocity profile
- water depth
- wind speed
- wave height
- volume scattering strength
- bottom scattering strength (at normal incidence)
- biological layer depth (below the layer)

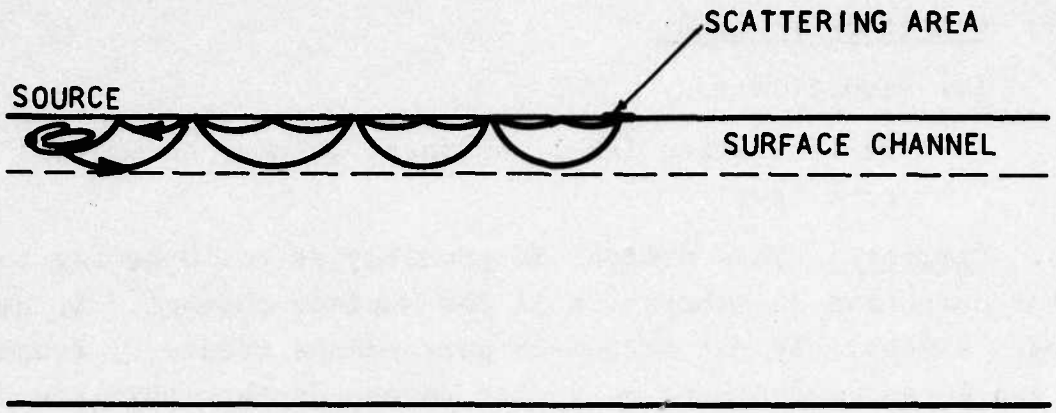

FIG. 3-1 COMPUTING SURFACE DUCT REVERBERATION

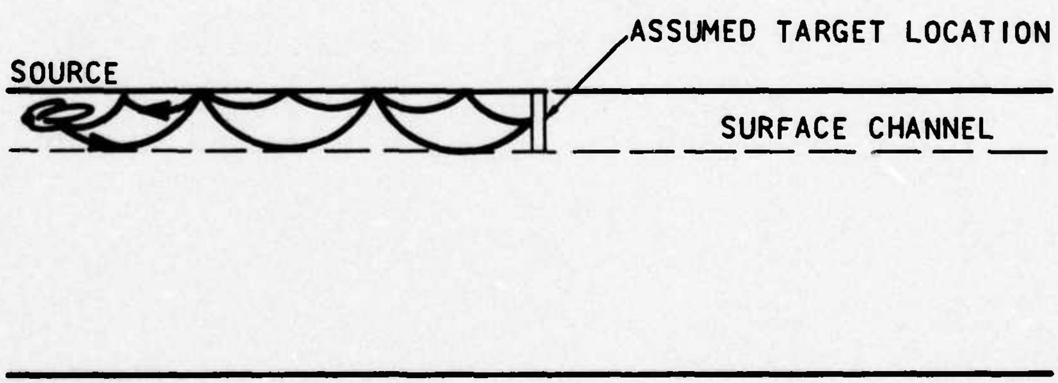

FIG. 3-2 COMPUTING TARGET ECHO LEVEL

3. Output Parameters:

For each time t:

reverberation level (surface, volume, or bottom)
echo level

4. Comments: This program is probably as valid as ray theory for computing reverberation in the surface channel. It has been used extensively for AN/SQS-26 performance studies. Propagation loss is assumed not to vary with target depth within the surface channel.

3.3 Reverberation/Echo Level, Bottom Bounce

1. Description: Reverberation and target echo levels are computed, as a function of time after transmission, or equivalent target range, for a near surface sonar operating bottom bounce in deep water. Account is taken of surface and volume reverberation and several orders of bottom reverberation. Target echo levels are based on a bottom reflected propagation path. Spreading loss is determined from ray theory using a velocity profile comprised of a series of linear segments. Three-dimensional transmitting and receiving beam patterns are used. Output levels are for a point immediately following the receiving beamformer. (See Sketches - Figs. 3-3, 3-4.)

2. Input Parameters:

Sonar

- 3-D beam patterns for transmit and receive
- source level
- pulse length
- array depth

Environment

- velocity profile
- water depth
- wind speed
- volume scattering strength
- bottom scattering strength (at normal incidence)
- bottom loss as a function of grazing angle at the sonar center frequency
- medium attenuation at the sonar center frequency

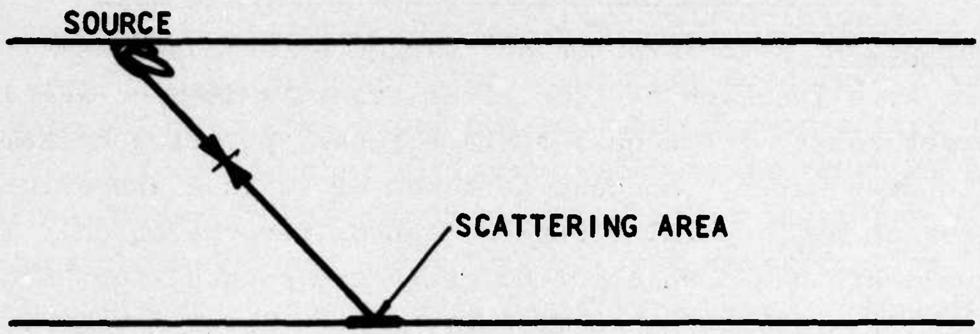

FIG. 3-3 COMPUTING BOTTOM REVERBERATION

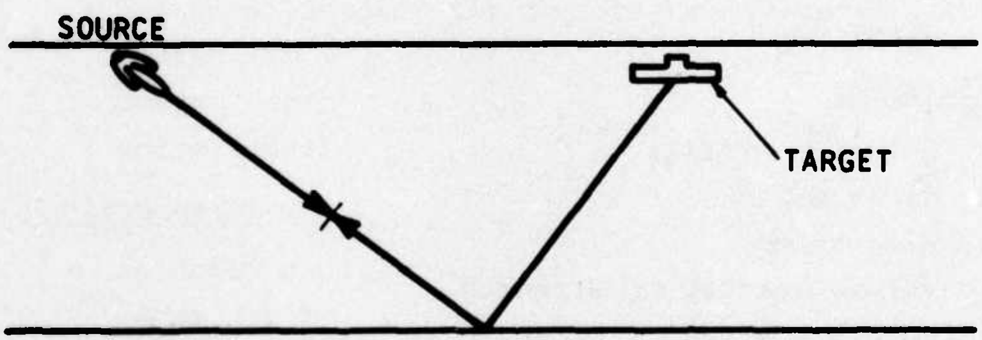

FIG. 3-4 COMPUTING TARGET ECHO LEVEL

Target

strength
depth

3. Output Parameters:

For each time t:

reverberation level
echo level

4. Comments: This program may be used efficiently for water depths greater than 2000 yards. It has been used extensively in AN/SQS-26 performance studies and compares well with empirical data.

5. Reference: Fowler, S., "Bottom Bounce Reverberation Model and Bottom Bounce Loss Analysis (U)," Technical Memorandum, TRACOR Document Number 66-355-C, NObsr-93140, 16 November 1966 (CONFIDENTIAL).

3.4 Reverberation/Echo Level/Signal-to-Noise Ratio

1. Description: Reverberation, target echo level, and signal-to-noise ratio (reverberation only) are computed as a function of time after transmission for a near-surface active sonar. Account is taken of surface reverberation and volume reverberation using three-dimensional beam patterns. Straight line geometry is used. Range is computed as CT/2 with propagation loss being computed by the AMOS empirical equations. Output levels are for the receiving beamformer output. (See Sketches - Figs. 3-5, 3-6.)

2. Input Parameters:

Sonar

3-D beam patterns for transmit and receive (from tape)
source level
pulse length
source depth
receiver beam width
sonar frequency

Environment

surface sound velocity
surface channel lower boundary sound velocity
surface temperature
wind speed
sea state
biological scattering strength
biological layer dapth
isothermal layer depth

Target

target depth

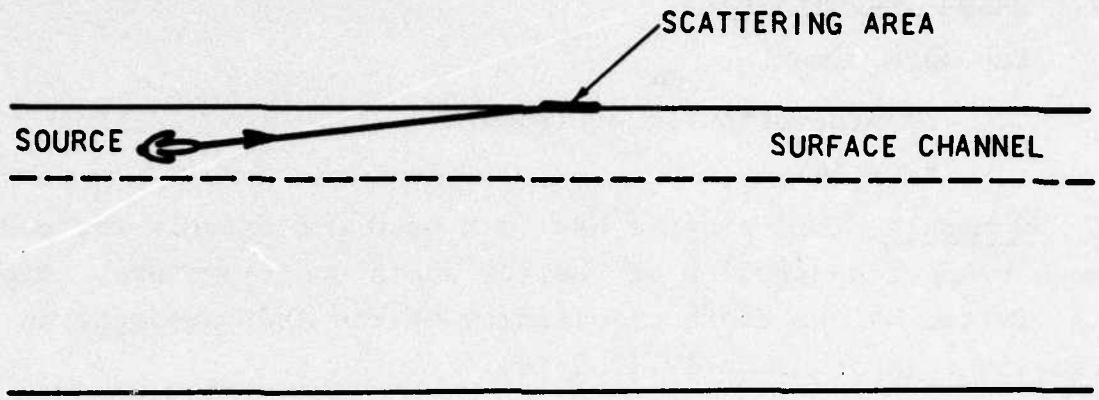

FIG. 3-5 COMPUTING SURFACE DUCT REVERBERATION

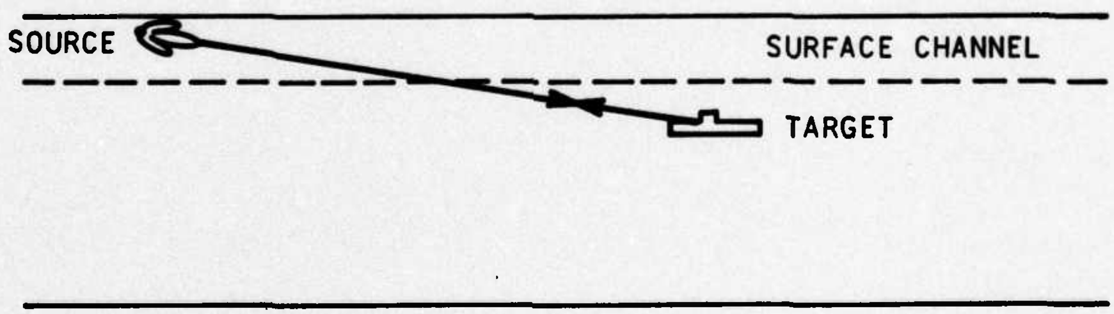

FIG. 3-6 COMPUTING TARGET ECHO LEVEL BELOW SURFACE DUCT

3. Output Parameters:

For each time t:

reverberation level (sum)
echo level

4. Comments: This program has been used extensively for performance prediction studies of shallow depth sonar systems. Depth is limited by the depth of validity of the AMOS propagation loss equations (approximately 1000 ft).

3.5 Rumble, Surface Duct

1. Description: The surface duct rumble level (bi-static surface reverberation experienced by one ship due to transmission by another) is computed as a function of time following transmission on the source ship. Three-dimensional beam patterns are used for the source and receiver. Input parameters are the same as those for surface duct reverberation with additional inputs describing ship separation and the relative orientation of transmitting and receiving beam patterns. Propagation loss is read into the program in tabular form and may thus be based on any of the in-house programs (ray theory, normal mode, AMOS). Computed levels are for a point immediately following the receiving beam-former. (See Sketch - Fig. 3-7.)

2. Input Parameters:

Sonar

- 3-D beam patterns for source and receiver
- orientation (bearing and depression) of transmit and receive patterns
- source level
- pulse length
- ship separation

Environment

- layer depth
- sound velocity at top and bottom of layer
- wind speed
- propagation loss table:
  Range (R) - propagation loss, H(R) for inputs concerning velocity profile, frequency, source and receiver depths.

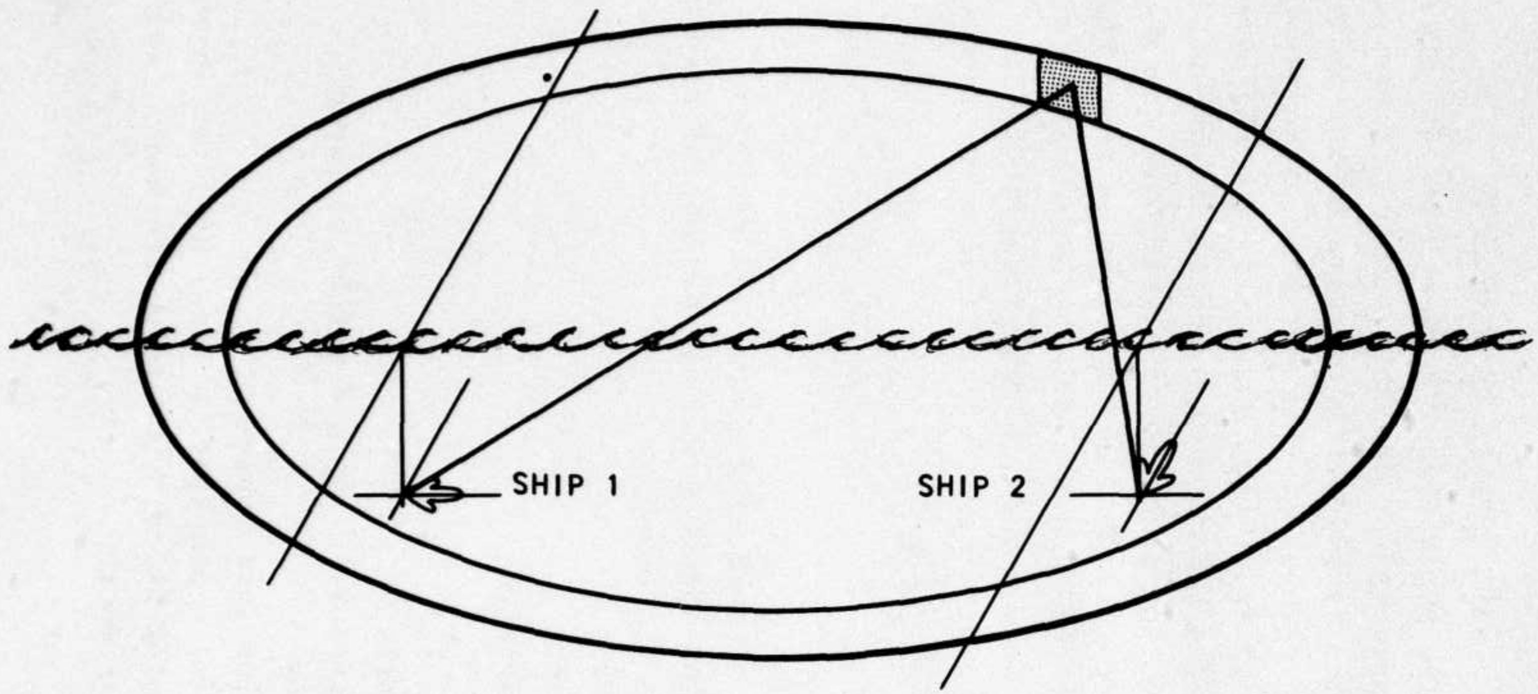

FIG.3-7 COMPUTING SURFACE RUMBLE

3. Output Parameters:

Rumble level for each time t

4. Comments: This program has been used extensively in mutual interference studies for the AN/SQS-26. Surface scattering strength is determined from the Chapman-Harris equation evaluated at the surface angle corresponding to the duct limiting ray.

5. Reference: Gullatt, John, "Performance Degradation of AN/SQS-26(CX) Sonars by Intership Acoustic Interference (U)," TRACOR Document Number 68-310-C, 19 February 1968.

3.6 Rumble, Deep Water Bottom

1. Description: The bottom rumble level (bi-static bottom reverberation experienced by one ship due to transmission by another) is computed as a function of time following transmission on the source ship. Three-dimensional beam patterns for the source and receiver are utilized. Input parameters are the same as those required for bottom reverberation with additional inputs describing ship separation and the relative orientation of transmitting and receiving beam patterns. Scattering area geometry and propagation loss equations assume an isovelocity medium. Computed levels are for a point immediately following the receiving beamformer. (See Sketch - Fig. 3-8.)

2. Input Parameters:

Sonar

- 3-D beam patterns for source and receiver
- orientation (bearing and depression) of transmit and receive patterns
- source level
- pulse length
- ship separation

Environment

- water depth
- medium attenuation
- bottom scattering strength

3. Output Parameters:

Rumble level for each time t

4. Comments: This program has been used extensively in mutual interference studies for which first order bottom rumble was the dominant contributor to the masking background. This will, in general, be the case for deep water operation of surface duct or

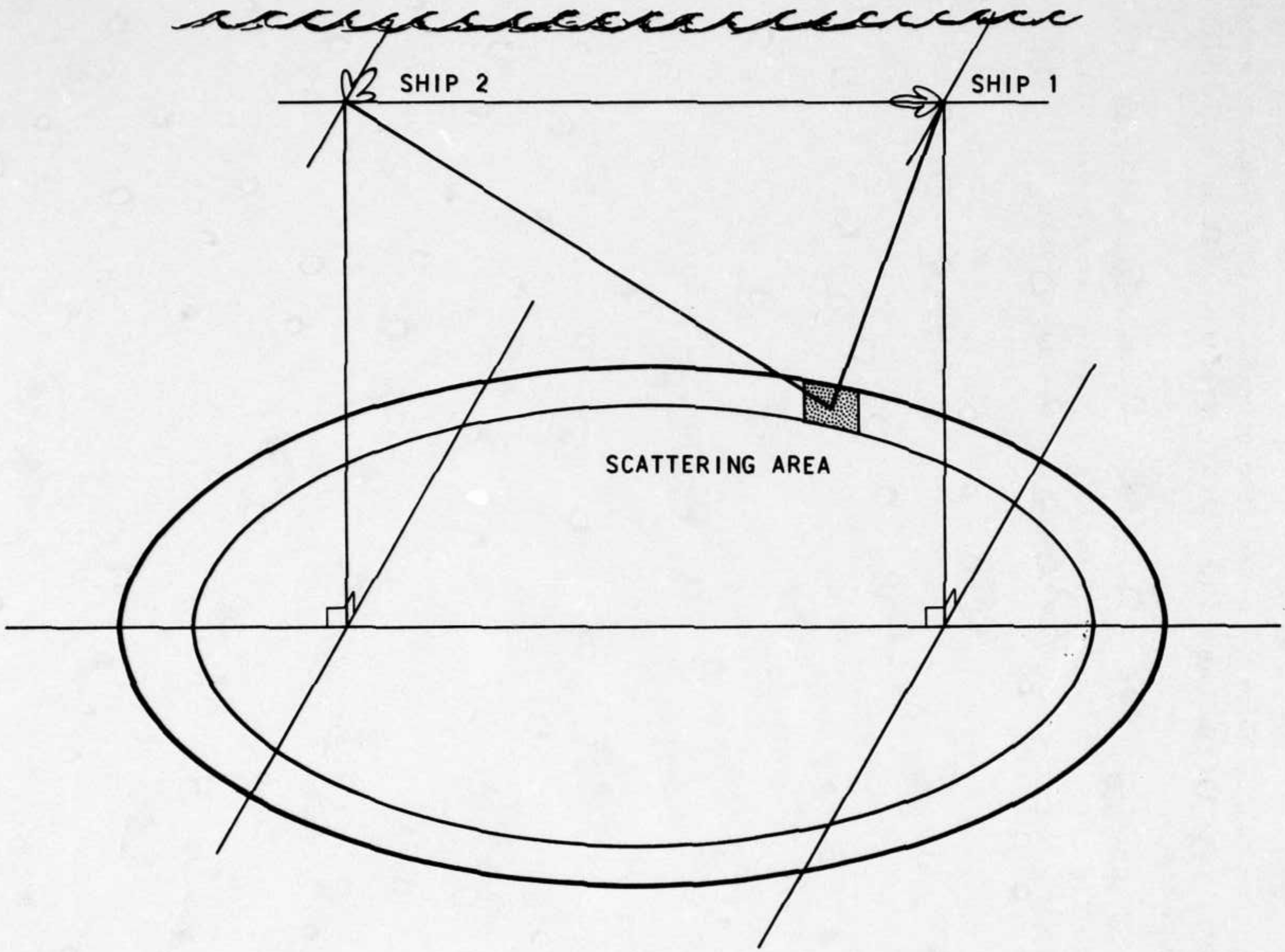

FIG. 3-8 COMPUTING BOTTOM RUMBLE

bottom bounce sonars. A modified version of this program, which will take into account the velocity profile, will be available shortly.

5. Reference: Gullatt, John, "Performance Degradation of AN/SQS-26 CX Sonars by Intership Acoustic Interference (U)," TRACOR Document Number 68-310-C, 19 February 1968.

4. ECHO SIMULATION AND COMPUTATION OF TARGET STRENGTH

4. ECHO SIMULATION AND COMPUTATION OF TARGET STRENGTH

A model is presented which synthesizes a realistic replica of a submarine echo from which its target strength may be computed. Perturbation of the geometrical scattering function from echo to echo provides a means for determining a mean target strength which compares favorably with measured values.

4.1 Echo Simulation and Computation of Target Strength

1. Description: The model simulates submarine echoes using rigid body reflection techniques. A "scattering function" is determined by approximating the hull and the sail of the submarine with geometric forms (e.g., an ellipsoid of revolution for the hull) and computing incremental projected areas along the submarine in the assumed direction of the incident sound wave. The scattering function is then "jittered" and correlated with the assumed incident pulse form to produce a realistic appearing echo from which relative target strength can be computed. Any aspect or depression angle may be chosen, and "shadowing" of the sail by the hull is accounted for when computing echoes for bottom bounce operation. Polar or distributive plots of target strength may be made using the computed target strengths.

2. Input Parameters:

Submarine Scattering Function Program

- aspect
- depression
- hull length
- hull breadth
- sail length
- sail breadth
- sail position with respect to hull
- distance between projected area increments

Jitter Program

- number of components
- standard deviation
- scattering function

Pulse Generation Program

length
total number of samples
starting phase
frequency

Correlation Program

pulse
scattering function

Target Strength Computation

simulated echo rms incident pulse power

3. Output Parameters:

For each submarine, aspect, depression, and scattering function "jitter", a simulated echo, realistic in appearance and target strength, computed from this echo. Also for several "jitters" of the same scattering function, a mean target strength together with the standard deviation of the target strengths, both in logarithmic form.

4. Comments: The model has been used to compute submarine target strengths for particular submarines. The computed target strengths compared favorably with those experimentally determined except in one instance. The model requires improvement; particularly, the "jitter" should be tied more explicitly to environmental conditions. The model is not now in operational form with respect to the present computer system.

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5. TRANSDUCER ELEMENT AND ARRAY INTERACTION MODELS

5. TRANSDUCER ELEMENT AND ARRAY INTERACTION MODELS

The first model presented in this section provides for a rather complete analysis of a transducer element including the non-piezoelectric, ceramic, and basic transducer properties. For given physical properties of the various components and characteristics of the ceramic stack, the allowable tolerances for ceramic parameters, mechanical components and tuning inductor can be determined. Other models compute element interaction coefficients, head velocities, and mutual impedances.

5.1 Transducer Element Analysis Program (XDUCE1)

1. Description: The program XDUCE1 enables one to determine a matrix defining the transfer function between the input voltage and current to the ceramic stack of the transducer and the force and velocity on the head of the transducer. It can also be used to analyze the non-piezoelectric and ceramic properties throughout the transducer element, allowing one to perform parameter variation or tolerance studies. Thus one can also use XDUCE1 to ascertain allowable manufacturing tolerances for the ceramic parameters, mechanical components of the transducer, or the tuning inductor parameters. The program inputs an equivalent circuit for the transducer element, the physical properties of the various component parts of the transducer, and the characteristics of the ceramic stack. It then performs an analysis of the transducer element and outputs the non-piezoelectric, ceramic, and basic transducer properties. The analysis is based on the piezoelectric equations describing the electrically forced motion of a longitudinally polarized cylindrical ceramic stack and relies on a general six-terminal equivalent circuit of the ceramic element that embodies its elastic-transmission-line properties. At present, the program will handle only 33-mode ceramic rings.

The program is organized so as to enable the user to have seven separate program options:

1. Regular Analysis Run. Given all parameters, this run does a straight evaluation at a single frequency of any transducer element properties specified through input data.

2. FMFN Determination. This determines the resonance and anti-resonance of the electrical admittance of the active transducer and the corresponding f_m and f_n, frequencies which maximize and minimize the admittance, respectively. After this determination, a regular analysis run is made at both f_m and f_n.

3. Tuning Inductor Determination. Given all parameters of the transducer element, this option computes the optimum tuning inductor for current or voltage control cases and does a regular analysis run with the tuning inductor which maximizes the internal and self-radiation impedance.

4. Find Parameters. From the experimental values of resonance data and capacitance and dissipation values, the ceramic parameters are determined; then a regular analysis run is made with these ceramic parameters.

5. Frequency Sweep. With all parameters specified, this run evaluates those properties desired over a given frequency band with a specified increment.

6. Special Frequency Sweep. With all parameters specified, this run evaluates the electrical admittance over a given frequency band with a specified increment.

7. XDUCE2. With all parameters specified, this run determines and outputs onto magnetic tape the equivalent transducer matrix without a tuning device (ABCD matrix) over a given frequency band with a specified increment.

2. Input Parameters:

The input to the program is in metric (MKS) units and includes:

1. A tag to denote the type of analysis to be made.
   a. Regular Analysis Run.
   b. FMFN Determination.
   c. Tuning Inductor Determination.
   d. Find Parameters.
   e. Frequency Sweep.
   f. Special Frequency Sweep.
   g. XDUCE2 Run.

2. A tag to specify the type of output desired.
3. Transducer element description and parameters.
   a. The input voltage or current to the transducer element.
   b. The radiation impedance at the face and tail end of of the element.
   c. The transducer equivalent circuit including the pieces in each section, their shapes, densities, lengths, and areas.
4. The description and ceramic parameters for the ceramic stack (active and dummy).
   a. The number of ceramic rings in the ceramic stack.
   b. The density, area of interface, length, and the ceramic parameters for the ceramic rings.
5. The tuning inductor used in the tuning circuit.
6. FMFN Determination.
   a. Frequency band of interest.
   b. Estimates of the properties of the frequencies of maximum (f_m) and minimum (f_n) admittances of the transducer including $|f_m - f_n|$, and an estimate of f_m.
7. Tuning Inductor Determination: The self radiation impedance of the element.
8. Find Parameters.
   a. The input required for an FMFN Determination, i.e., set 6 above.
   b. The frequency F_{LO}.
   c. The frequencies of maximum and minimum admittance, the magnitude of the maximum and minimum admittance, the parallel capacitance and dissipation of the system at the specified frequency F_{LO}.
   d. Initial estimates and convergence criteria for the ceramic parameters.

9. Frequency Sweep and Special Frequency Sweep: The frequency band and a frequency increment.

10. XDUCE2 Run: Tape and file number for the ABCD matrix output.

3. Output Parameters:

The output from the program is in metric (MKS) units and includes:

1. Applicable under the Analysis, FMFN, Tuning Inductor, Find Parameters, and Frequency Sweep options, the seven printing options given as input to the program correspond to the following output:

   a. Non-piezoelectric quadrupole impedances for each piece in each section, and for each compacted section.
   b. Non-piezoelectric forces and velocities from left to right.
   c. Non-piezoelectric stresses and strains at the center of each piece of each section.
   d. Ceramic properties.
   e. Currents, stresses, strains, power losses, and efficiencies for each ring in the ceramic stack, and total efficiency and total power loss for the stack.
   f. Forces and velocities from left to right through a ceramic stack.
   g. Basic transducer properties.

2. The output for a Special Frequency Sweep consists of the frequency and the electrical admittance at each frequency in a frequency band.

3. The output under the XDUCE2 option includes, for a frequency band, the frequency and the ABCD matrix for that frequency written on magnetic tape.

4. Comments: The program has been used extensively to analyze several proposed transducer element configurations for the Conformal Planar Array program. It has also been used with reasonable success for the analysis of the AN/SQS-26 element.

5.2 IMPED - Element Interaction Coefficients for Rectangular Elements Mounted in an Infinite Cylindrical Baffle

1. Description: The model consists of a pair of rectangular pistons mounted in an infinite rigid cylindrical baffle. The mutual radiation impedance, or interaction coefficient, between the elements is computed according to the formula of Greenspon and Sherman (*J. Acoust. Soc. Am.*, Vol. 36, No. 1, p. 149).

2. Input Parameters:

   Array

   frequency, array radius, half angle element width, center to center azimuthal angle separation, half height of element, vertical center to center separation of elements, number of layers separation between interacting elements, number of staves separation between interacting elements.

3. Output Parameters:

   Element interaction coefficients

4. Comments: This program has been used to compute element interactions and beam patterns for the AN/SQS-26.

5. Reference: LaGrone, F. S., "Acoustic Interaction Effects and the Theoretical Calculations of the Farfield Transmit Beam Pattern for the AN/SQS-26(CX) Sonar (U)," TRACOR Document Number 67-437-C, 9 June 1967.

5.3 IMPED - Acoustic Self and Mutual Impedances for Circular Elements on a Spherical Baffle Within a Spherical Dome

1. Description: The mutual impedance between pairs of circular elements on a rigid spherical baffle within a spherical elastic shell is computed as a function of element center to center separation. The self impedance is given for zero separation. The shell may be deleted to obtain mutual impedances for a bare array. (See Sketch - Fig. 5-1.)

2. Input Parameters:

   Elements

   - element dimensions
   - radius of baffle
   - wave number

   Dome

   - radius
   - thickness
   - mass density of dome material
   - elastic parameters

   Water

   - sound speed
   - mass density

3. Output Parameters:

   Mutual impedance for specified angular spacing

4. Comments: The mutual impedances for the circular elements on a spherical baffle are good approximations to rectanguler elements on spherical or cylindrical baffles if beam tilt angles are small.

5. Reference: Moyer, W. and J. Duran, "Acoustic Interaction in a Spherical Dome Array (U)," TRACOR Document Number 68-741-U, 14 June 1968.

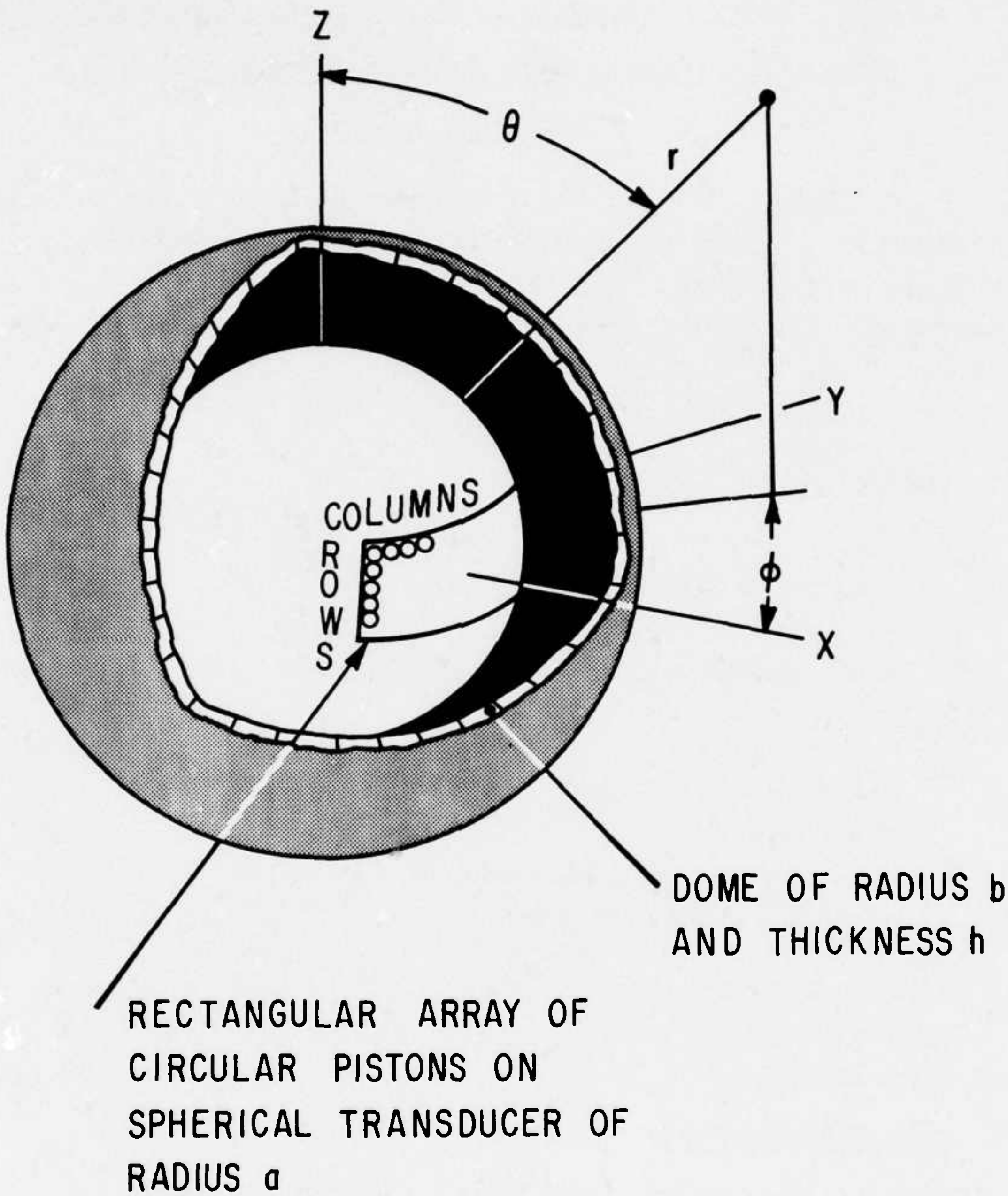


FIG. 5-1

ARRAY ON SPHERICAL TRANSDUCER WITHIN CONCENTRIC SPHERICAL DOME

5.4 PLNZIJ - Element Radiation Impedance Interaction Coefficients for Circular or Rectangular Elements of a Planar Array

1. Description: The model consists of a pair of rectangular or circular pistons mounted in an infinite rigid planar baffle. The interaction coefficients are computed by the method of Prichard (J. Acoust. Soc. Am., Vol. 32, p. 730) for circular elements and by the method of Arase (J. Acoust. Soc. Am., Vol. 36, p. 1521) for rectangular elements. (See Figs. 5-2, 5-3.)

2. Input Parameters:

   Array

   frequency, element radius (circular), width and height (rectangular), layer separation, stave separation, number of layers, number of staves.

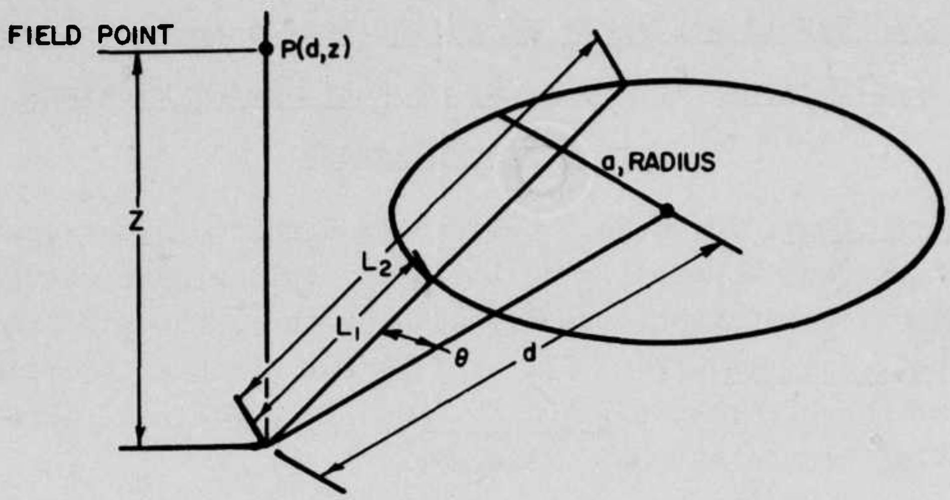
3. Output Parameters:

   Element interaction coefficients

4. Comments: The coefficients are output onto magnetic tape. A print option output is available.

5. Reference: Cates, K. N., "Transducer Array Performance Prediction Model Computer Implementation (U)," TRACOR Document Number 67-405-U, 31 May 1967.

   LaGrone, F. S., B. E. Jay, and R. E. Douglass, "Mathematical Models for the Conformal Planar Array Degradation Study (U)," TRACOR Document Number 67-143-U, 20 January 1967.



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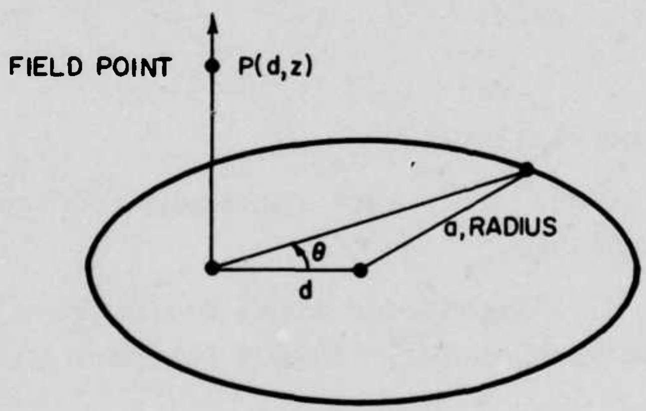

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FIG. 5-2 GEOMETRY AND COORDINATE SYSTEM FOR COMPUTING THE NEARFIELD PRESSURE PRODUCED BY A CIRCULAR PISTON IN AN INFINITE BAFFLE

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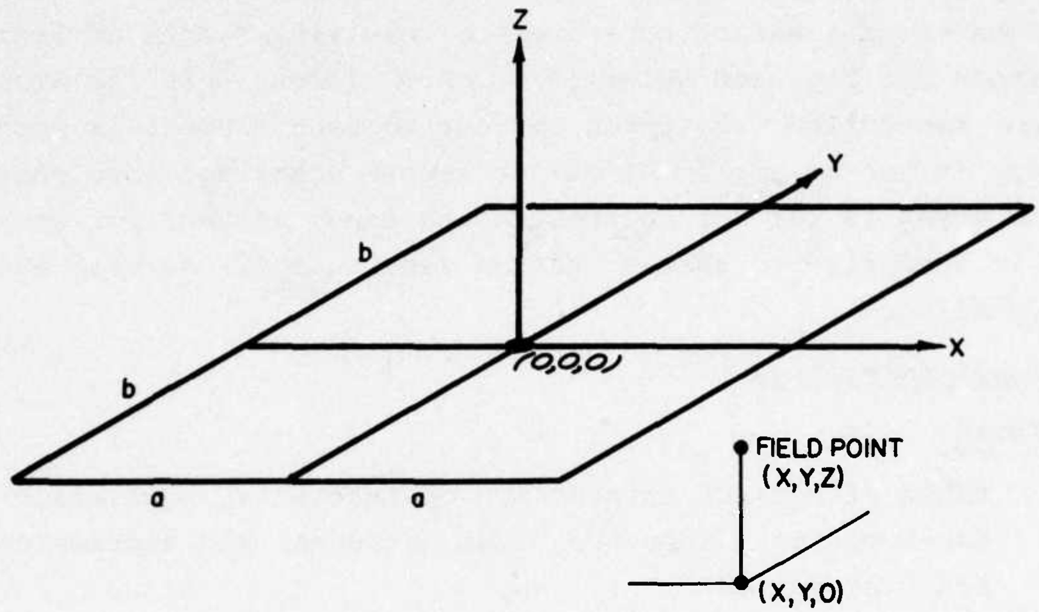

FIG. 5-3 COORDINATE SYSTEM AND GEOMETRY FOR COMPUTING THE NEARFIELD PRESSURE AT (X,Y,Z) PRODUCED BY A RECTANGULAR ELEMENT

5.5 PLAGUE - Head Velocities for a Transducer Array

1. Description: Program PLAGUE takes previously computed element interaction coefficients, the equivalent transducer matrix including any tuning device, and the beam steering angles, then utilizes the Gauss-Seidel Method to solve the resulting system of linear equations for the head velocity of each element. If the array is current controlled, the input current to each element is specified so that it has an amplitude of one ampere and plane wave phasing; if the array is voltage controlled the input voltage for each element is specified so that it has an amplitude of one volt and plane wave phasing.

2. Input Parameters:

   Array

   table of element interaction coefficients, equivalent transducer matrix, frequency, beam azimuthal and depression steering angles

3. Output Parameters:

   Head velocity for each element (MKS units)

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6. DOME/TRANSDUCER RADIATION AND BEAM PATTERN MODELS

6. DOME/TRANSDUCER RADIATION AND BEAM PATTERN MODELS

The models presented in this section are used to calculate functions of interest regarding arrays of transducer elements of specific or arbitrary configuration. Many of the models output a plot of the beam pattern. The effects of modifications in the composition of the dome, the dome slope, and transducer position in the dome may be investigated in some of these models.

Studies using these models involve such topics as the prediction of array performance, studies of the effect of domes on output power distribution and analysis of the effects of inoperative transducer array components.

6.1 Plane Wave Beam Pattern for an Arbitrary Array of Point Sources

1. Description: This program computes vertical and/or azimuthal plane wave beam patterns for an arbitrary array of point sources. The formula used is

$$B(\theta,\varphi,\theta_o,\varphi_o) = \frac{|b(\theta,\varphi)|^2}{|b(\theta_o,\varphi_o)|^2} ,$$

$$\text{where } b(\theta,\varphi) = \sum_n A_n \exp\{i(\vec{k}(\theta,\varphi) \cdot r_n - \psi_n)\}.$$

$B(\theta,\varphi,\theta_o,\varphi_o)$ is the beam pattern function, θ_o,φ_o are arbitrary vertical and azimuthal angles, θ_o,φ_o are reference vertical and azimuthal angles, A_n is the shading factor of the nth element, ψ_n is the phasing factor of the nth element, $\vec{r}_n$ is the position vector of the nth element, $\vec{k}(\theta,\varphi)$ is the wave vector and the summation is over all n elements of the array.

2. Input Parameters:

    Position vector of each element
    Phasing of each element
    Shading of each element
    The reference direction, (θ_o,φ_o)
    Wave length
    The angles over which the beam pattern is to be computed

3. Output Parameters:

    A polar plot of the beam pattern.

4. Comments: This program has the capability of dropping elements at random and computing the resulting beam pattern.

6.2 BEAMPL - Azimuthal, Horizontal, and Vertical Farfield Beam Patterns

1. Description: The model is that of a rectangular array of rectangular or circular pistons mounted in an infinite planar baffle. BEAMPL computes and plots on a digital plotter the farfield beam pattern resulting from taking an azimuthal, horizontal or vertical cut through the beam produced by the array specified. Idealized velocities for a planar array are computed internally, or a predetermined set of velocities can be read in. In addition, the program accepts inputs which describe hardware component failures which are assumed to have occurred, and the type of response function to be utilized in the computation of the farfield beam patterns.

2. Input Parameters:

Array

element diameter (circular), element height and width (rectangular), number of rows and columns, center to center spacing between adjacent rows and columns, azimuthal and depression steering angles, array depression angle, frequency, element velocities, velocity of sound.

Hardware

the percentage of the total number of units which are inoperative, the type of inoperative component ((1) random inoperative transducer elements or preamplifiers, (2) random inoperative beamformer time delay units, or (3) random inoperative first, second, or third stage multiplexer units)

Farfield response function

cardiod, circular element, rectangular element, omnidirectional

3. Output Parameters:

List of inactive elements because of simulated failure of hardware component, normalized pressure values in dB (optionally printed), farfield beam pattern (plotted)

4. Comments: The horizontal and vertical cuts are made such that they lie in a plane while the azimuthal cut lies on the surface of a cone (for depressed beams). The program has been used extensively for studies on the Conformal/Planar array.

6.3 PLARRY - Beam Patterns for a Strip Array Located in an Infinite Planar Baffle Under a Thin Plate Dome

1. Description: The elements of the transducer array are ribbon-like staves mounted in an infinite, rigid, planar baffle. The dome is modeled as a thin plate positioned above the baffle and transducer elements.

2. Input Parameters:

   Array

   number of rows and columns, dimensions and spacing of elements, frequency of operation

   Dome

   density of plate, Young's modulus, Poisson's ratio, thickness of plate, height of plate above array

   Water

   speed of sound, density

3. Output Parameters:

   Farfield beam patterns

4. Comments: This is not a production program.

6.4 STRIP - Farfield Beam Patterns for a Rectangular Array of Elements in a Ribbon-Like Rigid Baffle

1. Description: The elements of the rectangular transducer array are rectangular pistons positioned in a ribbon or strip-like baffle. The rigid baffle is finite in width and infinite in height. (See Sketch - Fig. 6-1.)

2. Input Parameters:

   Array

   number of elements, dimensions and spacing of elements
   width of baffle, frequency of operation

   Water

   speed of sound, density

3. Output Parameters:

   Horizontal beam patterns

4. Comments: This program allows for the effect of baffle width on beam patterns of planar arrays to be studied. Good agreement was obtained between converted beam patterns and beam patterns measured by Gordon Martin, Transducer Division, NUWC.

5. Reference: Douglass, R. E., "A Study of the Effect of Baffle Width on the Beam Patterns of Planar Arrays of Sonar Transducers," Dissertation, The University of Texas at Austin.

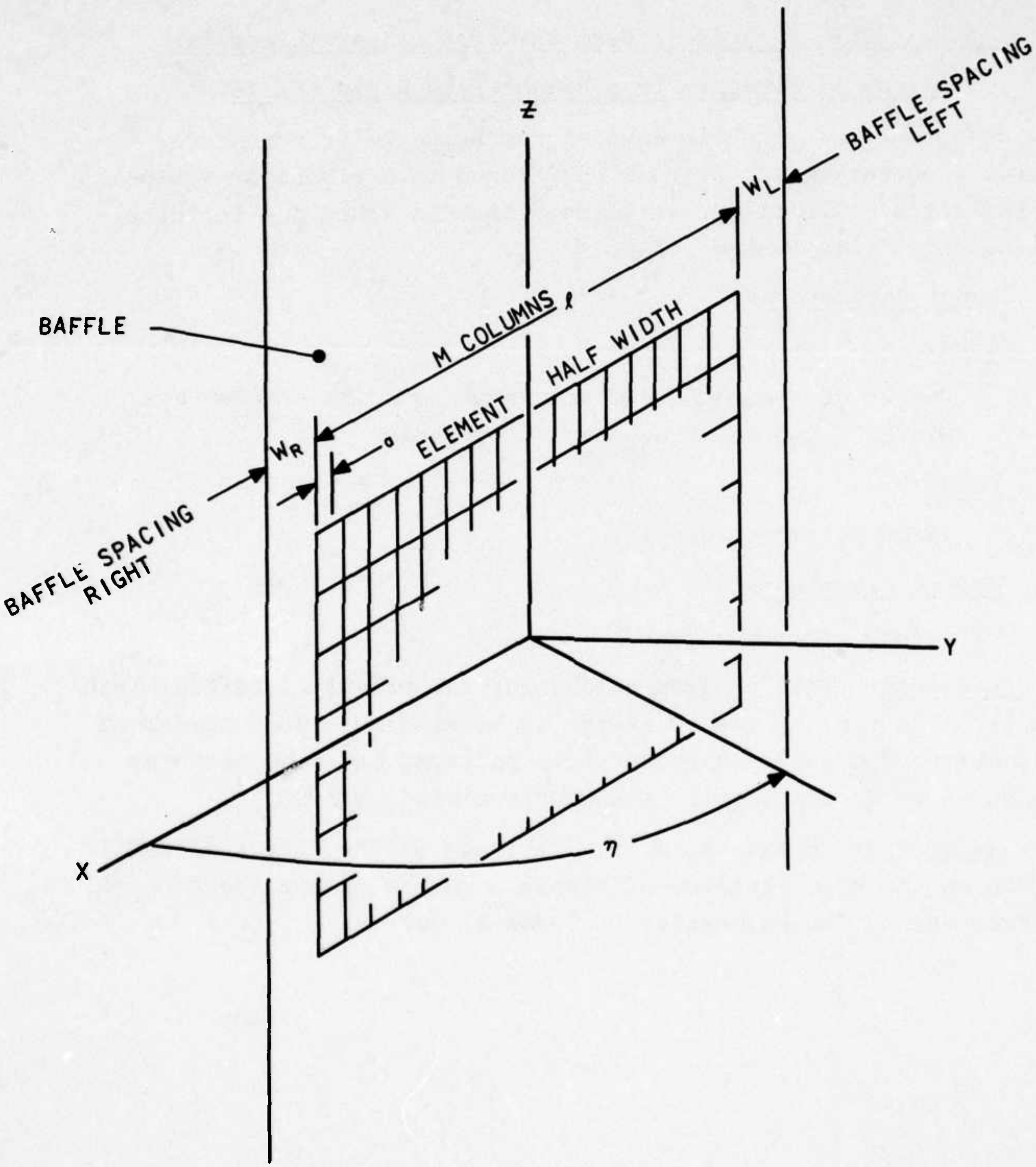

FIG. 6-1 GEOMETRICAL PARAMETERS

6.5 INCYL - Beam Patterns for Cylindrical Arrays of Rectangular Elements With Cylindrical Domes (Dome Optional in Program)

1. Description: Vertical or azimuthal beam patterns, source levels, and directivity indices may be computed for CW transmit modes of the array. The rectangular transducer elements are considered to be located in an infinitely long, rigid, cylindrical baffle, which is an improvement over earlier models because sound diffraction about the array (but not beneath the array) is included. The dome is modeled as an unstiffened, elastic, cylindrical shell mounted concentrically with the cylindrical array, thus the dome model is not as geometrically realistic as the array model. The dome may be deleted in running the computer program. The program may be employed to compute receive beam patterns if reciprocity (between transmit and receive cases) obtains. (See Sketch-Fig. 6-2.)

2. Input Parameters:

Array

number and spacing of layers and staves
element dimensions
element velocity magnitudes, shadings and phasings
radius of array
wave number (radian frequency/sound speed)

Dome

radius
thickness
mass density of dome material
elastic parameters

Water

sound speed
mass density

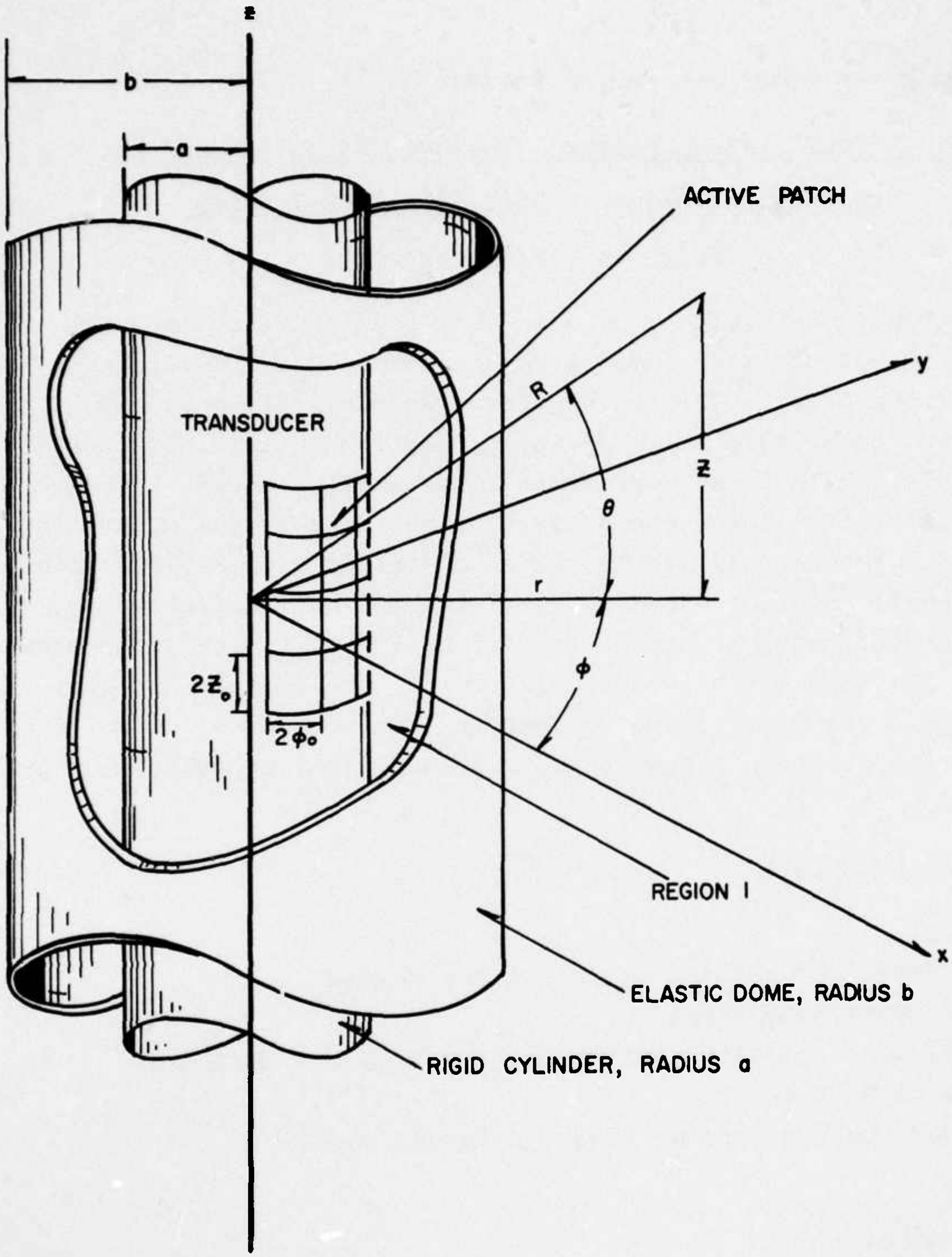

FIG. 6-2 GEOMETRY FOR A THREE-DIMENSIONAL CYLINDRICAL TRANSDUCER RADIATING INSIDE A CONCENTRIC DOME.

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3. Output Parameters:

Azimuthal or vertical beam pattern
Source level
Directivity index (obtained in vertical beam pattern computation only)

4. Comments: This model has been used extensively in performance prediction for the AN/SQS-26. At the time it was programmed, it was (and probably still is) the most realistic cylindrical array model extant.

5. Reference: Moyer, W. C., "Exploratory Development Dome Studies (U)," TRACOR Document Number 67-917-U, Vol. II, 9 October 1967.

6.6 GENERAL - Nearfield and Farfield Beam Patterns for Cylindrical Array Within a Concentric Dome

1. Description: The model is two dimensional. The transducer staves are located in an infinitely long, rigid, cylindrical baffle. The dome is modeled by a concentric cylindrical shell. Beam patterns can be computed at any distance from the array. (See Sketch - Fig. 6-3.)

2. Input Parameters:

Array

number of staves, width and spacing of staves
stave shadings and phasings
radius of array, frequency of operation

Dome

density of shell, Young's modulus, Poisson's ratio
thickness of dome, radius of dome

Water

speed of sound, density

3. Output Parameters:

Horizontal beam patterns at specified distances.

4. Comments: This program has the capability of computing beam patterns with predetermined staves being inactive.

5. Reference: Moyer, W. C., J. D. Morell, and K. Glass, "An Improved Analytical Model of the Interaction of Domes and Transducers During Transmission (U)," TRACOR Document Number 65-292-U, 31 August 1965.

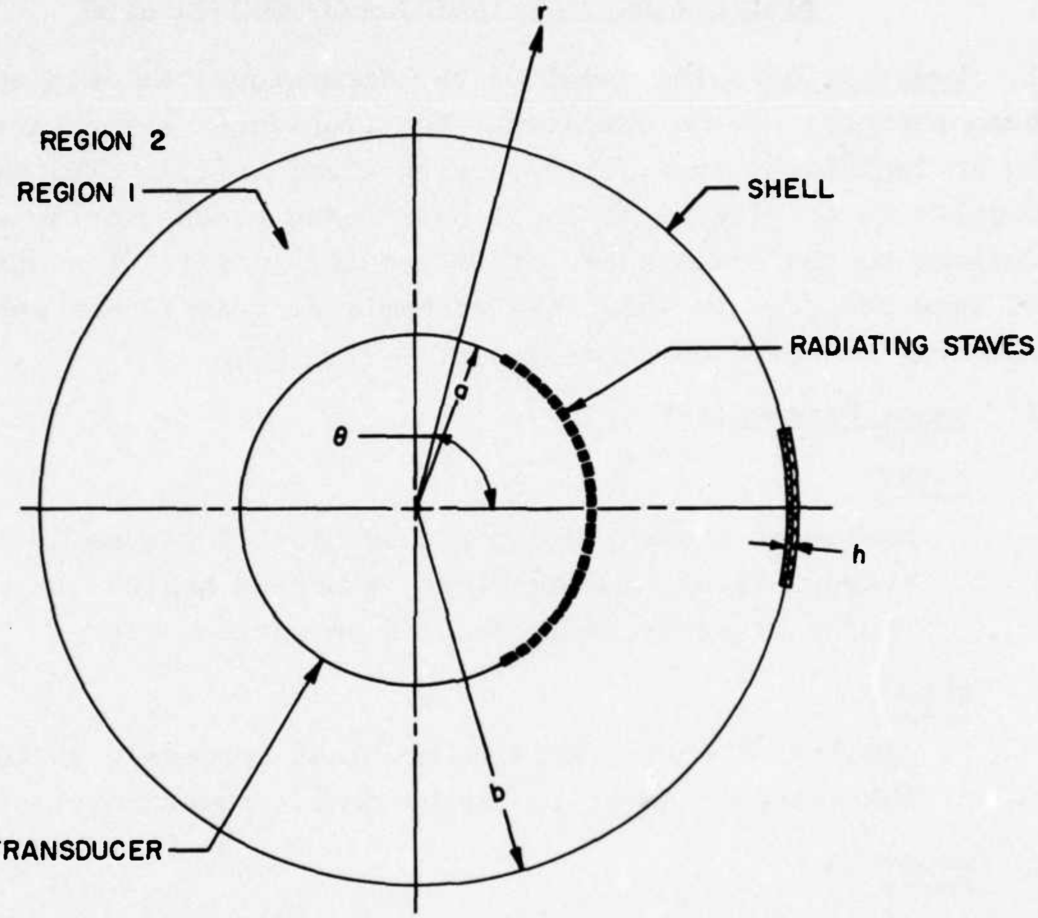

FIG. 6-3 GEOMETRY FOR A CYLINDRICAL TRANSDUCER RADIATING IN A CONCENTRIC SHELL

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6.7 NONCON - Beam Patterns for Cylindrical Array Within a Non-Concentric Cylindrical Dome

1. Description: The model is two dimensional so only azimuthal beam patterns can be computed. The transducer staves are located in an infinitely long, rigid, cylindrical baffle. The dome is modeled by a cylindrical shell positioned eccentrically with respect to the transducer. This geometry permits the computation of beam patterns in which the transmitted beam is not symmetrically incident on the dome. (See Sketch - Fig. 6-4.)

2. Input Parameters:

Array

number of staves, width and spacing of staves
stave shadings and phasings, steering angle
radius of array, frequency of operation

Dome

density of shell, Young's modulus, Poisson's ratio
thickness of dome, radius of dome, eccentricity of dome

Water

speed of sound, density

3. Output Parameters:

Horizontal beam patterns

4. Comments: This model was the first to indicate dependence of beam pattern structure on beam steering angle for domed sonar systems. The model is no longer utilized extensively due to the development of a more realistic model, DRIVEMF.

5. Reference: Moyer, W. C., "Radiation Characteristics of a Circular Transducer Surrounded by a Non-Concentric Circular Shell (U)," TRACOR Document Number 66-579-U, 11 October 1966.

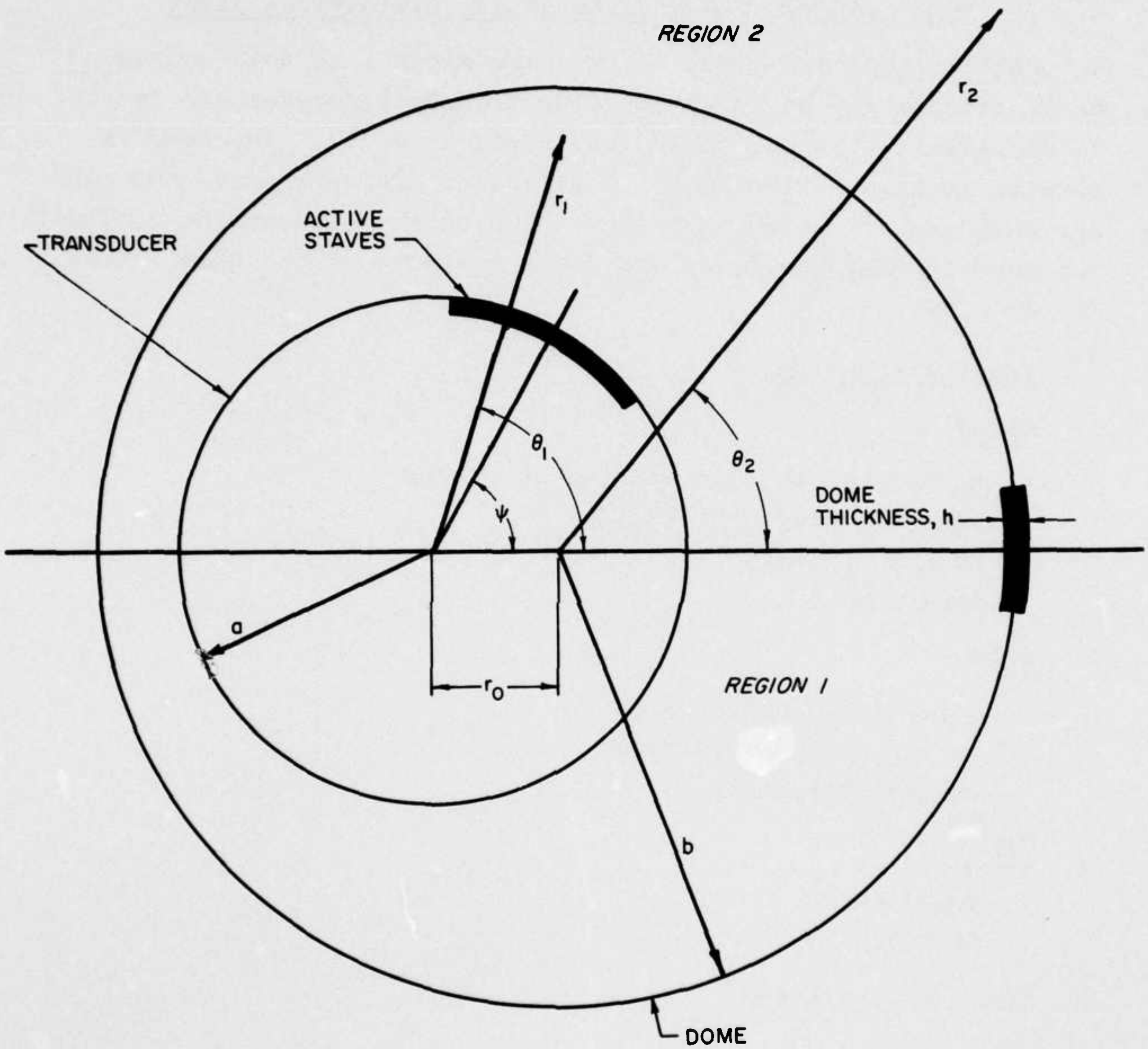

FIG.6-4 DOME-TRANSDUCER GEOMETRY

6.8 DRIVMF - Beam Patterns for Cylindrical Array

1. Description: The model is two dimensional, so only azimuthal beam patterns may be computed. The transducer staves are located in an infinitely long, rigid, cylindrical baffle. The dome is modeled as a mass-like acoustic impedance discontinuity, the mass per unit area of which varies as the distance between the confocal ellipses forming the inner and outer surfaces of the dome. (See Sketch - Fig. 6-5.)

2. Input Parameters:

   Array

   number, width, and spacing of staves
   stave shading and phasings
   radius of array
   wave number

   Dome

   major and minor axes
   mass density of material
   minimum thickness

   Water

   sound speed
   mass density

3. Output Parameters:

   Horizontal beam pattern

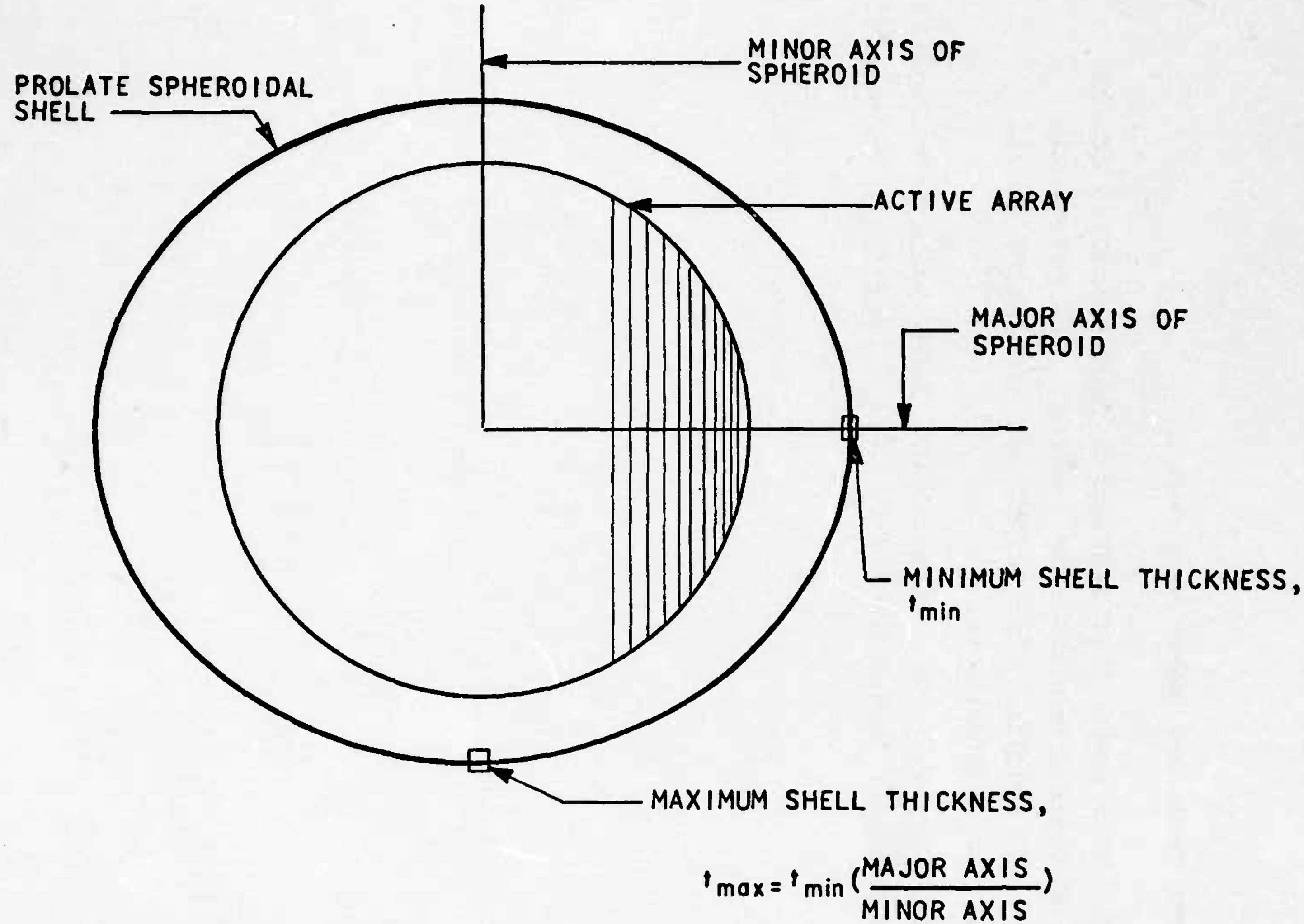

FIG. 6-5 GEOMETRY OF ELLIPTIC DOME AND CIRCULAR TRANSDUCER

TRACOR DWG. A6-72-176

4. Comments: This model is a reasonable representation of the dome window of typical surface ship systems. The parametric generality of the solution will permit the simulation of all current sonar dome/transducers.

5. Reference: Moyer, W. C., "Exploratory Development Dome Studies (U)," TRACOR Document Number 67-917-U, Vols. I and II, 9 October 1967.

6.9 STRUCT - Beam Patterns for Cylindrical Array Within a Structure Reinforced Cylindrical Dome

1. Description: The model is two dimensional, so only azimuthal beam patterns may be computed. The transducer staves are located in an infinitely long, rigid, cylindrical baffle. The dome consists of a concentric circular shell plus structure members. The structural properties are included by specifying the point driving impedance of a structure element at the location on the shell where it is attached. The attachments are considered to be ribs which extend indefinitely in the axial direction. The width of a rib is very small relative to a wavelength, and its effect is due to the added mass which must be driven by the shell. (See Sketch - Fig. 6-6.)

2. Input Parameters:

Array

half the number of staves, width and spacing of staves
stave shading and phasings
radius of array, frequency of operation

Dome

density of shell, Young's modulus, Poisson's ratio, thickness of dome, center to center separation of structure members, angular location of first structure members, structure coefficient, total number of structure members

Water

speed of sound, density

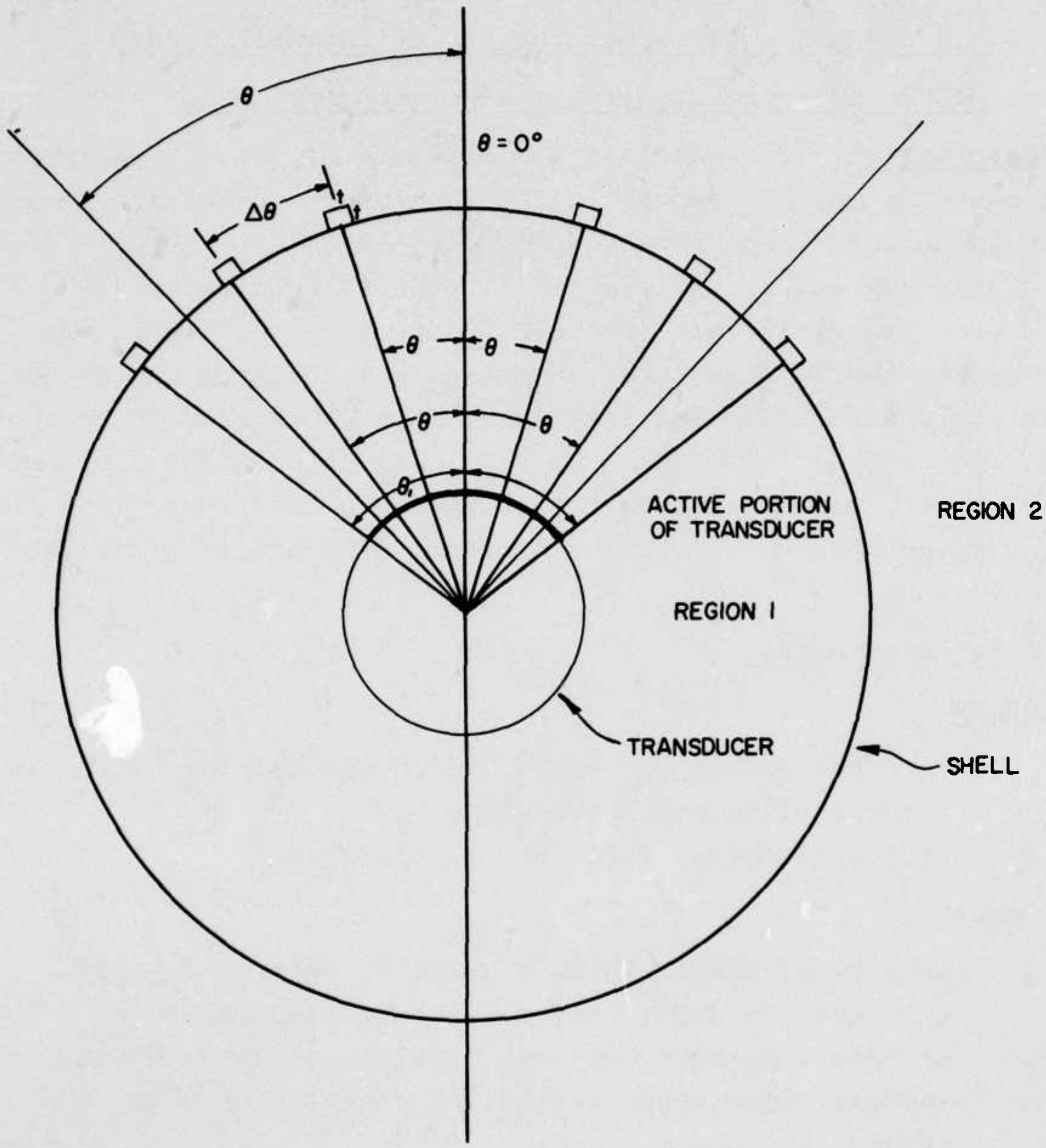

FIG 6-6 PLAN FORM GEOMETRY FOR A CYLINDRICAL TRANSDUCER RADIATING IN A CONCENTRIC NON-HOMOGENEOUS SHELL

3. Output Parameters:

Horizontal beam pattern
Total velocity of shell
Horizontal beam pattern (no structure)

4. Comments: Computed results have shown good agreement with experimental results obtained at USL for the AN/SQS-26. The model can be used to optimize dome structure design in terms of acoustic transmission properties.

5. Reference: Hamilton, K. B., "The Effect of Idealized Dome Structure on Dome Skin Velocity and Farfield Beam Patterns," TRACOR Document Number 68-934-U, 20 August 1968.

6.10 THICK - Beam Patterns for Cylindrical Array Within a Thick Concentric Dome

1. Description: The model is two dimensional so only azimuthal beam patterns can be computed. The transducer staves are located in an infinitely long, rigid, cylindrical baffle. The dome consists of a thick, concentric, circular annulus whose dynamic properties are described by the exact equations of elasticity. (See Sketch - Fig. 6-7.)

2. Input Parameters:

Array

frequency, radius of array, stave halfwidth, center to center stave separation

Dome

density, radius of inner surface, radius of outer surface, Young's modulus, Poisson's ratio, thickness of dome, radius of thin shell

Water

speed of sound, density

3. Output Parameters:

Farfield beam patterns for three cases, (a) thick dome, (b) thick dome no shear wave, (c) thin shell

Outer interface velocities for two thick cases plus velocity for thin shell case

4. Comments: This model is used in place of "General" for systems with thick domes, such as the AN/SQS-26 with rubber dome.

5. Reference: Hamilton, K. B., "Radiation Characteristics of a Sonar Array Surrounded by a Thick Dome," Thesis, The University of Texas at Austin.

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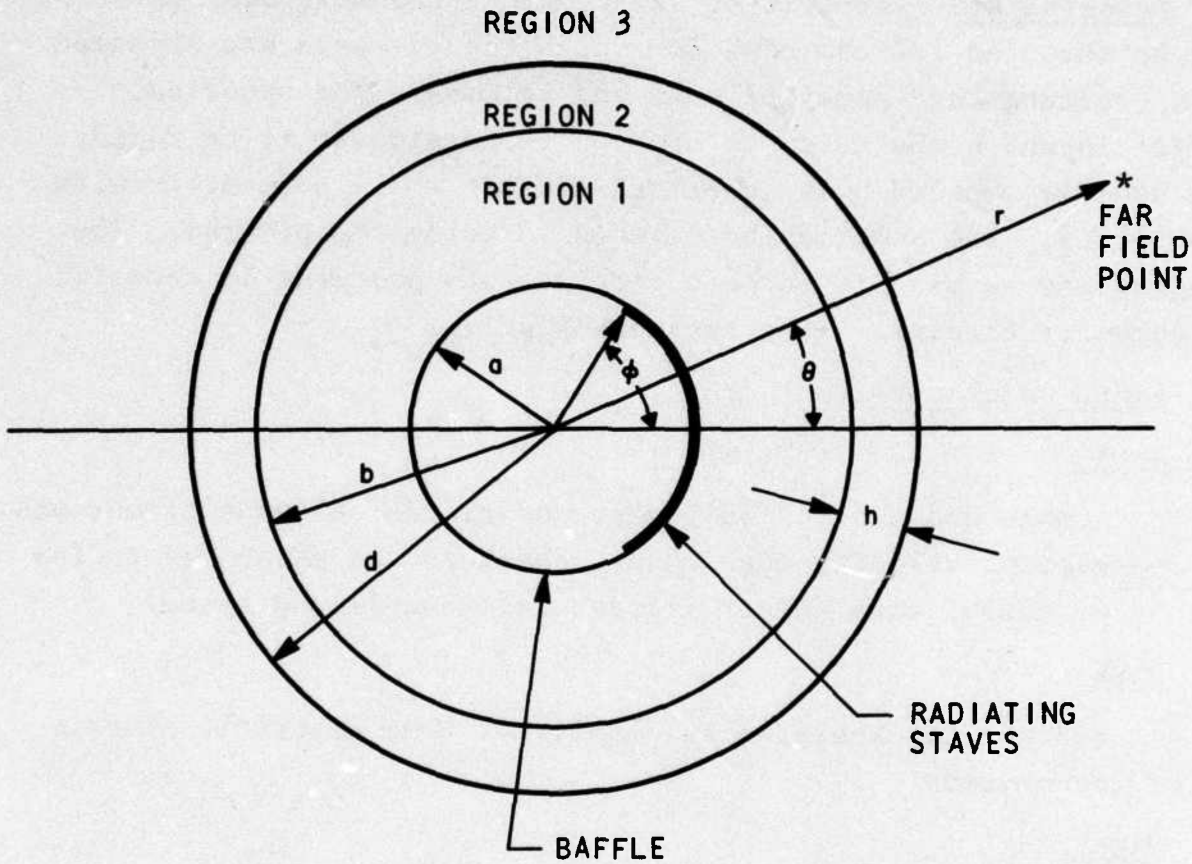


FIG. 6-7 PLAN FORM GEOMETRY OF TRANSDUCER AND CONCENTRIC THICK DOME

6.11. CAPS - Beam Patterns for Array of Circular Elements in Spherical Baffle Within Spherical Dome

1. Description: Vertical or azimuthal CW transmit beam patterns may be computed for the case for which the elements are arranged in a "rectangular" array of rows and columns. The spherical baffle in which the array is mounted is considered to be rigid. The dome is modeled by a spherical elastic shell concentric with the baffle. The dome may be deleted in using the program. The program may be used to compute receive beam patterns if acoustic reciprocity obtains. (See Sketch - Fig. 6-8.)

2. Input Parameters:

Array

number and spacing of layers and staves, element dimensions, element velocity magnitudes, shadings and phasings, radius of array, wave number (radian frequency/sound speed)

Dome

radius, thickness, mass density of dome material, elastic parameters

Water

sound speed, mass density

3. Output Parameters:

Azimuthal or vertical beam pattern

4. Comments: This model is probably the most realistic available for treating spherical sub-sonar arrays. The model has been used in conjuntion with "XDUCE1" and "IMPED" to compute farfield beam patterns with element electrical signals as input with element interaction and dome/array interaction included in the analysis.

5. Reference: Rasco, W. A., "Cost Proposal to Develop Radar and Guidance Computer Models in FORTRAN V for a UNIVAC 1108 Computer (U)," TRACOR Document Number 67-178-U, 7 July 1967.

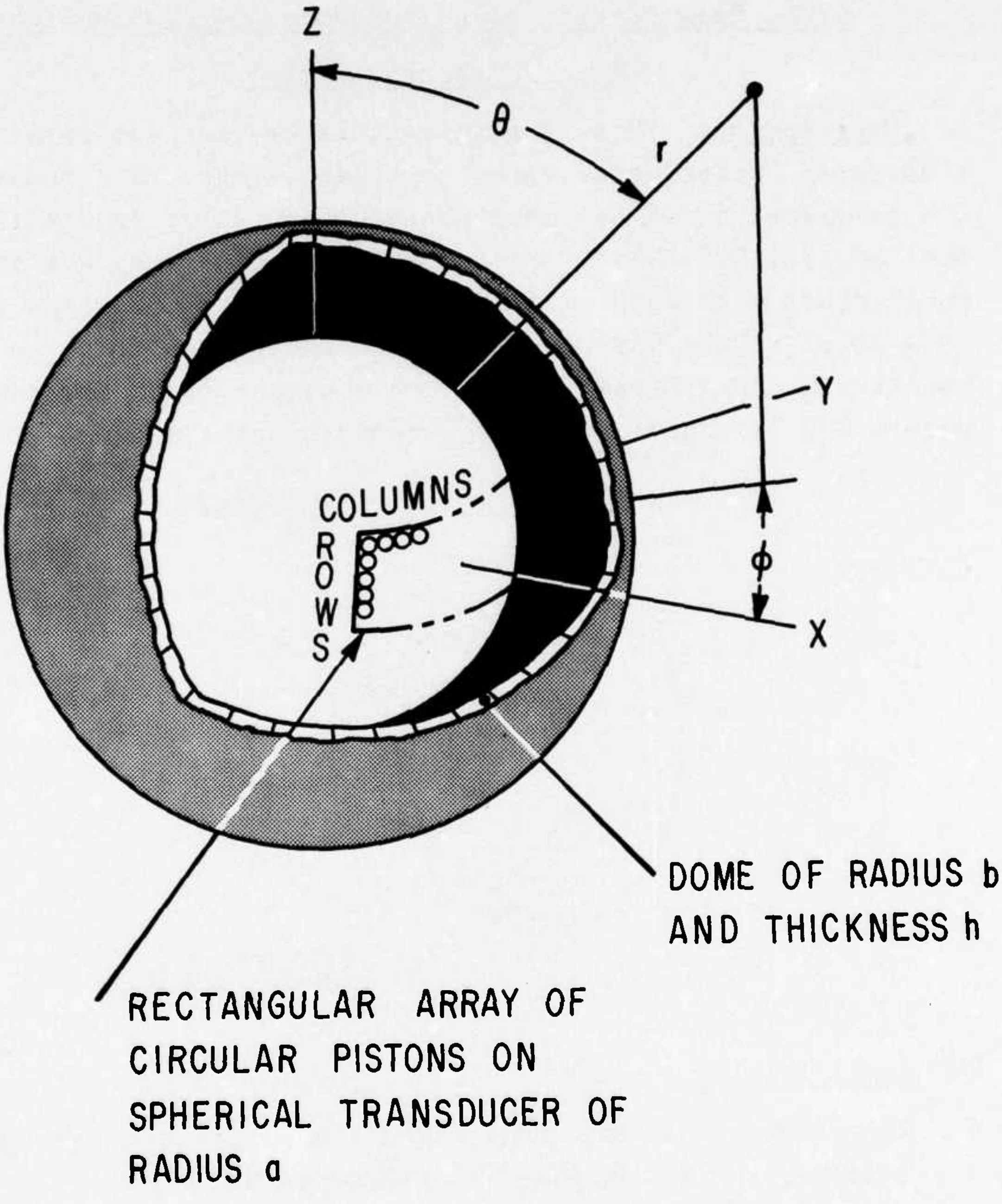
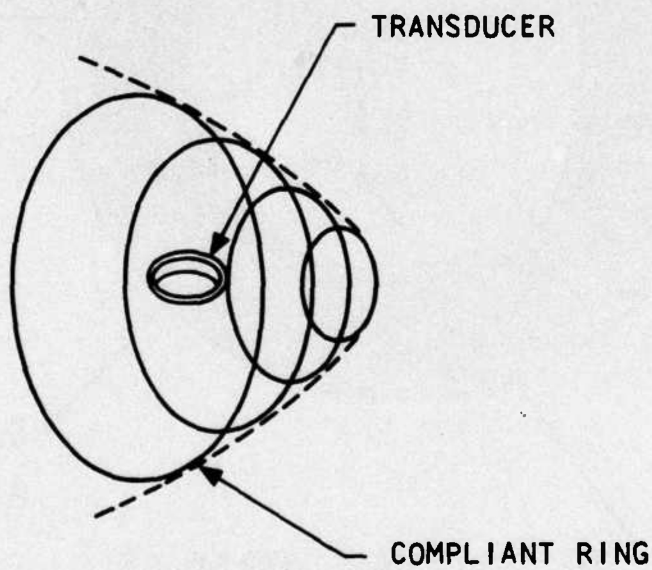


FIG. 6-8

ARRAY ON SPHERICAL TRANSDUCER WITHIN CONCENTRIC SPHERICAL DOME

6.12 Beam Pattern of a Transducer with a Compliant Ring Reflecting System

1. Description: This program calculates the beam pattern of a transducer backed by a set of compliant rings. The behavior of the compliant rings has been described by W. J. Toulis (J. Acoust. Soc. Am.,35, 286-292, 1963). In effect, the rings act as parasitic oscillators with each differential element of the rings radiating as a point source with a radiating power proportional to the exciting field at that point. The constant of proportionally is determined by experimental measurements using a single ring.



2. Input Parameters:

   Transducer position, ring sizes and positions, constant relating radiating field to incident field

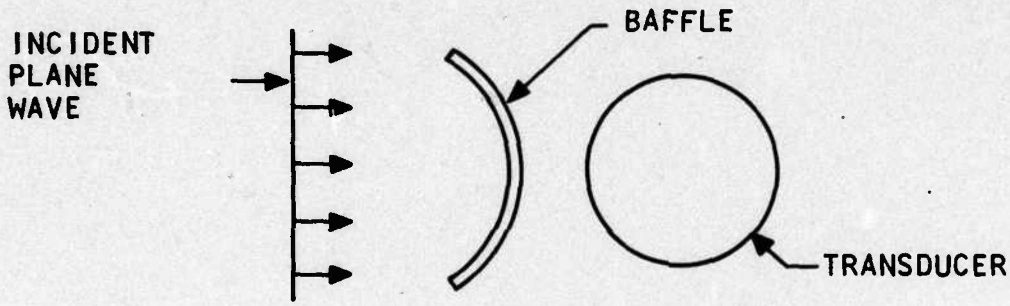
3. Output Parameters:

   Beam pattern

4. Comments: As an option, the ring positions will be adjusted by a search, iterate procedure to maximize the on-axis sound field. The program is written in FORTRAN 63 computer language.

6.13 Sonar Baffle Diffraction Characteristics

1. Description: The diffracted sound field incident on a cylindrical transducer resulting from a plane, steady state acoustic wave impinging on a baffle is given. The problem is two dimensional. The baffle geometry is an arc of a circle (see Sketch). The boundary conditions on each side of the baffle are arbitrary as is the radius of the baffle, angular width of the baffle, spacing of the baffle relative to the transducer, and transducer radius.



2. Input Parameters:

Baffle

radius, boundary conditions, angular width, spacing relative to transducer

Transducer

radius

Incident Plane Wave

frequency

3. Output Parameters:

Pressure amplitude and phase at transducer surface

4. Comments: This model has been used to determine optimum shapes for stern baffles in terms of minimizing self-noise due to ships' screws.

5. Reference: Moyer, W. C., "Analytical Determination of the diffraction Characteristics of Sonar Baffles," Dissertation, University of Texas at Austin, June 1966.

6.14 Noise Level Calculation for Beamformer Gain Computations in a Non-Uniform Noise Field

1. Description: In calculating the signal-to-noise ratio out of a beamformer, it is desirable to have the same input noise level present in each stave signal that is used to form the beam. Sonars such as the conformal array AN/BQR-7, however, have a non-uniform noise level from stave to stave. The model, adaptable to both linear and clipped stave beamformers, calculates the uniform noise level which will predict the same beamformer gain as do the actual non-uniform stave noise levels. The uniform stave noise levels are given by:

$$\text{linear:} \quad N = \frac{1}{M} \sum_{i=1}^{M} N_i$$

$$\text{clipped:} \quad N = \frac{M(M-1)}{2} \frac{1}{\sum_{i=1}^{M-1} \sum_{j=i+1}^{M} \left\{ \frac{1}{\sqrt{N_i N_j}} \right\}}$$

2. Input Parameters:

M = Number of staves used to form beam

N_i = Input noise power level in frequency band at stave #i

3. Output Parameters:

N = Equivalent uniform input power level in frequency band at each of M staves used to form a beam. Units same as N_i.

4. Comments: The analysis of the clipped case assumes signal plus noise is Gaussian, and that the input signal-to-noise ratio is small. Both the linear and the clipped case assume zero noise correlation between staves.

7. AN ADAPTIVE SPATIAL PROCESSING MODEL

7. AN ADAPTIVE SPATIAL PROCESSING MODEL

Because of its unique character, this model was allocated a section of its own in juxtaposition to the other spatial processing (beam pattern) models.

7.1 Wiener Adaptive Space Processing (WASP)

1. Description: Signal power out, noise power out, directivity index, spatial processing gain and beam patterns are computed for an array of point elements located in a specified signal and single frequency noise field. Filter weights for the point elements are calculated using the Wiener optimization technique.

2. Input Parameters:

   Element coordinates, single frequency noise field, signal (direction, power, etc.)

3. Output Parameters:

   Signal power out, noise power out, spatial processing gain, directivity index, beam pattern (plot optimal)

4. Comments: The program has been used in studies of a cylindrical array (ATSSS) to determine the effect of dimension variation on the beam patterns produced by filter weights calculated using the Weiner optimization procedure as compared to filter weights calculated using the Chebyshef technique.

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8. TIME FUNCTION ANALYSIS (TIMFAX)

8. TIME FUNCTION ANALYSIS (TIMFAX)

TIMFAX is an applications program used to analyze many kinds of time function data and to simulate time function processing systems. However, the system contains many features which are applicable to any type of data processing problem.

There are basically two uses of TIMFAX: systems simulation and data processing. The system was developed originally to process sonar data (either digitized recorded data or idealized computer-generated data), but it is equally capable of processing any large data base problem which can be digitized.

The widest use of the system has been in sonar signal processor simulations. In this case the black boxes model the elementary components of the processor and the topology is the circuit diagram. The flexibility of rearranging the components, or boxes, allows many schemes to be compared and evaluated. Using recorded sea data as an input, any sonar signal processor can be simulated and its performance compared with the expected ideal performance.

Figure 8-1A is an example of a processing problem that has been analyzed using TIMFAX. The function of this processor, which is called a synchronous detector, is to decorrelate the noise portion of a signal-plus-noise input. The quadrature, or phase shifted, channel is added to prevent decorrelation of the signal for large delays, δ. Due to the low pass filters immediately following the multipliers, a theoretical analysis of the output is intractable. Figure 8-1B shows the TIMFAX implementation of this detector. The two digital tapes contain samples of signal-plus-noise. Tape B contains samples that are 90° out of phase with the samples on tape A. These inputs could have been generated in a previous run or they could have been included in this diagram. For simplicity this step has been omitted. The box MTI inputs a fixed number of samples

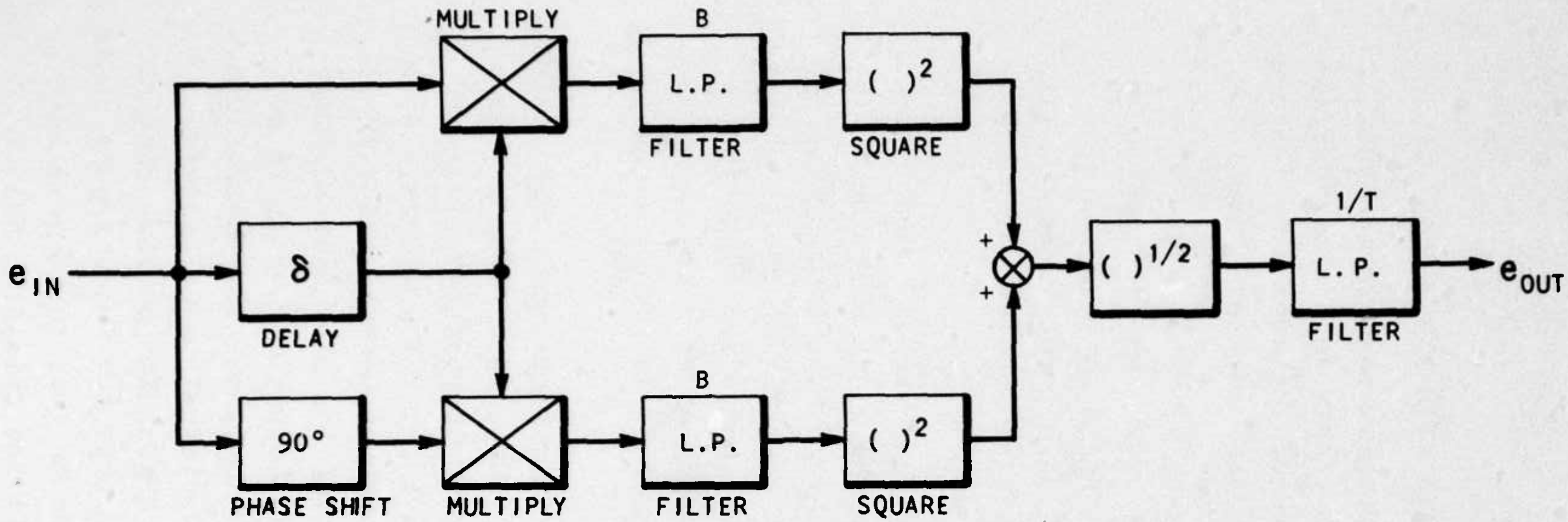

FIG.8-1A SYNCHRONOUS DETECTOR

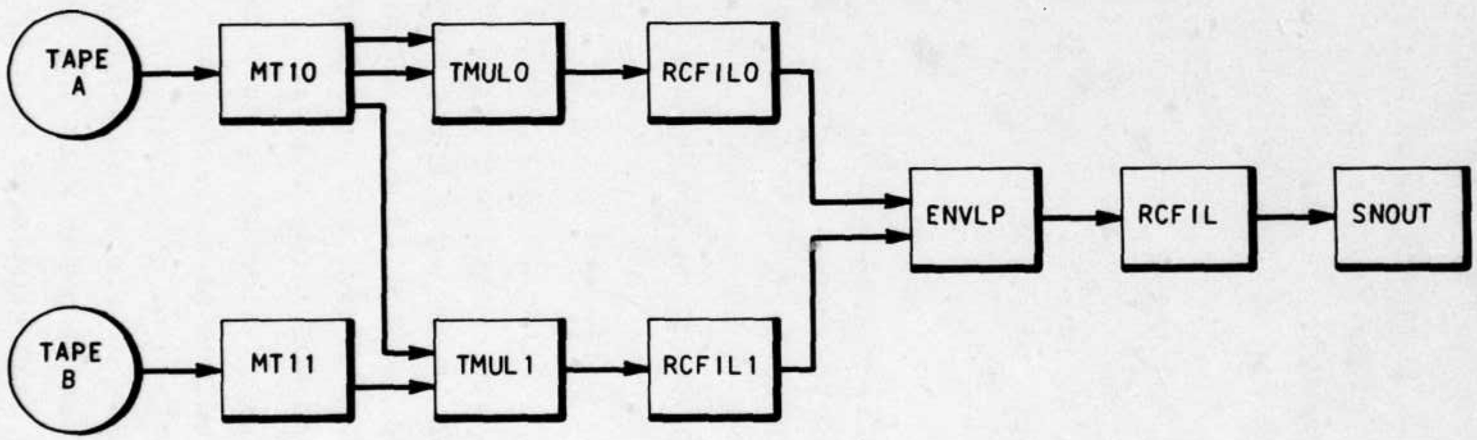

FIG.8-1B TIMFAX IMPLEMENTATION

TRACOR DWG. A6-108-12
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on each pass through the processor. The numerals denote multiple uses of the same box. The box TMUL takes two input time series, delays the second, and outputs a time series equal to the product. RCFIL is a digital version of an RC low pass filter. The output of ENULP is a time series equal to the square root of the sum of the squares of two input series. SNOUT is one of the analysis boxes used to compute the output signal-to-noise ratio. The values used for the delay, filter bandwidths, and input signal-to-noise ratio are all parameters that are inputs to the system and can be changed quite easily. The preceeding simulation was chosen as an example because it illustrates, quite simply, multiple uses of the same box and parallel channel processing.

Figure 8-2 shows a time function analysis problem that is easily studied using TIMFAX. White Gaussian noise is passed through a bandpass filter and then rectified in several different ways. Each output is then analyzed to show the probability density and power spectrum. The continuous version of this problem is treated in many texts on stochastic processes. TIMFAX has been used extensively to perform analysis on classical problems as shown above, or actual data from the fields of geophysics, vibro-acoustics, oceanography, and biomedics.

The features of the system that are used to solve problems in time series analysis can also be used to do the diverse jobs in the field of general data processing. Figure 8-3 shows an implementation of TIMFAX to study a channel transmission problem. The two tapes contain the text of messages sent to various receivers. The master tape was recorded at the encoder; the receive tape was made at the decoder. The purpose of the problem was to measure the errors in many consecutive transmissions and sort these errors according to categories found in a leader of information preceeding each transmission. A detailed description of the processing problem is not warranted. TIMFAX was used for this study because of the data handling capabilities of the system. Also, requests to sort

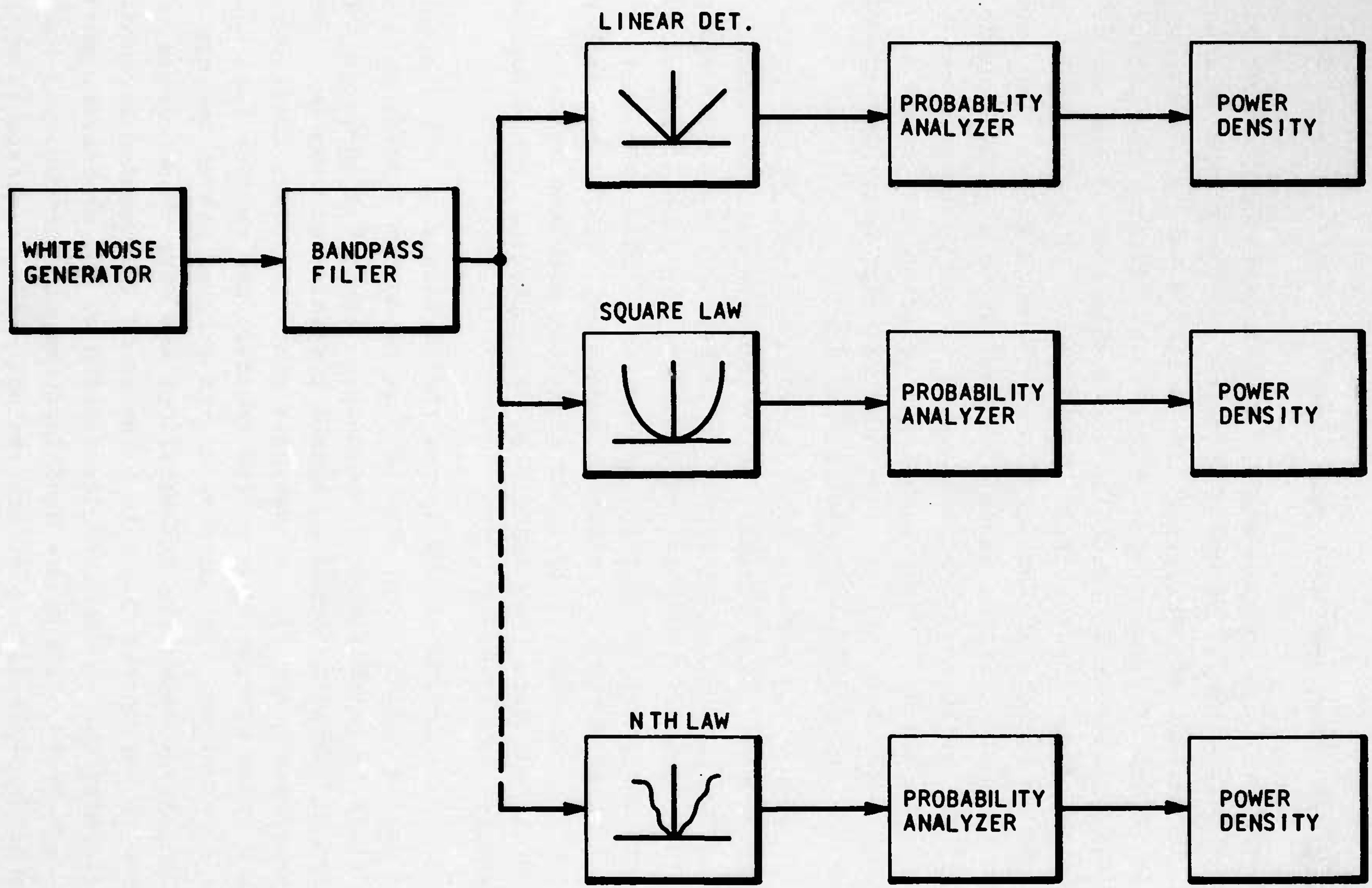
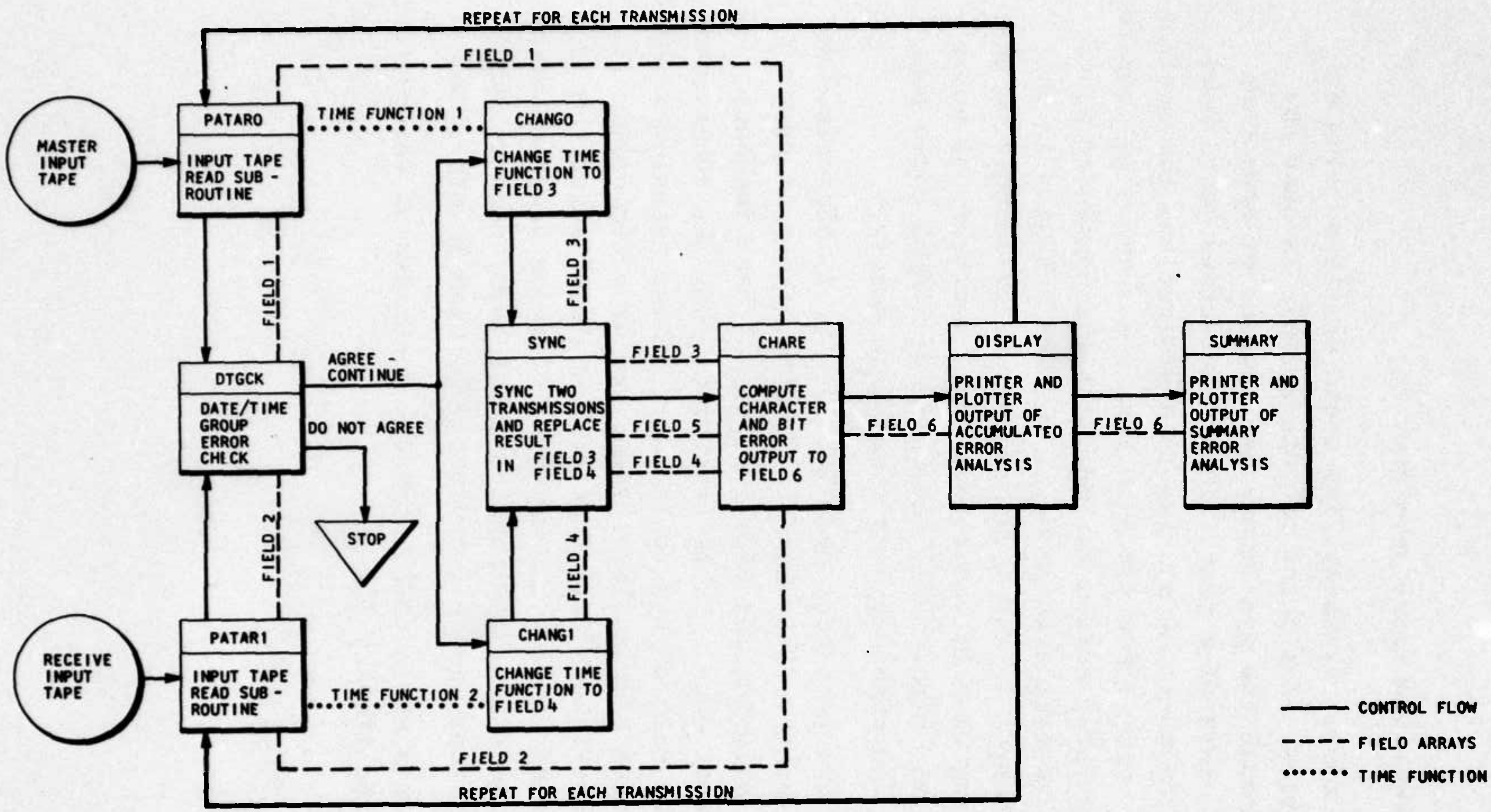


FIG. 8-2 TIME FUNCTION ANALYSIS PROBLEM

DWG. A6-108-13
STRANGE/JK



FIELO 1 - LEAOER OF MASTER TAPE
FIELO 2 - LEADER OF RECEIVE TAPE
FIELO 3 - SYNCHRONIZED CHARACTER OATA, MASTER TAPE
FIELD 4 - SYNCHRONIZED CHARACTER DATA, RECEIVE TAPE
FIELD 5 - ORIGINAL LENGTHS OF CHARACTER DATA
FIELO 6 - CHARACTER AND BIT ERROR INFORMATION
TIME FUNCTION 1 - ACTUAL CHARACTER OATA OF MASTER TAPE
TIME FUNCTION 2 - ACTUAL CHARACTER DATA OF RECEIVE TAPE

FIG. 8-3 N W C TEST PROGRAM
(COMPUTER PROGRAM BLOCK OIAGRAM)

the errors into different categories could easily be done by changing topologies. The point of this example is that the data flowing through the system are not samples of some time series but characters of a text. These characters could have as easily been the man-hour charges to a project and the sorting could have been into labor types so that costs could be computed. TIMFAX is particularly suited for applications suggested above in the field of general data processing. The problems in this field are not changes in the data base but daily changes in the type of processing that is requested. Once a library of boxes is established, the block model structure of TIMFAX would make such changes to the topology simple and less costly.

There are currently over 100 reentrant subprograms in the black box library. They can be linked together in many different ways, allowing for parallel, serial, and feedback processing of input data. It is noteworthy that the subprograms have been written with an eye to the most recent techniques for achieving increased computational speed and/or efficiency. For example, the Cooley-Tukey "Fast Fourier-Transform" algorithm is used in a number of boxes. The majority of these programs were developed for time series applications, but some, such as the Input/Output routines, could immediately be used in other areas.

The pages which follow present abstracts of the current black boxes in the library file.

TIMFAX BLACK BOX ABSTRACTS

THIS DOCUMENT PROVIDES TIMFAX USERS A CATALOG OF ALL THE ''BLACK BOX'' PROGRAMS AVAILABLE WITH THE SYSTEM. FOR EASIER REFERENCE THESE PROGRAMS ARE DIVIDED INTO NINE CATEGORIES ACCORDING TO THE PURPOSE OF THE PROGRAMS. A DESCRIPTION OF THE CATEGORIES FOLLOWS.

I. OPERATIONAL (TIME FUNCTION)

THE PROGRAMS IN THIS SECTION PERFORM THE MATHEMATICAL OPERATIONS ON TIMFAX TIME FUNCTION DATA. THE SECTION IS FURTHER DIVIDED INTO ZERO MEMORY TRANSFORMATIONS (THE OUTPUT SAMPLE DEPENDS ONLY UPON THE PRESENT INPUT SAMPLE), NON ZERO MEMORY TRANSFORMATIONS (THE OUTPUT SAMPLE DEPENDS UPON PAST INPUT SAMPLES AS WELL AS THE PRESENT INPUT SAMPLE), AND DIRECT CORRELATION.

II. OPERATIONAL (FIELD)

THIS SECTION CONTAINS PROGRAMS WHICH PERFORM MATHEMATICAL OPERATIONS ON TIMFAX FIELD DATA.

III. ANALYSIS

THIS SECTION CONTAINS PROGRAMS WHICH PERFORM CALCULATIONS TO OBTAIN AMPLITUDE STATISTICS OR TIME AND FREQUENCY INFORMATION FROM EITHER TIME FUNCTION OR FIELD DATA.

IV. TIME FUNCTION GENERATION

THESE PROGRAMS GENERATE TIME FUNCTION DATA OF SEVERAL TYPES EITHER MODULATED DATA, LIKE SINE WAVES, OR RANDOM DATA, SUCH AS GAUSSIAN NOISE. THESE PROGRAMS CAN ALSO BE USED TO CONTROL PROCESSING IN A TIMFAX LEVEL.

V. INPUT/OUTPUT

THE PROGRAMS IN THIS SECTION CONTROL INPUT AND OUTPUT TO AND FROM MAGNETIC TAPE, TO AND FROM THE FH 432 DRUMS, AND TO AND FROM FASTRAND.

VI. DISPLAY

THE PROGRAMS IN THIS SECTION HAVE AS THEIR MAIN PURPOSE PRINTER OR PLOTTER OUTPUT.

VII. DATA FORMATTING

THE PROGRAMS IN THIS SECTION CHANGE DATA FROM ONE FORM TO ANOTHER. FIELDS CAN BE CHANGED TO TIME FUNCTIONS AND VICE VERSA, FIXED POINT FIELDS CAN BE CONVERTED TO FLOATING POINT, AND CERTAIN TIME FUNCTION SAMPLES CAN BE REMOVED.

VIII. INITIALIZATION

THESE PROGRAMS SET UP ARRAYS THAT ARE NEEDED BY OTHER PROGRAMS.

TIMFAX BLACK BOX ABSTRACTS

IX. SYSTEM

SYSTEM PROGRAMS ARE OF TWO TYPES--DIAGNOSTIC ROUTINES WHICH HELP IN DETERMINING THE REASON FOR FAILURE OF A PARTICULAR JOB AND-- TOPOLOGY ALTERNATOR PROGRAMS WHICH ALLOW THE USER TO CHANGE THE ORDER OF PROGRAMS DURING A RUN.

TIMFAX BLACK BOX ABSTRACTS

I. OPERATIONAL (TIME FUNCTION)

A. ZERO MEMORY TRANSFORMATIONS

ACLIP — TIME FUNCTION SAMPLES WHICH ARE IN ABSOLUTE VALUE LESS THAN AN INPUT THRESHOLD VALUE ARE SET TO ZERO; OTHER INPUT SAMPLES ARE DRAWN IN ABOUT THE THRESHOLD VALUE.

ADPAV — INPUT TIME FUNCTION SAMPLES ARE CHANGED AT LOCATIONS SPECIFIED BY AN INPUT FIELD (FIELD 2) SO THAT THE NEW VALUES RANGE FROM 0 TO N TO 0 WHERE N IS THE NUMBER IN INPUT FIELD 1 CORRESPONDING TO THE LOCATION NUMBER OF THE SECOND FIELD. INPUT VALUE, P, SPECIFIES THE NUMBER OF SAMPLES TO REPLACE BEFORE THE LOCATION IN FIELD 2; 2P+1 SAMPLES ARE CHANGED PER LOCATION IN FIELD 2 WITH THE OTHER SAMPLES BEING COPIED AS THEY ARE.

BIAS — THIS PROGRAM ADDS A GIVEN CONSTANT VALUE TO EACH SAMPLE OF AN INPUT TIME FUNCTION.

CLIP — ALL POSITIVE TIME FUNCTION SAMPLES ARE SET TO +1 AND ALL NEGATIVE TIME FUNCTION SAMPLES TO -1.

DLETE — SAMPLES OF AN INPUT TIME FUNCTION ARE COMPARED WITH AN INPUT THRESHOLD VALUE AND ARE DELETED ACCORDING TO ANOTHER INPUT VALUE. IF THE SWITCH IS SET TO 1, TIME FUNCTION SAMPLES OUTPUT ARE LESS THAN THE THRESHOLD. IF THE SWITCH IS SET TO ZERO, TIME FUNCTION SAMPLES OUTPUT ARE GREATER THAN THE THRESHOLD.

ENVLP — THIS PROGRAM PRODUCES AN OUTPUT TIME FUNCTION, Z, FROM TWO INPUT TIME FUNCTIONS, X AND Y, SUCH THAT

$$Z = \text{SQUARE ROOT } (X^2 + Y^2)$$

MINUS — THIS PROGRAM COPIES THE INPUT TIME FUNCTION INTO THE OUTPUT TIME FUNCTION FOR SAMPLES GREATER THAN OR EQUAL TO ZERO. FOR NEGATIVE SAMPLES, A ZERO IS OUTPUT.

ORL — THIS PROGRAM OUTPUTS THE LARGEST OF THE CORRESPONDING WORDS OF TWO INPUT TIME FUNCTIONS.

PWLAW — THIS PROGRAM TAKES A FLOATING POINT INPUT TIME FUNCTION AND RAISES EACH SAMPLE IN THE FUNCTION TO A POWER SPECIFIED BY THE USER.

RECT — THIS PROGRAM OUTPUTS AS A TIME FUNCTION THE ABSOLUTE VALUE OF EACH SAMPLE IN THE INPUT TIME FUNCTION.

TIMFAX BLACK BOX ABSTRACTS

REFAD THIS PROGRAM ADDS A FIELD TO A SPECIFIED SECTION OF AN INPUT TIME FUNCTION.

SCLE THIS PROGRAM MULTIPLIES A FLOATING POINT INPUT TIME FUNCTION BY A SPECIFIED SCALE FACTOR AND OUTPUTS THE SCALED DATA AS A TIME FUNCTION.

SGHID THIS PROGRAM ADDS AN INPUT FIELD (USUALLY A SIGNAL) TO AN INPUT TIME FUNCTION (USUALLY NOISE) A SPECIFIED NUMBER OF TIMES AND A SPECIFIED NUMBER OF SIGNAL LENGTHS APART. THE SIGNAL AND THE SUM CAN BOTH BE SCALED.

SSQRT THIS PROGRAM OUTPUTS AS A TIME FUNCTION THE SQUARE ROOT OF EACH SAMPLE OF A FLOATING POINT INPUT TIME FUNCTION. IF NEGATIVE INPUT IS ENCOUNTERED, THE NEGATIVE NUMBER IS TRANSFERRED TO THE OUTPUT TIME FUNCTION.

TMUL THIS PROGRAM MULTIPLIES CORRESPONDING ELEMENTS OF TWO FLOATING POINT INPUT TIME FUNCTIONS, WHERE THE SECOND FUNCTION CAN BE DELAYED A SPECIFIED NUMBER OF SAMPLES, AND OUTPUTS THESE PRODUCTS AS A FLOATING POINT TIME FUNCTION.

TSUB THIS PROGRAM SUBTRACTS CORRESPONDING ELEMENTS OF THE SECOND OF TWO INPUT TIME FUNCTIONS FROM THE FIRST AND OUTPUTS THE REMAINDERS AS A FLOATING POINT TIME FUNCTION. THE SECOND INPUT TIME FUNCTION CAN BE DELAYED BY A SPECIFIED NUMBER OF SAMPLES.

TSUM THIS PROGRAM ADDS CORRESPONDING ELEMENTS OF TWO FLOATING POINT INPUT TIME FUNCTIONS, WHERE THE SECOND FUNCTION CAN BE DELAYED A SPECIFIED NUMBER OF SAMPLES, AND OUTPUTS THESE SUMS AS A FLOATING POINT TIME FUNCTION.

XSUM THIS PROGRAM PERFORMS A CROSS SUMMATION BETWEEN TWO FLOATING POINT FIELDS OF EQUAL LENGTH AND OUTPUTS A FLOATING POINT TIME FUNCTION CONTAINING TWICE THE LAG PLUS ONE SAMPLES. XSUM HAS AN OPTION TO USE AN ABSOLUTE VALUES METHOD OR SQUARING METHOD.

B. NON-ZERO MEMORY TRANSFORMATIONS

1. LINEAR

AVRG A RUNNING AVERAGE OF A SPECIFIED NUMBER OF WORDS (L) OF AN INPUT TIME FUNCTION IS COMPUTED. AN INITIAL LAG OF (L-1) WORDS IS SET TO ZERO TO PROVIDE AN OUTPUT TIME FUNCTION THE SAME LENGTH AS THE INPUT TIME FUNCTION.

TIMFAX BLACK BOX ABSTRACTS

DTAVG THIS PROGRAM IS A DETECTOR AVERAGER PROCESSOR OF THE FULL-WAVE, HALF-WAVE, OR SQUARE-LAW FORM.

POWER THIS PROGRAM COMPUTES AN ESTIMATE TO THE POWER SPECTRAL DENSITY FUNCTION OF A SAMPLED TIME FUNCTION. THE ''DIRECT'' APPROACH TO THE POWER ESTIMATE IS IMPLEMENTED USING THE COOLEY-TUKEY ''FAST FOURIER TRANSFORM'' ALGORITHM TO COMPUTE THE DISCRETE FOURIER TRANSFORM. FEATURES OF THE BLACK BOX INCLUDE ENSEMBLE AVERAGING OF SEVERAL PERIODOGRAMS TO INCREASE STABILITY AND SEVERAL DATA WINDOWS TO CONTROL SPECTRAL LEAKAGE.

RCFIL THIS PROGRAM MAY BE USED TO SIMULATE A LOW PASS RC FILTER.

2. NONLINEAR

COMB THIS PROGRAM SIMULATES A COMB FILTER NETWORK FOLLOWED BY A MAX-OR GATE. FOR EACH INPUT TIME FUNCTION SAMPLE COMB GENERATES TWO OUTPUT TIME FUNCTION SAMPLES. THE SAMPLE ON CHANNEL B IS THE OUTPUT OF THE MAX-OR GATE AND THE CORRESPONDING SAMPLE ON CHANNEL C IS A NUMBER BETWEEN 0 AND 1 WHICH CORRESPONDS TO THE STAGE PRODUCING THE SAMPLE ON CHANNEL B.

DLCLP THIS PROGRAM OUTPUTS A FIXED POINT TIME FUNCTION OF +1 OR -1. IF X IS A SAMPLE OF THE INPUT TIME FUNCTION, FOR X GREATER THAN SAMPLE (X-1), +1 IS OUTPUT, FOR X LESS THAN SAMPLE (X-1), -1 IS OUTPUT, FOR X EQUAL TO SAMPLE (X-1), THE PREVIOUS OUTPUT VALUE IS REPEATED.

TIMFAX BLACK BOX ABSTRACTS

NORM THIS PROGRAM TAKES A FLOATING POINT INPUT TIME FUNCTION AND NORMALIZES EACH POINT OF THE FUNCTION RELATIVE TO THE MEAN AND STANDARD DEVIATION OF SECTIONS OF DATA ON EITHER SIDE OF THE POINT. THE FLOATING POINT OUTPUT TIME FUNCTION IS NORMALIZED SUCH THAT THE OUTPUT MEAN IS ZERO AND THE STANDARD DEVIATION IS 1/K, WHERE K IS INPUT. LAG IS ADDED TO THE INPUT TIME FUNCTION SO THAT THE OUTPUT TIME FUNCTION WILL BE EQUAL TO THE INPUT TIME FUNCTION.

PLSTR THIS PROGRAM IS A PULSE STRETCHING PROCESSOR. IT LOCATES THE MAXIMUM PEAK IN A SECTION OF LENGTH N AND OUTPUTS THIS VALUE AS A TIME FUNCTION FOR THE DURATION OF THE NEXT SECTION OF LENGTH N. THE MAXIMUM PEAK FOR THE SECOND SECTION IS HELD FOR THE THIRD SECTION, ETC. THE FIRST SECTION OF THE OUTPUT TIME FUNCTION IS ZERO-FILLED, AND THE LAST SECTION OF THE INPUT TIME FUNCTION IS NOT OUTPUT.

C. CORRELATION

ACOR	TIME FUNCTION SAMPLES, X(I), OF LENGTH N AND A LAG OFFSET, L, ARE USED TO FORM THE L-1 VALUES OF THE AUTOCORRELATION FUNCTION, (X(I)) TIMES (X(I)) IN AN OUTPUT FIELD.
ATCOR	THE AUTOCORRELATION FUNCTION ESTIMATE OF A TIME SERIES IS COMPUTED BY INVERSE TRANSFORMING THE POWER SPECTRAL DENSITY ESTIMATE FROM POWER FIELDS AND IS PLOTTED ON THE CALCOMP 11 INCH PLOTTER.
CORR	THIS PROGRAM IS USED TO PERFORM LINEAR D.C. REPLICA CORRELATION WITH A CLIPPED REFERENCE. THE REFERENCE MUST BE SENT THROUGH BLACK BOX SCAT.
MCORR	THIS PROGRAM COMPUTES A MAGNITUDE CORRELATION OF AN INPUT REFERENCE (FIELD) AGAINST AN INPUT TIME FUNCTION.
XCORR	THIS PROGRAM PERFORMS A CROSS CORRELATION BETWEEN TWO FLOATING POINT FIELDS OF EQUAL LENGTH AND OUTPUTS A FLOATING POINT TIME FUNCTION CONTAINING TWICE THE LAG PLUS ONE SAMPLES.

II. OPERATIONAL (FIELD)

CLECT	INDIVIDUAL FLOATING POINT OUTPUT FIELDS FROM LOCAL ARE COLLECTED INTO TWO FLOATING POINT OUTPUT FIELDS.
CORGN	THIS BLACK BOX GENERATES A SINE OR COSINE CORRELATOR REFERENCE (FIELD) IN UNCLIPPED MODE FOR MCORR AND OTHER PROGRAMS. BEGINNING AND ENDING FREQUENCIES, TIME INCREMENT AND TOTAL TIME ARE INPUTS TO THE PROGRAM.
FLIP	THIS PROGRAM TAKES A FLOATING POINT INPUT FIELD OF LENGTH N AND COMPLETELY REVERSES THE ORDER OF THE DATA WORDS.
SCAT	THIS PROGRAM IS USED TO CONVERT A CORRELATOR REFERENCE INTO A STRING OF INSTRUCTIONS SUITABLE FOR USE BY CORR TO ACCOMPLISH LINEAR D.C. REPLICA CORRELATION WITH A CLIPPED REFERENCE.
ZOTT	THIS PROGRAM TAKES TWO FLOATING POINT INPUT FIELDS AND COMPARES THE FIRST INPUT FIELD TO A GIVEN THRESHOLD. VALUES OF THE FIRST FIELD WHICH ARE LESS THAN THE THRESHOLD ARE REDUCED TO A VERY SMALL NUMBER (INPUT BY THE USER). THE CORRESPONDING SAMPLES OF THE SECOND FIELD ARE ALSO REDUCED TO THIS INPUT NUMBER.

III. ANALYSIS

A. AMPLITUDE STATISTICS

BP THIS PROGRAM NORMALIZES THE PEAKS FROM PKPK, SORTS THEM INTO BINS, AND REPLACES THE PEAK VALUES IN THE PKPK FIELD WITH BIN NUMBERS. THE MAXIMUM PEAK AMPLITUDE IS OUTPUT AS A FIELD FOR USE IN NAD.

DBPRC THIS PROGRAM PERFORMS DB ANALYSIS ON A FLOATING POINT INPUT TIME FUNCTION AND PROVIDES THE RESULTS OF THIS ANALYSIS AS SEVEN COLUMNS OF PRINTED OUTPUT. THE DATA IS ANALYZED IN SECTIONS WITH THE LARGEST VALUE, AND THE MEAN AND STANDARD DEVIATION BEING CALCULATED AND PRINTED FOR EACH SECTION.

ENGSP USING TWO OUTPUT FIELDS FROM LOCAL, AND A TIME FUNCTION, THIS PROGRAM COMPUTES ENERGY SPLITTING STORING THESE VALUES IN AN OUTPUT FIELD AND PRINTING THE LOCATION OF THE PEAK VALUE, TIME TO PEAK, SIGNAL-TO-NOISE RATIO, NORMALIZED PEAK, AND ENERGY SPLITTING FACTOR.

FAC THIS PROGRAM IS A FALSE ALARM COUNTER. IT SELECTS PEAKS FROM THE OUTPUT TIME FUNCTION FROM LPEAK SUCH THAT EACH PEAK IS THE LARGEST WITHIN A BLANKING INTERVAL, SORTS THEM INTO A SET OF SORTING BINS, AND CALCULATES THEIR SUM AND SUM OF SQUARES.

INFSN THIS PROGRAM COMPUTES INFERRED SIGNAL-TO-NOISE RATIOS AT THE INPUTS TO CODED (FM) PULSE AND CW PULSE PROCESSORS.

LOCAL FOR TWO GIVEN FLOATING POINT INTEGERS N AND M, LOCAL WILL DETERMINE THE N LARGEST SAMPLES IN A FLOATING POINT INPUT TIME FUNCTION, SUCH THAT AT LEAST M SAMPLES LIE BETWEEN EACH OF THE N LARGEST SAMPLES. THE PEAKS ARE STORED IN ONE OUTPUT FIELD AND THEIR LOCATIONS ARE STORED IN THE SECOND OUTPUT FIELD.

LOCPR THIS PROGRAM PRINTS THE RESULTS OF BLACK BOX LOCAL. THE PRINTOUT CONSISTS OF THE WORD NUMBER OF THE PEAK, THE TIME AT WHICH THE PEAK WAS ENCOUNTERED, THE OUTPUT SIGNAL-TO- NOISE RATIO OF THE PEAK AND THE VALUE OF THE PEAK TIMES K, THE NORMALIZING CONSTANT.

TIMFAX BLACK BOX ABSTRACTS

LPEAK THIS PROGRAM SELECTS ALL LOCAL PEAKS FROM AN INPUT TIME FUNCTION AND PRODUCES TWO OUTPUT TIME FUNCTIONS, THE FIRST CONTAINING THE PEAK VALUES, AND THE SECOND CONTAINING THE PEAK POSITIONS IN REFERENCE TO THE INPUT TIME FUNCTION. THE POSITION IS GIVEN AS A DIFFERENCE FROM THE PREVIOUS PEAK POSITION. A PEAK IS DEFINED AS A SAMPLE X_I, FOR WHICH

$$X_{I-1} < X_I \text{ AND } X_{I+1} < X_I .$$

LSTSQ THIS PROGRAM FITS A COLLECTION OF DATA POINTS TO A STRAIGHT LINE USING THE METHOD OF LEAST SQUARES.

NAD THIS PROGRAM TAKES THE OUTPUT OF SORT AND RESORTS IT INTO A SPECIFIED NUMBER OF SORT BINS USING A NEW MAXIMUM BIN ON THE INPUT FIELD.

PFLD FROM THE TWO TIME FUNCTIONS PRODUCED BY LPEAK, PFLD LOCATES AND OUTPUTS IN FIELD 1 THOSE PEAK VALUES GREATER THAN A GIVEN THRESHOLD, T, AND CALCULATES AND OUTPUTS IN FIELD 2 THEIR SAMPLE NUMBER WITHIN THE TIME FUNCTION.

PKPK THIS PROGRAM CHOOSES ONE MAXIMUM PEAK PER FILE USING SPECIFIED SKIP FACTORS AND WINDOW LENGTHS AND PRODUCES ONE FLOATING POINT OUTPUT FIELD CONTAINING THE PEAK VALUES AND THEIR LOCATION IN THE FILES.

PKPRC THIS PROGRAM SCANS SPECIFIED SECTIONS OF A TIME FUNCTION FOR THE LARGEST PEAK. THE VALUE OF THE PEAK AND THE SIGNAL-TO-NOISE RATIO IN DB ARE PRINTED. (THE MEAN AND STANDARD DEVIATION USED IN THE DB CALCULATION MAY BE INPUT OR MAY BE CALCULATED BY PKPRC). AN AVERAGE PEAK HEIGHT MAY BE OBTAINED AND THE SIGNAL-TO-NOISE RATIO CALCULATED FROM IT.

PSCAN THIS PROGRAM PRODUCES AN OUTPUT TIME FUNCTION CONSISTING OF THE MAXIMUM VALUE IN EACH SECTION OF LENGTH N OF AN INPUT TIME FUNCTION.

RUNS THIS PROGRAM PERFORMS A STATISTICAL STATIONARITY TEST BY COMPARING ALL MEMBERS OF AN INPUT FIELD WITH THE MEDIAN OF THE FIELD.

RUST THIS PROGRAM PRODUCES TWO OUTPUT FIELDS CONTAINING THE MEAN AND STANDARD DEVIATION OF EACH SECTION OF LENGTH N OF AN INPUT TIME FUNCTION.

TIMFAX BLACK BOX ABSTRACTS

SBSN — THIS PROGRAM CALCULATES THE OUTPUT SIGNAL-TO-NOISE RATIO FOR THE PEAK SPECIFIED BY PKPK USING THE NOISE SORTED INTO A SET FIELD TO CALCULATE THE NOISE STATISTICS. THE OUTPUT IS STORED IN THE PKPK FIELD.

SCSCN — THIS PROGRAM SCANS SPECIFIED SECTIONS OF AN INPUT TIME FUNCTION FOR THE MAXIMUM VALUE IN EACH SECTION. ONE MAGNITUDE VALUE FROM EACH SECTION IS STORED IN THE OUTPUT TIME FUNCTION CHANNEL A. THE RELATIVE LOCATION OF THE PEAK VALUE IN THE SECTION IS STORED IN THE SECOND OUTPUT TIME FUNCTION CHANNEL B.

SMRAT — THIS PROGRAM COMPUTES THE RATIO OF THE STANDARD DEVIATION TO THE MEAN FROM TWO EQUI-LENGTH FLOATING POINT FIELDS.

SNOUT — GIVEN AN INPUT SET OF SAMPLES IN FLOATING POINT FIELD FORMAT, COMPUTE AND PRINT THEIR AVERAGE SIGNAL-TO-NOISE RATIO USING AN INPUT MEAN AND STANDARD DEVIATION.

SORT — THIS PROGRAM SORTS THE DATA IN AN INPUT TIME FUNCTION INTO A SPECIFIED NUMBER OF COUNTING LOCATIONS. THE SUM AND SUM OF SQUARES OF THIS DATA ARE ALSO COMPUTED.

B. TIME AND FREQUENCY

DCFFT — THIS PROGRAM COMPUTES THE DISCRETE FOURIER TRANSFORM OF A REAL OR COMPLEX TIME SERIES. THE DISCRETE INVERSE FOURIER TRANSFORM MAY ALSO BE COMPUTED PROVIDED THE FREQUENCY SERIES IS CONVERTED TO THE FORMAT OF A TIMFAX TIME FUNCTION BY THE BLACK BOX FLDTM. THE ROUTINE USES THE COOLEY-TUKEY ''FAST FOURIER TRANSFORM'' ALGORITHM.

FLTPL — THIS PROGRAM IMPLEMENTS A NETWORK OF PARALLEL RECURSIVE DIGITAL FILTER SECTIONS. THE INPUT COEFFICIENTS WHICH DETERMINE THE CHARACTERISTICS OF EACH FILTER SECTION IN THE NETWORK CAN BE CALCULATED BY THE FORTRAN PROGRAM DIGFLT AND THEN ENTERED BY THE BLACK BOX FSET.

FCRTM — THIS PROGRAM ANALYZES TIME FUNCTION DATA AND GENERATES A FIELD OF POWER CONSTANTS.

FRGAL — THIS PROGRAM COMPUTES A FREQUENCY ANALYSIS OF AN INPUT TIME FUNCTION. MAXIMUM FREQUENCIES ARE SCALED TO +1 AND MINIMUM FREQUENCIES TO -1.

TIMFAX BLACK BOX ABSTRACTS

PHASM GIVEN A SET OF SAMPLES REPRESENTING WAVE PERIODS AND SCALED BETWEEN 0 AND 5 VOLTS - (0 AND .5 IN FLOATING POINT), - PHASM CONVERTS THESE TO FREQUENCIES SCALED BETWEEN +.5 (MAXIMUM FREQUENCY) AND -.5 (MINIMUM FREQUENCY) AND OUTPUTS THEM AS A TIME FUNCTION.

STIME THIS PROGRAM COMPUTES THE TIME BETWEEN SUCCESSIVE UPWARD CROSSINGS OF A SPECIFIED THRESHOLD BY THE SAMPLES OF AN INPUT TIME FUNCTION. THESE TIMES ARE THEN SORTED INTO COUNTING LOCATIONS. THEIR SUM AND SUM OF SQUARES ARE ALSO COMPUTED.

IV. TIME FUNCTION GENERATION

A. MODULATION

PGEN THIS BLACK BOX GENERATES A MAGNITUDE CORRELATOR TIME FUNCTION. PGEN IS CAPABLE OF GENERATING ANY COMBINATION OF EQUAL LENGTH PULSES OF FM OR CW TYPES.

PIP GIVEN TWO INTEGERS N AND K AND TWO SAMPLE VALUES V1 AND V2, PIP WILL GENERATE AN OUTPUT TIME FUNCTION OF LENGTH R, HAVING N SAMPLES EQUAL TO V1, K SAMPLES EQUAL TO V2, AND ALL REMAINING SAMPLES EQUAL TO V1.

SINER THIS PROGRAM GENERATES A CONTINUOUS SINE WAVE WITH A MEAN OF ZERO AND A STANDARD DEVIATION OF .707.

SSGEN THIS PROGRAM IS A SINE SIGNAL GENERATOR WHICH OUTPUTS THE SIGNAL AS A TIME FUNCTION.

B. RANDOM

V. INPUT/OUTPUT

A. MAGNETIC TAPE

MTI THIS IS A MAGNETIC TAPE INPUT PROGRAM WHICH READS TIME FUNCTION DATA FROM MAGNETIC TAPE. THIS VERSION WAS WRITTEN TO READ TAPES CONTAINING 512 TIME FUNCTION SAMPLES PER RECORD. IT WILL READ TAPES WRITTEN ON THE UNIVAC 1108, CDC 3200, OR CDC 160-A.

MTIF THIS PROGRAM IS A MAGNETIC TAPE INPUT BLACK BOX WRITTEN TO INPUT FIXED OR FLOATING POINT FIELDS FROM TAPES WRITTEN ON THE UNIVAC 1108, AND FIXED POINT FIELDS WRITTEN ON THE CDC 3200, OR CDC 160-A. AN INPUT DATA OPTION CONTROLS CONVERSION OF DATA INPUT FROM 24 BIT SIGNED INTEGER FORMAT TO EXTENDED SIGN 36 BIT INTEGER FORMAT FOR DATA WRITTEN ON THE CDC 3200 OR CDC 160-A.

MTIFL THIS PROGRAM IS A MAGNETIC TAPE INPUT BLACK BOX FOR FLOATING POINT TIME FUNCTIONS. THE INPUT RECORDS ARE OF VARIABLE LENGTH. MTIFL WILL PROVIDE TIME FUNCTION INPUT IN A SAMPLE SIZE EQUAL TO THE INPUT RECORD LENGTH. THE MAXIMUM SIZE IS 1680.

MTO THIS PROGRAM WRITES A FIXED POINT TIME FUNCTION ON MAGNETIC TAPE IN RECORD LENGTHS OF 171 WORDS - THREE TIME FUNCTION SAMPLES TO A 36 BIT WORD. OPTIONAL INPUT ALLOWS A PARTIAL RECORD OF DATA TO BE DROPPED OR ZERO FILLED TO MAKE A COMPLETE RECORD. FILE MERGING - MAKING MANY INPUT FILES OF DATA INTO ONE OUTPUT FILE IS ALSO POSSIBLE. A CAPABILITY IS INCLUDED SO THAT AN END OF FILE ON INPUT DOES NOT AUTOMATICALLY TRIGGER AN END OF FILE ON OUTPUT UNLESS MTO HAS ACTUALLY RECEIVED DATA.

MTOF THIS PROGRAM WRITES FIXED POINT OR SINGLE PRECISION FLOATING POINT FIELDS ON MAGNETIC TAPE.

MTOFL THIS PROGRAM WRITES FLOATING POINT TIME FUNCTIONS ON MAGNETIC TAPE. THE OUTPUT RECORD LENGTH MAY BE SPECIFIED.

TFIN THIS PROGRAM IS USED TO READ A TIME FUNCTION FROM AN INPUT TAPE AND TO DEMULTIPLEX THE DATA ACCORDING TO A KEY SPECIFIED IN THE FIRST RECORD. A SECTION EXTRACT OPTION IS ALSO AVAILABLE. TIME FUNCTION DATA WRITTEN ON THE DDP 116 IS OF THE FORM EXPECTED BY TFIN.

TIMFAX BLACK BOX ABSTRACTS

TFOUT THIS PROGRAM IS USED TO MULTIPLEX ACCORDING TO AN INPUT KEY UP TO NINETEEN CHANNELS OF DATA OF WHICH AT MOST THREE ARE DIGITAL AND SIXTEEN ARE ANALOG DATA. THE MULTIPLEXED DATA IS PACKED INTO RECORDS AND OUTPUT TO MAGNETIC TAPE. OPTIONS ARE AVAILABLE FOR MERGING FILES OR FILE BREAKING A FILE USING FBRK. DATA WRITTEN WITH TFOUT MAY BE READ BY THE DDP 116 COMPUTER OR MAY BE INPUT TO THE TIMFAX SYSTEM WITH BLACK BOX TFIN.

B. FH 432 DRUMS

DMO THIS PROGRAM READS FIELDS FROM THE FH 432 DRUMS AND OUTPUTS THEM AS TIME FUNCTION DATA. THE FIELD FROM DMWR IS INPUT SPECIFYING THE BEGINNING LOCATION ON DRUM AND HOW MUCH TO READ.

DMRD THIS PROGRAM READS FIELDS FROM THE FH 432 DRUMS AND OUTPUTS THEM IN FLOATING POINT FIELD FORMAT. THE FIELD FROM DMWR IS INPUT TO DMRD SPECIFYING THE BEGINNING LOCATION ON THE DRUM AND HOW MUCH TO READ.

DMWR THIS PROGRAM WRITES FLOATING POINT FIELDS ON THE FH 432 DRUMS AT THE RATE OF ONE FIELD PER FILE AND OUTPUTS AN ADDRESS FIELD AFTER PROCESSING IS COMPLETED.

DREP THIS PROGRAM READS A FIELD FROM THE FH 432 DRUMS AND REPLICATES IT A SPECIFIED NUMBER OF TIMES FORMING A FIXED POINT OUTPUT TIME FUNCTION.

DREXT THIS PROGRAM EXTRACTS A REFERENCE FROM A FIXED POINT INPUT TIME FUNCTION AND STORES THIS FIELD ON THE FH 432 DRUMS.

FLDID THIS PROGRAM READS FROM THE FH 432 DRUMS A FIELD OR A PART OF IT, IN FIXED OR FLOATING POINT, WHICH HAS BEEN WRITTEN THERE BY THE BLACK BOX FLDOD.

FLDOD THIS PROGRAM READS A FIELD OR PORTION THEREOF FROM CORE AND WRITES IT ON THE FH 432 DRUMS. IT ALSO OUTPUTS A ONE WORD FIELD TO BE USED BY FLDID TO RECALL THE FIELD INTO CORE WHEN NEEDED.

TFIO THIS PROGRAM READS A FIELD FROM THE FH 432 DRUMS AND REPLICATES IT A SPECIFIED NUMBER OF TIMES, FORMING A FIXED OR FLOATING POINT OUTPUT TIME FUNCTION. IF FLOATING POINT, THE DATA MAY BE SCALED BY THE MAXIMUM VALUE IN THE SECTION READ IN.

TIMFAX BLACK BOX ABSTRACTS

TFOD THIS PROGRAM EXTRACTS A FIELD FROM A FIXED OR FLOATING POINT INPUT TIME FUNCTION AND STORES THE REFERENCE ON THE FH 432 DRUMS. EACH SAMPLE IS EXAMINED FOR THE MAXIMUM VALUE IF THE TIME FUNCTION IS FLOATING POINT TO ENABLE THE USER TO SCALE THE DATA UPON READING THE DATA WITH TFID.

C. FASTRAND

FTRNR THIS PROGRAM READS FIELDS FROM THE FASTRAND DRUM. ONLY ENTIRE FIELDS WHICH HAVE BEEN WRITTEN BY FTRNW MAY BE READ.

FTRNW THIS PROGRAM STORES FIELDS ON THE FASTRAND DRUM. THE FILE ON THE FASTRAND DRUM IN WHICH THE FIELDS ARE TO BE STORED MUST HAVE BEEN PREVIOUSLY ACQUIRED. THE FIELDS WRITTEN MAY THEN BE READ BY FTRNR.

VI. DISPLAY

A. PRINTER

DSPLY — A CONDENSED PRINTER DISPLAY OF MULTIPLE ECHO CYCLE PROCESSING RESULTS IS PROVIDED. IF FOR EACH OF N ECHO CYCLES, THE RANGE AND AMPLITUDE OF K PEAKS HAVE BEEN OBTAINED, DSPLY WILL PRODUCE AN N LINE DISPLAY.

PRNT — GIVEN AN INPUT FIELD WHICH CONTAINS EITHER FLOATING POINT OR FIXED DECIMAL DATA, PRNT WILL PRINT THIS FIELD EIGHT NUMBERS TO A LINE IN EITHER FLOATING POINT FORMAT OR OCTAL FORMAT.

B. PLOTTER

ACORP — THE FIELD FROM ACOR CONTAINING THE VALUES OF THE AUTOCORRELATION FUNCTION IS PLOTTED VERSUS THE LAG VALUE ON THE CALCOMP 11 INCH PLOTTER.

CUMPR — THIS PROGRAM COMPUTES A CUMULATIVE POWER SPECTRUM AND THE CORRESPONDING POWER DENSITY ON AN INPUT FIELD FROM ACOR USING A METHOD DESCRIBED BY BLACKMAN AND TUKEY. THE RESULTS CAN BE PRINTED AND/OR GRAPHS OF THE CUMULATIVE POWER AND/OR THE POWER DENSITY CAN BE OBTAINED.

PSPLT — THIS PROGRAM PLOTS THE POWER SPECTRAL DENSITY AND DISTRIBUTION FUNCTION ESTIMATES THAT WERE GENERATED BY BLACK BOX POWER. SMOOTHED ESTIMATES CAN BE OBTAINED BY USING A TRIANGULAR SMOOTHING FEATURE.

SAXES — THIS PROGRAM PLOTS A FIELD USING THE PLOT ROUTINES AXES2, PTITLE, DASHXY, PLOTXY, AND PLTEND. THE USER DETERMINES THE SIZE AND TYPE OF THE SET OF AXES, THE TITLE TO BE USED, THE TYPE OF PLOTTING SYMBOL, AND THE NUMBER OF CURVES PLOTTED ON THE AXES.

SRTPC — THIS PROGRAM COMPUTES A STATISTICAL ANALYSIS OF A FLOATING POINT INPUT FIELD, PRINTS THE NUMBER OF SAMPLES, MEAN, MEAN SQUARE, VARIANCE, AND STANDARD DEVIATION, AND OPTIONALLY GRAPHS THE CUMULATIVE PROBABILITY AND ONE MINUS THE CUMULATIVE PROBABILITY ON THE 11 INCH CALCOMP PLOTTER.

TFP — THIS PROGRAM PLOTS UP TO FOUR CHANNELS OF TIME FUNCTION DATA EITHER HORIZONTALLY OR VERTICALLY IN SIMULATED SANBORN OUTPUT FORMAT ON THE 11 INCH CALCOMP PLOTTER.

VII. DATA FORMATTING

DEMPX — THIS PROGRAM SEPARATES A MULTIPLEXED CHANNEL OF TIME FUNCTION DATA INTO ONE OR MORE CHANNELS.

FBRK — FILE BREAK TAKES A FIXED POINT INPUT TIME FUNCTION AND BREAKS IT INTO N FILES OF M SAMPLES EACH, WHERE N AND M ARE INPUT PARAMETERS. THIS BOX MUST BE USED IN CONJUNCTION WITH WEOF.

FLDTM — THIS PROGRAM CONVERTS AN INPUT FIELD INTO A TIME FUNCTION OF SPECIFIED RECORD LENGTH AND A SPECIFIED NUMBER OF FILES.

FLDX — THIS PROGRAM BREAKS AN INPUT FIELD INTO A SPECIFIED NUMBER OF OUTPUT FIELDS. IF L IS THE LENGTH OF EACH OUTPUT FIELD, THEN THE FIRST OUTPUT FIELD OF FLDX CONTAINS THE FIRST L WORDS OF THE INPUT FIELD, THE SECOND OUTPUT FIELD CONTAINS THE SECOND L WORDS OF THE INPUT FIELD, ETC.

FLFLD — THIS PROGRAM CONVERTS A FIXED POINT FIELD INTO A FLOATING POINT OUTPUT FIELD.

FXFLD — THIS PROGRAM CONVERTS A FLOATING POINT FIELD INTO A FIXED POINT OUTPUT FIELD.

LAG — THIS PROGRAM DELAYS AN INPUT TIME FUNCTION UNTIL A SPECIFIED NUMBER OF SAMPLES HAVE PASSED THROUGH THE NORMAL ENTRY OF THE BOX.

MPX — THIS PROGRAM IS USED TO MULTIPLEX UP TO SIXTEEN EQUAL LENGTH INPUT TIME FUNCTION CHANNELS AND OUTPUTS A SINGLE MULTIPLEXED TIME FUNCTION. IF N IS THE NUMBER OF INPUT CHANNELS, THE OUTPUT TIME FUNCTION IS N TIMES LONGER THAN ANY ONE OF THE INDIVIDUAL INPUT CHANNELS.

MRFEX — THIS PROGRAM CONVERTS SECTIONS OF A TIME FUNCTION TO FIELD FORMAT.

ORKIN — GIVEN AN INPUT TIME FUNCTION, ORKIN PRODUCES AN OUTPUT TIME FUNCTION WHICH INCLUDES THE FIRST M SAMPLES OF THE INPUT FUNCTION, SKIPS N SAMPLES, INCLUDES S SAMPLES, SKIPS N SAMPLES, INCLUDES S SAMPLES, ETC.

PKFLD — THIS PROGRAM REDEFINES OUTPUT CHANNEL 8 (LOCATION OF PEAKS) FROM SCSCN IN TERMS OF THE NUMBER OF SAMPLES FROM THE BEGINNING OF THE FILE (SAMPLE#1).

REJ — THIS PROGRAM OUTPUTS ONE SAMPLE OF A TIME FUNCTION EVERY N SAMPLES OF AN INPUT TIME FUNCTION.

TIMFAX BLACK BOX ABSTRACTS

RFEXT THIS PROGRAM TAKES A SECTION OF A TIME FUNCTION AND OUTPUTS IT AS A FIELD. THIS FIELD IS IN SUITABLE FORM FOR A CORRELATOR REFERENCE IN MCORR OR FOR THE BLACK BOX PRNT.

SCEXT THIS PROGRAM EXTRACTS A SPECIFIED SECTION OF DATA FROM AN INPUT TIME FUNCTION AND OUTPUTS THIS SECTION IN TIME FUNCTION FORM.

SWAP THIS PROGRAM PROVIDES A WAY TO INSERT THE MEAN AND STANDARD DEVIATION OF ONE INPUT FIELD INTO A SECOND INPUT FIELD FOR LATER USE IN SRTPC, WHERE THE INPUT FIELDS ARE OF THE FORMAT OUTPUT BY SORT.

TRUST THIS PROGRAM TAKES AN INPUT FIELD OF LENGTH K TIMES N AND PRODUCES AN OUTPUT FIELD CONSISTING OF EVERY NTH SAMPLE OF THE INPUT FIELD. THIS PROCESS IS REPEATED K TIMES FORMING AN OUTPUT FIELD OF LENGTH K.

WDEXT THIS PROGRAM EXTRACTS ANY WORD OR SEQUENCE OF WORDS FROM A GIVEN INPUT FIELD AND OUTPUTS A FIELD CONTAINING THE DESIRED WORDS. THE WORDS TO BE EXTRACTED MAY BE A SEQUENCE OF ADJACENT WORDS, OR THEY MAY BE A SEQUENCE OF REGULARLY SPACED WORDS. AN EXAMPLE OF THE LATTER WOULD BE TO EXTRACT EVERY THIRD WORD OR EVERY FIFTH WORD.

WEOF THIS PROGRAM MUST BE USED IN CONJUNCTION WITH FBRK AND IMMEDIATELY FOLLOWING AN MTO OR TFOUT BOX IN THE TOPOLOGY. ITS PURPOSE IS TO RE-ESTABLISH KEOC, THE END-OF-FILE, END-OF-SET FLAG AS IT WAS SET PRIOR TO FBRK.

VIII. INITIALIZATION

FFTIN THIS PROGRAM SETS UP A FIELD TO BE USED BY THE VARIOUS FREQUENCY ANALYSIS BLACK BOXES THAT UTILIZE THE ''FAST FOURIER TRANSFORM''.

FSET THIS PROGRAM ENABLES A USER TO SET A FLOATING POINT FIELD OF VARIABLE LENGTH N, N LESS THAN OR EQUAL TO 99, TO VALUES SPECIFIED ON STANDARD DATA CARDS.

MARK THIS PROGRAM PLACES THE CURRENT VALUE OF MTOD$ AND THE REAL TIME CLOCK IN AN OUTPUT FIELD. MARK IS INTENDED TO BE USED IN CONJUNCTION WITH TIME TO MEASURE THE EXECUTION TIME OF BLACK BOXES.

RESET THIS PROGRAM SETS AN INPUT FIELD TO A GIVEN VALUE AFTER A GIVEN NUMBER OF FILES.

SET THIS PROGRAM SETS A FIELD OF SPECIFIED LENGTH TO A SPECIFIED VALUE.

IX. SYSTEM

A. DIAGNOSTICS

DIAGN THIS PROGRAM CAUSES DIAGNOSTIC DUMPS TO BE TAKEN AT CERTAIN TIMES IN A TOPOLOGY. IT SHOULD BE USED ONLY WHEN A TOPOLOGY IS FAILING FOR NO APPARENT REASON.

FOLLO FOLLOW, DURING ITS DEFINITION ENTRY, SETS A FLAG IN SNRX WHICH CAUSES PRINTOUTS DURING THE EXECUTION OF THE RUN INDICATING ITS PROGRESS. THE PRINTOUTS OCCUR AT THE BEGINNING OF THE NORMAL PROCESSING OF EACH SECTION EACH TIME IT IS ENTERED.

TIME THIS PROGRAM COMPARES THE CURRENT VALUE OF MTODS AND RO WITH THE VALUES SUPPLIED IN AN INPUT FIELD FROM MARK TO PROVIDE A PRINTOUT OF ELAPSED TIME.

B. TOPOLOGY ALTERNATOR

RENAM THIS PROGRAM SIMPLY RE-NAMES A CHANNEL. IT MAY BE USED WHEN ALTERNATE BRANCHES OF A TOPOLOGY CAN BE CHOSEN.

SKPTO THIS BLACK BOX, WHEN PROCESSED THROUGH ITS NORMAL ENTRY, EFFECTS A SKIP IN THE PROCESSING TO ANOTHER BOX IN THE SAME SECTION OF THE TOPOLOGY OR TO THE END OF THE SECTION. THE BOX HAS BEEN WRITTEN TO FACILITATE THE IMPLEMENTATION OF THE ''ALTERNATOR'' CAPABILITY OF TIMFAX. IT CAN ALSO BE USED TO ALTER THE TOPOLOGY FOR DIFFERENT DATA SETS FOR A SINGLE TIMFAX RUN.

STSKP THIS BOX, SET SKIP, HAS ONE INPUT FIELD FROM ANY CRITERION OR DECISION-MAKING BOX. WHEN DATA WORD 1 OF THAT FIELD IS NON-ZERO, THE BOX SETS THE APPROPRIATE ENTRIES WITHIN SNRX TO CAUSE A SKIP IN THE PROCESSING OF THE BOXES BETWEEN STSKP AND THE BOX NAMED IN THE DATA INPUT. WHEN THE FIRST DATA WORD IN THE INPUT FIELD IS ZERO, PROCESSING CONTINUES THROUGH THE TOPOLOGY IN NORMAL SEQUENCE.

WHICH THIS BOX CHOOSES THE FIRST NON-VOID INPUT TIME FUNCTION CHANNEL AND SETS IT UP AS ITS SINGLE OUTPUT TIME FUNCTION CHANNEL. (THE BOX HAS BEEN WRITTEN TO FACILITATE THE IMPLEMENTATION OF THE TOPOLOGY ALTERNATOR EXTENSION TO THE TIMFAX SYSTEM.)

TIMFAX BLACK BOX ABSTRACTS

SUPPLEMENTARY TO THE BLACK BOX PROGRAM DOCUMENTATION ARE PROCESSING METHOD DESCRIPTIONS AND TIMFAX TECHNICAL DESCRIPTIONS. THE PROCESSING METHOD DESCRIPTIONS CONTAIN EXPLANATIONS OF PROCESSES INVOLVING MORE THAN ONE BLACK BOX AND EXAMPLES OF TOPOLOGIES WHERE THESE PROGRAMS HAVE BEEN USED. THE PROCESSING METHOD DESCRIPTIONS AVAILABLE ARE:

1. SCAT/CORR PROCESS DESCRIPTION
2. STATISTICAL ANALYSIS
   SECTION 1: MEAN, STANDARD DEVIATION, CUMULATIVE PROBABILITY
   SECTION 2: DETERMINATION OF FALSE ALARM RATE VS THRESHOLD CURVES

THE TIMFAX TECHNICAL DESCRIPTIONS AVAILABLE ARE:

1. THE DISCRETE FOURIER TRANSFORM
2. THE THEORY AND APPLICATIONS OF THE Z TRANSFORM

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

9. SIGNAL PROCESSING MODELS

9. SIGNAL PROCESSING MODELS

The models briefly described in this section will eventually be categorized in one of the preceding sections - most of them probably in Section 8. However, at the present time they have not yet been integrated into the TIMFAX system or suffiently documented to warrant their inclusion in a specific category. The majority will carry out some signal processing functions, hence, the title for this section.

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PROGRAM ABSTRACTS

1. Cubic Spline Function Interpolation Program: This program fits segments of third degree polynomials to a series of data points taking into account first and second derivatives of the polynomial segments.

2. Digital Filter Design Program: This program determines the z-plane coefficients of a recursive digital filter to implement any of four types of analog Butterworth filters, i.e., low-pass, high-pass, band-pass, or band-reject, as specified in the input to the program.

3. PUFFS Simulation Program: The PUFFS program may be used to calculate the cross-correlation function between two specified beam outputs. The beam outputs are formed by specifying two sub-arrays of n staves each, into which properly phased signals and independent noise may be injected. Beam forming may be specified to be linear or clipped.

4. PAIR CW Marking Program: This program computes the marking density and display amplitude as a function of target bearing and range in the PAIR passive display.

5. Generalized Least-Square Curve-Fitting Program: This program will fit a curve to a series of data points, using power series, exponential, or cosine series as specified.

6. Algorithm for Computer-Aided Sequential Detection: This program takes as input ping return data and performs adaptive maximum-likelihood ratio processing to produce range and bearing information as a function of time.

7. Mutual Interference Simulation Program: This program simulates the PAIR sonar system active display (search and track) in the presence of mutual interference due to other PAIR equipped ships in the same area. Outputs of the program may be displayed on either CRT or pen plotter.

8. Power Contour Plotting Program: This program breaks a long time series into segments and computes the power density spectrum for each time segment. The output of the program is plotted as a power density contour as a function of time and frequency.

9. Method of False Position: This program computes a real root of an equation once the root is known to exist between two given function points. The root is approximated to be the axis crossing of a straight line constructed between the two given function points. The process is repeated until a root is located within the desired accuracy.

10. Lagrangian Modification of Least Squares Curve Fit: This program computes coefficients for an N^{th} order polynomial curve fit based on the least squares method. In addition, Lagrangian multipliers are used so that end point slopes may be included into the curve fit.

11. Cubic Spline Curve Fit Program: In this program cubic polynomials are fitted to a given set of points so that the polynomial curve and its first and second derivative are continuous throughout the set of given data points. An option is provided to allow the end point slopes to be specified or to be computed as a linear function.

12. MREVRB: MREVRB computes reverberation levels and target echoes, as functions of time, as detected by the active AN/SQS-26 Sonar System in the bottom bounce mode. The program can simulate variable depth targets and varying environmental conditions.

13. SURF: SURF performs the same function as MREVRB for the active AN/SQS-26 Sonar System in the surface duct mode.

14. ATSSS Reverberation and Target Echo Model: This program computes reverberation levels and target echoes as detected by the active ATSSS variable depth sonar system. This program can simulate variable depth targets and varying environmental conditions.

UNPUBLISHED BLACK BOXES FOR THE TIMFAX SYSTEM

1. ACUMF: ACUMF takes a one word output field from a previous box, and accumulates a field.

	Input Field	Output Field
File 1	x_1	$1, x_1$
File 2	x_2	$2, x_1, x_2$
.	.	.
.	.	.
.	.	.
File n	x_n	$n, x_1, x_2, \ldots, x_n$

P(1) = number of files processed

Output field has P(1) + 1 words.

1	2	3	- - - - -	P(1) + 1
n	x_1	x_2	- - - - -	x_n

2. CALDB: CALDB calibrates a time function with a given calibration signal.

Input: CALDB requires one floating point input field.

Output: CALDB produces one floating point output field.

Word 1: number of words in input field
Word 2: signal, noise, or transponder level
Word 3: signal, noise, or transponder excess.

3. FIXITO: This box takes one input field and produces two output fields. The two output fields produce only one output word each per file. Field 1 puts out words 3, 6, 9, 12, ... from the input field, while Field 2 puts out words 4, 7, 10, 13,... from the input field.

Input Field: one - any length

Output Field: two - 1 → 1., FINPi(I) I = 3,6,9,12,...
2 → 1., FINPi(J) J = 4,7,10,13,...

I,J increment once per file

4. LEVLR: LEVLR performs the function of a 3-bit linear correlator upon input time series.

5. FIRST and LAST: These two boxes are used to move Fastrand blocks to and from the FH 432 drums.

FIRST: Fastrand → FH 432
LAST: FH 432 → Fastrand

6. PROTS: PROTS calculates propogation loss and target strength given the transponder source level, the transmission level, and the target ship source level, in the active AN/SQS-26 Sonar System.

7. PSN: Given an input time function, PSN will skip N samples, scan M samples for a peak, then look at the next X samples to determine an $\overline{X}$ and σ. The $\overline{X}$ and σ found are used to calculate (S/N) out.

8. SETDM, DRMRD, and DRMWR: These programs are used to initiate, read, and write data on the FH 432 drums.

9. SNIN: SNIN infers an input signal-to-noise ratio to the coded pulse processor in the AN/SQS-26 Sonar System, given the output signal-to-noise ratio.

10. TCTRN: This program translates the time code channel on TECHEVAL ping data tapes to a particular time for each desired sample of the ping data.

11. TIMRR: TIMRR computes the error in the time of ping return for a given number of pings and a given target - source closing rate.

12. WRDXT: WRDXT extracts one word from a field each time a TIMFAX level is processed during a particular run.

13. XSNIN: XSNIN infers the input signal-to-noise ratio to the CW Processor on the AN/SQS-26 Sonar System, given the output signal-to-noise ratio.

10. PERFORMANCE PREDICTION MODELS

10. PERFORMANCE PREDICTION MODELS

In principle, selected models from the preceding sections could be employed in a sequential manner to predict the performance capability of a specified sonar system operating in a given environment. The desired ultimate output is, of course, probability of detection as a function of target range. The models presented here illustrate this principle.

10.1 Performance Prediction for a RAP Depth Sonar

1. Description: Reverberation, target echo level, signal-to-noise ratio, and probability of detection are computed as a function of target range for an active sonar system operating at "RAP" depth. Account is taken of surface reverberation, biological reverberation, and several orders of bottom reverberation. Target echo levels are based on a direct path to the target. Spreading loss is determined using ray theory with a series of linear segments approximating the velocity profile. Signal-to-noise ratio is computed by adding reverberation and ambient noise level intensities in their respective bandwidths. Probability of detection is found by interpolation on the processor performance curve for the computed signal-to-noise ratio. Three-dimensional beam patterns are used with the transmit beam being computed in the program. (See Sketches - Figs. 10-1, 10-2.)

2. Input Parameters:

Sonar

- 3-D beam pattern for the receive beam
- source level
- pulse length
- transmit bandwidth
- receiver bandwidth
- source depth

Environmental

- sound velocity profile
- biological layer depth
- biological scattering strength
- number of wind speeds to be considered
- values for each wind speed
- ambient noise corresponding to each wind speed

Target

- target depth

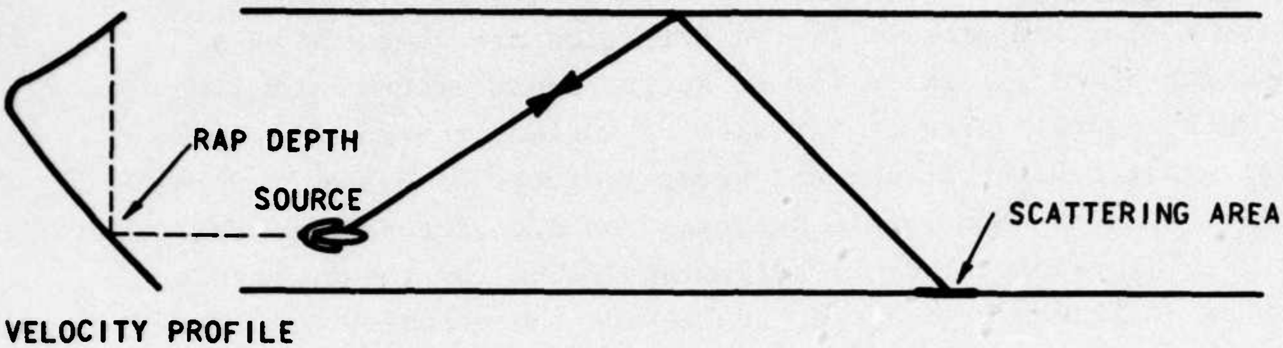

FIG. 10-1 COMPUTING BOTTOM REVERBERATION

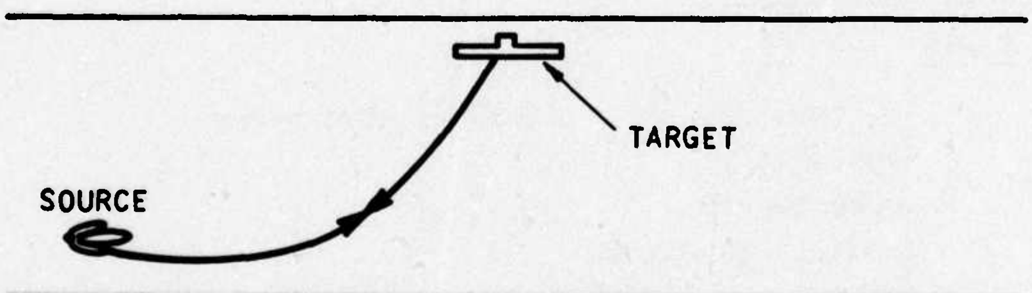

FIG. 10-2 COMPUTING TARGET ECHO LEVEL

3. Output Parameters:

For each time t:

reverberation sum
echo level

A computer plot is produced showing probability of detection as a function of range.

4. Comments: As the program exists, it is somewhat limited in application because of the computed transmit beam pattern. With modification to permit reading in a transmit pattern, it could be used for any active RAP depth sonar. It has been used to predict performance of the ATSSS and Deep Julie systems.

10.2 Shallow Water Performance Prediction Model

1. Description: Reverberation and target echo levels are computed as a function of time after transmission or equivalent target range for a sonar system operating in shallow water under downward refracting conditions. Surface and bottom reverberation are computed (assuming first order scattering) for the many paths which contribute to the total reverberation at any time. Multipath contributions to the target echo level at a particular range are averaged over the particular system resolution interval.

Bottom and surface grazing angles and departure and arrival angles at the source, as determined by straight line geometry, are corrected by approximating the velocity profile with a single negative gradient and adjusting the angles by ray theory. Path lengths are determined assuming straight line acoustic propagation. Vertical transmitting and receiving beams are used and the reverberation level is decreased by the horizontal directivity index of the receive pattern. Output levels are for a point immediately following the receiving beamformer. (See Sketches - Figs. 10-3, 10-4.)

2. Input Parameters:

Sonar

vertical beam patterns for transmit and receive
source level
pulse length
array depth
resolution time
reverberation index
operating frequency
bandwidth

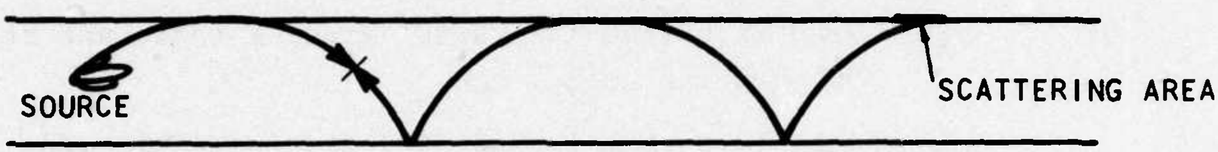

FIG. 10-3 COMPUTING SURFACE REVERBERATION

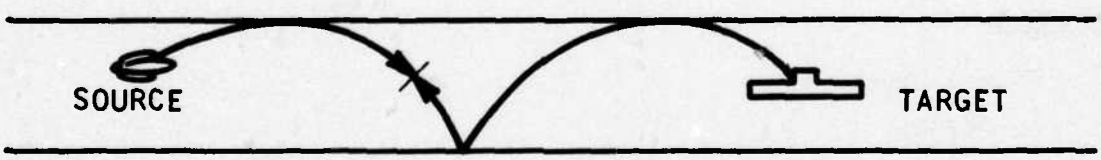

FIG. 10-4 COMPUTING TARGET ECHO LEVEL

Environment

velocity gradient (surface to bottom)
water depth
wind speed
bottom scattering strength at normal incidence
bottom loss options:

(1) Read in bottom loss at 0° grazing angle and at 90° grazing angle.

(2) Read in bottom loss at 90° grazing angle and bottom loss for a minimum grazing angle (which must also be read in).

(3) Read in density, speed of sound, and volume attenuation in bottom, density of sea water for Mackenzie bottom loss curve.

medium attenuation at the system center frequency
speed of sound (average over velocity profile)

Target

strength
depth

3. Output Parameters:

Reverberation level at one second intervals after transmission

Echo level at ranges from 1 kyd out to 40 kyd at 1 kyd intervals

4. Comments: This program may be used for shallow water (depth considerably less than 100 fathoms). As written, the program assumes downward refraction of acoustic energy. This model has been used in the performance prediction studies of the Shallow Julie system and results compare well with the limited amount of shallow water data available.

5. Reference: Lobdill, J. J. "Shallow Water Performance Prediction Model," TRACOR Document Number 68-399-U, March 1968.

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11. SPECIAL PURPOSE MODELS

11. SPECIAL PURPOSE MODELS

In the previous sections, the models presented had familial relationships. The models in this section, in contrast, do not derive from other, similar models in TRACOR's library of simulation models and will ordinarily be used independently.

11.1 Life Cycle Cost (LCC) Model

1. Description: Life Cycle costs are computed by this model as a function of physical and performance characteristics, cost estimating relationships (CER's), empirical equations, and other cost related factors. The LCC model contains two libraries -- one used as a general data bank and the other used for CER storage -- and four computational routine submodels. The four submodels compute: RDT&E (research, development, test and evaluation) costs; Investment (or procurement) costs; Operating costs (including replacement spares and maintenance costs; and, Total Life Cycle Costs (the sum of the costs computed by the RDT&E, Investment and Operating Cost submodels). Table 11.I shows the components entering into the above categories of cost.

Figure 11-1 illustrates the level of spending versus time relationships between the RDT&E, Investment, and Operating Cost Phases of the Procurement Cycle.

2. Input Parameters:

Options are provided which allow any of the cost/functional categories to be either thruput values or calculated values. If a thruput is desired, the value is a direct input. If a calculated value is desired, the inputs required consist of the number of the proper equation to be used plus the appropriate value for each variable in the equation which is not fixed. These inputs range from physical and performance characteristics, number of personnel required, maintenance factors, number of overhauls, etc., to time period considered.

3. Output Parameters:

(1) RDT&E Total Costs
(2) Investment Total Costs
(3) Operating Total Costs
(4) Total Life Cycle Costs
(5) Summary of up to twenty systems Life Cycle Costs.

TABLE 11-I

SURFACE SHIP SONAR
LIFE CYCLE COST
CATEGORIES

RDTE - TOTAL RDT & E (DDPE +DDSE +STE +SEM +DMS)

$DDPE_j$ - DESIGN & DEVELOPMENT OF PRIMARY SYSTEM
$DDSE_j$ - DESIGN & DEVELOPMENT OF SUPPORT EQUIPMENT
STE_j - SYSTEM TEST & EVALUATION
SEM_j - SYSTEM ENGINEERING/MANAGEMENT
DMS_j - MISCELLANEOUS

INV - TOTAL PROCUREMENT (PPE + PSE + PINS + INST + IT + IMS)

PPE_j - PROCUREMENT OF PRIMARY SYSTEM
PSE_j - PROCUREMENT OF SUPPORT EQUIPMENT
$PINS_j$ - PROCUREMENT OF INITIAL SPARES
$INST_j$ - INSTALLATION COSTS (INCLUDES SHIP MODIFICATION COSTS, IF REQUIRED)
IT_j - INITIAL TRAINING (INCLUDES COST OF TRAINERS, INSTRUCTIONS, ETC.)
IMS_j - MISCELLANEOUS

OPS - TOTAL OPERATING COST (SER +MO +PERS +OMS)

SER_j - SPARES & EQUIPMENT REPLACEMENT
MO_j - MAINTENANCE OVERHAULS
$PERS_j$ - PERSONNEL RELATED COSTS (PAY AND ALLOWANCES, REPLACEMENT TRAINING, ETC.)
OMS_j - MISCELLANEOUS

EXAMPLE: SONAR FUNCTIONAL CATEGORIES

J_1 - ARRAY - TRANSDUCERS
J_2 - POWER SUPPLY
J_3 - TRANSMITTER GROUP
J_4 - BEAMFORMING GROUP
J_5 - PROCESSING GROUP
J_6 - DISPLAY
J_7 - AUXILIARY (FAULT LOCATOR, SIMULATORS, ETC.)

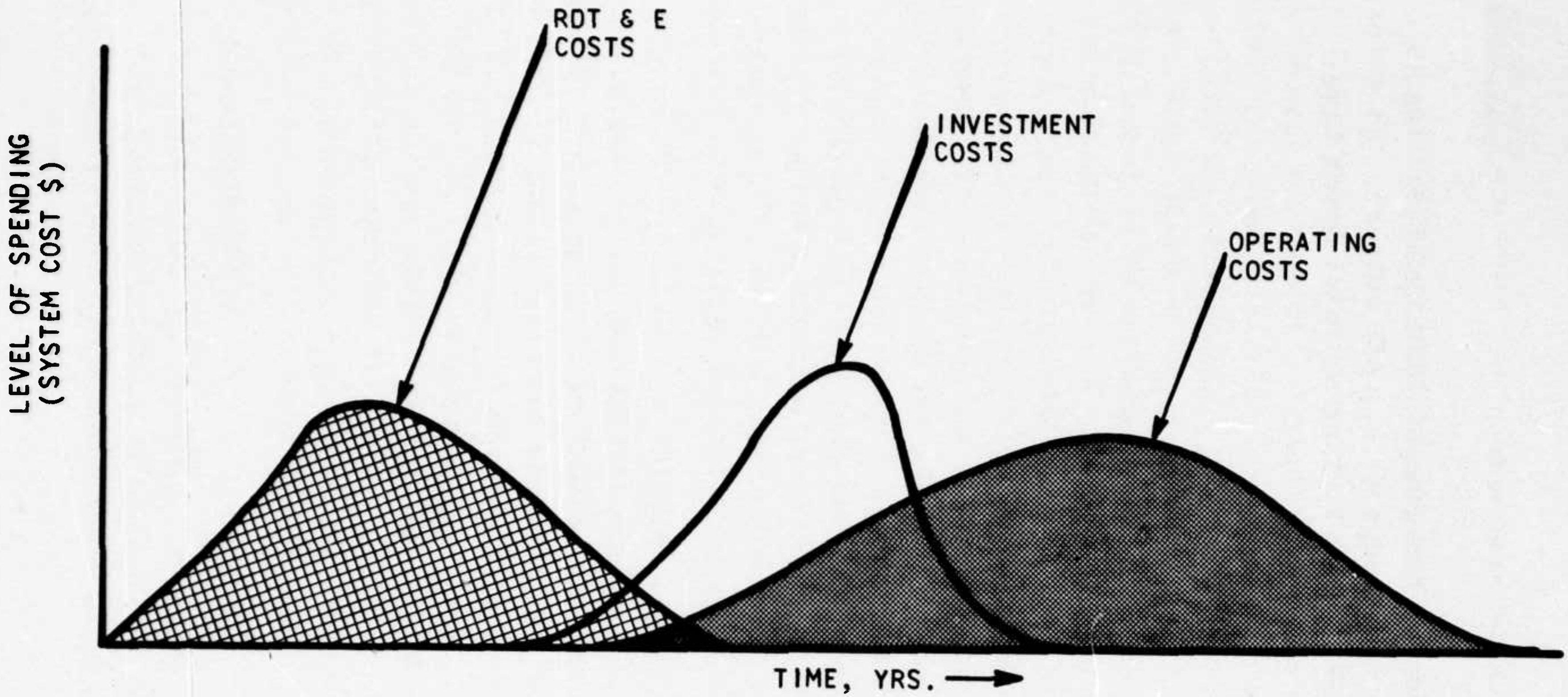

FIG. 11-1 TIME PHASING OF LIFE CYCLE COSTS

TRACOR DWG. A6-6-383
8/20/88 SCHWARTZ/JK

4. Comments: Can be adapted for general Life Cycle Costing of (1) Equipment, (2) Equipment Groups (i.e., ASW suites), (3) Ships, (4) Missiles, (5) Aircraft, and (6) Fleet or Total Force Life Cycle Costs.

11.2 TRADOM - Integral Solution to Scalar Wave Equation

1. Description: Solution of radiation problems can be approached in several directions. Typically a boundary value problem must be solved for a given radiator geometry with boundary conditions specified on the radiator. The scalar wave equation is the governing partial differential equation. Solutions of the wave equation can be obtained by the separation of variables technique. These solutions are in terms of infinite series of special functions characteristic of the radiator geometry, e.g., Hankel functions for cylindrical radiators, with each term having an arbitrary constant. The constants are determined by satisfying the boundary conditions specified on the radiator. The dome/transducer models described in Sections 5 and 6 are typical of the class of problem which can be solved with this approach. The chief disadvantage of this approach is the limitation imposed on radiator geometry. The radiator is limited to a coordinate description for which the wave equation is separable; basically, planar, spherical, and cylindrical.

Alternatively, a solution can be obtained through direct integrations of the partial differential equation. This approach has the advantage that, in theory, the radiator geometry can be completely general. In the past this approach has been limited to small radiators -- not of particular interest in sonar applications -- because of large computer requirements. However, TRADOM incorporates certain analytical developments which permit the solution of radiation problems for large radiators. The model can be applied to simple radiators, e.g., submarine hulls and bare transducers, and coupled systems such as dome-transducers.

2. Input Parameters:

Radiator geometry, frequency, boundary conditions, e.g., specified particle velocity or pressure on a simple radiator, response characteristics of coupled radiator, (e.g., normal acoustic impedance of a dome.)

3. Comments: This model permits a realistic simulation of a wide class of radiators. Inputs may be derived analytically, such as specification of element velocities for a transducer, or experimentally such as measured submarine hull response. The model has been used to predict the effect of a Joukowski dome on the radiation characteristics of a cylindrical array.

4. Reference: Pohler, R. F., "An Application of the Helmholtz Integral Formulation to the Problem of Transducer-Dome Interaction," TRACOR Document Number 68-968-U, Vols. I and II, 10 September 1968.

11.3 Computer Simulation of the AN/SQS-26CX Active Displays in a Mutual Interference Environment

1. Description: For any predetermined screen geometry of AN/SQS-26CX equipped ships, data are generated that may be displayed in the TRACOR black and white CRT display facility (see Section 14.)

These displayed data simulate the effects of mutual interference as a result of a multi-ship operation for AN/SQS-26CX equipped ships. Three displays and four AN/SQS-26 receivers are presently simulated, i.e., the A-scan coded pulse and CW pulse channels, the B-scan, and the PPI (plan position indicator).

The simulation program as it is presently configured can be broken down into three major divisions.

The first of these divisions is the transmission and environment section. Here, the interfering pulses and their levels at the input to the receive ship (denoted JSHIP) transducer array, resulting from the search transmissions of the other N-1 ships (denoted ISHIPS) in an N ship screen,* are generated. These levels and their corresponding arrival times relative to some arbitrary start time for the simulation, reflect the many tactical, environmental, and AN/SQS-26CX system parameters that are involved. In addition to the interfering levels of the N-1 ISHIPS transmissions, target echo levels resulting from JSHIP transmissions are generated. The targets may be programmed for continuous motion in range and bearing and to start or stop in any prescribed ping cycle. Furthermore, the targets are programmed to mark each successive ping cycle with a prescribed probability that reflects a realistic standard deviation in the variables of the sonar equation.

*The present configuration of the computer program allows static screen geometries only.

The second division simulates the various receivers of the AN/SQS-26CX. Here all signals arriving at the transducer array are received and processed through the appropriate pre-selected receive channel, e.g., A-scan (FM), A-scan (CW), B-scan, etc. This portion of the program is based on a thorough system analysis of the AN/SQS-26CX receivers, and artifically performs operations such as beamforming, filtering, and signal processing. Thus, the simulated receiver does not serially process an actual time function but rather operates on a set of parameters which describes a pulse, and then outputs a set of parameters which are characteristic of an output time function. This output is then presented on the display and causes the same marking pattern as that of a serially processed time function.

The third division simulates the display. With the pre-selection of a particular receive channel and display, arrays of marking or blanking intensities are formed. The individual displays for each ping cycle are then combined into prescribed multi-ping histories. This information is written onto magnetic tape and in turn is played back into the CRT display tape read unit.

2. <u>Parameters to be Specified for the Simulation of the AN/SQS-26CX Active Displays in the Presence of Mutual Interference:</u>

A. <u>Tactical Parameters</u>:

<u>Input Parameters</u>

(1) N, the number of ships in the screen
(2) JSHIP, the ship whose displays are to be studied
(3) ISHIPS, the remaining N-1 ships in the screen, i.e., I=1,...,N, I≠J.

(4) Geometry of ISHIPS relative to JSHIP
  (a) THETA (I, J), the relative bearing of ISHIP
  (b) R (I,J), the separation of ISHIP from JSHIP
  (c) SS (I), the ship speed of the N ships in the screen, I=1,...,N

(5) NPING, the number of ping cycles to be generated at JSHIP, JN=1,...,NPING

(6) IFREQ (I), the frequency band of each ship, i.e., 1, 2, or 3

(7) SECTHD (I), the search sector heading of the Ith ship, I=1,...,N

(8) SECWD (I), the search sector width of the Ith ship, I=1,...,N

(9) NTARG, the number of targets to be displayed, L=1, 2,...,NTARG

(10) IPING (L), the ping cycle in which the Lth target should first appear

(11) FPING (L), the ping cycle in which the Lth target should appear last

(12) Initial position of Lth target
  (a) RTARG (L), the initial target range
  (b) BTARG (L), the initial target relative bearing

(13) Motion of the Lth target
  (a) RDOT (L), the range rate
  (b) BDOT (L), the bearing rate

(14) VALUE (L), level in dB//1μbar of Lth target

(15) MARK (L), the probability that the Lth target will mark in each successive ping

Computed Parameters

(1) The updated position of the Lth target in the JNth ping cycle of JSHIP
  (a) RTARG (L, JN), the updated range position
  (b) BTARG (L, JN), the updated relative bearing

B. Environmental Parameters:

Input Parameters

(1) H (I, J, K), propagation losses for up to K=4 paths between ISHIPS and JSHIP
(2) TT (I, J, K), propagation times for up to K=4 paths between ISHIPS and JSHIP
(3) Ocean depth

C. AN/SQS-26 System Parameters:

Input Transmission Parameters

(1) IMODE (I), the transmission mode of ISHIPS; BB/ODT, CZ or PDT/ODT, and ODT only
(2) FREQ (I, IP), the specific frequency of each pulse (IP=1,...,7) in the transmission sequence of ISHIPS; FREQ (I, IP) = 1,...,6, i.e., a CW and FM frequency per band
(3) CODE (I, IP), the code, i.e., up-slide, down-slide, CW, ODT, rumble, etc., for each pulse in the transmission sequence of ISHIPS
(4) PULSEL (I, IP), the pulse length of each pulse in the transmission sequence of ISHIPS

(5) BEAMD (I), transmit beam depression angle of ISHIPS
(6) PHIT (I, K), vertical transmit angle for up to K=4 paths between ISHIPS and JSHIP
(7) ZONEW (I), the detection zone width of ISHIPS
(8) DEADT (I), dead time arbitrarily added to ISHIPS transmission listen period to vary the total transmission period of ISHIPS
(9) STTIME (I), start time relative to zero for ISHIPS

Input Receive Parameters

(1) JSCOPE, the display to be simulated, i.e., CW A-scan, FM A-scan, ODT B-scan, etc.
(2) JFREQ, the receive frequency of the display processor to be simulated
(3) JCODE, the code(s) of the display processor
(4) ATT (JFREQ, FREQ (I, IP)), the total filter losses of the JSHIP receiver to be simulated to pulses with frequency FREQ (I, IP) from ISHIPS
(5) JRC, the RC time constant for the CW and ODT linear detector-averagers
(6) JBKGND, a stored background function of reverberation-plus-noise for the processor to be simulated
(7) JBANDN, the bandwidth at the input to the processor of the background function
(8) JCLUT, noise clutter density of the display
(9) JRODT, ODT range scale of JSHIP
(10) ZONEW (J), the zone width of JSHIP

(11) DEADT (J), the dead time of JSHIP

(12) Processing gain curves for each processor to be simulated operating on
   (a) Interfering pulse codes
   (b) Targets

(13) Output signal-to-noise ratio required for 0.5 probability of marking the display for the specified clutter density

Computed Transmission Parameters

(1) BP (IFREQ (I), IP, K), the beam pattern for up to K=4 paths along the bearing of propagation for each pulse in the transmission sequence of ISHIPS

(2) ZSTART (I), the range of zone start of ISHIPS

(3) TSTART (I), the start time of the detection zone of ISHIPS relative to start time of ISHIPS transmission

(4) TSTOP (I), the stop time of the detection zone of ISHIPS relative to start time of ISHIPS transmission

(5) PER (I), transmission period of ISHIPS

Computed Receive Parameters

(1) BP (IFREQ (I), IFREQ (J), M, K), the beam pattern sensitivity of M=1, 72 (B-scan) or M=1, 12 (A-scan) preformed beams along the relative bearing of ISHIPS for up to K=4 paths between JSHIP and ISHIPS

(2) ZSTART (J), the range of zone start of JSHIP

(3) TSTART (J), the start time of the detection zone relative to start time of JSHIP transmission

(4) TSTOP (J), the stop time of the detection zone relative to start time of JSHIP transmission

(5) THOLD, the threshold relative to the processor output noise level

(6) PER (J), the transmission period of JSHIP

3. Output Parameters:

There are several forms of intermediate printout that indicate whether the program is functioning properly. These printouts may be suppressed by the user.

The primary output is a magnetic tape that is input to the TRACOR black and white CRT display facility.

A secondary output is the fraction of the total display blanked or marked by interference averaged over the number of ping cycles displayed in the sequence. This fraction is also printed on an individual ping basis.

4. Comments: The overall structure of the program is very general. The specifics such as AN/SQS-26CX transmission modes or receive channels are programmed as modules, i.e., different portions of the program are selected by the input of different parameters. Therefore, one could simulate the displays of other sonar systems within the framework of this program, e.g., AN/SQS-35, etc., by adding the coding necessary to simulate their receivers and transmitters.

The program is not yet completed but should be fully operational in the near future. Even at this stage, however, AN/SQS-26CX display experts have commented favorably regarding the realism of the simulation.

The only major limitation to the program, as it is presently configured are: the screen must be static and limited to six ships.

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12. ANTISUBMARINE WARFARE TACTICAL ENGAGEMENT SIMULATION MODELS

12. ANTISUBMARINE WARFARE TACTICAL ENGAGEMENT SIMULATION MODELS

TRACOR has developed a number of ASW Tactical Engagement simulation models. These models serve as tools for the evaluation of mission effectiveness in terms of relevant tactical, system, and environmental parameters. The question of mission effectiveness is fundamental in each of the following types of analyses.

(a) The analysis of real or hypothetical military systems in given situations for specific tactical doctrines;

(b) The analysis of real or hypothetical tactical doctrines in given situations for specific military systems;

(c) The analysis of both tactical doctrine and military system requirements necessary to accomplish particular types of missions.

The programs have the capability of simulating the course of an engagement from initial encounter through attack and kill verification. The status of the engagement during the course of time may thus be displayed and analyzed if desired. An executive routine is provided. This executive routine is capable of exercising the models repeatedly to produce statistically significant results. For example, kill probability averaged over geometry of encounter, range at weapon launch, or environmental parameters can be generated by this executive program.

The major features of the simulation are:

(1) Parameterized subsystems, weapons, and environment,

(2) Time incrementation, and

(3) Modular and flexible program construction.

The parameterization of subsystem, weapon, and environment is primarily for the purpose of program running speed. The parameterization is based upon detailed analysis of the system or environment. Thus, for example, the performance of a sonar is represented by probability of detection, range and bearing error, time, and other relevant parameters. No attempt is made to simulate the signal processing in detail. Similarly, weapon performance is expressed as kill probability as a function of quality of fire control solution, weapon performance parameters, and evasive maneuvers of the target.

Time incrementation rather than event incrementation is required to provide overall flexibility in the program. With event incrementation the important event must be selected before the construction of the program. The resulting program is inflexibly tied to the events. However, with time incrementation the tactics and hence the course of events can be made flexible. Furthermore, any results deemed important can be displayed as a function of time.

Modular and flexible program construction is required so that the program can include a fairly large number of participants and so that the program can be useful for a variety of situations. It further allows the program to be extended to other engagements without major reprogramming.

Figure 12-1 is a schematic of the simulation of each participant and the interaction of that participant with the environment and the other participants. Figure 12-2 is a more detailed schematic of the command and control function of each participant. Figure 12-3 illustrates the overall program flow.

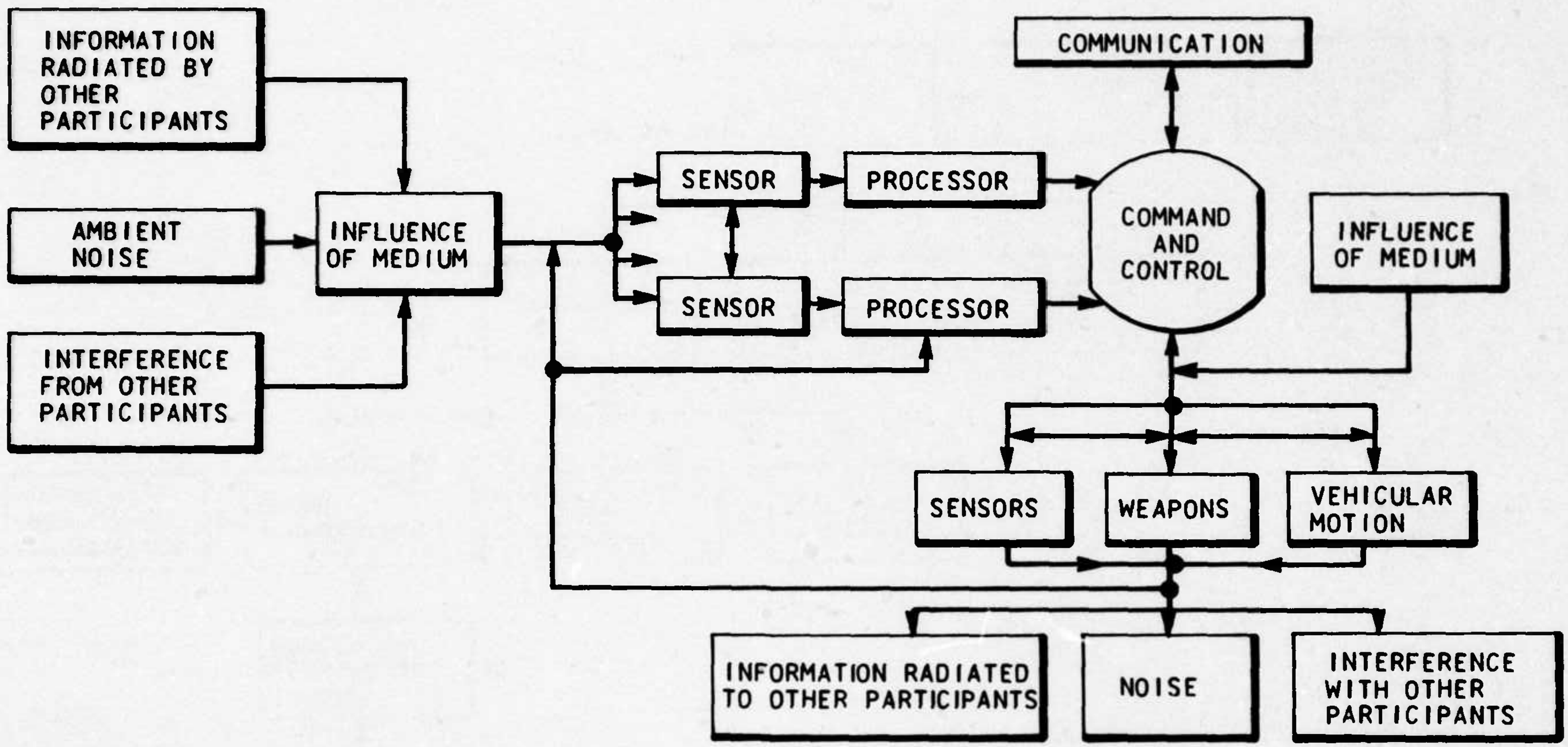

FIG. 12-1 DIRECT INTERACTION OF MAJOR COMPONENTS IN ASW COMBAT SIMULATION

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4/18/68 WEIDMANN/JK

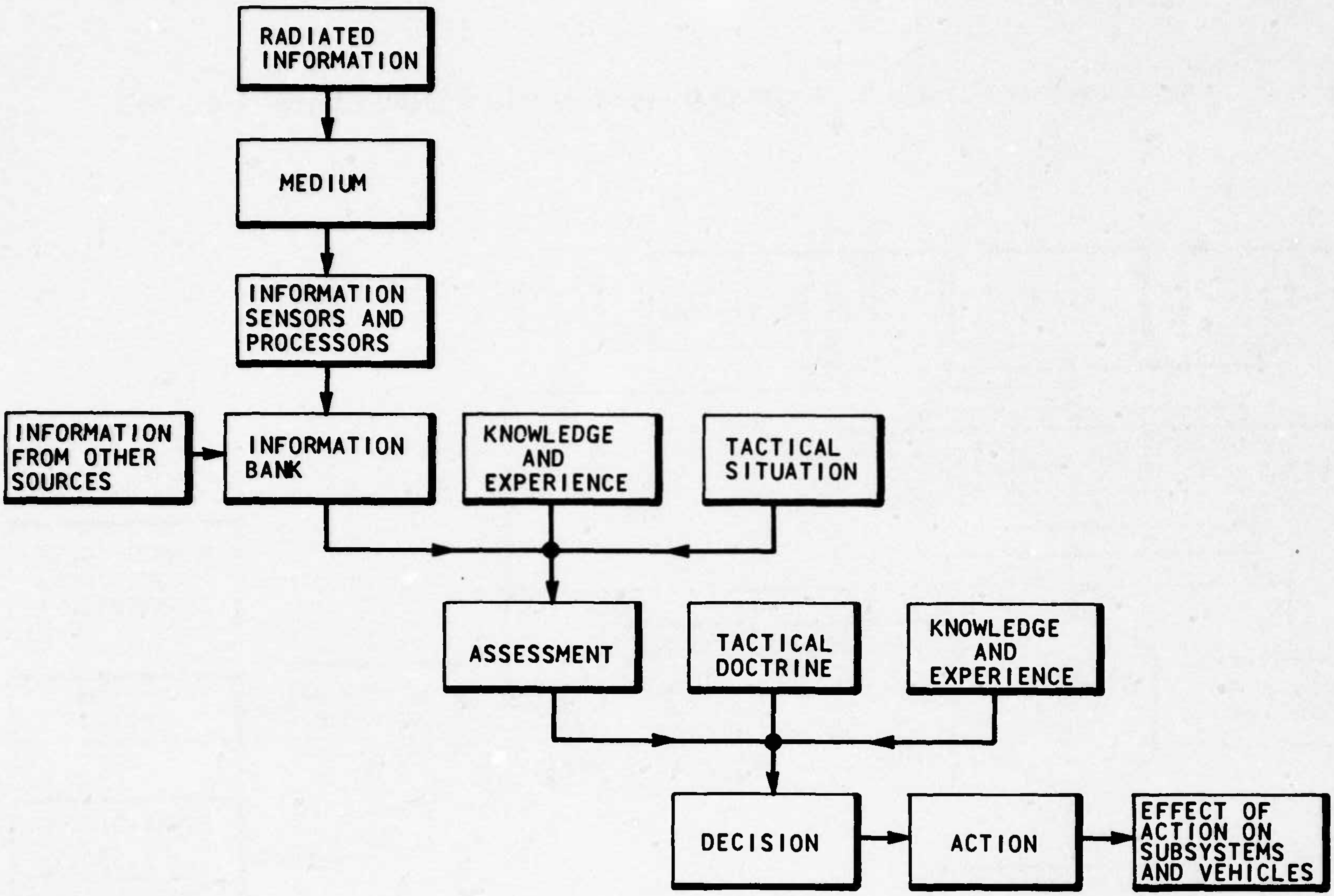


FIG. 12-2 COMMAND AND CONTROL FUNCTION AND ITS INTERFACES

TRACOR DWG. A6-2-646
4/18/68 WEIDMANN/JK

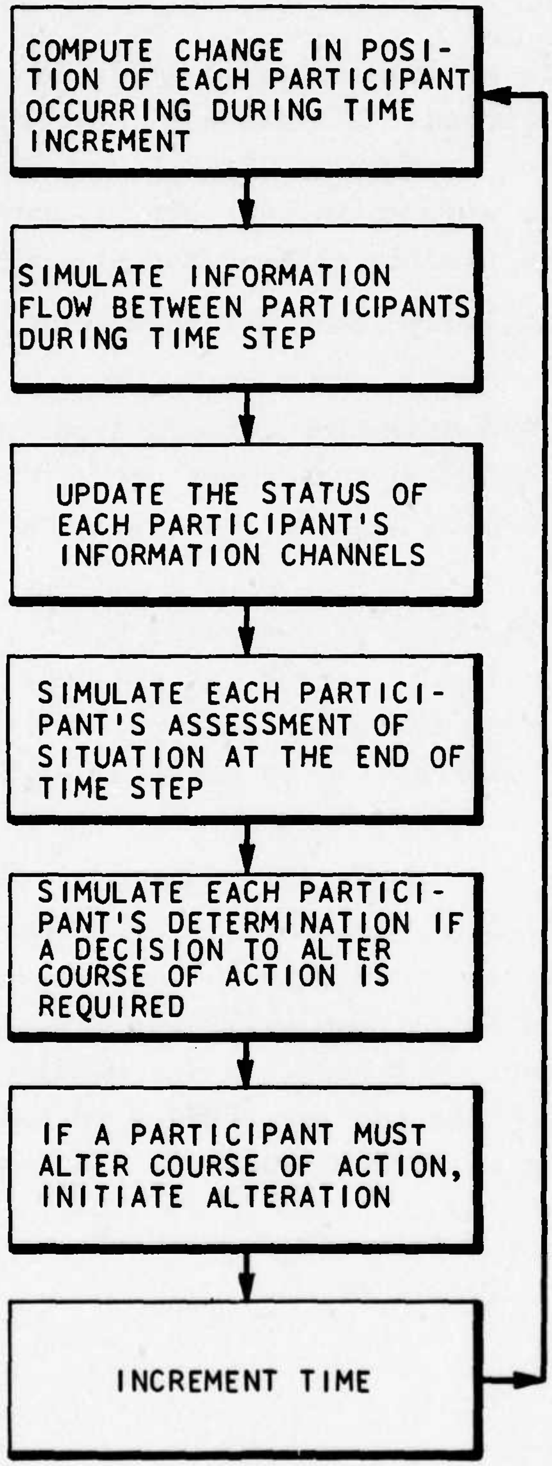


FIG. 12-3 BASIC PROGRAM FLOW FOR TACTICAL ENGAGEMENT SIMULATION

Simple program logic is employed, so that the program can be easily altered. The value of any program is enhanced if it is amenable to convenient alteration. Indeed, the flexibility required in this simulation can only be provided by producing a code that can be readily altered and extended.

The following Tactical Engagement Simulations have been developed:

(1) The Submarine Forward Area Patrol Mission. - This model simulates an engagement between two submarines each equipped with certain passive sonar systems and certain weapon systems.

(2) The Line of Searchers Mission. - This model simulates a coordinated search for a single submarine by an arbitrary number of submarine searchers. Evasion by the single submarine is considered. Only passive detection systems are considered.

(3) Lead Escort ASW Mission. - This model simulates an encounter between a lead escort destroyer and a single submarine. The destroyer is equipped with an active sonar and the submarine with a passive sonar. Each participant is equipped with appropriate simulated weapons. While this model considers only a one-on-one engagement, it can be easily extended to include other surface and submarine units as well as air-ASW units.

13. HYDRODYNAMIC MODELS

13. HYDRODYNAMIC MODELS

Three examples of hydrodynamic, rather than acoustic, models are presented in this section. These models provide numerical solutions of the complete Navier-Stokes equation in two dimensions. They are valuable tools in such studies as the transition phenomena of waves progressing from deep to shallow-water, the design of coastal structures, beach erosion, the distribution of pollutants in estuaries, etc.

13.1 The TRACOR Hydrodynamic Model

1. Description: The TRACOR Hydrodynamic Model solves the complete Navier-Stokes equation in two dimensions. The model obtains a solution to the equation of fluid motion by using the equation in a finite-difference form which is solved numerically. The fluid is represented by a two-dimensional rectangular lattice of cells. With each cell is associated both a horizontal and vertical component of velocity, as well as a pressure value. The mesh size and time increment are dictated by the desired resolution and stability requirements.

Currently, the most important application of the TRACOR Hydrodynamic Model is the study of the propagation of surface waves from deep to shallow water. The study involves simulation of the large wave tank at the Coastal Engineering Research Center, Department of the Army. The model simulates a piston-type wave generator and predicts the time history of the water level at various stations along the tank as the waves progress through deep water, up a sloped beach, and into shallow water. The model also provides a complete description of both the pressure and velocity fields in the fluid medium at any instant of time. Results from the computer model compare favorably with small amplitude wave theory and with experimental results.

With further verification, the Hydrodynamic Model is applicable to the study of numerous fluid dynamics problems, where in many cases, it is practically impossible to obtain reliable experimental or field measurements. This capability provides a valuable tool for theoretical studies of wave propagation and the transition phenomena of waves as they progress from deep to shallow water. The model can also be helpful in design of coastal structures.

2. Input Parameters:

The following pages list the input parameters of the model and a description of the variable fields defined over the cell structure. In addition to these input parameters, the geometry of the wave tank and sloped beach, the wave generator boundary conditions, and the initial fluid configuration are prescribed in the program. Also, a general flow chart of the computer program is included. (Figure 13-1 and 13-2.)

3. Reference: Huston, R. J., J. E. Stover, and W. H. Espey, Jr., "Computer Simulation of the Propagation of Surface Waves," TRACOR Document Number 68-544-U, 29 April 1968.

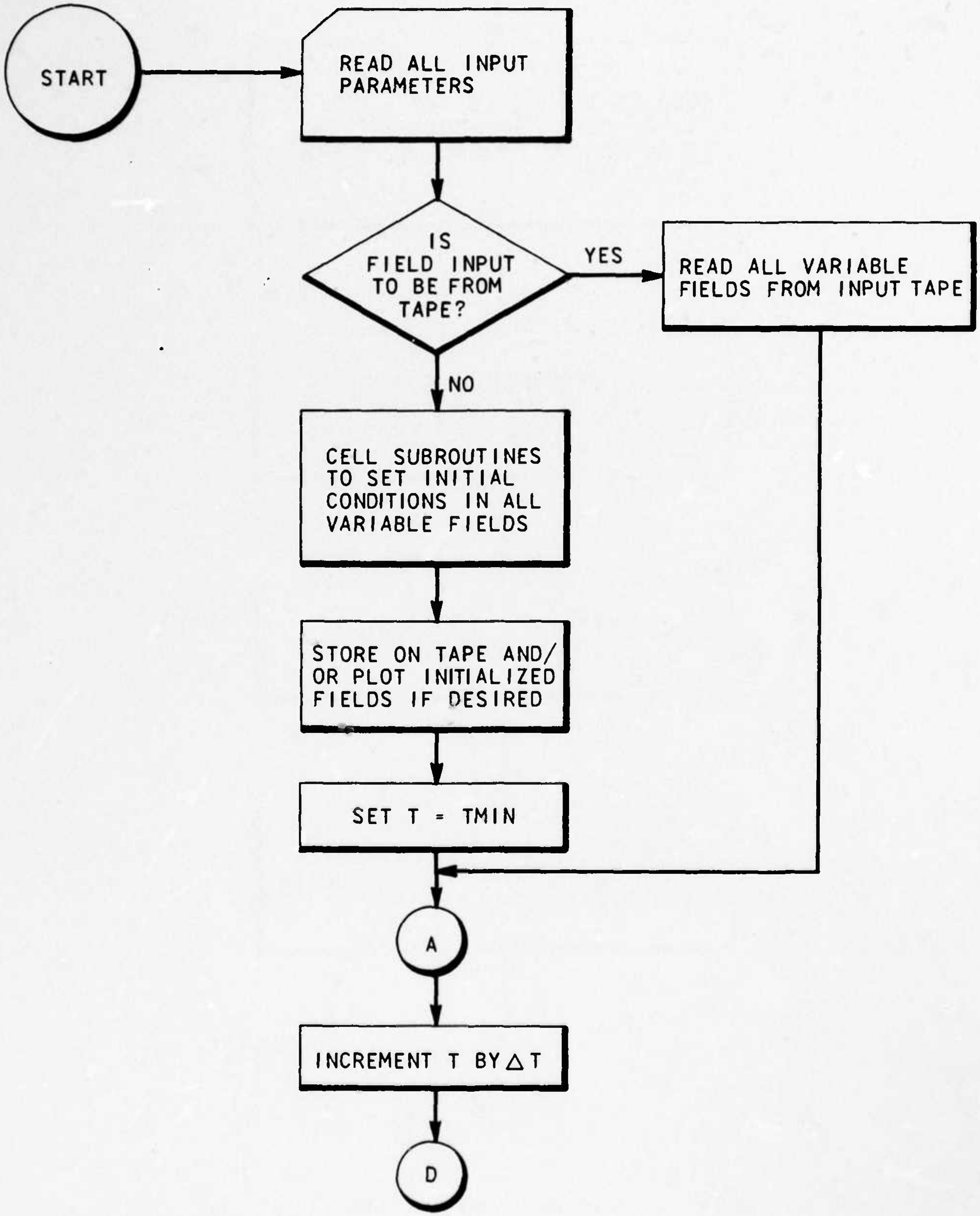
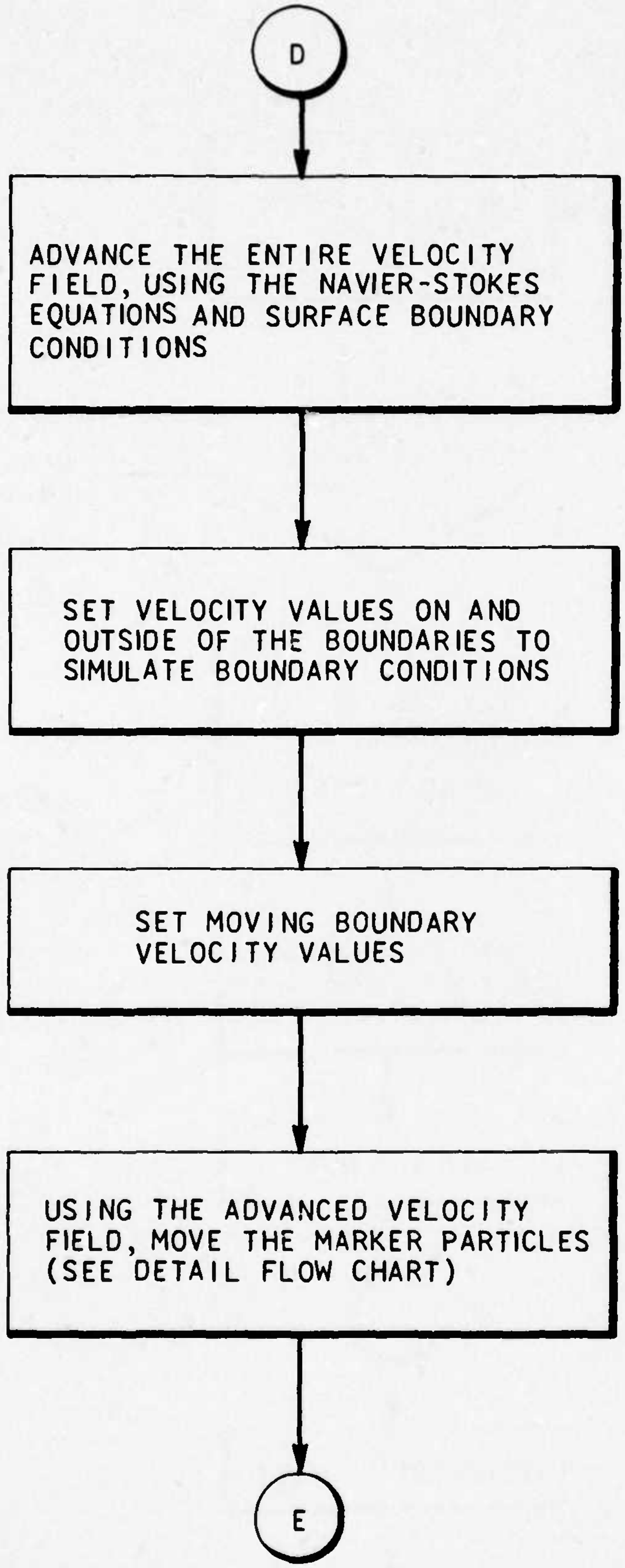


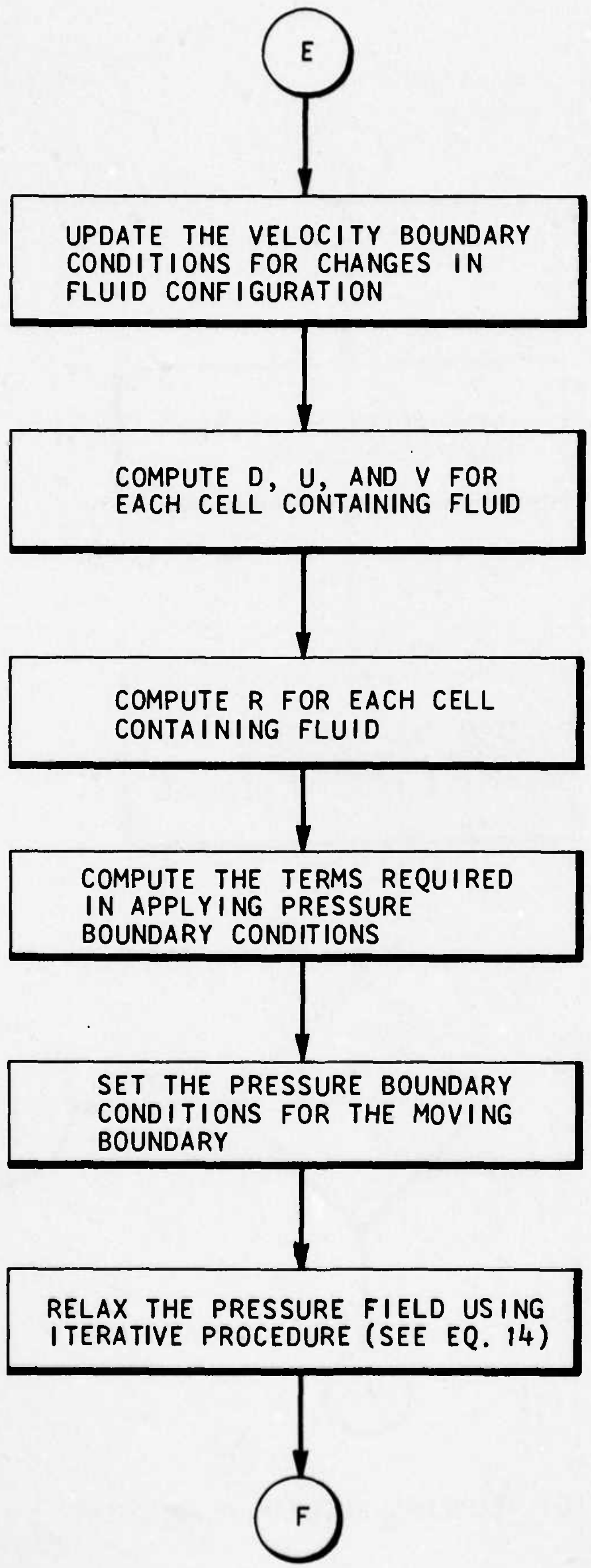
FIG. 13-1 GENERAL PROGRAM FLOW CHART (CONT'D)

TRACOR DWG. A6-3-495
4/17/68 STOVER/JK



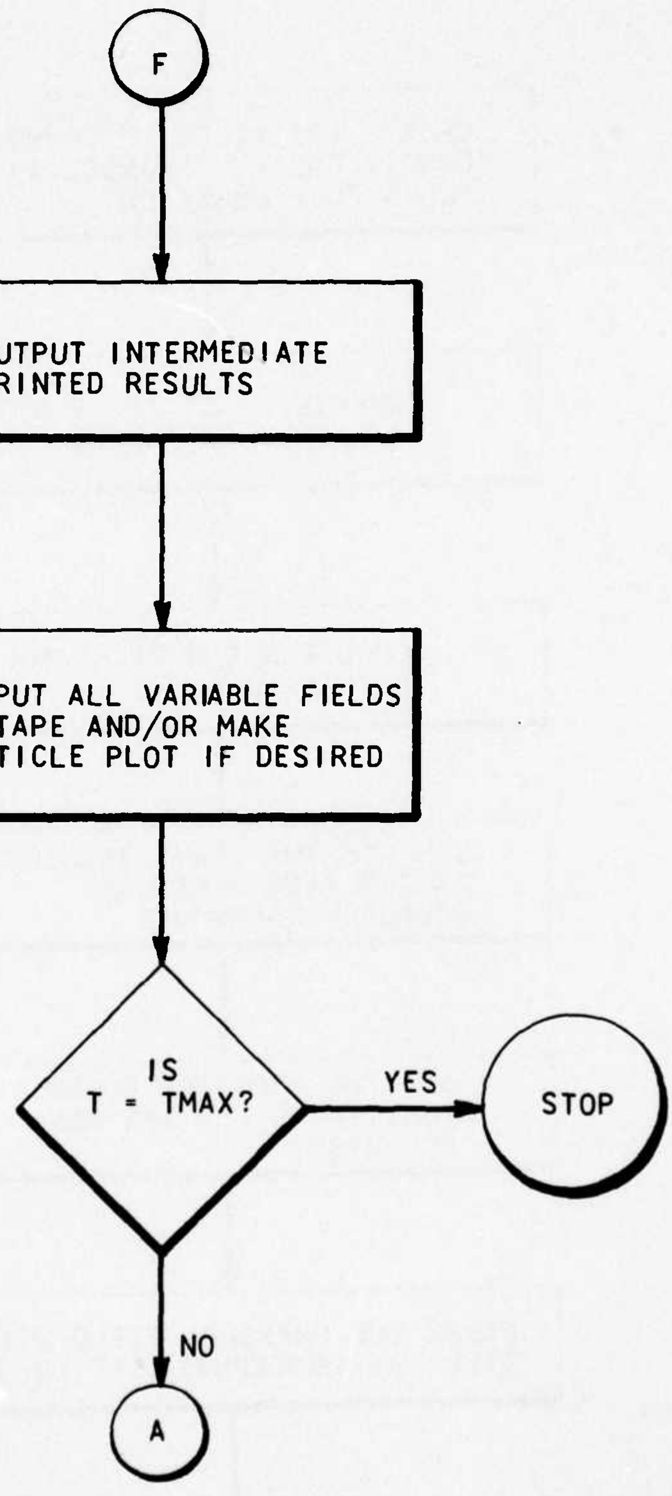
(CONT'D) GENERAL PROGRAM FLOW CHART

TRACOR DWG. A6-3-494



(CONT'D) GENREAL PROGRAM FLOW CHART

TRACOR DWG. A6-3-491



(CONT'D) GENERAL PROGRAM FLOW CHART

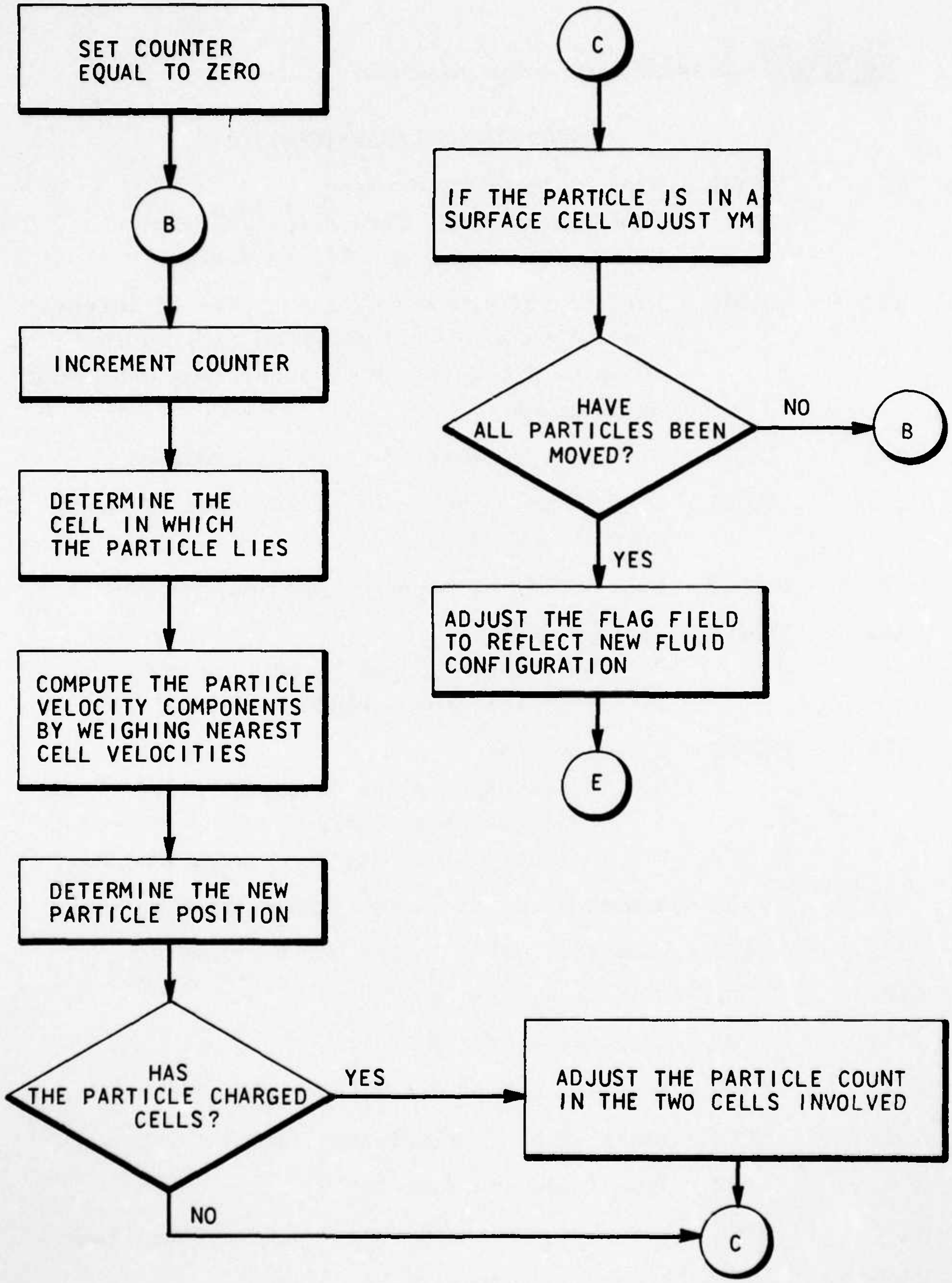


FIG. 13-2 DETAILED FLOW OF PARTICLE MOVEMENT

TRACOR DWG. A6-3-493

MODEL INPUT PARAMETERS

(1) ITYPE - Type of boundary desired
FRSLP - indicates free slip condition
NOSLP - indicates no slip condition

(2) LUNIN - Logical unit number of input tape if initial conditions are set from taped information (0 value indicates input conditions generated by program)

(3) IFLIN - File number of taped input information

(4) LUNOUT - Logical unit number of output tape if taped output is desired

(5) IFLOUT - File number of taped output information

(6) ITCODE - Taping code
0 - indicates no taped output desired
1 - indicates taped output desired

(7) IPCODE - Plotting code
0 - indicates no plots desired
1 - indicates plots desired
2 - indicates plots desired except at time 0

(8) NDX - Number of cells in the X-Direction

(9) NDY - Number of cells in the Y-Direction

(10) DX - Cell Length (ft.)

(11) DY - Cell Height (ft.)

(12) TMIN - Initial time of calculation (sec.)

(13) TMAX - Final time of calculation (sec.)

(14) DT - Time increment (sec.)

(15) TPFR - Time between taped output and/or plots (sec.)

(16) VIS - Kinematic viscosity ($ft.^2/sec.$)

(17) EPSI - Epsilon value used in pressure relaxation test

VARIABLE FIELD DESCRIPTION

(1) U - Horizontal velocities, defined on vertical walls (ft./sec.)

(2) V - Vertical velocities, defined on horizontal cell walls (ft./sec.)

(3) UT - Partial term used in advancing the horizontal velocity field

(4) VT - Partial term used in advancing the vertical velocity field

(5) P - Pressure divided by density, defined at cell centers ($ft.^2/sec.^2$)

(6) R - Partial term used in Poisson's equation

(7) F - Flag field, used to designate cell type

(8) PT - Pressure boundary condition information

(9) D - Divergence ($sec.^{-1}$)

(10) UC - Horizontal velocity at cell center (ft./sec.)

(11) VC - Vertical velocity at cell center (ft./sec.)

(12) UV - Product velocity at cell corner ($ft.^2/sec.^2$)

(13) PS - Number of marker particles in each cell

(14) X - Horizontal particle position (ft.)

(15) Y - Vertical particle position (ft.)

(16) YM - Maximum particle height in each cell (ft.)

13.2 Galveston Bay Hydraulic Model

1. Description: A dynamic hydraulic simulation model has been developed for the Galveston Bay estuary. The model obtains a solution to the equation of fluid motion by using the two-dimensional dynamic Navier-Stokes equations in a finite-difference form, and advancing the solution through finite time increments over a grid structure which has been superimposed over the bay area. The basic framework of the hydraulic model is the two-dimensional grid system over the entire bay area with each cell assigned a depth and frictional coefficient representative of bottom composition. The parameter values for each cell represent averages over the area represented by that particular cell. Also associated with each cell is the necessary information to determine that cell's orientation with respect to surrounding land barriers and internal boundary constraints. The model requires a set of initial conditions, as well as a complete set of boundary conditions, such as tidal action, fresh water inflow, and topography.

2. Input Parameters:

   Number of cells and cell size
   Time duration of run and time increment
   Frictional coefficients
   Depth
   Wind direction and intensity
   Tidal action
   Fresh water inflow
   Flag field which designates cell type and orientation

3. Output Parameter:

The output of the model consists of tidal records at any point in the bay, as well as a complete description of the water velocity in the bay as a function of time. This velocity information can serve as input to the Galveston Bay Water Quality-Transport Models of conservative and non-conservative substances (see 13.3.)

4. Comments: The Galveston Bay Hydraulic Model is quite applicable to other estuaries where vertical velocity gradients are not significant. Because the vertical component has been neglected, the model is limited to horizontal spatial output and cannot predict vertical gradients. An intended enhancement of the model is the addition of two-dimensional channel models within the bay which require consideration of the vertical component, and the subsequent linking of these channel models to the bay model.

Another refinement which is to be made in the hydraulic model is the inclusion of a finer grid spacing in certain areas of the bay which require detailed study. It is anticipated that in certain areas a fine grid will be used in conjunction with a coarse grid over the remainder of the area to better simulate the hydraulic conditions in the bay.

5. References: Espey, W. H. Jr., "Galveston Bay Study Phase I," TRACOR Document Number 68-566-U, September 1968.

13.3 Galveston Bay Water Quality-Transport Models

1. Description: Models are being developed which obtain a numerical solution of the two-dimensional mass balance equation using transport characteristics provided by the Galveston Bay Hydraulic Model. The mathematical expression of the transport characteristics throughout the bay system, coupled with the sources and sinks of the substance within the system, describes the distribution of the substance in the estuary. As in the Hydraulic Model, a grid structure is superimposed over the bay area, and the solution of the finite-difference form of the mass balance equation is advanced through time in discrete time increments. Since the Transport Model depends directly upon the output of the Hydraulic Model, it is important that the grid structure of the two models be compatible.

2. Input Parameters:

   Number of cells and cell size
   Time duration of run and time increment
   Velocity components as a function of time
   Mathematical description of sources and sinks
   Flag field which designates cell type and orientation

3. Output Parameter:

   The output of the model consists of concentration distributions of the particular conservative or non-conservative substance under investigation. This information is generally displayed as a contour map.

4. Comments: The Galveston Bay Water Quality-Transport Models, like the Hydraulic Model, are applicable to many other estuaries, especially the shallow bays along the Gulf Coast. For example, this model has been applied to obtain temperature contours in Nueces Bay. Any water quality parameter can be modeled provided the sources and sinks of the substance in the watercourse can be

characterized mathematically. Parameters for which the model is to be applied in Galveston Bay are DO (dissolved oxygen), BOD (biochemical oxygen demand), salinity, temperature, coliforms and nutrients.

5. References: Espey, W. H., Jr., "Galveston Bay Study Phase I," TRACOR Document Number 68-566-U, September 1968.

14. TRACOR DISPLAY FACILITY

14. TRACOR DISPLAY FACILITY

TRACOR, Inc.'s display facility, associated primarily with the Sensory Information Research Group, is a stand-alone, digital television type display. The unit will accept digital data from computer generated magnetic tape, providing a dynamic, continuous display of information. The programmable control unit can provide a wide variety of formats for the display. Information may be displayed in eight levels of grey, ranging from black to bright white, or the display may be in color, where there are 512 different colors available. The active color screen area is square and covers over 110 square inches. There are over 40,000 independent data spots on the color screen, each of which may assume one of the 512 available colors. The black and white screen has over 120,000 data spots, with eight levels of grey available for each spot.

The digital display unit is not limited to graphics, in that information may cover the entire active screen. Lines may still be represented, but backgrounds may be shaded, either in solid colors or in continuous color gradation. The legibility of topographic displays, such as maps, constant contour plots, and bar graphs may be improved by the use of colors. Up to 64 alphanumeric characters are available on both color and black and white displays. The standard character set contained in the graphics program includes the 26 characters of the English alphabet, the 10 Arabic numerals, and 28 special symbols which include those designating algebraic operations. The symbols may be translated and rotated to arbitrary positions on the screen. The displays are dynamic, that is, the information displayed may be continuously varied with time. A very important application of this feature has been the simulation of many different types of sonar displays, both operational and conceptual.

In this simulation, bearing, range, and/or time information from active or passive sonars is presented to an operator just as if he were aboard ship. There are three anechoic, acoustically isolated booths available for the operator, with separate controls so that he may also initiate ping cycles or stop the input of new information, providing a static, flicker free display. With the isolation booths, studies also may be performed with a combination of audio and visual information, providing the capability to simulate virtually any sonar operator environment, existing or theoretical.

Existing sonar displays which have been simulated include the AN/SQS-26 (A-scan and B-scan) and the AN/SQQ-23 PAIR displays. The effects of mutual ship interference were studied effectively with a realistic sonar environment for these sonars. Studies have been made to determine optimum pulse shapes for detection and classification of underwater targets. Much exploratory development has been performed concerning the use of color displays in future sonar systems, utilizing colors to represent such quantities as Doppler shifts, amplitude, and bearing angles. The simulated displays have also been used in a series of psychophysical experiments to determine the effect of information presentation technique on human observers. Through this human factor research, the present understanding of the man-machine interface may be greatly increased.

These display facilities are by no means limited to sonar applications. The color display has been utilized to display the results from various other system simulation models. The results from the hydrodynamic model have been effectively presented as a dynamic representation of fluid motion on the color screen. Industrial acoustic environments have been displayed in color. Natural gas pipeline maps, air pollution topography, and rainfall contour maps are among the applications of the color display. Visual aided instruction has also been studied by the Human Factors Research Group.

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SCIENCES AND SYSTEMS DIVISION SIMULATION MODELS CATALOG.(U)

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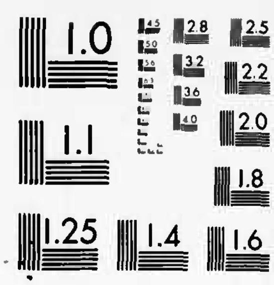

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

Photographic equipment and developing facilities supplement this display capability. Color slides and prints of the display screen may be made for permanent records and presentation aids. Items such as bar graphs, "pie" graphs, and other management aids may be displayed on the screen and photographed for presentation.

The capabilities of the display facility are presently being enhanced by the incorporation of the DDP-116 computer into the display system, as well as by providing a direct interaction capability of the DDP-116 with the UNIVAC 1108 system scheduled for later this year. With this advancement will come the ability to display and photograph data as it is processed by the computers. Formats, as well as the processing method used on the data, may be changed at the discretion of the operator. Also scheduled is the incorporation of a light pen to be used with the display. These and future advancements will provide TRACOR, Inc., with a most versatile display system, allowing advanced research and modern, efficient display of almost any type of information as it is generated by the computers.

1. Description of Digital Display System: This digital display system was designed to obtain dynamic displays of information in widely varied formats. The display facility consists of four standard black and white television monitors, a color television monitor, and two smaller monitors, color and black and white, fed by a core memory through a digital control system. The core memory is updated by a digital tape transport. A general block diagram of the system is shown in Fig. 14-1.

The general operation of the system is:

(1) Magnetic tapes are generated using the computer facility. These tapes contain digital information and can represent any encoded analog signals.

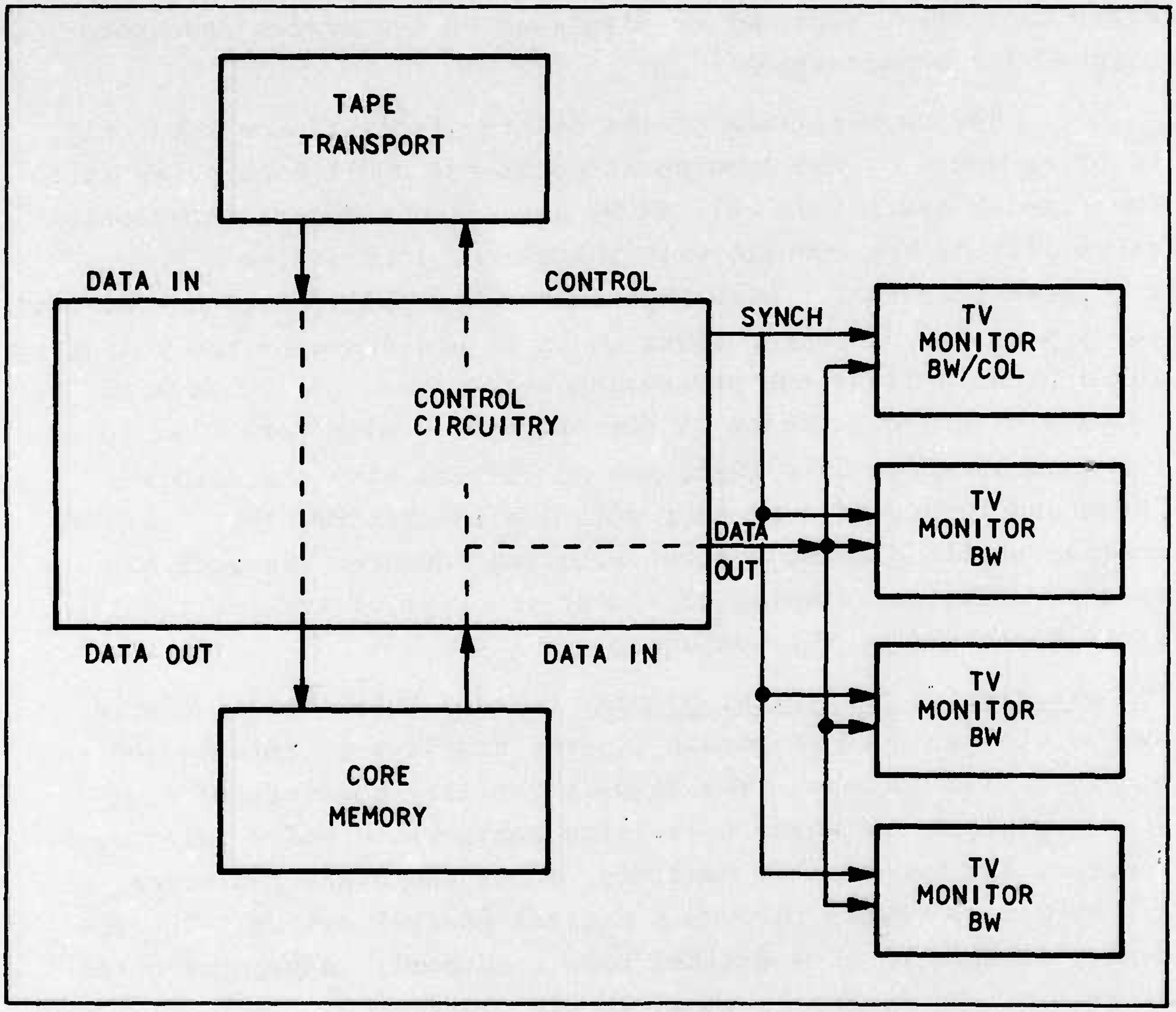

FIG. 14-1 BASIC DIGITAL DISPLAY SYSTEM BLOCK DIAGRAM

(2) The digital tape transport is then used to transfer information from the magnetic tape to the core memory.

(3) The system control unit sequentially scans the core memory and transfers the information to the television display monitors. This is done at an equivalent 60 Hz rate so that a flicker free display is obtained. A 30 Hz rate can be selected to simulate some existing sonar displays in which flicker is present.

(4) New information from the digital tape input can be supplied to the core memory at any time, allowing real time changes in displayed information. The display output is completely determined by the computer program, making the display very flexible.

2. Introduction to Microfilm Plotter/Printer: TRACOR, Inc., has recently obtained a microfilm plotter/printer, a modern, efficient unit which can record on 35 mm or 16 mm microfilm the image from a digital black and white television graphic display unit, similar to the unit described earlier. The resolution of this device is very fine, and will allow expanded visibility of minute details. This microfilm system is a complete system from data input to data display, supplied by the Stromberg-Carlson Company. The unit is under the control of a DDP-516 computer, a medium size, general purpose computer, large enough to permit limited data processing on some input data, or to actually generate data from smaller simulation programs.

Included in the package is a library of programs for the DDP-516 which allows the system to interpret data from UNIVAC 1108 generated magnetic tape and present the data in a wide variety of ways. This display system operates in much the same manner as the BW digital display, but is limited to graphic presentations. The same characters and graph formats are available, as are used on the Cal Comp plotters. This system is much faster than the plotters, however, and produces clear, labeled diagrams and graphs which may be used directly in reports. The printer operates in much the same way as conventional Xerox copying machines, and can produce paper prints, view graphs, or vellum copies. Forms-overlay slides which project onto the microfilm during exposure are available, and can eliminate much of the computer effort in drawing standard forms, backgrounds, and borders on the prints. Cross-hatching is quick and uniform.

The display can be used as a high speed microfilm printer, a high speed digital plotter, a high speed drafting machine, and as a general purpose graphics device. It will also permit drawings and other records to be stored completely and permanently, available for rapid machine retrieval and printing.

3. Description of Microfilm Plotter/Printer: The microfilm unit is an advanced electronic system, complete within itself. Included in the system are two magnetic-tape units, a DDP-516 computer with teletype control, a black and white television monitor, a microfilm camera, a developing unit, and a printer. Operation of the system is outlined as follows:

(1) Data is generated and written on magnetic tape by the DDP-116 or UNIVAC 1108 computers, (smaller simulations may be done with the DDP-516) and placed on the data tape transport.

(2) The desired program for displaying the data is chosen from the library and placed on the program tape transport. (The programs are placed on magnetic tape for rapid compilation, otherwise paper tape would be fed into the teletype.)

(3) The operator initiates operation of the unit through the teletype control.

(4) The television monitor is tuned as desired, overlays may be placed over the camera lens, and a photograph is taken.

(5) The film is developed and the desired print is obtained from the printer.

Abstracts of routines available for use with the display facility make up the remainder of this section.

PROGRAM NAME: SPOT
NATURE OF WORK: TRACOR COLOR DISPLAY

PROGRAM FUNCTION

BASIC ROUTINE TO DRIVE THE TRACOR COLOR DISPLAY; CAUSES ONE SPOT OF SPECIFIED HUE TO BE DISPLAYED USING THE SPECIFIED LINE-SPOT COORDINATES.

OPERATING INSTRUCTIONS

1. CALLING SEQUENCE: FORTRAN V SUBROUTINE

2. PARAMETERS:
   ISPOT = NUMBER OF SPOT POSITION; 1 .LE. ISPOT .LE. 190. SPOT NO. 1 IS AT LEFT OF SCREEN, NO. 190 AT RIGHT EDGE.
   LINE = NUMBER OF LINE ON WHICH SPOT IS TO OCCUR; 1 .LE. LINE .LE. 215. LINE NO. 1 IS AT TOP OF SCREEN, 215 AT BOTTOM.
   IHUE = HUE WHICH SPOT IS TO HAVE; 0 .LE. IHUE .LE. 511. IHUE MAY BE THOUGHT OF AS A THREE DIGIT OCTAL NUMBER IN WHICH THE LEAST SIGNIFICANT DIGIT CONTROLS THE INTENSITY OF THE GREEN COMPONENT, THE MIDDLE DIGIT THE BLUE COMPONENT, THE MOST SIGNIFICANT DIGIT THE RED. THE MAGNITUDE OF EACH DIGIT IS DIRECTLY PROPORTIONAL TO THE BRIGHTNESS OF THE CORRESPONDING COLOR COMPONENT. IHUE = R B G

3. EXAMPLE:
   CALL SPOT(ISPOT,LINE,IHUE)

4. OPERATION:
   A REPLICA OF THE DISPLAY CORE UNIT IS MAINTAINED. THE DESIRED HUE CODES ARE PLACED INTO THIS REPLICA AND THEN 90 BIT SEGMENTS ARE MOVED TO THE TAPE BUFFERS ALONG WITH THEIR ADDRESS, IN DISPLAY FORMAT.

5. EXTERNAL REFERENCES: TCDOUT.

PROGRAM NAME: TCDOUT
NATURE OF WORK: TRACOR COLOR DISPLAY

PROGRAM FUNCTION

WRITE CODES FOR TRACOR COLOR DISPLAY ONTO TAPE.

OPERATING INSTRUCTIONS

1. CALLING SEQUENCE: FORTRAN V SUBROUTINE.

2. PARAMETER: LETTER OF THE LOGICAL TAPE UNIT RIGHT JUSTIFIED IN FIELD DATA CODE. THIS IS OPTIONAL AND IF NOT SPECIFIED THE PREVIOUSLY USED UNIT IS ASSUMED.

3. EXAMPLES:

```
CALL TCDOUT(1RA)
CALL TCDOUT
```

4. OPERATION:
VARIABLE LENGTH RECORDS ARE WRITTEN IN BINARY OR ODD PARITY. THE NUMBER OF WORDS WRITTEN IS IN LOCATION OUTWRD IN ROUTINE SPOT. THE CODES WRITTEN ARE IN BUFFER OBUFF IN ROUTINE SPOT.

5. ERROR MESSAGES:
ERROR MESSAGE ARE PRINTED IF TAPE ERRORS OCCUR.

6. EXTERNAL REFERENCES: OUTWRD, OBUFF BOTH LOCATED IN ROUTINE SPOT.

PROGRAM NAME: TCDBTR
NATURE OF WORK: TRACOR COLOR DISPLAY

PROGRAM FUNCTION

INITIALIZE TAPE BUFFER TO RESTART A LOGICAL RECORD.

OPERATING INSTRUCTIONS

1. CALLING SEQUENCE:
   FORTRAN V SUBROUTINE.

2. PARAMETERS: NONE

3. OPERATION:
   IF IN THE FILLING OF A LOGICAL RECORD, IT IS DESIRED TO BEGIN AGAIN ON THAT RECORD, TCDBTR CAN BE USED TO SUPPRESS SOME (PROBABLY ALL) UNDESIRED TAPE UNIT MOTION BY REINITIALIZING THE OUTPUT ROUTINE. TO DO THIS, OUTWRD IS SET TO ZERO.

4. EXTERNAL REFERENCES:
   OUTWRD IN ROUTINE SPOT.

PROGRAM NAME: TCDON
NATURE OF WORK: TRACOR COLOR DISPLAY

PROGRAM FUNCTION

INITIALIZES DISPLAY BY CLEARING SCREEN AND SETTING UP A NEW TAPE RECORD.

OPERATING INSTRUCTIONS

1. CALLING SEQUENCE:
   FORTRAN V SUBROUTINE.

2. PARAMETER:
   TAPE UNIT DESIGNATOR LETTER IN FIELD DATA CODE, RIGHT JUSTIFIED.

3. OPERATION:
   THE REPLICA ARRAY OF THE DISPLAY SCREEN IS SET TO ZERO; TWO RECORDS ARE WRITTEN TO ZERO THE DISPLAY CORE.

4. EXAMPLE:

   CALL TCDON(1RA)

5. EXTERNAL REFERENCES:
   SUBROUTINE TCDOUT, LOCATIONS OUTWRD, OBUFF, SCREEN WHICH ARE IN ROUTINE SPOT.

PROGRAM NAME: TCDPTP
NATURE OF WORK: TRACOR COLOR DISPLAY

PROGRAM FUNCTION

ROUTINE TO DRAW A STRAIGHT LINE SEGMENT DEFINED BY THE TWO END POINTS ON THE TRACOR COLOR DISPLAY.

OPERATING INSTRUCTIONS

1. CALLING SEQUENCE:
   FORTRAN V SUBROUTINE

2. PARAMETERS:
   IX1 = SPOT COORDINATE OF ONE END OF SEGMENT
   IY1 = LINE COORDINATE OF END CORRESPONDING TO IX1
   IX2 = SPOT COORDINATE OF OTHER END OF SEGMENT
   IY2 = LINE COORDINATE OF END CORRESPONDING TO IX2
   IHUE = HUE OF SEGMENT - SEE SPOT FOR DEFINITION.

3. EXAMPLE:

```
CALL TCDPTP(IX1,IY1,IX2,IY2,IHUE)
```

4. OPERATION:
   A LINE IS DISPLAYED FROM POSITION (IX1,IY1) TO POSITION (IX2,IY2).

5. EXTERNAL REFERENCES:
   NON-STANDARD SUBROUTINE REFERENCED IS SPOT; SEE WRITE-UP IN THIS PACKAGE FOR ITS OPERATION.

PROGRAM NAME: TCDPLA
NATURE OF WORK: TRACOR COLOR DISPLAY

PROGRAM FUNCTION

ROUTINE TO DISPLAY A STRAIGHT LINE SEGMENT DEFINED IN POLAR FORM ON THE TRACOR COLOR DISPLAY.

OPERATING INSTRUCTIONS

1. CALLING SEQUENCE:
   FORTRAN V SUBROUTINE

2. PARAMETERS:
   IX = SPOT NUMBER OF THE ORIGIN OF THE VECTOR.
   IY = LINE NUMBER OF THE ORIGIN OF THE VECTOR.
   DIST = LENGTH IN INCHES OF THE VECTOR (DISPLAY IS 16.5 X 14.0 INCHES)
   THETA = ANGLE OF VECTOR IN DEGREES MEASURED ON A STANDARD CARTESIAN COORDINATE SYSTEM WITH (IX,IY) THE ORIGIN OF THE SYSTEM.
   IHUE = HUE OF VECTOR - SEE SUBROUTINE SPOT

3. EXAMPLE:

```
CALL TCDPLA(IX,IY,DIST,THETA,IHUE)
```

4. OPERATION:
   THE END POINTS OF THE VECTOR ARE COMPUTED AND TCDPTP USED TO DRAW THE LINE.

5. EXTERNAL REFERENCE: TCDPTP

PROGRAM NAME TCDARC
NATURE OF WORK: TRACOR COLOR DISPLAY

PROGRAM FUNCTION

SUBROUTINE TO DISPLAY ARC SEGMENTS ON THE TRACOR COLOR DISPLAY. ENDS OF SEGMENTS ARE SPECIFIED IN POLAR COORDINATES.

OPERATING INSTRUCTIONS

1. CALLING SEQUENCE:
   FORTRAN V SUBROUTINE

2. PARAMETERS:
   IX = SPOT NUMBER OF ORIGIN OF POLAR COORDINATE SYSTEM.
   IY = LINE NUMBER OF ORIGIN OF POLAR COORDINATE SYSTEM.
   R1 = LENGTH OF RADIUS VECTOR TO POINT 1 IN FLOATING POINT INCHES
   T1 = ANGLE OF RADIUS VECTOR TO POINT 1 IN FLOATING POINT DEGREES
   R2 = LENGTH OF RADIUS VECTOR TO POINT 2 IN FLOATING POINT INCHES
   T2 = ANGLE OF RADIUS VECTOR TO POINT 2 IN FLOATING POINT DEGREES
   IHUE = COLOR OF ARC

3. EXAMPLE:

```
CALL TCDARC(IX,IY,R1,T1,R2,T2,IHUE)
```

4. OPERATION:
   THE POLAR COORDINATE SYSTEM IS ORIENTED SO THAT THE 0-180 DEGREE LINE IS HORIZONTAL, IN STANDARD POLAR FORM. BEGINNING WITH POINT (R1,T1) THE END POINTS OF STRAIGHT LINE SEGMENTS ARE CALCULATED WITH THE ANGLE CHANGING IN 1/2 DEGREE STEPS AND THE RADIUS LENGTH CHANGING LINEARLY. THESE LINE SEGMENTS ARE DRAWN USING TCDPTP.

5. EXTERNAL REFERENCES:
   SUBROUTINE TCDPTP

PROGRAM NAME: COORD
NATURE OF WORK: TRACOR COLOR DISPLAY

PROGRAM FUNCTION

ROUTINE TO PERFORM COORDINATE UNIT CHANGE FROM INCHES TO SPOTS-LINES.

OPERATING INSTRUCTIONS

1. CALLING SEQUENCE:
   TWO FORTRAN V FUNCTION SUBPROGRAMS:
   TCDITS - CONVERTS INCHES TO SPOT NUMBER
   TCDITL - CONVERTS INCHES TO LINE NUMBER

2. PARAMETERS:

   TCDITS(XINCH)

   IF XINCH .GE. 0 EQUIVALENT SPOT NUMBER FOR XINCH AS MEASURED FROM LEFT OF SCREEN IS RETURNED.
   IF XINCH .LE. 0 EQUIVALENT SPOT NUMBER FOR XINCH AS MEASURED FROM RIGHT OF SCREEN IS RETURNED.

   TCDITL(XINCH)

   IF XINCH .GE. 0 EQUIVALENT LINE NUMBER FOR XINCH AS MEASURED UP FROM BOTTOM IF SCREEN IS RETURNED.
   IF XINCH .LE. 0 EQUIVALENT LINE NUMBER FOR XINCH AS MEASURED DOWN FROM TOP OF SCREEN IS RETURNED.

3. EXAMPLES:
   ABSCSA = TCDITS(XINCH)
   ORDANT = TCDITL(XINCH)

PROGRAM NAME: TCDSTU
NATURE OF WORK: TRACOR COLOR DISPLAY

PROGRAM FUNCTION

ROUTINE SELECTS WHICH TAPE UNIT WILL RECEIVE THE CODES FOR THE TRACOR COLOR DISPLAY.

OPERATING INSTRUCTIONS

1. CALLING SEQUENCE:
   FORTRAN V SUBROUTINE

2. PARAMETER:
   THE LETTER OF THE TAPE LOGICAL UNIT SPECIFIED IN FIELD DATA CODE, RIGHT JUSTIFIED.

3. EXAMPLE:

```
CALL TCDSTU(6H     A)
```

THIS WILL CAUSE UNIT 'A' TO BE USED.

4. EXTERNAL REFERENCES:
   LOCATIONS OTPARM, CKPARM IN TCDOUT.

PROGRAM NAME: TCDELR
NATURE OF WORK: TRACOR COLOR DISPLAY

PROGRAM FUNCTION

WRITE CODES ON TAPE TO TERMINATE THE CURRENT LOGICAL RECORD. THERE IS ONE LOGICAL RECORD PER 'FRAME' DISPLAYED.

OPERATING INSTRUCTIONS

1. CALLING SEQUENCE:
   FORTRAN V SUBROUTINE

2. PARAMETER:
   LETTER OF THE LOGICAL TAPE UNIT RIGHT JUSTIFIED IN FIELD DATA CODE. THIS IS OPTIONAL AND IF NOT SPECIFIED THE PREVIOUSLY USED UNIT IS ASSUMED.

3. EXAMPLE:

```
CALL TCDELR(6H     A)
```

4. OPERATION:
   THE CURRENT CONTENTS OF THE TAPE BUFFER ARE WRITTEN ON TAPE AND AN END OF FILE WRITTEN TO TERMINATE THE LOGICAL RECORD.

5. EXTERNAL REFERENCES:
   TCDOUT

ATE

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