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GENERALIZED DIGITAL SIMULATION OF A CDA DIRECTION FINDING SYSTEM

by
EDWARD W. ERNST
R. E. HUNNINGHAUS

RRL PUBLICATION NO. 382

November 1970

Technical Report No. 21
Contract N00014-67-A-0305-0002

Supported by
Office of Naval Research
and the
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RADIOLOCATION RESEARCH LABORATORY
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ABSTRACT

The simulation program GCAAS (General Circular Antenna Array Simulator) has been developed to simulate the output data from a circularly disposed antenna array (CDAA)-direction finding system under known input signal conditions. The CDAA system which has been simulated is similar to the Wullenweber Direction Finding System at the University of Illinois and may consist of as many as 360 antenna elements in a circular array of any reasonable dimensions and simulates the outputs obtained from the array used in a scanning mode.

The input signal conditions may include up to five incoming signals at different azimuthal and elevation angles of arrival with time-dependent relative phase shifts between the incoming signals. The output consists of the sum, difference and differential phase data sampled at regular intervals of azimuth and stored on magnetic tape for further use in the determination of the direction of arrival. A maximum of 100 samples of the output data set may be obtained from each scan.

I. INTRODUCTION

This generalized simulator of a circularly disposed antenna array (CDAA) direction finding system has been developed to satisfy the need for a means of producing simulated system output data, under known input conditions, to be used in future studies relating to the different methods for direction of arrival calculation. As a consequence of the general nature of the simulator, it may also be used in studies related to the construction and operation of the CDAA system.

The system outputs simulated are the scanning mode sum, difference, and differential phase information; it is possible in this simulator to produce these outputs corresponding to a series of related time-dependent scans. The primary needs for this simulated data are for use in: 1) development of a difference method for direction of arrival calculation, 2) a study of the presently used sum and differential phase methods for direction of arrival calculation, and 3) a comparison of the three methods for direction of arrival calculation.

The known input conditions this simulator has been designed to handle are:

- 1) Single input signal.
- 2) Multiple input signals from the same source (wave interference).
- 3) Amplitude modulation of the signal.
- 4) Addition of random noise to the signal.

The individual signal conditions which comprise the total input signal conditions are to be specified (for each input signal) by azimuthal and elevation angle, relative amplitude, initial reference phase and a time-dependent reference phase shift.

II. THE PHYSICAL SYSTEM

The CDAA direction finding system to be simulated is similar to the Wullenweber Direction Finding System at the University of Illinois.

The array consists of a number of identical folded vertical monopole antenna elements, mounted on a ground mat, evenly spaced around the circumference of a circle. Within this circular array and concentric to it is located a vertical reflecting cylinder of a height somewhat greater than that of the antenna elements. The output of each antenna element is connected by a matched cable to a multicoupling device; each cable has the same electrical length. Each multicoupler is a wide band amplifier with a gain of unity and several outputs with the same output signal are available at each of the multicoupler outputs. (Refer to Figure 1.)

One output from each multicoupler is fed into an electro-mechanical scanner. This scanner selects a group of consecutive antenna elements to produce a number of scanning element voltages. These scanning elements have the same angular spacing as the antenna elements and are subdivided into a right and left bank, each of which has the same number of elements. Midway between the two banks is a plane of symmetry referred to as the boresight. The scanner is also set to rotate at a constant speed in the clockwise direction. Thus, the scanner is continually selecting new antenna elements to produce the scanning element voltages as the boresight moves to the right. (Note: The clockwise direction is referred to as the right and the counter-clockwise direction as the left.)

The right and left scanning elements are connected to the inputs of two identical sets of delay lines, one set for each bank. The effect of

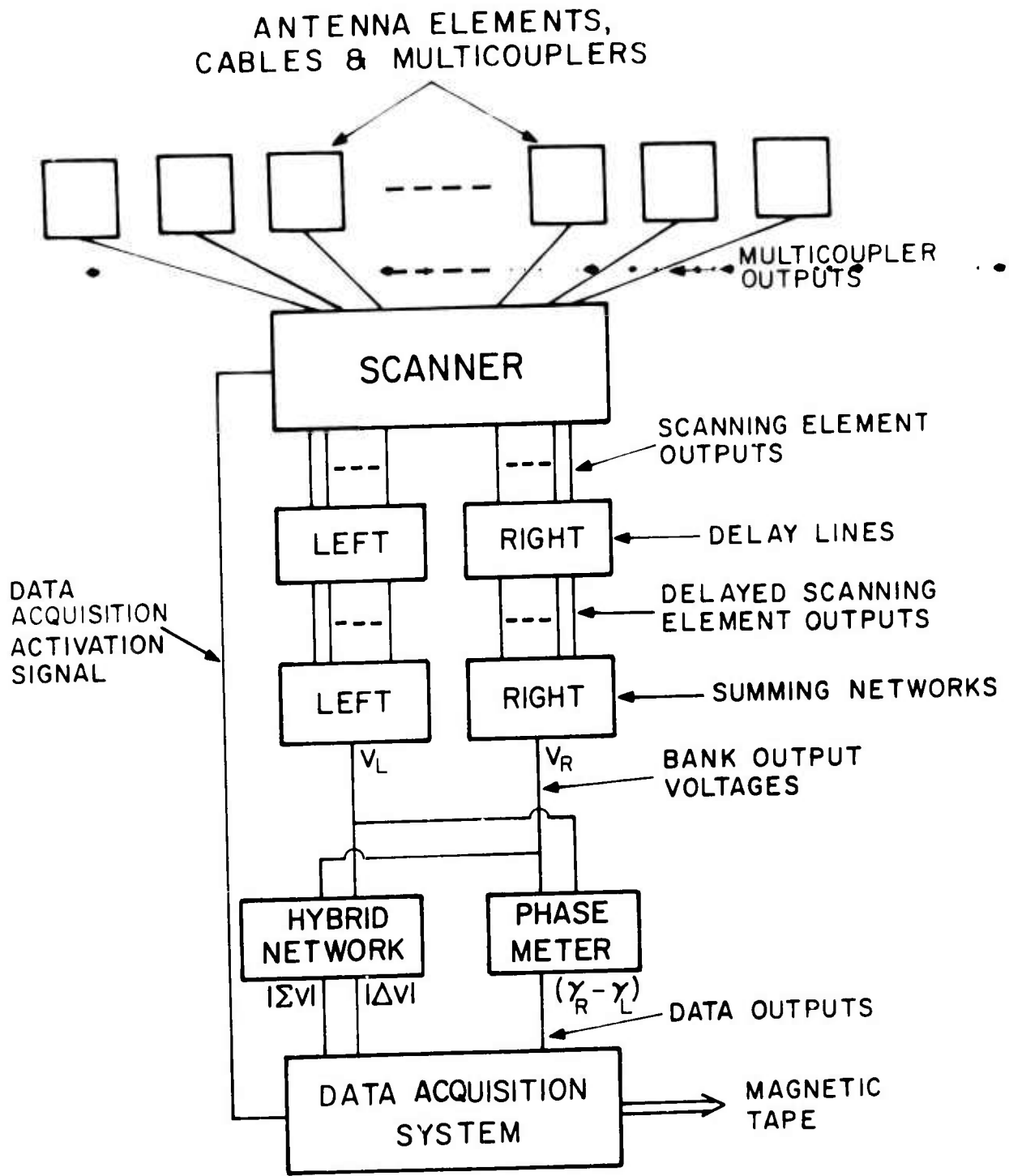


Figure 1. Block Diagram of CDA Direction Finding System.

the addition of the delay lines is to make the delayed scanning element voltages, for an incoming signal arriving at a particular elevation angle of arrival known as the cophasal angle, appear to be the same as the element voltages that would be received from a linear array of vertical antenna elements rotating about a vertical axis at the center of the array.

The outputs of the delay lines are tied to identical summing networks, one for each bank. These summing networks perform the phasor addition of the delayed scanning element voltages that are the inputs to the network. The outputs of the summing networks are the right and left bank voltages.

It is from these two bank voltages that the system outputs are obtained. Feeding the bank voltages into the hybrid network, the sum and difference voltages are obtained; feeding the bank voltages into the phase meter yields the differential phase data.

The system produces continuous analog data, but for acquisition and storage of the data in a digital format the data must be in a discretely sampled format. The data acquisition system¹ performs the necessary sampling and analog-to-digital conversion to put the output in a format suitable for tape storage.

The data acquisition system is activated by the position of the scanner boresight. Once the acquisition system is activated, the sum, difference, and differential phase data are sampled and converted from voltage level to digital representations and stored on magnetic tape. The activation settings in the scanner are such that a given number of sample points per scan is taken with equal angular intervals between the boresight positions for consecutive sample points. The entire angular interval over which the sample points are taken is referred to as the

sampling window. The window is always less than 90° and the center of the window has been designated the sector center.

It is from a later analysis of the information stored on the magnetic tape that the direction of arrival is calculated.

III. MATHEMATICAL MODEL OF THE SYSTEM

The model of the CDAA consists of NOA antenna elements located outside a reflecting cylinder of radius A with the distance from the antenna element to the reflecting cylinder surface equal to D.

In the model, an antenna element, cable, and multicoupler are considered one unit. Since all of the cables are of the same electrical length and the gain of each multicoupler is unity, the outputs of the multicouplers are taken to be the same as the outputs of the antenna elements to which they are connected. The phasor voltage output calculations used for the vertical folded monopole antenna elements, excited by a single signal are basically the same as those used by Jones.² These calculations have been expanded for multiple signals (wave interference) by the addition of a relative amplitude factor and a reference phase for each signal.

Jones' modified expressions for antenna element voltage, as modified for element i and signal w, are:

Amplitude

$$A_{iw}(\phi_{iw}, \theta_w) = [\cos(\theta_w) * \sin \frac{2\pi * D}{WL} * \cos(\phi_{iw}) * \cos(\theta_w)] * WAMP_w \quad (1)$$

Phase

$$P_{iw}(\phi_{iw}, \theta_w) = \frac{2\pi * A}{WL} * \cos(\phi_{iw}) * \cos(\theta_w) + WPHI_w \quad (2)$$

where

WL = Wavelength of the signal, calculated from the carrier frequency

FREQC (in MHz) as $WL = 299.8/FREQC$

A = Radius of the reflecting cylinder in meters

D = Antenna element to reflecting cylinder distance in meters

ϕ_{iw} = Difference between the azimuthal angle of the antenna element
i and the angle of arrival of signal w

θ_w = Elevation angle of signal w

$WAMP_w$ = Signal w relative amplitude factor

$WPHI_w$ = Signal w reference phase factor.

Figure 2 shows the geometry that relates these terms and Equations (1) and (2).

For the multiple input signal conditions the antenna element voltage, by superposition, is taken as the sum of the voltages excited by the individual signals. Since summations are more readily carried out in Cartesian coordinates rather than polar coordinates, the phasor voltages, which are excited by the individual signals, are converted from polar to Cartesian form and summed over the individual incoming signals to give the antenna element voltage. Thus for n incoming signals the complex antenna element voltage, for element i, is computed as:

$$RE_i = \sum_{w=1}^n [A_{iw} (\phi_{iw}, \theta_w) * \cos (P_{iw} (\phi_{iw}, \theta_w))] \quad (3)$$

$$IM_i = \sum_{w=1}^n [A_{iw} (\phi_{iw}, \theta_w) * \sin (P_{iw} (\phi_{iw}, \theta_w))]. \quad (4)$$

The superposition principle is also used to add the effect of the time-dependent phase shift, for the individual signals, to the antenna element voltage. The antenna element voltage is recalculated for the Time T by adding a phase shift voltage, for each incoming signal, to the element voltage at time T_0 . Thus for element i at time T, and n incoming signals, the element voltage is recalculated as:

$$RE_{i(T)} = RE_{i(T_0)} + [A_{iw} (\phi_{iw}, \theta_w) * (\cos (PA_2) - \cos (PA_1))] \quad (5)$$

$$IM_{i(T)} = IM_{i(T_0)} + [A_{iw} (\phi_{iw}, \theta_w) * (\sin (PA_2) - \sin (PA_1))], \quad (6)$$

where

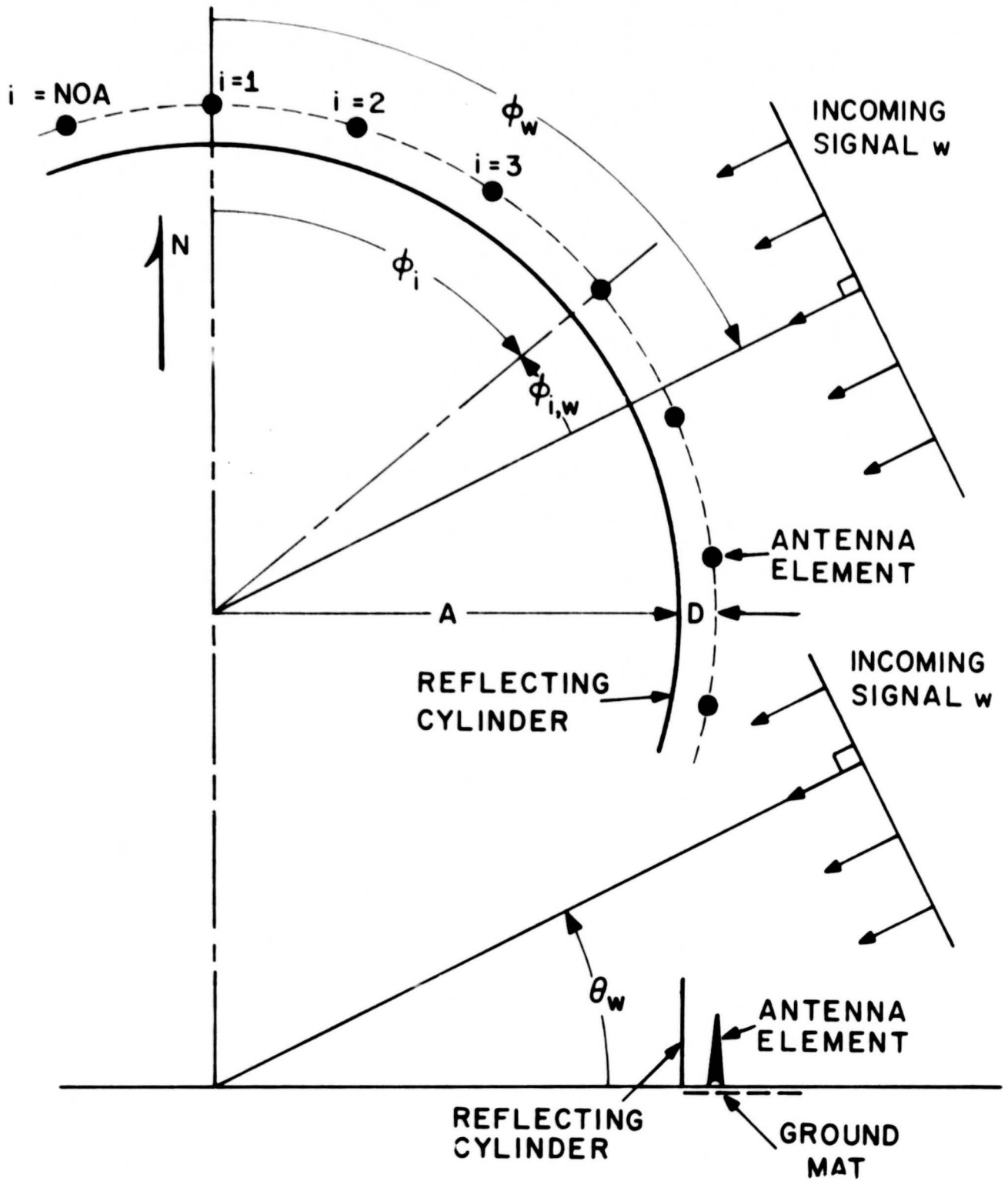


Figure 2. Antenna Array Geometry.

$$PA1 = P_{iw} (\phi_{iw}, w) + \text{Time Dep phase shift at } T_0, \text{ for signal } w \quad (7)$$

$$PA2 = P_{iw} (\phi_{iw}, w) + \text{Time Dep phase shift at } T, \text{ for signal } w. \quad (8)$$

For the calculation of the time dependent phase shift and the amplitude modulation of the incoming signals, it is necessary to compute simulated time. This simulated time has as its basis the rotation of the scanner. The scanner rotates once every SCANT seconds and if DEG is the angle of rotation of the boresight since $T=0$, then the simulated time T may be given by:

$$T = \text{SCANT} * (\text{DEG}/360) \quad (9)$$

Where PST_w is the amount of phase shift per scan for signal w , Equations (7) and (8) become

$$PA1 = P_{iw} (\phi_{iw}, \theta_w) + PST_w * (T_0/\text{SCANT}) \quad (10)$$

$$PA2 = P_{iw} (\phi_{iw}, \theta_w) + PST_w * (T/\text{SCANT}) \quad (11)$$

The scanner consists of NAS scanning elements with $NAS2 = NAS/2$ elements in each bank. The scanner will be set to take ISAM sample points per scan; the interval between the boresight for consecutive sample points in the scan is SAMI. The sector center is set at SECT and the width of the sampling window will be $WIDTH = (ISAM-1) * SAMI$.

The scanner reactively couples the scanning elements to the antenna elements to produce the scanning element voltage. The scanner is of such a nature that its coupling can be simulated by a direct (maximum to zero) relationship with the displacement of the boresight. When the scanning elements on the rotor are aligned with the antenna elements on the stator (or in other words, the boresight is exactly midway between two antenna elements), the scanning elements will have the same voltages as the antenna elements with which they are aligned and the adjacent

antenna elements will have no effect upon the scanning element voltages. As the rotor elements move out of direct alignment with the stator elements, the scanning element voltages will be taken as the sum of the effects of the two adjacent stator element voltages. (See Figure 3.) Consider a stator element 1 which is to the left or aligned with the rotor element i and the stator element r which is the first stator element to the right of element 1. The displacement between adjacent stator elements is $ANOA = (360/NOA)$ and if the displacement between stator element 1 and rotor element i is $CDEL$, the scanning element voltage will be taken as:

$$SRE_1 = [ARE_1 * (ANOA - CDEL) / ANOA] + [ARE_r * CDEL / ANOA] \quad (12)$$

$$SIM_1 = [AIM_1 * (ANOA - CDEL) / ANOA] + [AIM_r * CDEL / ANOA] \quad (13)$$

Since the scanner coupling is linearly related to displacement, it is possible to have sampling intervals which may have values other than multiples of an antenna spacing interval.

In modeling the system, the addition of signal amplitude modulation and random noise signals is most effectively done at the time the scanning element voltages are calculated. The amplitude modulation is added by multiplying the antenna element voltages by an amplitude factor calculated for the sample point of interest at that time, where it is considered that the sampling time is relatively short in comparison to the modulation period. The percent modulation is defined as $PCAM$ and the modulating frequency is $FREQM$ (in KHz). Using the simulated time T , for the sample point of interest, the amplitude modulation factor is:

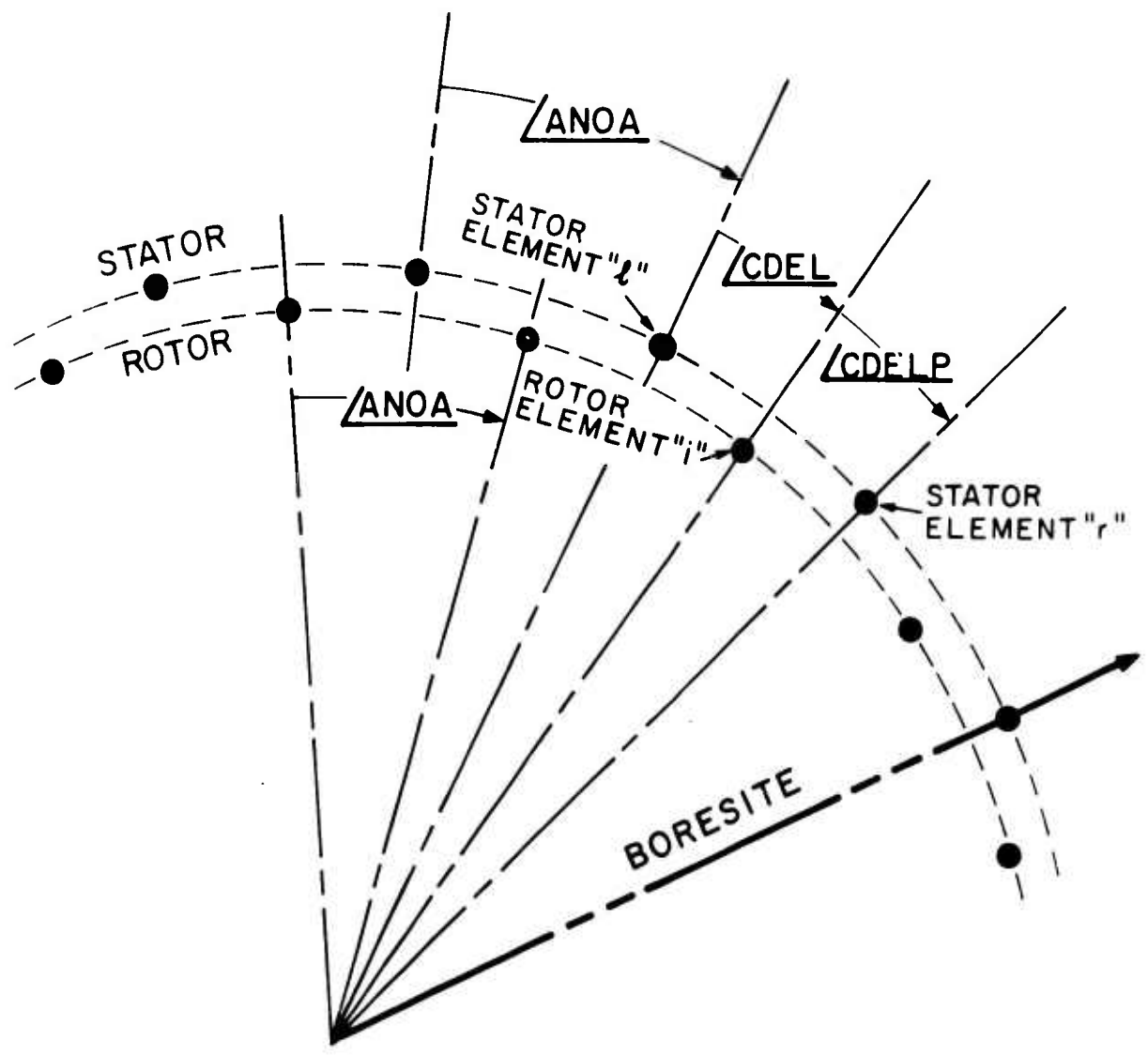


Figure 3. Scanner Geometry.

$$AMS = (1-PCAM) + PCAM * \cos(2\pi * FREOM * 1000 * T). \quad (14)$$

The noise signals are produced by the use of a random number generator. The random noise voltage (ANRE, ANIM) added to the antenna element voltages when the scanning element voltage is calculated, is determined by multiplying the relative noise level amplitude ANOISJ by successive real numbers supplied by a pseudo-random number generator. With the addition of amplitude modulation and random noise signals, Equations (12) and (13) become

$$\begin{aligned} SRE_1 = & [(AMS * ARE_1 + ANRE_1) * (ANOA-CDEL)/ANOA] \\ & + [(AMS * ARE_r + ANRE_r) * CDEL/ANOA] \end{aligned} \quad (15)$$

$$\begin{aligned} SIM_1 = & [(AMS * AIM_1 + ANIM_1) * (ANOA-CDEL)/ANOA] \\ & + [(AMS * AIM_r + ANIM_r) * CDEL/ANOA]. \end{aligned} \quad (16)$$

The delays which should be introduced by the phase delay lines are calculated from the antenna array geometry; for these calculations it is assumed that the scanning elements are aligned with the antenna elements around the circumference of the array. The phase delay that will be introduced for element i , which is i elements from the boresight, is directly proportional to the distance of signal propagation, along the boresight, from element i to the furthest element from the boresight, where the signal azimuthal angle of arrival is taken as the boresight setting. This distance can be realized as:

$$\begin{aligned} A * \cos(CPHI) * (\cos((i-1) * ANOA + ANOA2) \\ - \cos((NAS2-1) * ANOA + ANOA2)) \end{aligned}$$

where $ANOA2 = ANOA/2$ and $CPHI$ is the cophasal or assumed elevation angle of arrival. (See Figure 4.) The phase delay is then determined in radians

$$\text{as: } PDELAY_1 = (2\pi * A/WL) * \cos(CPHI) * (\cos((i-1) * ANOA + ANOA2) - \cos((NAS2-1) * ANOA + ANOA2)). \quad (17)$$

In modeling the system it is possible to combine the addition of the phase delays to the scanning element voltages and the operation of the summing network so that the bank voltages may be calculated directly from the scanning element voltages. The phase delays are added to the scanning element complex voltages, to obtain the delayed scanning element complex voltages, as if the phase delays were a rotation of the axes in a Cartesian coordinate system. The summing network, as the name implies, produces the complex voltage for the bank by computing the complex sum of the delayed scanning element voltages. Thus the combined effect of the delay lines and the operation of the summing network will determine the bank voltage as:

$$\text{SUMI} = \sum_{i=1}^{\text{NAS2}} [\text{SIM}_i * \text{COS} (\text{PDELAY}_i) - \text{SRE}_i * \text{SIN} (\text{PDELAY}_i)] \quad (18)$$

$$\text{SUMR} = \sum_{i=1}^{\text{NAS2}} [\text{SIM}_i * \text{SIN} (\text{PDELAY}_i) + \text{SRE}_i * \text{COS} (\text{PDELAY}_i)] \quad (19)$$

The system outputs are obtained as the outputs of the hybrid network and the phase meter with the right and left bank voltages used as the inputs.

The outputs of the hybrid network are the complex sum and difference of the bank voltages; the magnitudes of these two complex quantities are the sum and difference data outputs for the system. These two operations are carried out as:

$$\text{DATAST} = \text{SQRT} ((\text{SUMR}_r + \text{SUMR}_l) ** 2 + (\text{SUMI}_r + \text{SUMI}_l) ** 2) \quad (20)$$

for the sum data, and

$$\text{DATADT} = \text{SQRT} ((\text{SUMR}_r - \text{SUMR}_l) ** 2 + (\text{SUMI}_r - \text{SUMI}_l) ** 2) \quad (21)$$

for the difference data.

The differential phase measured by the phase meter provides the

differential phase data output and is computed as

$$\text{DATP} = \text{ATAN2}(\text{SUMI}_r, \text{SUMR}_r) - \text{ATAN2}(\text{SUMI}_1, \text{SUMR}_1) \quad (22)$$

where ATAN2 is $\tan^{-1}(\text{SUMI}/\text{SUMR})$ defined from -180 to $+180$ degrees.

In modeling the system on a digital computer the function of the data acquisition system has been simulated, as the output is already in a digital form and can be stored on magnetic tape in a digital format. It should be noted that in modeling the system the relationship between the position of the scanner boresight and the simulated time, for a given sequence of scans or sample points, is the same as the relationship between the position of boresight of the physical system and real time, for the same sequence.

IV. THE SIMULATION PROGRAM - OPERATION OF SIMULATION

The simulation program has been named GCAAS, standing for General Circular Antenna Array Simulator. A listing of this program is contained in Appendix A of this report

In an attempt to facilitate a rapid understanding of the basic operation of the Simulation Program, the program has been reduced, in Reduced Program listing number one, to the basic control statements and input operations and, in Reduced Program listings two thru eight, to the FORTRAN statements used in realizing the mathematical model of the system. These reduced program listings are contained in Appendix B of this report. All of the other program operations, which are not involved in simulation calculations, have been represented in the reduced listings as blocks.

Before explaining the operations of the program, it will be helpful to define certain variables and constants used in the program.

Reference Numbers

SETNUM is the number used to identify a given data set on the output data tape, where a data set is the output data stored on the tape for one execution of the program.

IRUN is the number used to identify a given data run, which is one of the NRUN data runs in the data set and where a data run is one simulation of a given antenna array under specified input and system operation conditions.

IWAVE is the number used to identify a given incoming signal condition, where there are N WAVE incoming signals in the data run.

IS is the number used to identify a given scan, where there are ISCAN

scans in the data run

IP is the number used to identify a given sample point, where there are ISAM sample points in each scan of the data run

IANT is the antenna element reference number, where element number one is defined as being at an azimuth of zero degrees and the reference numbers increase in the clockwise direction up to element number NOA, which is the first element to the left of element number one.

IAW is the number of elements an antenna element is located away from a given incoming signal azimuthal angle of arrival. (See Figure 4).

ISE is the scanning element reference number, where element number one is the element closest to the boresight and element number NAS2 is the furthest element from the boresight.

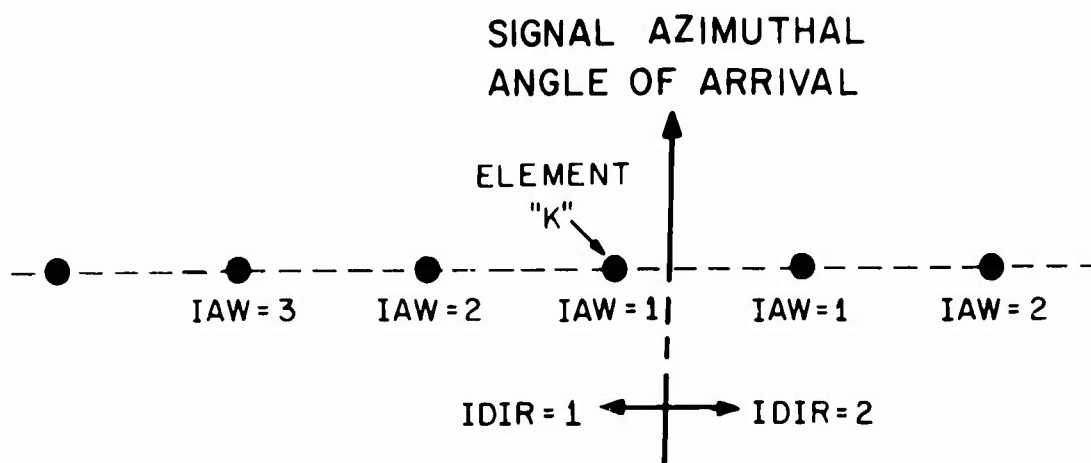
IDIR is used to specify if IAW or ISE is to the left (=1) or the right (=2) of the azimuthal angle of arrival or the boresight, respectively. It is also used to distinguish between the left (=1) and right (=2) scanning banks.

K is the reference number of the antenna element to the left of a given incoming signal azimuthal angle of arrival.

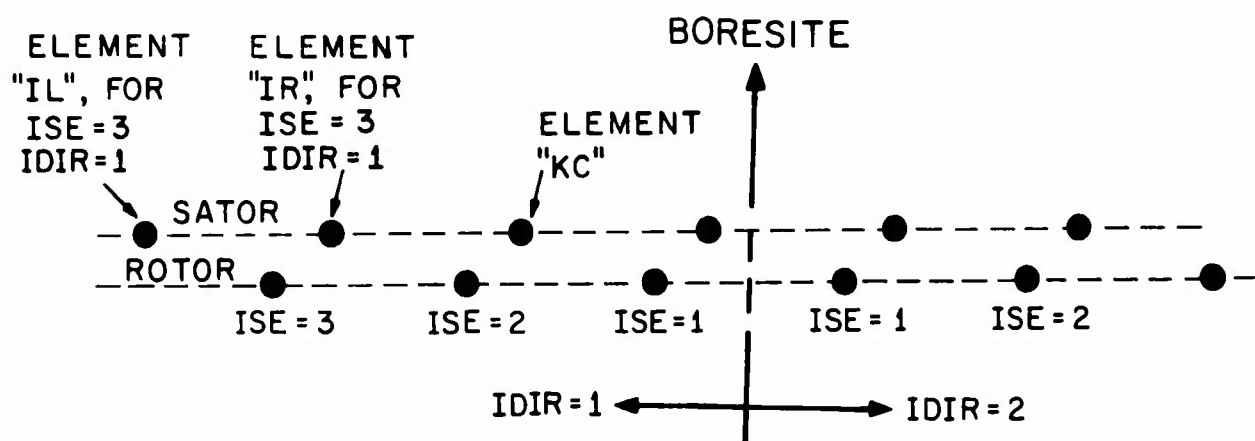
KC is the reference number of the antenna element to the left of the first scanning element in the left scanning bank for a given sample point.

IL is the reference number of the antenna element to the left of scanning element ISE for a given sample point.

IR is the reference number of the antenna element to the right of scanning element ISE for a given sample point.



FOR THE ANTENNA ARRAY



FOR THE SCANNER

Figure 4. Reference Numbers.

Natural Constants

VEC is the velocity of propagation (=299.8 meters/microsecond).

PI is set equal to the value π (=3.14159265).

TWOPI is set equal to the value 2π .

CONRAD is the radian to degrees conversion factor (=360/2 π).

Input Variables

ITAPE is the tape drive number (=1, 2, 3) on which the output data tape is mounted.

MODE specifies if a new (=1) or old (=2) output data tape is being used.

NRUN is the number of data runs in the data set.

NOA is the number of antenna elements in the array for a given data run.

A is the reflecting cylinder radius (in meters) for a given data run.

D is the reflecting cylinder to antenna element spacing (in meters) for a given data run.

NAS is the number of scanning elements for a given data run.

CPHI is the cophasal angle (in degrees) for a given data run.

NWAVE is the number of incoming signals for a given data run.

FREQC is the carrier frequency of the incoming signals (in MHz) for a given data run.

FREQM is the amplitude modulation frequency of the incoming signals (in KHz) for a given data run.

PCAM is the amplitude modulation factor for the incoming signals

($0 < PCAM < 1.0$) for a given data run.

WAMP is the relative RMS amplitude for a given incoming signal condition.

WPHI is the reference phase (in degrees) for a given incoming signal condition.

AZM is the azimuthal angle of arrival of a given incoming signal

($0 \leq AZM < 360$ degrees).

ELEV is the elevation angle of arrival for a given incoming signal
($0 \leq \text{ELEV} < 90$ degrees).

PST is the time-dependent reference phase shift per scan (in degrees)
for a given incoming signal condition.

ANOIS is the relative RMS value of the noise signal.

RN is the starting number for the pseudo-random number generator.
(Set $\text{RN}=0$ for normal operation.)

SECT is the sector center ($0 \leq \text{SECT} < 360$ degrees) for a given data run.

SCANT is the time taken to make one complete scan (in seconds) for a
given data run.

ISCAN is the number of scans in a given data run.

ISAM is the number of sample points in each scan for a given data run.

SAMI is the azimuthal angle between the boresight setting for two consecutive sample points in a scan (in degrees, $0 \leq \text{SAMI} * (\text{ISCAN} - 1) < 360$ degrees) for a given data run.

For the input formats of these input variables see the program forward
of the simulation program GCAAS.

The Basic Operation of the Program-
Reduced Program Listing Number One

The first necessary operation, after defining the natural constants (VEC, PI, TWOPI and CONRAD) and setting the data run reference number IRUN to zero, is to input the program operation variables (NRUN, ITAPE and MODE). Once ITAPE and MODE are known, then the output data tape can be properly positioned and SETNUM can be determined for the present execution of the program.

After the output tape has been positioned and SETNUM has been determined, the calculations for the first data run are begun by first incrementing the data run reference number by one, $IRUN=IRUN + 1$. It should be noted at the outset that the antenna array information (NOA, A, D, NAS, CPHI), the general signal information (NWAWE, FREQC, FREQM, PCAM), the noise signal information (ANOIS, RN) and the scanning operation information (SECT, SCANT, ISCAN, ISAM, SAMI) are all input once for the data run, and the incoming signal conditions (WAMP, WPHI, AZM, ELEV, PST) are input NWAWE times for the data run. It is necessary to re-supply all the input information for each data run in the data set, even if certain input variables are to be the same for different data runs in the data set.

The sequence of operations for the data set, after incrementing IRUN by one is:

- 1) Input the antenna and general signal information.
- 2) Calculate the phase delays for the delay lines .
- 3) Input one incoming signal condition.
- 4) Calculate the antenna element voltages for the given signal conditions.
- 5) Return to 3 until the calculations for all of the incoming signal

conditions have been completed.

- 6) Input the noise signal and scanning operation information.
- 7) Define the scan number IS and initialize the simulated time for the scan.
- 8) Define the sample point number IP and determine the boresight setting for the sample point.
- 9) Increment the simulated time by the time difference between sample points and determine the amplitude modulation factor from the simulated time.
- 10) Perform the time-dependent phase shift calculations for the sample point.
- 11) Calculate the scanning bank voltages for the sample points.
- 12) Calculate the output data for the sample point.
- 13) Return to 8 until all of the calculations for all of the sample points in the scan have been completed.
- 14) Return to 7 until all of the calculations for all of the scans in the data run have been completed.

If $IRUN \neq NRUN$, after the calculations for the data run have been completed increment $IRUN$ by one and begin the calculation for the next data run. If $IRUN = NRUN$, the execution of the program is terminated.

During the operation of the program, for a data run, several expressions appear several times or in operations that are repeated many times; in an attempt to reduce the execution time for the program, these expressions have been reduced to constants for the data run and incoming signal conditions. The data run constants are defined as:

$$\underline{\text{NOA4}} = \text{NOA}/4$$

$$\underline{\text{NAS2}} = \text{NAS}/2$$

$$\underline{\text{ANOA}} = 360/\text{NOA} \quad \text{The spacing between array elements}$$

$$\underline{\text{ANOAP}} = \text{ANOA}/2 \quad \text{One half the spacing between array elements}$$

$$\underline{\text{WL}} = \text{VEC}/\text{FREQ} \quad \text{The wavelength of the incoming signals}$$

$$\underline{\text{CONST1}} = \text{TWOPI} * \text{D}/\text{WL}$$

$$\underline{\text{CONST2}} = \text{TWOPI} * \text{A}/\text{WL}$$

$$\underline{\text{CONW}} = \text{TWOPI} * \text{FREQ} * 1000 \quad \text{The angular frequency of amplitude modulation}$$

$$\underline{\text{ANOISJ}} = \text{ANOIS} * .707 \quad \text{The relative RMS amplitude of the real and imaginary noise signals}$$

$$\underline{\text{WIDTH}} = (\text{ISAM}-1) * \text{SAMI} \quad \text{The width of the sampling window}$$

$$\underline{\text{SIDE}} = \text{SECT} - \text{WIDTH}/2 \quad \text{The first boresight setting in the scan}$$

$$\underline{\text{DELT}} = \text{SCANT} * \text{SAMI}/360 \quad \text{The time interval between two consecutive sample points.}$$

The incoming signal constants, used in the antenna element voltage calculations, are defined as:

$$\underline{\text{WPH}} = \text{WPHI}/\text{CONRAD} \quad \text{The reference phase in radians}$$

$$\underline{\text{COSELV}} = \text{COS}(\text{ELEV}/\text{CONRAD})$$

$$\underline{\text{COSAMP}} = \text{COSELV} * \text{WAMP}$$

$$\underline{\text{CONE1}} = \text{CONST1} * \text{COSELV}$$

$$\underline{\text{CONE2}} = \text{CONST2} * \text{COSELV} .$$

Both the boresight settings and the simulated time are calculated for the sample point from the scan and sample point reference number. The boresight setting can be found from IP alone, since the boresight settings will always be the same for each scan in a data run. The boresight setting for sample point IP is determined as:

$$\underline{\text{CENT}} = (\text{IP}-1) * \text{SAMI} + \text{SIDE} .$$

It should be noted that it may be necessary to correct CENT to lie between the limits $0 \leq \text{CENT} < 360$ degrees.

The simulated time is computed by initializing the simulated time at the beginning of the scan.

$T = (\text{IS} - 1) * \text{SCANT} - \text{DELT}$, and then increment the simulated time by the time interval between sample points, $T = T + \text{DELT}$, for each sample point. It is interesting to note that this method of computation of simulated time is equivalent to:

$$T = (\text{IS} - 1) * \text{SCANT} + (\text{IP} - 1) * \text{DELT}.$$

Once the simulated time is known for the sample point, the amplitude modulation factor is determined as:

$$\text{AMS} = (1 - \text{PCAM}) * \text{PCAM} * \text{COS}(\text{CONW} * T)$$

which is Equation (14).[†]

Phase Delay Calculations-

Reduced Program Listing Number Two

The first step in the phase delay calculation is to reduce redundant calculation by reducing the two terms in Equation (17), which are the same for all the scanning elements, to two constants. These two constants are defined as:

$$\text{CONCHI} = \text{COS}(\text{CPHI}/\text{CONRAD}) * \text{CONST2}$$

$$\text{COSM} = \text{COS}(((\text{NAS2} - 1) * \text{ANOA} + \text{ANOA2})/\text{CONRAD}).$$

Equation (17) is then implemented, for scanning element ISE, as:

$$\text{PDELAY} = \text{CONCHI} * (\text{COS}(((\text{ISE} - 1) * \text{ANOA} + \text{ANOA2})/\text{CONRAD}) - \text{COSM}).$$

The phase delay information is then stored as:

$$\text{COSP}(\text{ISE}) = \text{COS}(\text{PDELAY})$$

$$\text{SINP}(\text{ISE}) = \text{SIN}(\text{PDELAY}),$$

[†] Equation numbers refer to equations in Chapter 3.

since the sine and the cosine of the phase delays will be the only quantities used in further calculations.

Antenna Element Voltage Calculations-
Reduced Program Listing Number Three

After the conditions have been read and the repetitive terms used in the antenna element voltage calculation have been reduced to constants for the incoming signal IWA VE, the antenna element voltages excited by the given signal conditions are determined in the following manner:

- 1) Determine the element K to the left of the azimuthal angle of arrival as $K = (AZM/ANOA) + 1$.
- 2) Determine the spacing between the azimuthal angle of arrival and the first element to the left as $DELK = AZM - ANOA * (K-1)$ and the first element to the right as $DELKP = ANOA - DELK$.
- 3) For the elements to the left of the azimuth $IDIR = 1$.
- 4) Set $IAW = 1$ for the first element to the left of the signal azimuth.
- 5) Find the proper antenna reference number as $IANT = K + 1 - IAW$.
- 6) Determine the spacing between the azimuth and the element as $THE = ANOA * (1 - IAW) - DELK$.
- 7) Implement Equations (1) and (2) to find the voltage excited by the signal.
- 8) Implement Equations (3) and (4) to find the total element complex voltage.
- 9) For the next element to the left $IAW = IAW + 1$.
- 10) Return to 5 if $IAW \leq NOA4$.

Note that voltages will only be excited in antenna elements up to one fourth of the distance around the array from the azimuthal angle of arrival.

- 11) For the elements to the right of the azimuth $IDIR = 2$.
- 12) Set $IAW = 1$ for the first element to the right of the signal azimuth.
- 13) Find the proper antenna reference number as $IANT = K + IAW$.
- 14) Determine the spacing between the azimuth and the element as $THE = ANOA * (IAW - 1) + DELKP$.
- 15) Implement Equations (1) and (2) to find the voltage excited by the signal.
- 16) Implement Equations (3) and (4) to find the total element complex voltage.
- 17) For the next element to the right $IAW = IAW + 1$.
- 18) Return to 13 if $IAW \leq NOA4$.

It should be noted that it may be necessary to correct $IANT$ and THE to fit the limits $1 \leq IANT \leq NOA$ and $|THE| \leq 90$ degrees, before being used in any calculations.

Equation (1) and (2) are implemented in the program as:

$$\underline{AMP} = \text{COSAMP} * \text{SIN} (\text{CONE1} * \text{COSTHE})$$

and

$$\underline{PHI} = \text{CONE2} * \text{COSTHE} + \text{WPH}$$

where COSTHE is defined for the given element $IANT$ as:

$$\underline{\text{COSTHE}} = \text{COS}(\text{THE}/\text{CONRAD})$$

and where COSAMP , CONE1 , CONE2 and WPH are defined, in reduced listing number one, for the given incoming signal, $IWAVE$.

After Equations (1) and (2) have been implemented, Equations (3) and (4) can then be implemented, for antenna element IANT and incoming signal IWAVE, as:

$$\underline{ARE(IANT)} = ARE(IANT) + AMP * \cos(\phi)$$

and

$$\underline{AIM(IANT)} = AIM(IANT) + AMP * \sin(\phi).$$

ARE(IANT) and AIM(IANT), the antenna element voltage variables, were zeroed for all NOA elements before the calculations for the first incoming signal conditions were begun.

For the implementation of the time-dependent phase shift, it will be necessary to store certain intermediate values from the antenna element voltage calculation. These values are stored as:

WPHH(IWAVE) = 0.0, the old reference phase shift for signal IWAVE;

PSTEP(IWAVE) = PST/CONRAD, the reference phase step per scan, for signal IWAVE;

PHIH(IANT,IWAVE) = PHI, the base phase, for element IANT and signal IWAVE;

AMPH(IANT, IWAVE) = AMP, the base amplitude, for element IANT and signal IWAVE, which is also zeroed before calculations for the first incoming signal conditions were begun.

Time Dependent Phase Shift Calculations-

Reduced Program Listing Number Four

The time-dependent phase shift calculations are carried out for each sample point for those incoming signals which have a time dependent reference phase shift, i.e. PSTEP(IWAVE) \neq 0. It will also only be necessary to carry out the calculations for those elements which have a non-zero base amplitude for the given signal, i.e. AMPH(IANT,IWAVE) \neq 0.

The first step in the calculations, for a given signal IWAVE, is to determine the reference phase shift, for the present sample point at simulated time T, as: $WPPH = PSTEP(IWAVE) * T/SCANT$. The reference phases for the past and present sample points, Equations (7) and (8), are then obtained by adding the element base reference phase:

$$PA1 = PH1H(IANT, IWAVE) + WPHH(IWAVE)$$

and

$$PA2 = PH1H(IANT, IWAVE) + WPHH.$$

Equations (5) and (6) can then be implemented as:

$$ARE(IANT) = ARE(IANT) + AMPH(IANT, IWAVE) * (COS(PA2) - COS(PA1))$$

and

$$AIM(IANT) = AIM(IANT) + AMPH(IANT, IWAVE) * (SIN(PA2) - SIN(PA1)).$$

The last step in the calculation, for the given signal, is to store the present reference phase shift in the variable used as the old reference phase shift, i.e. $WPHH(IWAVE) = WPPH$.

It should be noted that these calculations are bypassed for $T = 0$, because the phase shift is zero.

Scanning Element and Scanning Bank Voltage Calculations-
Reduced Program Listing Number Five

Once CENT, T, and AMS have been determined for the sample point and the time dependent phase shift calculations have been completed, the scanning bank voltages are calculated in the following manner:

- 1) Determine the antenna element KC to the left of the first element in the left scanning bank as $KC = (CENT - ANOA2) / ANOA + 1$.
- 2) Determine the spacing between a scanning element and the first antenna element to the left as $CDEL = (CENT - ANOA2) - (ANOA * (KC - 1))$ and the first antenna element to the right as $CDELP = ANOA - CDEL$.

- 3) Determine the linear displacement factor for antenna elements to the left as $CDELAP = CDELP/ANOA$ and to the right as $CDELA = CDEL/ANOA$.
- 4) For the scanning elements in the left bank, $IDIR = 1$.
- 5) Zero the bank voltage accumulator $SUMI = SUMR = 0$.
- 6) Set $ISE = 1$ for the first element in the left bank.
- 7) Find the proper antenna element reference number for the element to the left of ISE as $IL = (KC - ISE + 1)$ and the element to the right as $IR = (IL + 1)$.
- 8) Determine the noise voltage for the element to the left as $ANREL, ANIML$, and the element to the right as $ANRER, ANIMR$.
- 9) Implement Equations (15) and (16) to find the scanning element voltage.
- 10) Implement Equations (18) and (19) to find the scanning bank voltage.
- 11) For the next scanning element in the left bank $ISE = (ISE + 1)$.
- 12) Return to 7 if $ISE \leq NAS2$.
- 13) Store the left scanning bank voltage as:
 $SUMRE(IDIR) = SUMR$
 $SUMIM(IDIR) = SUMI$
- 14) For the scanning elements in the right bank $IDIR = 2$.
- 15) Zero the bank voltage accumulator $SUMI = SUMR = 0$.
- 16) Set $ISE = 1$ for the first element in the right bank.
- 17) Find the proper antenna element reference number for the element to the left of ISE as $IL = (KC + ISE)$ and the element to the right as $IR = (IL + 1)$.

- 18) Determine the noise voltage for the element to the left as ANREL, ANIML and the element to the right as ANRER, ANIMR.
- 19) Implement Equations (15) and (16) to find the scanning element voltage.
- 20) Implement Equations (18) and (19) to find the scanning bank voltage.
- 21) For the next scanning element in the right bank $ISE = (ISE + 1)$.
- 22) Return to 17 if $ISE \geq NAS2$.
- 23) Store the right scanning bank voltage as:

$$\underline{SUMRE (IDIR)} = SUMR$$

$$\underline{SUMIM (IDIR)} = SUMI$$

Again it should be noted that it may be necessary to correct IR and IL to fall in the limits 1 to NOA before they are used in any calculations.

Equations (15) and (16) are implemented as:

$$SRE = (AMS * ARE(IL) + ANREL) * CDELAP + (AMS * ARE(IR) + ANRER) * CDELA$$

$$SIM = (AMS * AIM(IL) + ANRML) * CDELAP + (AMS * AIM(IR) + ANIMR) * CDELA$$

Equations (18) and (19) are implemented as:

$$SUMI = SUMI + SIM * COSP(ISE) - SRE * SINP(ISE)$$

$$SUMR = SUMR + SIM * SINP(ISE) + SRE * COSP(ISE)$$

where SINP(ISE) and COSP(ISE) are the stored sine and cosine of the phase delay for element ISE.

Determination of the Noise Signal Voltage-

Reduced Program Listing Number Six and Seven

The noise voltages are determined by making two successive calls to the computer library pseudo-random number generator (CALL RND(RN, RNDP)) and multiplying the supplied real number RNDP by the relative noise

voltage factor ANOISJ, where RNDP is from a Gaussian distribution and $|RNDP| \leq 5.0$. It is necessary to determine the noise voltages for the antenna elements to the right and left of the scanning elements in different manners for the left and right bank.

For the left bank, since the order in which calculations are made for the scanning elements proceeds from right to left, the noise voltages ANREL, ANIML for element (ISE-1) become the noise voltages ANRER, ANIMR; for element ISE and ANREL, ANIML is determined by consecutive calls to the random number generator. For (ISE= 1), it is necessary to make four calls to the random number generator to determine ANRER, ANIMR and ANREL, ANIML; it will also be necessary to store ANRER, ANIMR as ANRERF, ANIMRF since the antenna element to the right of the first element in the left bank is also the antenna element to the left of the first element in the right bank.

For the right scanning bank, since the order in which calculations are made for the scanning elements proceeds from the left to the right, the noise voltages ANRER, ANIMR for element (ISE-1) become the noise voltages ANREL, ANIML for element ISE and ANRER, ANIMR is determined by consecutive calls to the random number generator. For ISE = 1, the noise voltage ANREL, ANIML is set equal to ANRERF, ANIMRF and the noise voltage ANRER, ANIMR is determined by the random number generator.

Calculation of System Outputs-
Reduced Program Listing Number Eight

After the bank voltages have been determined, the output data are determined for the sample point.

The sum data are found as the magnitude of the complex sum of the right and left bank voltages, by implementing Equation (20) as:

$$\text{SUMR} = \text{SUMRE}(2) + \text{SUMRE}(1)$$

$$\text{SUMI} = \text{SUMIM}(2) + \text{SUMIM}(1)$$

$$\underline{\text{DATAST}} = \text{SQRT}(\text{SUMR} ** 2 + \text{SUMI} ** 2).$$

The difference datum is found as the magnitude of the complex difference between the right and left bank voltage, by implementing Equation (21) as:

$$\text{SUMR} = \text{SUMRE}(2) - \text{SUMRE}(1)$$

$$\text{SUMI} = \text{SUMIM}(2) - \text{SUMIM}(1)$$

$$\underline{\text{DATADT}} = \text{SQRT}(\text{SUMR} ** 2 + \text{SUMI} ** 2).$$

The differential phase datum is found as the difference between the phase of the right bank voltage and the phase of the left bank voltage, by implementing Equation (22) as

$$\text{ANGR} = \text{ATAN2}(\text{SUMIM}(2), \text{SUMRE}(1))$$

$$\text{ANGL} = \text{ATAN2}(\text{SUMIM}(1), \text{SUMRE}(2))$$

$$\text{DATP} = \text{ANGR} - \text{ANGL} .$$

where ATAN2 (IM, RE) is defined over the range $-180 < \text{ATAN2}(\text{IM}, \text{RE}) \leq +180$. It may be necessary to correct DATP to fall between the limits $-180 < \text{DATP} \leq +180$.

V. OUTPUT DATA

The simulation program produces both a hard copy and magnetic tape output.

On the first page of the hard copy, for each data run, the input conditions for the simulation are defined along with the data set and data run numbers which are used in locating the data run on the magnetic tape. Succeeding pages contain the output data for each scan in the data run.

After the calculations for each sample point have been completed, as discussed in the last chapter, the output data for sample point IP are stored as:

DATA (IP) = CENT
DATA (IP) = DATAST
DATA (IP) = DATADT
DATA (IP) = DATP .

As the sample point data are being stored, the sum and difference data are tested to determine their maximum values for the scan; these maximum values are then stored as DATASM and DATADM, respectively. After all of the calculations for the scan have been completed, the output data for the scan are then printed on hard copy.

Along with the numerical values of the output data, a fifty-one-point incremental line printer plot is also displayed on the hard copy. The sum and difference data are normalized by DATASM and DATADM respectively, and then plotted with the maximum values as the right-hand side of the plot. The differential phase data are plotted between the limits -180 degrees on the left and +180 degrees on the right hand side of the

plot. The symbols used in the plot to represent the output data are:

- * Sum
- + Difference
- X Differential Phase.

Appendix C contains the hard copy output for a sample execution of the program; the necessary input cards for the execution are also shown.

The organization of the output data tape is such that each data set will comprise one tape file. After the file for the last data set on the tape, there is a terminator file which is used in the tape handling procedure. The data set file consists of a series of logical records, one H (or input) record for each data run followed by one S (or output) record for each scan in the data run and a terminator file which consists of one E (or end) record. The structure of the H, S and E records is given in Tables 1, 2, and 3, respectively.

The simulation program, as was noted in the last chapter, has two modes for tape handling operations; the first mode is used for new tapes and the second mode is used for old tapes to which an additional file is to be added. In the first mode it is only necessary to open the tape and position it to its beginning and then the first data set file is written on the tape. The second mode is used to position the tape to the end of the last data set file on the tape; this is done by searching the tape for the terminator file and then writing the new data set file over it. In both modes one and two, after the new data set file has been added to the tape the terminator file is then added to the tape. The only information in the terminator file is the set number of the last data set file which is used in mode two to determine the set number for the next data set file to be added to the tape.

Table 1

The input information for the data run is organized in the H record

in the following manner:

AREA (1)	=	4H	H	
AREA (2)	=	SETNUM	-	Set number
AREA (3)	=	IRUN	-	Run number
AREA (4)	=	NRUN	-	Number of runs in the set
AREA (5)	=	NOA	-	Number of antenna elements in the array
AREA (6)	=	A	-	Radius of the reflecting cylinder
AREA (7)	=	D	-	Cylinder to element distance
AREA (8)	=	NAS	-	Number of scanning elements
AREA (9)	=	CPHI	-	Cophasel angle
AREA (10)	=	FREQC	-	Carrier frequency
AREA (11)	=	FREQM	-	Modulation frequency
AREA (12)	=	PCAM	-	Modulation factor
AREA (13)	=	NWAVE	-	Number of incoming signal conditions
AREA (14)	=	ANOIS	-	Relative noise level
AREA (15)	=	RN	-	Starting Number for pseudo random number gen.
AREA (16)	=	SECT	-	Sector center
AREA (17)	=	ISCAN	-	Number of scans in the run
AREA (18)	=	SCANT	-	Time to complete on scan
AREA (19)	=	ISAM	-	Number of sample points in each scan
AREA (20)	=	SAMI	-	<u>Spacing between sample points</u>
AREA (21)	=	WAMP	-	Relative signal amplitude
AREA (22)	=	WPHI	-	Reference phase For
AREA (23)	=	AZM	-	Azimuthal angle of arrival IWAVE = 1
AREA (24)	=	ELEV	-	Elevation angle of arrival
AREA (25)	=	PST	-	<u>Time Dept. phase shift</u>
AREA (26)	=	WAMP	-	
AREA (27)	=	WPHI	-	For
AREA (28)	=	AZM	-	IWAVE = 2
AREA (29)	=	ELEV	-	
AREA (30)	=	PST	-	
AREA (31)	=		-	
AREA ()	=		-	
AREA ()	=		-	
AREA ()	=		-	

To access the information for signal conditions IWAVE:

$WAMP = AREA(21 + (IWAVE-1) * 5)$
 $WPHI = AREA(22 + (IWAVE-1) * 5)$
 $AZM = AREA(23 + (IWAVE-1) * 5)$
 $ELEV = AREA(24 + (IWAVE-1) * 5)$
 $PSR = AREA(25 + (IWAVE-1) * 5)$

Table II

The output information for a scan is organized in the S record in the following manner:

AREA(1)	=	4H	S	
AREA(2)	=	SETNUM	- Set number	
AREA(3)	=	IRUN	- Run number	
AREA(4)	=	NRUN	- Number of runs in the scan	
AREA(5)	=	IS	-- Scan number	
AREA(6)	=	DATASM	- Maximum value of the sum data	
AREA(7)	=	DATADM	- Maximum value of the difference data	
AREA(8)	=			
AREA(9)	=		Blank	
AREA(10)	=			
AREA(11)	=	CENT	- Boresight setting	
AREA(12)	=	DATAS	- Sum data	For
AREA(13)	=	DATADT	- Difference data	IP=1
AREA(14)	=	DATP	- Differential phase data	
AREA(15)	=	CENT	- Boresight setting	
AREA(16)	=	DATAS	- Sum data	For
AREA(17)	=	DATADT	- Difference data	IP=2
AREA(18)	=	DATP	- Differential phase data	
AREA(19)	=	CENT	-	
AREA(20)	=	DATAS	-	For
AREA(21)	=	DATADT	-	IP=3
AREA(22)	=	DATP	-	
AREA(23)	=			
AREA(24)	=			
AREA()	=			
AREA()	=			
AREA				

To access the output data for sample point IP:

CENT	=	AREA(11 + (IP-1) * 4)
DATAS	=	AREA(12 + (IP-1) * 4)
DATADT	=	AREA(13 + (IP-1) * 4)
DATAP	=	AREA(14 + (IP-1) * 4)

Table III

The E record is organized in the following manner:

AREA(1)	=	4H	E
AREA(2)	=	SETNUM	- Set number of last data set file

The method that should be used to locate a given data run, defined by SETNUM, IRUN, is to test the first record in each file until AREA(2) = SETNUM and then check each record in the file until AREA(1) = 4H ___H and AREA(3) = IRUN. Appendix D contains a segment of a program which can be used to properly locate a given data run.

Appendix E contains the listing of program STRO, standing for Simulation Tape Read Out, which is used to obtain a hard copy print out of all the information on the output tape.

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2. E. Jones, Jr., A Digital Simulation of the Wullenweber Direction Finding System, (RRL Publication No. 296, University of Illinois Reports.) Technical Report No. 16, Contract NOBSR 89229, December 1965.
3. P. S. Carter, "Antenna Arrays Around Cylinders", Proceedings Institute of Radio Engineers, Vol. 31, No. 12, pp. 671-693, December 1943.

APPENDIX A

LISTING OF PROGRAM GCAAS

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H NAME GCAAS;
H EQUIP=CARDRF,PRINTF;
H SINGLE (AREA,DEAN);
C
C
C PROGRAM: GCAAS
C STANDING FOR: GENERAL CIRCULAR ANTENNA ARRAY SIMULATOR
C
C WRITTEN BY: RAY F. HUNNINGHAUS
C
C WRITTEN FOR: RADIOLOCATION RESEARCH LABORATORY
C DEPARTMENT OF ELECTRICAL ENGINEERING
C UNIVERSITY OF ILLINOIS
C
C COMPLETED: MAY, 1970
C REVISED: OCTOBER, 1970 - FOR NEW TAPE HANDLING PROCEDURES
C
C *****
C
C INPUT CARDS NECESSARY FOR OPERATION:
C
C ONE PROGRAM OPERATION CARD:
C (15) NRUN * NUMBER OF DATA RUNS IN DATA SET
C (15) ITAPE * TAPE DRIVE NUMBER
C (15) MODE * TAPE OPERATION MODE
C ENTER 1 IF DATA STARTS A NEW TAPE
C ENTER 2 IF DATA IS ADDED TO AN OLD TAPE
C
C THE FOLLOWING CARDS ARE NEEDED FOR EACH DATA RUN OF THE DATA SET
C ANTENNA INFORMATION CARD:
C (15) NOA * NUMBER OF ANTENNA ELEMENTS IN ARRAY
C (F10.2) A * DISTANCE FROM CENTER OF ARRAY TO THE REFLECTING
C SCREEN IN METERS
C (F10.2) B * DISTANCE FROM REFLECTING SCREEN TO THE ANTENNA
C ELEMENT IN METERS
C (15) NAS * NUMBER OF SCANNING ELEMENTS
C (F10.2) PHA * CIRCULAR ANGLE
C
C GENERAL SIGNAL INFORMATION CARD:
C (15) NWAVE * NUMBER OF INCOMING SIGNALS
C (F10.4) FRECC * CARRIER FREQUENCY IN MEG. HZ.
C (F10.4) FRECM * MODULATING FREQUENCY IN KIL. HZ.
C (F10.4) PCAM * AMPLITUDE MODULATION FACTOR (1.0 TO 0.0)
C
C INCOMING SIGNAL CONDITION CARD,
C ONE CARD FOR EACH SET OF SIGNAL CONDITIONS
C I. E. SAME NUMBER OF CARDS AS NUMBER ENTERED FOR NWAVE:
C (F8.2) WAMP * SIGNAL AMPLITUDE (0.0 TO 1.0)
C (F8.2) WPHT * SIGNAL PHASE IN DEGREES
C (F8.2) AZM * AZIMUTHAL ANGLE OF ARRIVAL IN DEGREES
C (F8.2) ELEV * ELEVATION ANGLE OF ARRIVAL IN DEGREES
C (F8.2) PST * SIGNAL PHASE STEP IN DEGREES PER SCAN
C
C NOISE INFORMATION CARD:
C (F10.4) NOISE * RMS VALUE OF NOISE SIGNAL (0.0 TO 1.0)
C (15) NIN * STARTING NUMBER FOR PSEUDO-RANDOM NO. GENERATOR
C ENTER 0
C
C SCANNING OPERATION INFORMATION CARD:
C (F10.2) SECT * SECTOR CENTER IN DEGREES
C (F10.2) SCANT * TIME FOR ONE SCAN IN SECONDS

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C      (15)   ISCAN * NUMBER OF SCANS IN THE DATA RUN
C      (15)   ISAM  * NUMBER OF SAMPLE POINTS IN EACH SCAN
C      (F10.2) SAMI * ANGLE BETWEEN SAMPLE POINTS IN DEGREES
C
C      *****
C      PROGRAM LIMITS
C
C      INPUT:
C      MAXIMUM NUMBER OF SIGNAL CONDITIONS          5
C      AZIMUTHAL ANGLES SHOULD BE EXPRESSED BETWEEN THE LIMITS OF
C      0.0 DEGREES AND 359.99- DEGREES
C
C      OUTPUT:
C      MAXIMUM NUMBER OF SAMPLE POINTS / SCAN   100
C
C      OPERATION:
C      MAXIMUM NUMBER OF ANTENNA ELEMENTS       360
C      MAXIMUM NUMBER OF SCANNING ANTENNA       100 (MUST BE AN EVEN NO.)
C
C      *****
C      TAPE HANDLING
C
C      THE OUTPUT DATA WILL BE STORED ON THE TAPE MOUNTED ON DRIVE 1 TAPE
C
C      THE OLD DATA TAPE, IF ANY, SHOULD BE MOUNTED ON DRIVE 1 TAPE
C      THE TAPE WILL BE ADVANCED TO THE END OF THE OLD DATA AND THE NEW
C      DATA WILL BE STORED BEGINNING AT THAT POINT ON THE TAPE
C
C      *****
C
C      DIMENSION ARRAYS
C
C      DIMENSION COSP(50),SINP(50)
C      DIMENSION ARE(360),AIM(360)
C      DIMENSION SUMRF(2),SUMIM(2)
C      DIMENSION DATAS(100),DATAI(100),DATAP(100),DATAQ(100)
C      DIMENSION WPHH(5),PSTEP(5)
C      DIMENSION PHIH(360,5),AMPH(360,5)
C      DIMENSION ALINE(51),AMARK(11)
C      DIMENSION AREA(410),DFAN(650)
C
C      H4=4H   H
C      S4=4H   S
C      E4=4H   E
C
C      INITIALIZE LINE PRINTER
C
C      D0 000 IPR=1,51
C      900 ALINE(I)=0
C      D0 001 IPR=1,11
C      901 AMARK(I)=27
C
C      DEFINE NATURAL CONSTANTS
C
C      V=C=299.8
C      PI=3.14159265
C      TAMP = 1E2
C      CONRAD=360/TAMP
C
C      READ PROGRAM OPERATION INFO FOR ALL N
C

```

```

      IRUN=0
      READ 9008,MRUN,ITAPE,MODE
C
C      OPEN TAPE ON DRIVE ITAPE
C
      DFAS=600
      CALL SETHN(ITAPE,1)
      CALL FXBLK(ITAPE,1)
      CALL BKLN(ITAPE,0,0)
C
      GO TO (924,914),MODE
C
C      TAPE MODE NO. 2
C      ADVANCE TAPE TO END OF OLD DATA
C
914 CONTINUE
915 ASSIGN 8800 TO LAST
916 CALL OPEN(DFAN,DFAS,ITAPE,0,4HSIMU)
      CALL RULER(DFAN,AREA,LAST)
      CALL CLOSE(DFAN)
      IF (AREA(1)-EH) 917,918,917
917 CALL SETFD(DFAN)
      GO TO 916
918 CALL SETHK(DFAN)
      CALL OPEN(DFAN,DFAS,ITAPE,0,4HSIMU)
      SETNUM=AREA(2)
      GO TO 930
C
C      TAPE MODE NO. 1
C
924 CONTINUE
925 CALL OPEN(DFAN,DFAS,ITAPE,0,4HSIMU)
      SETNUM=0
C
930 SETNUM=SETNUM+1000
C
C      BEGINNING OF DATA RUN
C
950 IRUN=IRUN+1
C
C      READ ANTENNA INFORMATION AND GENERAL SIGNAL INFORMATION
C
      READ 9009,NOA,A.D,NAS,CPhi
      READ 9010,NWAVE,FREQC,FREQM,PCAM
C
C      DETERMINE DATA RUN OPERATION CONSTANTS
C
      NOA4=NOA/4
      ANOA=360/NOA
      ANOA2=NOA/2
      NAS2=NAS/2
      WL=VFC/FREQC
      CONST1=TWOPI*D/L
      CONST2=TWOPI*A/WL
      CONW=TWOPI*FREQM*1000
C
C      CALCULATE PHASE DELAYS FOR SCANNING ANTENNA ELEMENTS
C
      CONCHI=COS(CPHI/CONRAD)*CONST1
      COSM=COS(((NAS2-1)*ANOA+ANOA2)/CONRAD)

```

```

DO 999 ISF=1,NA-2
PDELAY=C*CNCHI*(COS(((ISE-1)*ANOA+ANOA2)/CONRAD))-COSM)
COSPI(SF)=COS(PDELAY)
SINPI(SF)=SIN(PDELAY)
999 CONTINUE
C
C PRINT H RECORD INFORMATION
C
PRINT 9019,SETNUM,IRUN,NRUN
PRINT 9020,NOA,A,D,NAS,CPHI,FREQC,FREQM,PCAM,NWAVE
PRINT 9021
C
C STORE H RECORD INFORMATION
C
AREA( 1)=HH
AREA( 2)=SETNUM
AREA( 3)=IRUN
AREA( 4)=NRUN
AREA( 5)=NOA
AREA( 6)=A
AREA( 7)=D
AREA( 8)=NAS
AREA( 9)=CPHI
AREA(10)=FREQC
AREA(11)=FREQM
AREA(12)=PCAM
AREA(13)=NWAVE
KKK=21
C
C ZERO ANTENNA ELEMENT ARRAYS
C
DO 1000 IANT=1,NCA
ARE(IANT)=0.0
AIM(IANT)=0.0
DO 1000 IWAVE=1,NWAVE
AMP(IANT,IWAVE)=0.0
1000 CONTINUE
C
IWAVE=1
C
C READ AND PRINT SIGNAL CONDITION
C
1001 READ 9011,WAMP,WPHI,AZM,ELEV,PST
PRINT 9022,IWAVE,WAMP,WPHI,AZM,ELEV,PST
C
WPH=WPPI/CONRAD)
COSSELV=COS(ELEV/CONRAD)
COSAMP=COSSELV*WAMP
CONE1=CONST1*CONELV
CONE2=CONST2*CONELV
WPHH(IWAVE)=0.0
PSTEE(IWAVE)=PST/CONRAD
C
C STORE H RECORD INFORMATION
C
AREA(KKK )=WAMP
AREA(KKK+1)=WPHI
AREA(KKK+2)=AZM
AREA(KKK+3)=ELEV
AREA(KKK+4)=PST
KKK=KKK+5

```

```

C
C DETERMINE ANTENNA ELEMENT TO THE LEFT OF THE SIGNAL AZIMUTH
C AND THE ANGLES BETWEEN THE AZIMUTH AND ADJACENT ANTENNA ELEMENTS
C
K=(AZM/ANOA)+1
DELK=A/M-ANOA*(K-1)
DELPK=ANOA-DELK
C
C GO TO LEFT FOR IDIR=1 AND RIGHT FOR IDIR=2
C
DO 1014 IDIR=1,2
C
C PERFORM OPERATION FOR ANTENNA ELEMENTS UP TO 90 DEG. FROM AZIMUTH
C
1002 DO 1013 IAW=1,NOA4
GO TO (1003,1008),IDIR
C
C FIND ANTENNA NUMBER FOR OPERATION TO LEFT
C
1003 IANT=K+1-IAW
IF (IAW) 1004,1004,1005
1004 IANT=NOA+IAW
1005 THE=ANOA*(1-IAW)-DELPK
IF (ARSE(THE)-90) 1007,1007,1006
1006 THE=-90
1007 GO TO 1012
C
C FIND ANTENNA NUMBER FOR OPERATION TO RIGHT
C
1008 IANT=K+IAW
IF (NOA-IANT) 1009,1010,1010
1009 IANT=IANT-NOA
1010 THE=DELPK+ANOA*(IAW-1)
IF (ARSE(THE)-90) 1012,1012,1011
1011 THE=90
C
C CALCULATE THE COMPLEX ANTENNA VOLTAGE OF THE GIVEN ANTENNA
C
1012 COSTHE=COS(THE/CCNPAID)
AMP=COSAMP*SIN(CCANF1*COSTHE)
PHI=COSPH2*COSTHE+WPH
ARF(IANT)=ARF(IANT)+AMP*CCS(-PHI)
AIM(IANT)=AIM(IANT)+AMP*SIN(PHI)
C
C STORE CASE PHASE STEP INFORMATION
C
PHI(IANT,[WAVE])=PHI
AMP(IANT,[WAVE])=AMP
1013 CONTINUE
1014 CONTINUE
IAW=IAW+1
IF (IAW>=(NOA+1)) 1016,1001,1001
1016 CONTINUE
C
C READ NOISE AND SCANNING OPERATION INFORMATION
C
READ 9013,ANOS,ARN
READ 9012,SECT,SCANT,ISCAN,ISAM,SAM1
C
C CALCULATE SCANNING OPERATION CONSTANTS
C

```

```

      WIDTH=(ISAM-1)*SAMI
      SIDE=SHFT-WIDTH/2
      IF (SIDE) 1150,1151,1151
1150 SIDE=360+SIDE
1151 CONTINUE
      DELT=SCANT*SAMI/360
      ANOISJ=.707*ANOIS
C
C      PRINT H RECORD INFORMATION
C
C      PRINT 9023,ANOIS,RN,SECT,ISCAN,SCANT,ISAM,SAMI
C
C      STORE H RECORD INFORMATION
C
      AREA(14)=ANOIS
      AREA(15)=RN
      AREA(16)=SECT
      AREA(17)=ISCAN
      AREA(18)=SCANT
      AREA(19)=ISAM
      AREA(20)=SAMI
C
C      WRITE H RECORD INFORMATION ON TO TAPE
C
C      CALL WRLR(DFAN,AREA,50)
C
C      BEGINNING OF SCAN
C
C      DO 1250 IS=1,ISCAN
C
C      STORE S RECORD INFORMATION
C
      AREA( 1)=SH
      AREA( 2)=SFTNUM
      AREA( 3)=IPUN
      AREA( 4)=NRUN
      AREA( 5)=IS
C
C      ZERO MAX OUTPUT DATA VARIABLES
C
      DATASM=0.0
      DATAPM=0.0
C
C      INITIA LIZE TIME
C
C      T=(IS-1)*SCANT-DELT
C
C      BEGINNING OF CALCULATIONS FOR SAMPLE POINT
C
C      DO 1228 IP=1,ISAM
C
C      CALCULATE SAMPLE CENTER
C
      CENT=(IP-1)*SAMI+SIDE
      IF (CENT-360) 1153,1152,1152
1152 CENT=CENT-360
1153 CONTINUE
C
C      ADVANCE TIME
C
      T=T+DELT

```

```

C
C   SKIP WAVE PHASE STEP CALCULATIONS FOR FIRST SCAN, FIRST SAMPLE
C
C   IF (T) 1190,1190,1160
C
C   BEGINNING OF WAVE PHASE STEP CALCULATIONS
C
1160 DO 1172 IWAVE=1,NWAVE
C
C   IF WAVE PHASE STEP =0.0 SKIP CALCULATIONS
C
C   IF (PSTEP(IWAVE)) 1161,1172,1161
C
C   CALCULATE PRESENT WAVE PHASE
C
1161 WPPH=PSTEP(IWAVE)*T/SCANT
C
C   CALCULATE NEW ANTENNA VOLTAGE FOR ALL ELEMENTS IN ARRAY
C
C   DO 1170 IANT=1,NOA
C   IF (AMPH(IANT,IWAVE)) 1169,1170,1169
1169 PA1=PHI(IANT,IWAVE)+WPPH(IWAVE)
PA2=PHI(IANT,IWAVE)+WPPH
ARE(IANT)=ARE(IANT)+AMPH(IANT,IWAVE)*(COS(PA2)-COS(PA1))
AIM(IANT)=AIM(IANT)+AMPH(IANT,IWAVE)*(SIN(PA2)-SIN(PA1))
1170 CONTINUE
C
C   STORE PRESENT WAVE PHASE
C
C
1171 WPHH(IWAVE)=WPPH
1172 CONTINUE
1190 CONTINUE
C
C   CALCULATE MODULATING FACTOR FOR TIME T
C
C   AMS=(1-PCAM)+PCAM*COS(CONW*T)
C
C   DETERMINE ANTENNA ELEMENT TO THE LEFT OF THE SAMPLE CENTER AND THE
C   ANGLES BETWEEN THE SAMPLE CENTER AND ADJACENT ANTENNA ELEMENTS
C
C
KC=(CENT-ANOA2)/ANOA+1
CDEL=(CENT-ANOA2)-ANOA*(KC-1)
CDELP=ANOA-CDEL
C
C   CALCULATE THE LINEAR INTERPOLATION FACTORS
C
C
CDELA=CDEL/ANOA
CDEIAP=CDELP/ANOA
C
C   IF KC IS NOT BETWEEN THE LIMITS 1 - NOA, CORRECT THE VALUE OF KC
C
C   IF (KC) 1194,1194,1195
1194 KC=NOA+KC
1195 IF (KC-NOA) 1197,1197,1196
1196 KC=KC-NOA
C
C   LEFT BANK FOR IDIR=1 AND RIGHT BANK FOR IDIR=2
C
1197 DO 1220 IDIR=1,2
C
C   ZERO BANK ACCUMULATOR

```

46

```
C
  SJMI=0
  SJMR=0
C
C   PERFORM OPERATION FOR EACH ELEMENT IN THE BANK
C
1199 DD 1217, ISF=1, NAS2
    GO TO (1200, 1204), IDIR
C
C   FIND ELEMENTS TO THE LEFT AND RIGHT OF SCANNING ELEMENT ISF
C   FOR THE LEFT SCANNING BANK
C
1200 IL=KC-(ISF-1)
    IR=IL+1
C
C   CALCULATE THE NOISE VOLTAGE FOR THE ANTENNA ELEMENT COMMON TO
C   BOTH THE LEFT AND RIGHT SCANNING ANTENNA BANKS
C
    IF (ISF=1) 1201, 1201, 1202
1201 CALL RND(RN, RNDP)
    AVREF=ANOISJ*RNDP
    CALL RND(RN, RNDP)
    AVIMRF=ANOISJ*RNDP
    AVREF=ANREF
    AVIMF=ANIMRF
    GO TO 1203
C
C   CALCULATE THE NOISE VOLTAGE FOR THE ANTENNA ELEMENTS TO THE
C   LEFT AND RIGHT OF THE SCANNING ELEMENT
C
1202 AVREF=ANREL
    AVIMF=ANIML
1203 CALL RND(RN, RNDP)
    AVREF=ANOISJ*RNDP
    CALL RND(RN, RNDP)
    AVIMF=ANOISJ*RNDP
    GO TO 1208
C
C
C   FIND ELEMENTS TO THE LEFT AND RIGHT OF SCANNING ELEMENT ISF
C   FOR THE RIGHT SCANNING BANK
C
1204 IL=KC+ISF
    IR=IL+1
C
C   CALCULATE THE NOISE VOLTAGE FOR THE ANTENNA ELEMENTS TO THE
C   LEFT AND RIGHT OF THE SCANNING ELEMENT
C
    IF (ISF=1) 1205, 1205, 1206
1205 AVREF=ANREF
    AVIMF=ANIMRF
    GO TO 1207
1206 AVREF=ANREF
    AVIMF=ANIMR
1207 CALL RND(RN, RNDP)
    AVREF=ANOISJ*RNDP
    CALL RND(RN, RNDP)
    AVIMF=ANOISJ*RNDP
C
C   CORRECT IR AND IL TO FIT BETWEEN THE LIMITS 1 - NOA
C
C
```

```

1208 IF (IL) 1209,1209,1210
1209 IL=NOA+IL
1210 IF (IL-NOA) 1212,1212,1211
1211 IL=IL-NOA
1212 IF (IR) 1213,1213,1214
1213 IR=NOA+IR
1214 IF (IR-NOA) 1216,1216,1215
1215 IR=IR-NOA
1216 CONTINUE
C
C FIND THE VOLTAGE OF THE SCANNING ELEMENT
C
SRE=(AMS*ARE(IL)+ANREL)*CDELA+(AMS*ARE(IR)+ANRER)*CDELA
SIM=(AMS*AIM(IL)+ANIML)*CDELA+(AMS*AIM(IR)+ANIMR)*CDELA
C
C ADD ON THE PHASE DELAY AND ADD THE VOLTAGE TO THE BANK ACCUMULATOR
C
SJM1=SUM1+SIM*COSP(ISE)-SRE*SINP(ISF)
SJM2=SUM2+SIM*SINP(ISE)+SRE*COSP(ISE)
1217 CONTINUE
C
C STORE THE BANK VOLTAGE
C
SJMRE(IDIR)=SUMR
SJMIM(IDIR)=SUMI
1220 CONTINUE
C
C CALCULATE THE VOLTAGE SUMM OF THE RIGHT AND LEFT BANK
C
SJMR=SUMRE(1)+SUMRE(2)
SJM1=SUMIM(1)+SUMIM(2)
DATAST=SQRT(SUMR**2+SUMI**2)
C
C CALCULATE THE VOLTAGE DIFFERENCE BETWEEN THE RIGHT AND LEFT BANK
C
SJMR=SUMRE(2)-SUMRE(1)
SJM1=SUMIM(2)-SUMIM(1)
DATAIT=SQRT(SUMR**2+SUMI**2)
C
C CALCULATE THE PHASE DIFFERENCE BETWEEN THE RIGHT AND LEFT BANK
C AND ADJUST TO FIT BETWEEN THE LIMITS -179.999 TO 180 DEGREES
C
ANGR=ATAN2(SUMIM(2),SUMRE(2))*CONRAD
ANGL=ATAN2(SUMIM(1),SUMRE(1))*CONRAD
DATP=ANGR-ANGL
IF (DATP+180) 1221,1221,1222
1221 DATP=DATP+360
GO TO 1224
1222 IF (DATP-180) 1224,1224,1223
1223 DATP=DATP-360
1224 CONTINUE
C
C STORE THE SCAN OUTPUT DATA
C
DATAS(IP)=DATAST
DATAI(IP)=DATAIT
DATAF(IP)=DATP
DATAO(IP)=CENT
C
C STORE S RECORD INFORMATION
C

```

```

      III=(IP-1)*4+11
      AREA(III )=CENT
      AREA(III+1)=DATAST
      AREA(III+2)=DATADT
      AREA(III+3)=DATP
C
C      FIND THE MAXIMUM SUM AND DIFFERENCE VALUE
C
      IF (ARSE(DATAST)-DATASM) 1226,1226,1225
1225 DATASM=DATAST
1226 IF (ARSE(DATADT)-DATADM) 1228,1228,1227
1227 DATADM=DATADT
1228 CONTINUE
C
C      STORE S RECORD INFORMATION
C
      AREA( 6)=DATASM
      AREA( 7)=DATADM
C
C      WRITE S RECORD INFORMATION ON TO TAPE
C
      CALL WFLR(DFAN,AREA,410)
C
C      PRINT S RECORD INFORMATION
C
      PRINT 9019,SFTNUM,IRUN,NRUN
      PRINT 9025,IS,DATASM,DATADM
      PRINT 9026
C
C      PRINT S RECORD SAMPLE POINT OUTPUT DATA
C      PRINT S FILE SAMPLE POINT OUTPUT DATA
C
      DO 1240 IP=1,ISAM
      PRINT 9027,DATAS(IP),DATAST(IP),DATAD(IP),DATAP(IP),
1(A MARK(1),II=1,11)
C
C      PERFORM OPERATIONS FOR THE LINE PRINTER PLOT
C
      I1=((DATASM/100+DATAST(IP))/DATASM)*50+1
      I2=((DATADM/100+DATAD(IP))/DATADM)*50+1
      I3=((DATAP(IP)+183.6)/360)*50+1
      A_LINE(I1)=46
      PRINT 9030,(A_LINE(I1),II=1,51)
      A_LINE(I1)=0
      A_LINE(I2)=44
      PRINT 9030,(A_LINE(I2),II=1,51)
      A_LINE(I2)=0
      A_LINE(I3)=24
      PRINT 9030,(A_LINE(I3),II=1,51)
      A_LINE(I3)=0
1240 CONTINUE
1250 CONTINUE
C
C      END OF DATA RUN. START CALCULATIONS OVER FOR NEXT DATA RUN,
C      OR CLOSE TAPE AND EXIT PROGRAM IF LAST DATA RUN HAS BEEN COMPLETED
C
      IF (NRUN-IRUN) 8995,8995,950
C
C      THE OLD DATA RUNS OFF THE END OF THE TAPE, PRINT ERROR STATEMENT
C      AND TERMINATE EXECUTION OF PROGRAM
C

```

```

8800 PRINT 9050
      GO TO 8999
C
C   WRITE THE TERMINAL FILE ONTO THE END OF THE TAPE
C
8995 CALL CLOSE(DFAN)
8996 CALL OPEN(DFAN,DFAS,ITAPE,0.4HSIMU)
      AREA(1)=FH
      CALL WRTR(DFAN,AREA,2)
C
C   CLOSE AND REWIND THE TAPE AND EXIT THE PROGRAM
C
8999 CALL CLOSE(DFAN)
      CALL SETRN(ITAPE,1)
      CALL EXIT
C
C *****
C
C   THE I/O FORMATS ARE AS FOLLOWS
C
9008 FORMAT (3I5)
9009 FORMAT (15,2F10.2, 15, F10.2)
9010 FORMAT ( 15,3F10.4)
9011 FORMAT (5F8.2)
9012 FORMAT (2F10.2,2I5,F10.2)
9013 FORMAT (F10.4,15)
9019 FORMAT (1H1/5X,13HSET NUMBER = ,110,14H * RUN NUMBER ,13,4H OF ,
           113,5H RUNS)
9020 FORMAT (           /5X,25HANTENNA ARRANGEMENT
           1Y INFORMATION// 5X,20HNUMBER OF ANTENNAS =,17X,F6.2/5X,32HDISTANCE
           2E FROM CENTER TO SCREEN =,5X,F6.2,7H METERS/ 5X,33HDISTANCE FROM
           3SCREEN TO ANTENNA =,4X,F6.2,7H METERS// 5X,12HSCANNER MODE//
           45X,20HNUMBER OF SCANNING ANTENNAS =,8X,F6.2/ 5X,16HCOPHASAL ANGLE
           5=,21X,F6.2,8H DEGREES// 5X,14HWAVE INFORMATION// 5X,19HCARRIER FRE
           6QUENCY =,18X,F6.2,4H MHZ/ 5X,22HMODULATION FREQUENCY =,15X,F6.2,4H
           7 KHZ/5X,23HPERCENT OF MODULATION =,14X,F6.2/ 5X,31HNUMBER OF INC
           8IDENT WAVEFRONTS =,6X,F6.2/)
9021 FORMAT (5X,4HWAVE,5X,4HWAVE,4(6X,4HWAVE),6X,5HPHASE/5X,4HNUMR,5X,
           13HAMP,7X,5HPHASE,5X,3HAZM,7X,4HFLLEV,6X,4HSTEP/)
9022 FORMAT (5X,13,1Y,5(4X,F6.2))
9023 FORMAT (/5X,17HNOISE INFORMATION// 5X,19HSTANDARD DEVIATION =,18X,F
           16.2 / 5X,13HPRND STARTER =,24X,F6.2// 5X,27HANTENNA ARRAY
           2 SCAN SETTINGS//5X,15HSECTOR CENTER =,22X,F6.2,8H DEGREES/
           3 5X,18HNUMBER OF SPANS = ,19X,F6.2/ 5X,15H
           4CANTILE = ,22X,F6.2,8H S-C / 5X,25HNUMBER OF SAMPLE POINTS
           5=,12X,F6.2/ 5X,26HINCREMENT BETWEEN POINTS =,11X,F6.2,8H DEGREES)
9025 FORMAT ( 5X,13HSCAN NUMBER =,13// 5X,14HMAX SUM DATA =,2X,F8.2/
           15X,14HMAX DIF DATA =,2X,F8.2/)
9026 FORMAT (/7X,4HNOISE,7X,3HSLM,8X,3HDIF,8X,5HPHASE/ 7X,5HSIGFI,6X,4HD
           1ATA,2(7X,4HDATA)/)
9027 FORMAT (2X,4(3X,F8.2),5X,A1.4,10(4X,A1.4))
9030 FORMAT (1H+,50X.5141.4)
9050 FORMAT (1H1/ 5X, 32HTHE DATA RUNS OFF THE END OF THE TAPE/
           1 5X, 28HPROGRAM WILL NOT BE EXECUTED)
C
C *****
C
      END

```

APPENDIX B

REDUCED PROGRAM LISTINGS

REDUCED PROGRAM LISTING NUMBER ONE
THE BASIC OPERATION OF THE PROGRAM

+ • START
+

VEC #299.8
PI #3.14159265
TWOPI #PI*2
CONRAD#360/TWOPI

+
+

IRUN #0
READ 9008,NRUN,ITAPR,MODE

+
+

914 GO TO (924,914),MODE
 CONTINUE

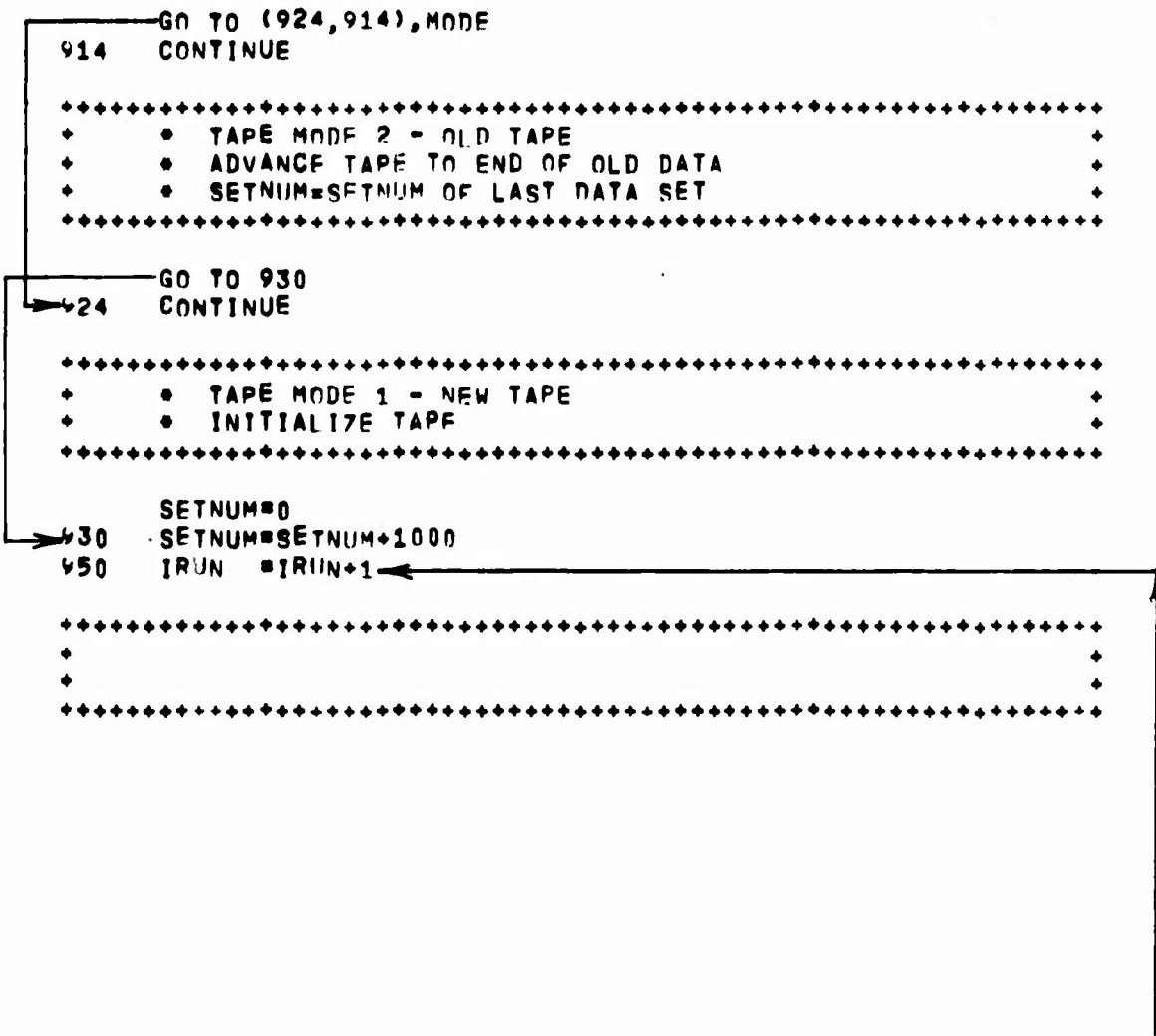
+ • TAPE MODE 2 - OLD TAPE
+ • ADVANCE TAPE TO END OF OLD DATA
+ • SETNUM=SETNUM OF LAST DATA SET

924 GO TO 930
 CONTINUE

+ • TAPE MODE 1 - NEW TAPE
+ • INITIALIZE TAPE

930 SETNUM#0
 SETNUM#SETNUM+1000
950 IRUN #IRUN+1

+
+



```

READ 9009,NOA,A,D,NAS,CPI
READ 9010,NWAVE,FREQC,FREQM,PCAM
NOA4  =NOA/4
ANOA  =360/NOA
ANOA2 =ANOA/2
NAS2  =NAS/2
WL    =VEC/FREQC
CONST1=TWOPID/WL
CONST2=TWOPID/A/WL
CONW  =TWOPID*FREQM*1000

```

```

*****
*   • PHASE DELAY CALCULATIONS   *
*                               *
*****

```

```

DO 1000 IANT=1,NOA
AIM(IANT)=0.0
ARE(IANT)=0.0
DO 1000 IWAVE=1,NWAVE
AMPH(IANT,IWAVE)=0.0
1000 CONTINUE
IWAVE =1
1001 CONTINUE
READ 9011,WAMP,WPHI,AZM,ELEV,PST
WPH  =WPHI/CONRAD
COSELV=COS(ELEV/CONRAD)
COSAMP=COSELV*WAMP
CONE1  =CONST1*COSELV
CONE2  =CONST2*COSELV

```

```

*****
*   • ANTENNA ELEMENT VOLTAGE CALCULATIONS   *
*                               *
*****

```

```

IWAVE =IWAVE+1
IF (NWAVE-IWAVE) 1016,1001,1001
1016 CONTINUE
READ 9013,ANOIS,RN
ANOISJ=.707*ANOIS
READ 9012,SECT,SCANT,ISCAN,ISAM,SAM2
WIDTH =(ISAM-1)*SAMI
SIDE  =SECT-WIDTH/2
IF (SIDE) 1150,1151,1151
1151 SIDE  =360+SIDE
1151 CONTINUE
DELT  =SCANT*SAMI/360

```

```

*****
*
*
*****

```

```
DO 1250 IS=1,ISCAN
```

```

*****
*
*
*****

```

```

T      =(IS-1)*SCANT-DELT
DO 1228 IP=1,ISAM
CENT  =(IP-1)*SAMI+SIDE
IF (CENT-360) 1153,1152,1152
1152  CENT  =CENT-360
1153  CONTINUE
T      =T+DELT
AMS   =(1-PCAM)*PCAM*COS(CONW*T)

```

```

*****
*      * PHASE STEP CALCULATIONS
*
*****

```

```

*****
*      * SCANNING BANK VOLTAGE CALCULATIONS
*
*****

```

```

*****
*      * OUTPUT DATA CALCULATIONS
*
*****

```

```

*****
*
*
*****

```

```
1228 CONTINUE
```

```

*****
*
*
*****

```

```

1250 CONTINUE
IF (NPUN-TRUN) 8995,8995,950
8995 CONTINUE

```

```

*****
*
*
*      * END
*
*****

```

REDUCED PROGRAM LISTING NUMBER TWO
PHASE DELAY CALCULATIONS

```

CONCHI=COS(CPHI/CONRAD)*CONST2
COSM  =COS(((NAS2-1)*ANOA+ANOA2)/CONRAD)
DO 999 ISE=1,NAS2
PDELAY=CONCHI*(COS(((ISE-1)*ANOA+ANOA2)/CONRAD)-COSM)
COSP(ISE)=COS(PDELAY)
SINP(ISE)=SIN(PDELAY)
999 CONTINUE

```

REDUCED PROGRAM LISTING NUMBER THREE
ANTENNA ELEMENT VOITAGE CALCULATIONS

```

K      =(A7M/ANOA)+1
DELK  =AZM-ANOA*(K-1)
DELKP =ANOA-DELK
WPHW(IWAVE)=0.0
PSTEP(IWAVE)=PST/CONRAD
DO 1014 IDIR=1,2
DO 1013 IAW=1,NOA4
GO TO (1003,1008),IDIR
1003  IANT =K+1-IAW
      IF (IAW) 1004,1004,1005
1004  IANT =NOA+IAW
1005  THE  =ANOA*(1-IAW)-DELK
      IF (ARSF(THE)-90) 1007,1007,1006
1006  THE  =-90
1007  GO TO 1012
1008  IANT =K+IAW
      IF (NOA-IAW) 1009,1010,1010
1009  IANT =IAW-NOA
1010  THE  =DELKP+ANOA*(IAW-1)
      IF (ARSF(THE)-90) 1012,1012,1011
1011  THE  =90
1012  COSTHE=COS(THE/CONRAD)
      AMP  =COSAMP*SIN(CONE1*COSTHE)
      PHI  =CONE2*COSTHE+WPH
      ARE(IAW)=ARE(IAW)+AMP*COS(PHI)
      AIM(IAW)=AIM(IAW)+AMP*SIN(PHI)
      PHIH(IAW,IWAVE)=PHI
      AMPH(IAW,IWAVE)=AMP
1013  CONTINUE
1014  CONTINUE

```

REDUCED PROGRAM LISTING NUMBER FOUR
TIME DEPENDENT PHASE SHIFT CALCULATIONS

55

```
IF (T) 1190,1190,1160
1160 DO 1172 IWAVE=1,NWAVE
IF (PSTEP(IWAVE)) 1161,1172,1161
1161 WPPH =PSTEP(IWAVE)*T/SCANT
DO 1170 IANT=1,NOA
IF (AMPH(IANT,IWAVE)) 1169,1170,1160
1169 PA1 =PHI(IANT,IWAVE)+WPHH(IWAVE)
PA2 =PHI(IANT,IWAVE)+WPPH
ARE(IANT)=ARE(IANT)+AMPH(IANT,IWAVE)*(COS(PA2)-COS(PA1))
AIM(IANT)=AIM(IANT)+AMPH(IANT,IWAVE)*(SIN(PA2)-SIN(PA1))
1170 CONTINUE
1171 WPHH(IWAVE)=WPPH
1172 CONTINUE
1190 CONTINUE
```

The flowchart annotations illustrate the control flow of the program. Arrows indicate the following paths:

- From line 1160 to line 1172.
- From line 1161 to line 1172.
- From line 1169 to line 1170.
- From line 1170 to line 1169.
- From line 1171 to line 1172.
- From line 1172 to line 1160.
- From line 1190 to line 1160.

REDUCED PROGRAM LISTING NUMBER FIVE
SCANNING ELEMENT AND SCANNING RANK VOLTAGE CALCULATIONS

```

      KC      =(CENT-ANOA2)/ANOA+1
      CDEL    =(CENT-ANOA2)-ANOA*(KC-1)
      CDELP   =ANOA-CDEL
      CDELA   =CDEL/ANOA
      CDELAP  =CDELP/ANOA
      IF (KC) 1194,1194,1195
1194  KC      =NOA+KC
1195  IF (KC-NOA) 1197,1197,1196
1196  KC      =KC-NOA
1197  DO 1220 IDIR=1,2 ←
      SUMI    =0.0
      SUMR    =0.0
1199  DO 1217 ISE=1,NAS? ←
      GO TO (1200,1204),IDIR
1200  IL      =KC-ISE+1
      IR      =IL+1

      +-----+
      + * NOISE SIGNAL CALCULATION FOR LEFT * +
      +-----+

      GO TO 1208
1204  IL      =KC+ISE
      IR      =IL+1

      +-----+
      + * NOISE SIGNAL CALCULATIONS FOR RIGHT * +
      +-----+

1208  IF (IL) 1209,1209,1210
1209  IL      =NOA+IL
1210  IF (IL-NOA) 1212,1212,1211
1211  IL      =IL-NOA
1212  IF (IR) 1213,1213,1214
1213  IR      =NOA+IR
1214  IF (IR-NOA) 1216,1216,1215
1215  IR      =IR-NOA
1216  CONTINUE
      SRE     =(AMS*ARE(IL)+ANREL)*CDELAP+(AMS*ARE(IR)+ANREL)*CDELA
      SIM     =(AMS*AIM(IL)+ANIML)*CDELAP+(AMS*AIM(IR)+ANIMR)*CDELA
      SUMI    =SUMI+SIM*COSP(ISE)-SRE*SINP(ISE)
      SUMR    =SUMR+SIM*SINP(ISE)+SRE*COSP(ISE)
1217  CONTINUE
      SUMRE(IDIP)=SUMR
      SUMIM(IDIP)=SUMI
1220  CONTINUE

```

REDUCED PROGRAM LISTING NUMBER SIX
DETERMINATION OF THE NOISE SIGNAL VOLTAGE - FOR LEFT BANK

57

```
IF (ISE-1) 1201,1201,1202
1201 CALL RND(RN,RNDP)
      ANRERF=ANOISJ*RNDP
      CALL RND(RN,RNDP)
      ANIMRF=ANOISJ*RNDP
      ANRER =ANRERF
      ANIMR =ANIMRF
      GO TO 1203
1202 ANRER =ANREL
      ANIMR =ANIML
1203 CALL RND(RN,RNDP)
      ANREL =ANOISJ*RNDP
      CALL RND(RN,RNDP)
      ANIML =ANOISJ*RNDP
```

REDUCED PROGRAM LISTING NUMBER SEVEN
DETERMINATION OF THE NOISE SIGNAL VOLTAGE - FOR RIGHT BANK

```
IF (ISE-1) 1205,1205,1206
1205 ANREL =ANRERF
      ANIML =ANIMRF
      GO TO 1207
1206 ANREL =ANPER
      ANIML =ANIMR
1207 CALL RND(RN,RNDP)
      ANRER =ANOISJ*RNDP
      CALL RND(RN,RNDP)
      ANIMR =ANOISJ*RNDP
```

REDUCED PROGRAM LISTING NUMBER EIGHT
CALCULATION OF SYSTEM OUTPUTS

```
SUMR =SUMRE(1)+SUMRE(2)
SUMI =SUMIM(1)+SUMIM(2)
DATAST=SQRT(SUMR**2+SUMI**2)
```

```
SUMR =SUMRE(2)-SUMRE(1)
SUMI =SUMIM(2)-SUMIM(1)
DATADT=SQRT(SUMR**2+SUMI**2)
```

```
ANGR =ATAN2(SUMIM(2),SUMRE(2))*CONRAD
ANGL =ATAN2(SUMIM(1),SUMRE(1))*CONRAD
DATP =ANGR-ANGL
```

```
IF (DATP+180) 1221,1221,1222
```

```
1221 DATP =DATP+360
```

```
GO TO 1224
```

```
IF (DATP-180) 1224,1224,1223
```

```
1223 DATP =DATP-360
```

```
1224 CONTINUE
```

APPENDIX C

SAMPLE INPUTS, FOR GCAAS, AND
HARD COPY OUTPUT

SAMPLE INPUT CONDITIONS FOR GCAAS

COL.	5	10	20	30	40	50	60	72
1	↓	↓	↓	↓	↓	↓	↓	↓
1	1	1						
12 ⁿ	145.50		6.00	48	20.00			
2	7.0000		5.0000	0.0000				
1.00	0.00		90.00	30.00	0.00			
.50	10.00		85.00	35.00	30.00			
0.0000	0							
90.00		2.00	2	30	2.00			

THE HARD COPY OUTPUT FOR THESE SAMPLE INPUT CONDITIONS
IS CONTAINED IN THE FOLLOWING THREE PAGES OF THIS APPENDIX

SET NUMBER = 1000 * RUN NUMBER 1 OF 1 RUNS

ANTENNA ARRAY INFORMATION

NUMBER OF ANTENNAS = 120.00
 DISTANCE FROM CENTER TO SCREEN = 145.50 METERS
 DISTANCE FROM SCREEN TO ANTENNA = 6.00 METERS

SCANNER MODE

NUMBER OF SCANNING ANTENNAS = 48.00
 COPHASAL ANGLE = 20.00 DEGREES

WAVE INFORMATION

CARRIER FREQUENCY = 7.00 MHZ
 MODULATION FREQUENCY = 5.00 KHZ
 PERCENT OF MODULATION = 0.00
 NUMBER OF INCIDENT WAVEFRONTS = 2.00

WAVE NUMR	WAVE AMP	WAVE PHASE	WAVE AZM	WAVE ELEV	PHASE STEP
1	1.00	0.00	90.00	30.00	0.00
2	0.50	10.00	85.00	35.00	30.00

NOISE INFORMATION

STANDARD DEVIATION = 0.00
 RND STARTER = 0.00

ANTENNA ARRAY SCAN SETTINGS

SECTOR CENTER = 90.00 DEGREES
 NUMBER OF SCANS = 2.00
 SCAN TIME = 2.00 SEC
 NUMBER OF SAMPLE POINTS = 30.00
 INCREMENT BETWEEN POINTS = 2.00 DEGREES

SET NUMBER = 1000 * RUN NUMBR 1 OF 1 RUNS
 SCAN NUMBER = 1

MAX SUM DATA = 26.30
 MAX DIF DATA = 17.89

30RF SIGHT	SUM DATA	DIF DATA	PHASE DATA
61.00	2.87	3.43	-100.44
63.00	2.77	5.05	-123.30
65.00	2.14	6.60	-144.26
67.00	1.08	7.83	-167.76
69.00	2.24	8.32	170.13
71.00	4.41	8.69	155.60
73.00	6.27	9.40	162.53
75.00	6.74	11.26	-177.99
77.00	6.76	14.24	175.26
79.00	7.35	17.07	151.99
81.00	10.79	17.89	122.36
83.00	16.18	17.04	93.23
85.00	21.68	13.04	60.56
87.00	24.96	6.78	27.66
89.00	26.30	2.46	-5.07
91.00	24.11	8.70	-39.44
93.00	19.13	13.94	-72.17
95.00	13.07	17.41	-106.31
97.00	6.73	17.61	-140.26
99.00	3.64	15.16	-170.52
101.00	5.22	11.78	156.91
103.00	6.15	8.22	137.19
105.00	5.23	6.56	-144.88
107.00	3.40	6.79	-143.65
109.00	0.84	7.06	-171.63
111.00	1.26	6.51	160.65
113.00	2.81	5.43	129.57
115.00	3.30	3.81	99.73
117.00	2.91	2.23	72.14
119.00	2.11	0.78	34.77

SET NUMBER = 1000 * RUN NUMBER 1 OF 1 RUNS
 SCAN NUMBER = 2

MAX SUM DATA = 27.52
 MAX DIF DATA = 18.87

RORF SIGHT	SUM DATA	DIF DATA	PHASE DATA
61.00	2.82	3.69	-106.17
63.00	2.59	5.29	-130.69
65.00	1.80	6.72	-152.76
67.00	0.23	7.67	-177.02
69.00	2.10	7.79	160.34
71.00	4.25	7.81	145.73
73.00	5.87	8.41	165.17
75.00	5.93	10.62	-168.98
77.00	5.37	13.98	179.45
79.00	5.90	17.12	153.59
81.00	10.25	18.04	122.78
83.00	16.31	17.22	93.16
85.00	22.35	13.04	60.29
87.00	25.96	6.37	27.39
89.00	27.52	1.24	-5.15
91.00	25.41	9.09	-39.19
93.00	20.40	14.72	-71.46
95.00	14.32	18.40	-104.86
97.00	8.04	18.87	-137.74
99.00	4.86	16.52	-166.44
101.00	5.82	13.24	164.23
103.00	6.50	9.68	150.98
105.00	5.48	7.79	-166.67
107.00	3.63	7.62	-155.32
109.00	1.16	7.59	-177.38
111.00	1.36	6.88	157.90
113.00	2.85	5.71	129.34
115.00	3.33	4.03	102.17
117.00	2.91	2.41	78.09
119.00	2.07	0.94	47.83

APPENDIX D

LISTING OF PROGRAM SEGMENT OF TAPE HANDLING

NAME STHPS)
 EQUIP=CARDRE,PRINTF)
 SINGLE (AREA,DFAN))

PROGRAM: STHPS
 STANDING FOR: SAMPLE TAPE HANDLING PROGRAM SEGMENT

WRITTEN BY: ROY F HUNNINGHAUS

WRITTEN FOR: RADIOLOCATION RESEARCH LABORATORY
 DEPARTMENT OF ELECTRICAL ENGINEERING
 UNIVERSITY OF ILLINOIS

.....
 INPUT CARDS NECESSARY FOR OPERATION:

ONE PROGRAM OPERATION CARD:
 (15) NSET * NUMBER OF DATA SETS TO BE LOCATED
 (15) ITAPE * TAPE DRIVE NUMBER

THE FOLLOWING CARDS ARE NEEDED FOR EACH DATA SET TO BE LOCATED
 DATA SET AND RUN NUMBER CARD:

(110) SETNUM * DATA SET REFERENCE NUMBER TO BE LOCATED
 (15) IRUN * DATA RUN REFERENCE NUMBER TO BE LOCATED

.....
 PLACE ANY ADDITIONAL INPUT CARDS FOR THE GIVEN DATA SET - RUN
 AT THIS POINT

.....
 DIMENSION AREA(500),DFAN(650)

EH=4H F
 FH=4H H
 SH=4H S
 DFAS=600

READ 9000,NSET,ITAPE

CALL SFTRN(ITAPE,1)
 CALL FXBLK(ITAPE,1)
 CALL BLKLN(ITAPE,0,0)

ISET=0
 GO TO 101
 100 CALL SETRN(ITAPE,1)
 101 ISET=ISET+1
 IF (NSET-ISET) 8500,102,102
 102 REAL 9001,SETNUM,IRUN
 ASSIGN 8000 TO LAST
 GO TO 104
 103 CALL CLOSE(DFAN)
 CALL SETFD(DFAN)
 104 CALL OPEN(DFAN,DFAS,ITAPE,0,4HSTMU)

```

66      CALL RDLR(DFAN,AREA,LAST)
      105 IF (AREA(2)-SETNUM) 103,107,103

      106 PRINT 9050,SETNUM

      107 NRUN=AREA(4)
      IF (NRUN-IRUN) 108,111,111

      108 PRINT 9051,SETNUM,IRUN,NRUN
      109 CALL CLOSE(DFAN)
      GO TO 100

      110 CALL RDLR(DFAN,AREA,LAST)
      111 IF (IRUN-AREA(3)) 110,112,110
      112 CONTINUE
      PRINT 9049,SETNUM,IRUN
      ISCAN=AREA(17)
      ISAM =AREA(19)

      *****

      PLACE ALL OPERATIONS FOR THE INPUT INFORMATION AT THIS POINT

      *****

      DO 2999 IS=1,ISCAN
      CALL RDLR(DFAN,AREA,LAST)

      *****

      PLACE ALL OPERATIONS FOR THE SCAN AT THIS POINT

      *****

2999 CONTINUE

      CALL CLOSE(DFAN)
      GO TO 100

8000 CALL CLOSE(DFAN)
      CALL SETRN(ITAPE,1)
      PRINT 9052
      CALL EXIT

8500 PRINT 9099
      CALL EXIT

      *****

9000 FORMAT (2I5)
9001 FORMAT (1I10,15)
9040 FORMAT (1H1/5X,12HSET NUMBER ,110/ 5X,12HRUN NUMBER ,13,6H FOUND

```

```
1 )
9050 FORMAT (1H1/5X,12HSET NUMBER ,110/ 5X,17HNOT FOUND ON TAPE )
9051 FORMAT (1H1/5X,12HSET NUMBER ,110/ 5X,12HRUN NUMBER (,
1 42H( GREATER THAN NUMBER OF RUNS IN THE SET (,13,14) )
9052 FORMAT (//5X,24HTAPE OPERATION OR TAPE ERROR )
9099 FORMAT (1H1/5X,3AHALL OPERATIONS COMPLETED - PROGRAM END )
9100 FORMAT (1H1/5X,12HSET NUMBER ,110,14H * RUN NUMBER ,13,4H OF .
1 13, 5H RUNS)
```

END

APPENDIX E

LISTING OF PROGRAM STRO

```

NAME STRO;
EQUIP=CANDRE,PRINTF;
SINGLE (AREA,DFAN);

PROGRAM:      STRO
STANDING FOR: SIMULATOR TAPE READ OUT

WRITTEN BY:   ROY E HUNNINGHAUS

WRITTEN FOR:  RADIOLOCATION RESEARCH LABORATORY
              DEPARTMENT OF ELECTRICAL ENGINEERING
              UNIVERSITY OF ILLINOIS

COMPLETED:   MAY, 1970
REVISED:     OCTOBER, 1970 - FOR NEW TAPE HANDLING PROCEDURES
.....

INPUT CARDS NECESSARY FOR OPERATION:

ONE PROGRAM OPERATION CARD:
(15)  ITAPE * TAPE DRIVE NUMBER
.....

DIMENSION ARRAYS

DIMENSION ALINE(51),AMARK(11)
DIMENSION AREA(410),DFAN(650)

SET OPERATION CONSTANTS

EH=4H  F
DFAS=600

REAL PROGRAM OPERATION INFORMATION

REAL 9000,ITAPE

INITIALIZE LINE PRINTER

DO 900 II=1,51
900  ALINE(II)=0
DO 901 II=1,11
901  AMARK(II)=27

OPEN TAPE ON UNIT NO. ITAPE

CALL SETRN(ITAPE,1)
CALL FXBLK(ITAPE,1)
CALL BLKLN(ITAPE,0,0)
ASSIGN 4000 TO LAST
GO TO 1001

ADVANCE TAPE AND PRINT OUTPUT DATA UNTIL TERMINAL FILE IS REACHED

1000 CALL CLOSE(DFAN)

```

```
CALL SETFD(DFAN)
1001 CALL OPEN(DFAN,DFAS,ITAPE,0,4HS1MU)
CALL RDLR(DFAN,AREA,LAST)
IF (AREA(1)-EM) 1100,3000,1100
C
C
C PRINT H RECORD INFORMATION
1100 NRUN=AREA(4)
GO TO 1102
1101 CALL RDLR(DFAN,AREA,LAST)
1102 NWAVE=AREA(13)
IRUN=AREA(3)
PRINT 9019,(AREA(II),II=2,4)
PRINT 9020,(AREA(II),II=5,13)
PRINT 9021
KKK=21
DO 1105 IWAVE=1,NWAVE
KKK4=KKK+4
PRINT 9022,IWAVE,(AREA(II),II=KKK,KKK4)
1105 KKK=KKK+5
PRINT 9023,(AREA(II),II=14,20)
ISCAN=AREA(17)
ISAM=AREA(19)
C
C
C PRINT S RECORD INFORMATION FOR EACH SCAN IN THE DATA RUN
DO 1260 IS=1,ISCAN
CALL RDLR(DFAN,AREA,LAST)
1200 PRINT 9019,(AREA(II),II=2,4)
DATASH=AREA(6)
DATADM=AREA(7)
PRINT 9025,(AREA(II),II=5,7)
PRINT 9026
DO 1250 IP=1,ISAM
III=(IP-1)*4+11
CENT =AREA(III)
DATAST=AREA(III+1)
DATADT=AREA(III+2)
DATAP =AREA(III+3)
PRINT 9027,CENT,DATAST,DATADT,DATAP,(AMARK(II),II=1,11)
C
C
C PERFORM OPERATIONS FOR LINE PRINTER PLOT
I1=((DATASH/100+DATAST)/DATASH)*50+1
I2=((DATADM/1000+DATADT)/DATADM)*50+1
I3=((DATAP+183.6)/360)*50+1
ALINE(I1)=46
PRINT 9030,(ALINE(II),II=1,51)
ALINE(I1)=0
ALINE(I2)=44
PRINT 9030,(ALINE(II),II=1,51)
ALINE(I2)=0
ALINE(I3)=24
PRINT 9030,(ALINE(II),II=1,51)
ALINE(I3)=0
1250 CONTINUE
1260 CONTINUE
```

PAGE 003

```

C      GO BACK AND PRINT H RECORD INFORMATION FOR THE NEXT DATA RUN
C      IF LAST DATA RUN IN THE DATA SET HAS BEEN PRINTED, ADVANCE TAPE
C      TO NEXT DATA SET

      IF (NRUN-IRUN) 1000,1000,1101

      TERMINAL FILE HAS BEEN REACHED, PRINT ALL DATA PRINTED STATEMENT

3000 PRINT 9070
      GO TO 5000

      ENL OF TAPE HAS BEEN REACHED, PRINT ERROR STATEMENT

4000 PRINT 9060
      GO TO 5000

      CLOSE AND REWIND TAPE AND EXIT PROGRAM

5000 CALL CLOSE(DFAN)
      CALL SETRN(ITAPE,1)
      CALL EXIT

.....

      THE I/O FORMATS ARE AS FOLLOWS

9000 FORMAT (I5)
9010 FORMAT (1H1/5X,13HSET NUMBER = ,I10,14H * RUN NUMBER ,I3,4H OF ,
1I3,5H RUNS)
9020 FORMAT ( /5X,25HANTENNA ARRA
1Y INFORMATION// 5X,20HNUMBER OF ANTENNAS =,17X,F6.2/5X,32HDISTANC
2E FROM CENTER TO SCREEN =,5X,F6.2,7H METERS/ 5X,33HDISTANCE FROM
3SCREEN TO ANTENNA =,4X,F6.2,7H METERS// 5X,12HSCANNER MODF//
45X,29HNUMBER OF SCANNING ANTENNAS =,8X,F6.2/ 5X,16HCOPHASAL ANGLE
5=,21X,F6.2,8H DEGREES// 5X,16HWAVE INFORMATION// 5X,19HCARRIER FRE
6QUENCY =,18X,F6.2,4H MHZ/ 5X,22HMODULATION FREQUENCY =,15X,F6.2,4H
7 KHZ/5X,23HPERCENT OF MODULATION =,14X,F6.2/ 5X,31HNUMBER OF INC
8IDENT WAVEFRONTS =,6X,F6.2/)
9021 FORMAT (5X,4HWAVE,5X,4HWAVE,3(6X,4HWAVE),6X,5HPHASE/5X,4HNUMB,5X,
13HAMP,7X,5HPHASE,5X,3HAZM,7X,4HFLEV,6X,4HSTEP/)
9022 FORMAT (5X,I3,1X,5(4X,F6.2))
9023 FORMAT (/5X,17HNOISE INFORMATION// 5X,19HSTANDARD DEVIATION =,18X,F
16.2 / 5X,13HPRD STARTEP =,24X,F6.2// 5X,27HANTENNA ARRAY
2 SCAN SETTINGS//5X,15HSECTOR CENTER =,22X,F6.2,8H DEGREES/
3 5X,18HNUMBER OF SCANS =,19X,F6.2/ 5X,15HS
4CAN TIME =,22X,F6.2,8H SEC / 5X,25HNUMBER OF SAMPLE POINTS
5=,12X,F6.2/ 5X,26HINCREMENT BETWEEN POINTS =,11X,F6.2,8H DEGREES)
9025 FORMAT ( 5X,13HSCAN NUMBER =,I3// 5X,14HMAX SUM DATA =,2X,F6.2/
15X,14HMAX DIF DATA =,2X,F6.2/)
9026 FORIAT (/7X,4HRORE,7X,3HSUM,8X,3HDIF,8Y,5HPHASE/ 7X,5HSIGHT,6X,4HD
1ATA,2(7X,4HDATA)/)
9027 FORMAT (2X,4(3X,F6.2),5X,A1.4,10(4Y,A1.4))
9030 FORMAT (1H+,50X,51A1.4)
9060 FORMAT (1H1/5X, 36HTHE END OF THE TAPE HAS BEEN REACHED)
9070 FORMAT (1H1/5X, 38HALL THE DATA ON THE TAPE HAS BEEN READ)

.....

      END

```

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13. ABSTRACT The simulation program GCAAS (General Circular Antenna Array Simulator) has been developed to simulate the output data from a circularly disposed antenna array (CDAA)-direction finding system under known input signal conditions. The CDAA system which has been simulated is similar to the Wullenweber Direction Finding System at the University of Illinois and may consist of as many as 360 antenna elements in a circular array of any reasonable dimensions and simulates the outputs obtained from the array used in a scanning mode. The input signal conditions may include up to five incoming signals at different azimuthal and elevation angles of arrival with time-dependent relative phase shifts between the incoming signals. The output consists of the sum, difference and differential phase data sampled at regular intervals of azimuth and stored on magnetic tape for further use in the determination of the direction of arrival. A maximum of 100 samples of the output data set may be obtained from each scan.		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
CDAAs Simulator						
Wullenweber Simulator						
CDAAs						
Wullenweber						
Digital Simulation						
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