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ANTENNA EVALUATION STUDY FOR THE SHUTTLE MULTISPECTRAL RADAR: PHASE I

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FINAL REPORT

by

Edgar L. Coffey, III
Keith R. Carver

prepared for

NASA Johnson Space Center
Houston, Texas

Contract No.
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December 1976

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1.0 INTRODUCTION

This report presents the results of the first phase of the Antenna Evaluation Study for the Shuttle Multispectral Radar (SMR). The original goals of Phase I were to make preliminary indentification cf those critical parameters of the Shuttle Multispectral Radar Antenna (SMRA) which most affect antenna performance and to write a first draft of specifications for the subarrays which will be analyzed in Phases III and IV. During the course of this research it was decided to expand the scope of Phase I to include the development of a preliminary mathematical model describing SMRA performance under the influence of various physical and environmental factors. Th.. was necessary to identify those key antenna parameters and environmental conditions which might degrade SMRA performance. This has allowed more time in Phase II for the simulation and study of critical factors which may create or influence these error-causing conditions.

1.1 Some Projected User Needs

A key and as yet not completely answered question is the instrumentation requirement of the rather nebulously defined user community. Studies by Hughes Aircraft Co. and JPL have suggested L and X-bands as a dual-frequency choice best suited to the needs of potential users, yet realizable in terms of development. In addition, dual polarization capability has been specified along with three incidence angles and various swath widths.

Space radars with imaging capabilities have a considerable potential applicability in the following areas:

1. Soil moisture determination
2. Flood area monitoring
3. Crop discrimination
4. Crop yield estimates
5. Plant biomass
6. Mineral and petroleum exploration
7. Sea and lake ice mapping
8. Iceberg monitoring

These application areas have been discussed in two Active Microwave Workshops (Fall, 1974 and Fall, 1976 at NASA/JSC) along with an additional October, 1976 Shuttle Multispectral Radar Applications Meeting held at NASA/JSC. These meetings have also pointed out that L and X-bands are not optimum for some prime application areas. For example, C-band and K_u-band are optimum for soil moisture measurement and vegetation classification, respectively. At the time of this writing, the user groups have not been able to agree on two optimum frequencies best suited for the broadest range of application; this has imposed additional delays on detailed specification of optimum incidence angles, registration of cross-band beams, etc. For example, it has been shown that soil moisture determination is best carried out at about 4.5 GHz and for incidence angles in the $7^\circ - 12^\circ$ range, whereas crop classification is optimally accomplished at 14 GHz and with a $40^\circ - 50^\circ$ incidence angle range.

This situation of uncertainty requires that the present antenna study incorporate frequencies ranging from 1.2 - 14.5 GHz as well as a consideration of incidence angles from near-nadir to nearly 50°. In fact, one of the eventual goals of this project is to provide simulated performance data at a variety of frequencies, incidence angles, etc.; this may impose additional hardware-related restrictions on finalized choices of SMR design parameters.

1.2 The Need For A Comprehensive and Independent Antenna Evaluation Study

The Shuttle Multispectral Radar Antenna, being an electrically large radiator, has several characteristics that require a thorough analysis. Preliminary studies indicate that the SMRA must be a large structure, on the order of 12 m by 3 m which can operate in a space environment. The determination of its electrical behavior (gain, beamshape, pointing accuracy, etc.) is vital to the calibration of the overall SAR system and thus to the success of the mission itself. Since the antenna development cost is by far the largest system development budget item, it is economically imperative that critical antenna parameters and potential calibration problems be identified early in order to avoid costly mechanical and electrical redesign phases which might otherwise be required. In effect, a macro developmental and simulation exercise such as described herein seeks to clearly identify at a very early stage those most likely technological problem areas which invariably accompany the development of a state-of-the-art instrument such as the Shuttle Multispectral Radar; this not only helps to avoid costly development errors but also permits a realistic prediction of the performance of the instrument itself and thus allows design/performance tradeoffs to be made at a much earlier stage of development.

The huge electrical size of the total antenna structure suggests that conventional techniques for measurement of important electrical parameters will be of little use and that novel calibration schemes must be devised. In addition, electrical and mechanical tolerance errors, particularly systematic ones, are more likely to seriously degrade the performance of a large antenna. In preliminary investigations by Hughes Aircraft Co. and Ball Brothers Research Corp., the antenna configuration and size was specified, but no bounds were placed on tolerance errors or performance indices. These bounds should be determined as soon as possible to avoid the expense of constructing either an antenna whose parameters are overly restricted or an antenna whose performance will be inadequate for the desired applications.

In addition to determining antenna performance in an idealized environment, it is also necessary to predict in situ performance and to devise means for assurance of calibration stability. This prediction requires an adequate mathematical model which describes the SMRA performance including space environmental factors such as thermal gradient effects on electrical flatness, beam pointing stability, material stability in a near-vacuum environment, and effects of multiple scatter from the shuttle bus itself.

Although the effect of the SAR processor on the synthetic antenna performance has not been considered in this report, it will be discussed in subsequent reports. The quality of the image processors currently being considered may have little effect on the image if the antenna performance is significantly degraded by external factors, or vice versa. A related consideration is the study of realistic system calibration techniques. System development must be planned with calibration as an integral part of the design process; calibration must not be an afterthought. Since the SMR can only be calibrated to within a specified uncertainty, the antenna should not be overspecified to a level which cannot even be measured. For example, it should be possible to answer the question, "What level of antenna cross-polarization rejection is actually necessary in light of: 1) user requirements, and 2) ability to calibrate cross-polarized performance?"

1.3 A Two-Path Approach To The Antenna Study Problem

An answer to the questions in the last section requires the development of both mathematical techniques and computer programs to analyze random and systematic electrical and mechanical SMRA errors, and a method of measuring and testing antennas representing the competing approaches. This dual approach has been followed in Phase I and will continue to be used in subsequent phases.

The mechanical model and computer simulation relate electrical and mechanical tolerances to performance indices. The model is being designed to that tradeoffs can be made between the quality of performance and the expense of tight tolerances. It is also capable of predicting SMRA performance under various space environmental conditions. Finally, through analysis of the results of several simulations, the model is able to flag any possible problems that one of the competing designs might incur. In Phase I antenna parameters have been identified which are critical to both antenna and system performance. Furthermore, a preliminary mathematical model and a computer program have been developed and tested. Subsequent phases will deal with refinement of the model and the simulation of a number of scenarios.

The measurement/testing problems can be alleviated by performing appropriate tests on macro model subarray antennas representing the competing design approaches. These measurements will include near-field and far-field electrical performance tests and thermal cycling tests with mechanical flatness measurements. The results of these tests will be entered into the SMRA simulation model to predict the performance of the full size array. In Phase I, those parameters which must be measured have been identified.

1.4 Scope of Work

This report presents the results of several activities associated with the development of the mathematical model, the computer program, and the subarray panel requirement. These activities were:

1. A review of the antenna designs from the definition phase.
2. An identification of critical SMRA performance parameters.
3. An identification of conditions which may degrade SMRA performance.
4. An identification of factors which may create or influence error-causing conditions.
5. The development of a preliminary SMRA mathematical model.
6. The organization of the SMRA computer simulation program.
7. A demonstration of the flexibility of the SMRA computer program.
8. The identification of requirements and specifications for the subarray panels.
9. The development of an interface data tape for the University of Texas Applied Research Laboratory image processor simulation program.

The prinicpal results obtained to date are:

1. A cause-effect relationship for various environmental and physical factors on the antenna electrical and mechanical behavior.
2. A baseline mathematical model for the electrical and mechanical behavior of the SMRA in a space environment.
3. A compilation of results of the simulation of the baseline designs for both competing approaches and several sample scenarious demonstrating the flexibility of the mathematical simulation.

2.0 IDENTIFICATION OF IMPORTANT PARAMETERS, THEIR EFFECT ON SMR SYSTEM PERFORMANCE AND POSSIBLE TRADEOFFS

2.1 A Review Of The Antenna Designs From The Definition Phase

A review of the candidate SMR system approaches and synthetic aperture techniques was conducted early in Phase I in order to establish a familiarity with both the antennas themselves and the interaction between the antenna and the image processor. It was found that although preliminary specifications had been placed on some of the antenna parameters, there was not a tolerance budget (or rationale for one) for each major component of the overall system. Because the performance of the overall system is set by both the antenna and the image processor, and because these cannot be designed independently, it is our opinion that further refinement of antenna performance parameters be withheld pending dual simulation of antenna and processor. To this end, we have developed an auxiliary computer program which generates real antenna pattern data for use by the Applied Research Laboratories (University of Texas) in their image processor simulations.

Both Hughes and JPL have suggested in independently conducted studies that the SMR antenna be a large, planar array of approximately three meters by twelve meters. The twelve meter azimuth dimension was predicated upon the resolution requirement. The three meter elevation dimension was based upon the swath width requirement, space required for both L- and X-band antennas, and payload weight/size restrictions. Both designs would use uniform illumination and would achieve three different elevation beamwidths by switching between two panels. The angle of incidence would be controlled by the attitudes of the shuttle. Hughes proposed to use crossed dipoles at L-band and waveguides slots at X-band, whereas Ball Brothers (under contract to JPL) would use microstrip elements at both frequencies. For launch and boost, the antenna would be folded twice in the azimuth dimension and stowed within the shuttle payload compartment. After orbit insertion, the antenna would be deployed to its nominally flat shape. A comparison of the Hughes and JPL/Ball Brothers antenna specifications is given in Table 1. More detailed information can be found in the Hughes report to NASA/JSC of October 1975 and the JPL report to NASA/JSC of March 1976.

TABLE 1. A comparison of JPL/Ball Brothers and Hughes antenna specifications.

Specification	JPL/BB						HUGHES					
	L-band			X-band			L-band			X-band		
Frequency, GHz	1.302			8.33			1.04			9.00		
Polarization	HH,HV,VH,VV			HH,HV,VH,VV			HH,HV,VH,VV			HH,HV,VH,VV		
Azimuth dimension, m	12			12			12			12		
Azimuth Peak-to-Null beamwidth, deg	1.1			0.172			1.287			0.153		
Efficiency, %	70			70			---			---		
Peak power rating, KW	6			20			6.8			17		
Pointing accuracy, deg	± 0.5			± 0.5			---			---		
Peak sidelobe level, dB	13.5			13.5			13			13		
Element type	microstrip			microstrip			crossed dipoles			waveguide slots		
Off-nadir angle, deg	25	38	50	25	38	50	10 - 60			10 - 60		
Peak gain, dB.	32	36	38	41	45	46	29*	32*	34*	38*	42*	43*
Elevation dimension, m[†]	0.65	1.55	2.2	0.12	0.24	0.36	0.81	1.62	2.53	0.094	0.188	0.282
Elevation Peak-to-Null beamwidth, deg.	20.8	8.5	6.0	17.45	8.63	5.74	18.87	9.44	6.29	18.87	9.44	6.29

*Gain figures include 2.4 dB system loss

[†]The two panels are combined to form the narrow beam panel

The similarity of the two designs makes it possible to model both antennas with the same algorithm and computer program. The only significant electrical difference is the element type, and this may be handled with only a minor change in one subprogram.

2.2 Critical Antenna Parameters

Six antenna electrical parameters have been identified as being critical to the SMR performance. They are:

1. Antenna gain and efficiency.
2. Main beam shape.
3. Side lobe level.
4. Polarization purity.
5. Beam pointing accuracy.
6. Cross-band and cross-polarization beam coincidence.

For each of these parameters, both static errors and dynamic errors must be considered. In many cases, static errors, or those errors which do not change during a mission, can be compensated. On the other hand, dynamic errors whose effect on performance may change during a mission, are quite difficult to handle. For example, the shape of the main beam will modulate the data. If the beam shape is known, this effect may be processed out of the final image. But if the beam shape changes during flight, as it may due to thermal distortion of the antenna structure, it may be impossible to compensate for the time-varying modulation without real-time knowledge of the antenna pattern.

In the following, each of the above six parameters will be discussed considering both types of errors and possible tradeoffs with other system components.

Antenna Gain & Efficiency -- Static errors will affect the system signal-to-noise ratio (SNR). Tradeoffs are with transmitter power, receiver sensitivity, and minimum detectable scattering cross section. Slow changes in the antenna gain or efficiency over a period of hours or days cause instability in the system calibration.

Main Beam Shape -- The azimuth beam shape does not affect the system as much as the elevation beam shape, since each resolution cell "sees" the entire azimuth beam but only sees a portion of the elevation beam. As mentioned above, the static antenna gain pattern weights the amplitude of the data, but this effect can be compensated by using the appropriate (in elevation) processor demodulation algorithm. However, dynamic changes in the beam (e.g., caused by thermal deformations related to changing sun angle) are largely uncorrectable and lead to a degradation in image quality.

Side Lobe Level (SLL) -- The prinicpal impact of the side lobe level on the overall system is one of ambiguities within the processed image. Uniform illumination of the SMRA will produce a theoretical SLL of -13.3 dB (one-way), but this level may rise due to panel folding/unfolding errors, mechanical and thermal distortions, etc. However, azimuth ambiguities can be suppressed further by proper choice of the Doppler processing bandwidth and the pulse repetition frequency (PRF). Range ambiguities are the result of ground point returns that are outside the desired image swath width which arrives at the receiver simultaneously with the return from a point which lies within the desired swath width. Unfortunately, their control is provided almost exclusively by the antenna elevation pattern. Consequently, any rise in the side lobes, static or time-varying, will decrease the imaged signal-to-ambiguity ratio. Furthermore, an increase in the SLL indicates that the antenna gain has decreased, degrading the SNR as well. Elevation side lobes are the most critical since no compensation can be performed on the processed image.

Another quality criterion is that of total peak to total side lobe power ratio. Even though all side lobes may fall below some relative level (for example, -20 dB), the integrated SLL power level may completely mask the presence of a fairly strong point target.

One obvious, but expensive, solution to the ambiguities problem would be to overdesign the range pattern of the SMRA by tapering the range excitation amplitude to produce an even lower side lobe level. There are two other tradeoffs to be considered. First, the SMRA would be more susceptible to errors induced by mechanical and thermal distortions since tighter control on magnitude and phase excitation tolerances is necessary to obtain the low side lobe pattern. Secondly, the three required beamwidths could not be obtained simply by switching between the two subarrays as in the case of uniform illumination.

Polarization Purity -- No adequately substantiated performance guideline for polarization purity has yet been announced. However, it is felt that this parameter will be important to the scientific community and should be considered. In theory, the presence of any cross-polarized field at the antenna output will degrade the quality of the data. However, the cross-polarization level performance actually required depends on the intended use of the data and the sophistication of the σ^0 classification models. For example, in the X-band GEMS SAR, most users feel that a -20 dB cross-polarization level is quite adequate. The level of this unwanted component can be controlled to some degree by the selection of the array element type and the fabrication of a supporting structure that will allow little, if any, deviation of the array surface from mechanical flatness. The principal tradeoffs are against expense and technical risk. It is conceivable that any static purity problems might be compensated in the processing hardware, but certainly, time-changing instabilities would be uncontrollable.

Beam Pointing Accuracy -- The items basic to the subject of antenna pointing are: 1) The position of the antenna beam relative to the zero Doppler plane; and 2) The rate of change of that position. Both of these items must be considered when attempting to locate the plane of zero Doppler for the processor. In the process of forming the synthetic aperture, it is necessary to sense any changes in the position of the antenna beam relative to the isodops (surfaces of constant Doppler frequency) so that the resulting image may be compensated. One way of doing this is to monitor in real time the average Doppler shift of the radar data and use this information to keep the beam centered about the required isodop. Unfortunately, this requires precise control of the beam pointing direction, and any errors, static or dynamic, will tend to invalidate this approach.

A second approach would be to monitor the data and dynamically adjust the processor to compensate for deviations in beam position as well as orbit eccentricity and angular velocity (combined pitch, roll, and yaw velocities) of the spacecraft. Using this approach, the antenna requirements are reduced (at the expense of increased processor complexity) to placing limits on the angular excursions of the combined antenna electrical/mechanical beam pointing directions and on the rate of change of this angular motion.

The following antenna pointing and stability limits have been recommended†:

± 0.5 degrees in pitch, roll and yaw.

0.01 degrees per second maximum in pitch, roll, and yaw rates.

In summary, a tradeoff exists between processor complexity and antenna beam pointing requirements.

Cross-Band and Cross-Polarization Beam Coincidence -- No information is yet available on beam coincidence requirements. Obviously, the closer the coincidence of footprint registration, the more meaningful the cross-band and cross-polarization data becomes. Again, the intended uses of the SMR data must be considered in attempting to qualify beam coincidence requirements. Two major projected uses are: 1) Crop classification, and 2) Soil moisture measurement, with the high frequency being most useful for (1) and the lower frequency most useful for (2). Thus, in specifying the cross-band beam coincidence, one must ask how the data are to be used in an interpretive model. See Section 1.1.

It is conceivable that any static errors could be compensated by increasing the processor complexity. However, dynamic changes in beam coincidence seem to be undetectable and hence uncompensatable.

2.3 Conditions Which May Degrade Antenna Performance

The six critical antenna parameters of the last section are directly affected by both random and systematic errors in the electrical excitation and/or mechanical construction and orientation of the SMR array. This section

† J.G. Mehlis, Shuttle Synthetic Aperture Radar Implementation Study, Vol. 1, Jet Propulsion Laboratory Document 750-73, Pasadena, California, March 8, 1976, p. 2-42.

discusses the effect of various types of errors upon the performance of the antenna.

2.3.1 Electrical Errors

Electrical errors are classified into two types, random and systematic. While both classes will be discussed, it is felt that the effects of systematic errors on SMRA performance will be the more important consideration in the performance of the real antenna since the overall effect of small random errors diminish as the size of the array increases due to an averaging effect. It should be pointed out that random errors <u>do</u> affect the performance of the synthesized antenna pattern (e.g., synthetic beam pointing errors caused by phase decorrelation due to random phase errors), but the extent to which these errors degrade overall system performance cannot be predicted without further study and a knowledge of the image processor operation.

Random electrical errors may be divided into three catagories:

1. Amplitude errors.
2. Phase errors.
3. Errors in the individual element patterns.

Random amplitude errors will cause a loss of gain, a broadening of the main beam, a reduction in null depths, and to a lesser extent, a rise in the side lobe level. Random phase errors affect the real beam pointing direction and SLL, as do errors in the characteristics of the individual element patterns. These errors arise from the manufacturer-controlled tolerances placed on the antenna which are the result of element-to-element variations in the feed arrangement, power dividers, waveguide slot width and placement, etc. A given random error will affect X-band performance more than L-band performance since phase tolerances are relative to wavelength.

Systematic electrical errors are much more difficult to analyze than random errors since the more important systematic errors depend upon the antenna structure and geometry. Consequently, little <u>a priori</u> information is available for the systematic errors which may influence the performance of the SMRA. The more common (and most easily analyzed) errors are:

1. Linear phase errors.
2. Quadratic phase errors.
3. Cubic phase errors.
4. Periodic errors.

A systematic linear phase shift across the array will change the beam pointing direction, broaden the main beam, decrease the gain, increase the SLL, and degrade polarization purity. Quadratic phase errors tend to raise the null depths between side lobes, widen the main beam, reduce gains, and increase the level of the near-in side lobes. However, the beam direction remains unchanged. Cubic phase errors will shift the beam position, decrease the gain, and produce asymmetrical side lobes. Periodic errors create two additional side lobes and a loss of gain, but no beam pointing errors.

Errors which cannot be classified into one of the above categories must be analyzed separately. The only efficient method of tackling this problem is to simulate the effect of such errors on a digital computer. In this way, information concerning footprint shape, gain, etc., can be obtained for a large class of systematic errors.

The mathematical algorithms for the simulation will be analyzed in Section 3, the organization of the computer program will be discussed in Section 4, and the source listing for the computer program is given in the appendix.

2.3.2 Mechanical Errors

Both random and systematic mechanical errors arise from manufacturer-induced tolerances; space environmental effects on the antenna and its supporting structure induce additional systematic departures from flatness. Systematic mechanical errors will likely be more detrimental to SMRA performance than random errors.

The most significant mechanical error problems will be concerned with deviations of the array from nominal flatness. The effect of this error on performance will be the same as a systematic electrical phase error since the change in element path-length distance introduced by this distortion can be viewed as an electrical phase difference. Hence, a mechanical distortion will exhibit the same effects as the phase distortions of the last section. These include beam defocusing, gain reduction, an SLL increase, and polarization purity degradation.

Another source of mechanical errors is the random and systematic errors in the element locations. Translational errors will change the beam shape, raise the side lobe level, and may introduce other lobes. The effect of rotational errors would be to destroy the polarization purity and to decrease the gain. As with electrical errors, the only efficient method for determining the effect of mechanical errors to devise a suitable computer algorithm. One such algorithm is described in Sections 3 and 4.

2.3.3 Other Sources of Errors

One source of error that should not be ignored is the multipath effects caused by reflection from the Shuttle body and/or other experiments. A ray-optics treatment of the problem shculd be sufficient to identify any possible problems, and to suggest ways of reducing multipath effects to a minimum.

Another consideration to the overall performance of the antenna is the degradation of materials due to the space environment and exhaust envelopes of the Shuttle engines. This could become important for the dielectric used in a microstrip antenna element.

2.3.4 Summary of Errors

The effects of various electrical and mechanical errors on SMRA performance is summarized in Table 2.

2.4 Summary

The four cause-effect relationships discussed in Section 2 are graphically portrayed in Figure 1. Briefly, manufacturing, environmental, and deployment

TABLE 2. The effects of electrical and mechanical errors on SMRA performance.

Error Type	Gain	Beam Shape	Sidelobe Level	Polarization Purity	Beam Pointing	Beam Coincidence
<u>Electrical</u>						
Random Amplitude	X	X	X			
Random Phase			X		X	X
Linear Phase Shift	X	X	X	X	X	X
Quadratic Phase	X	X	X			
Cubic Phase	X	X			X	X
Periodic Errors	X		X		X	X
<u>Mechanical</u>						
Deviation from Surface Flatness	X	X	X	X	X	X
Translational Errors in Element Location		X	X			
Rotational Errors in Element Location	X			X		

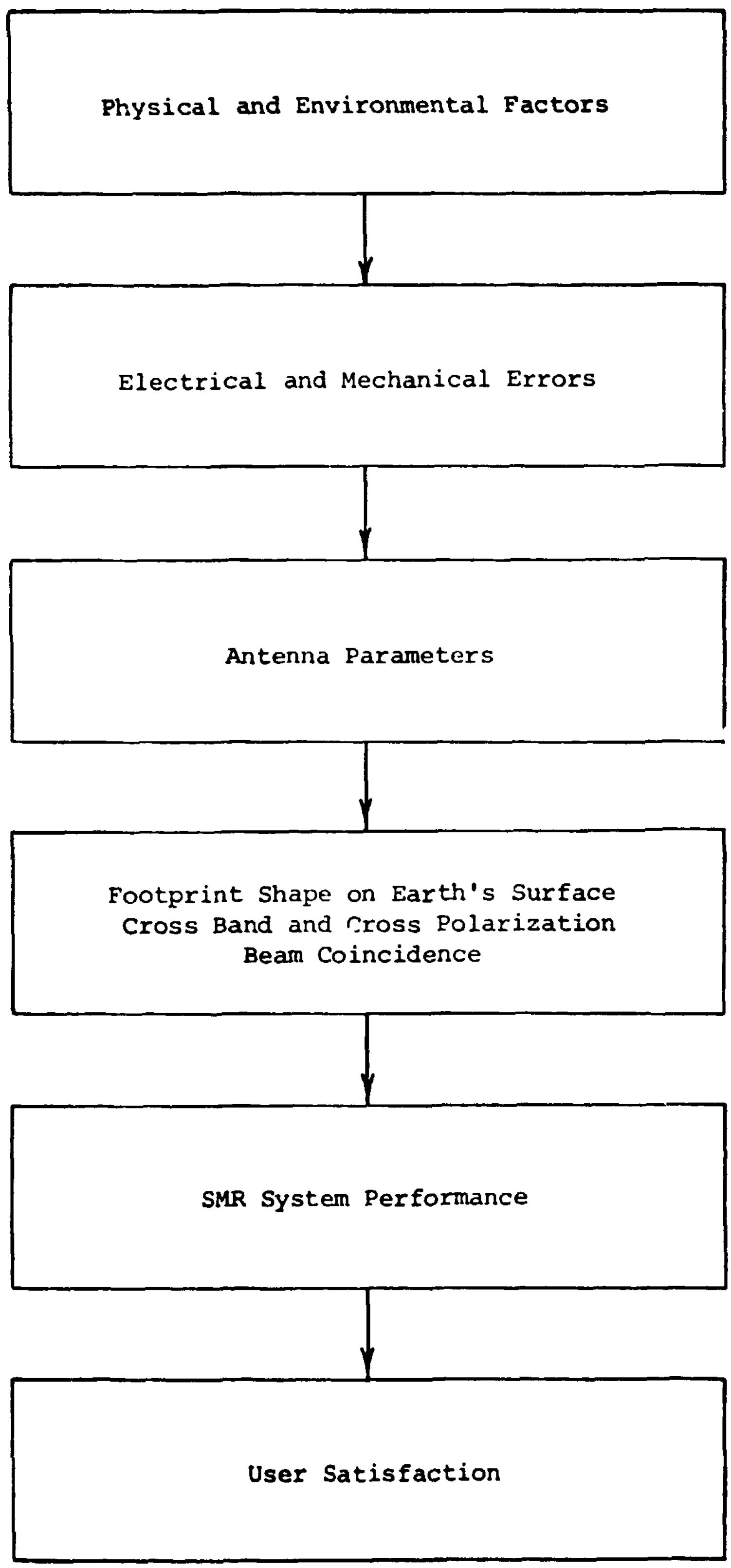


Figure 1. Cause-effect relationships for the SMR Antenna.

factors will create electrical and mechanical errors. These errors in turn affect the performance of the SMR antenna which then changes the characteristics of the ground footprint. Finally, the footprint shape is a major determinant of quality of the overall system.

3.0 THE DEVELOPMENT OF A PRELIMINARY SMRA MATHEMATICAL MODEL

To obtain predictions of the behavior of the Shuttle Multispectral Radar Antenna under a wide variety of electrical, mechanical, and environmental conditions, a number of algorithms simulating the SMRA were developed. Emphasis was given to developing mathematical models that would predict the effect of systematic departures from mechanical and electrical flatness on beam pointing accuracy, beam efficiency, etc. Later phases of this work will add to the initial model additional algorithm modules that will take into account the results from thermal, mechanical and electrical tests.

The theory and practical considerations behind the PSL approach to large-scale array modeling was presented in Section 2.2 of the Phase I Interim Report. This method has been expanded upon and implemented in the computer program discussed in Section 4 of this report. The results from a few selected examples are given in Section 5.

3.1 Antenna Electrical and Mechanical Characteristics

A flat uniformly excited rectangular electrically large array of equally-spaced elements lying in the (x, y)-plane will produce a far-field radiation pattern of the form:

$$E = E_0 \frac{\sin M\psi_x/2}{M \sin \psi_x/2} \cdot \frac{\sin N\psi_y/2}{N \sin \psi_y/2} \tag{3-1}$$

where: E_0 = constant

M = number of array elements in azimuth (x)

N = number of array elements in elevation (y)

$\psi_x = \beta d_x u + \alpha_x$

$\psi_y = \beta d_y v + \alpha_y$

$\beta = 2\pi/\lambda$ = wave number

d_x = x-axis interelement spacing

d_y = y-axis interelement spacing

u = cosine of pointing direction with respect to the x-axis

v = cosine of pointing direction with respect to the y-axis

α_x = x-axis interelement phase shift

α_y = y-axis interelement phase shift

However, the presence of random and systematic electrical and mechanical errors in the array structure requires a much more general model. Three mechanical and electrical models were considered in the Phase I Interim Report. In essence, each model incorporated an approximation of the electrical and mechanical surfaces. The three varying degrees of approximation are described below.

1. The array factor is the sum of the patterns of each individual element, each of which has its own location, orientation, and excitation. (No approximation)
2. The electrical/mechanical deformation of the array is approximated by a function or sum of functions whose closed-form array factor(s) can be found.
3. The electrical/mechanical deformation of the array is approximated by piecewise bilinear error-minimizing rectangular sections.

The first two of these were either too time-consuming or unable to model adequately severe systematic errors. The third alternative was considered to be the best compromise, especially if the number of subarray sections could be varied to reflect the severity of the distortion.

The geometry of the approximated antenna surface is explained in Figure 2, while Figure 3 shows an individual subarray unit in local coordinates.

3.1.1 The Antenna Radiation Pattern Algorithm

Consider an array antenna composed of M x N subarray sections. The antenna is nominally located in the z=0 plane and it is centered about the z-axis as illustrated in Figure 4. The far-field radiation pattern of such an antenna may be written as the weighted sum of the contributions from each subarray.

$$\overline{E}(r,\theta,\phi) = \frac{j\beta\eta}{4\pi} \frac{e^{-j\beta r}}{r} \sum_{m=1}^{M} \sum_{n=1}^{N} a_{mn} e^{j\phi_{mn}} \overline{g}_{mn}(u,v) \exp\left[j\psi\right]$$

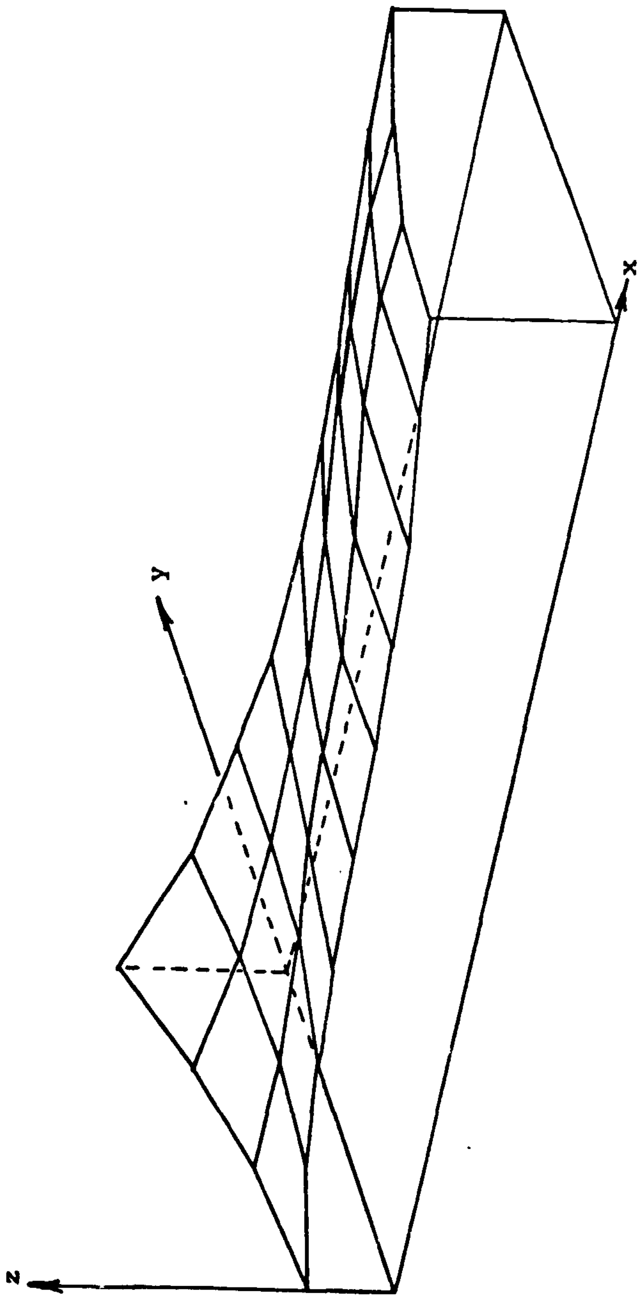


Figure 2. Geometry of the approximated antenna surface.

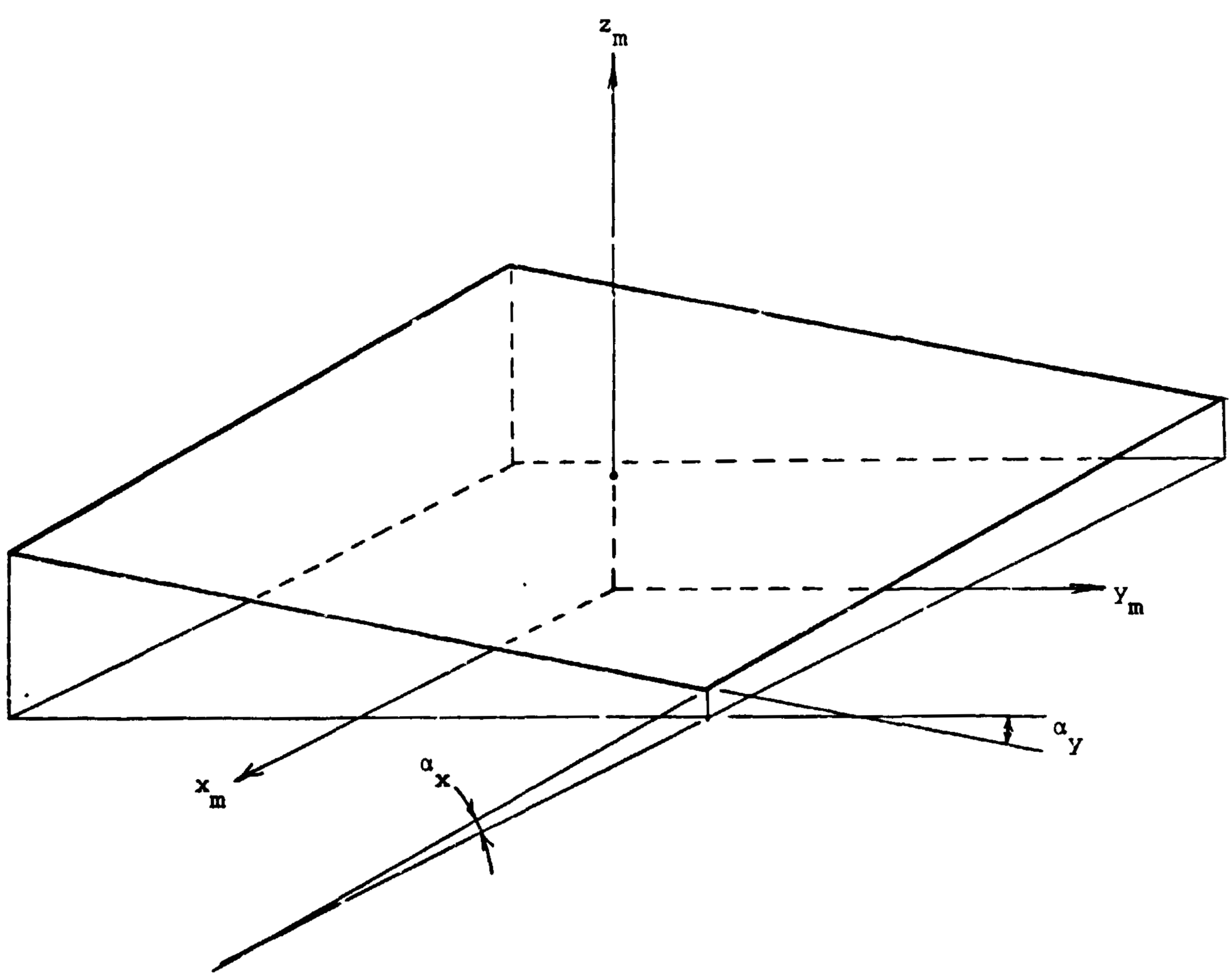


Figure 3. Single subarray section in local coordinates.

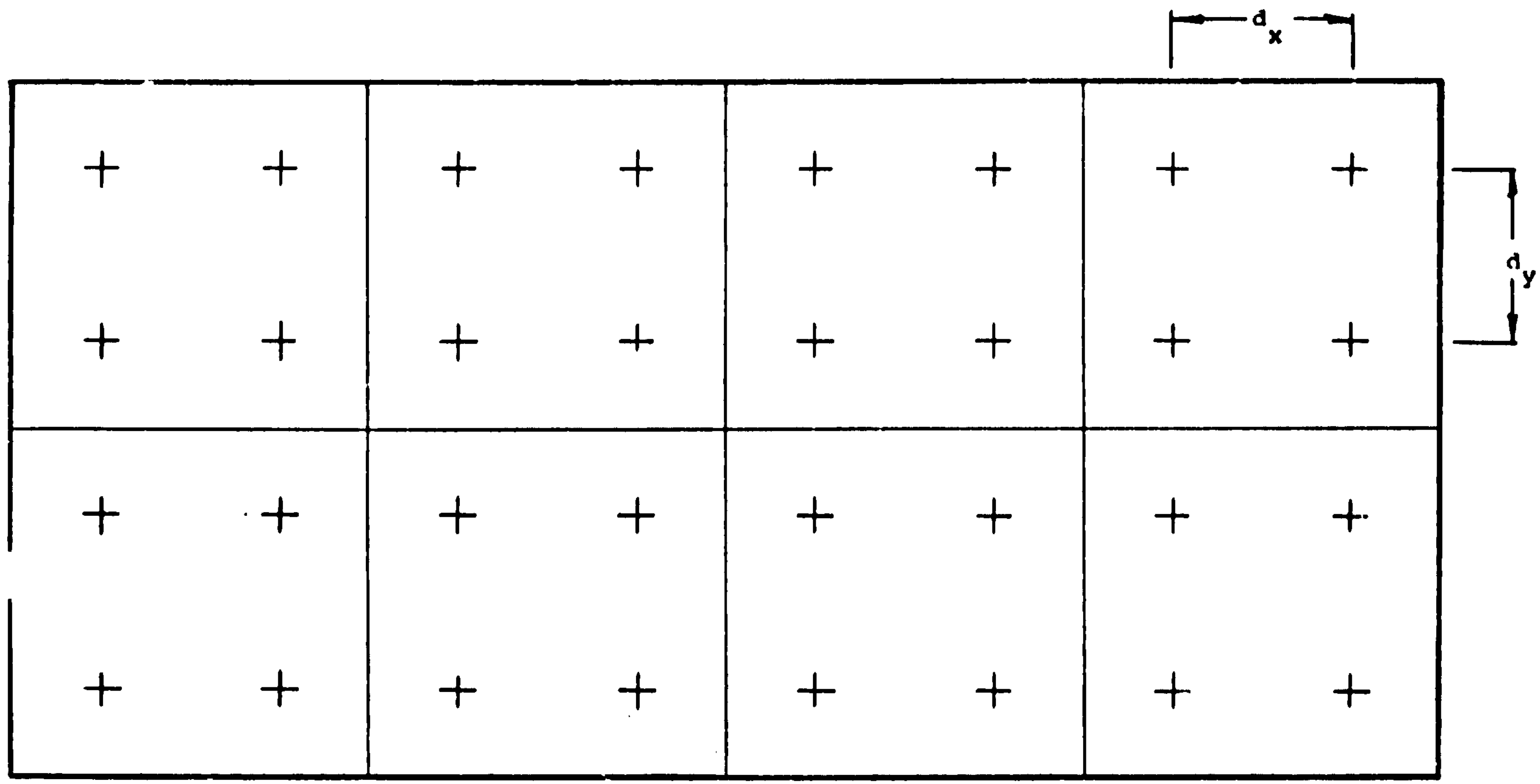


Figure 4. An array antenna of 8 x 4 elements divided into 4 x 2 subarrays. The element spacings d_x and d_y are indicated.

where: $a_{mn}e^{j\phi_{mn}}$ = the complex excitation of the mn^{th} subarray.

(u, v, w) = $(\sin\theta\cos\phi, \sin\theta\sin\phi, \cos\theta)$, the cosines of the beam pointing direction with respect to the x, y, and z axes.

$\beta=2\pi/\lambda$ = wave number of the source.

$\eta=\sqrt{\frac{\mu}{\varepsilon}}$ = intrinsic impedance of the medium.

$\bar{g}_{mn}(u, v)$ = vector array factor of the mn^{th} subarray.

ψ = $(x_{mn}u + y_{mn}v + z_{mn}w)$

(x_{mn}, y_{mn}, z_{mn}) = location of the center of the mn^{th} subarray.

For rectangular sections with dipole elements, the vector "subarray factor" has the form:

$$\bar{g}_{mn}(u,v) = \frac{\sin N_x\psi_x/2}{N_x \sin\psi_x/2} \; \frac{\sin N_y\psi_y/2}{N_y \sin\psi_y/2} \begin{cases} \dfrac{\cos\frac{\pi}{2}u}{\sqrt{1-u^2}} & \hat{x} \text{ Horizontal Polarization} \\[2ex] \dfrac{\cos\frac{\pi}{2}v}{\sqrt{1-v^2}} & \hat{y} \text{ Vertical Polarization} \end{cases} \tag{3-3}$$

where: N_xN_y = number of elements in the subarray.

ψ_x = $\beta d_x \cos(\cos^{-1}u - \alpha_x) + \phi_x$

ψ_y = $\beta d_y \cos(\cos^{-1}v - \alpha_y) + \phi_y$

d_x, d_y = interelement spacing.

ϕ_x, ϕ_y = interelement phase shift.

α_x, α_y = the x-axis and y-axis angular tilt of the section.

The (m,n) subscripts have been dropped for clarity.

Notice that for a given linear polarization, $|\bar{g}_{mn}|$ may be written as:

$$|\bar{g}_{mn}(u,v)| = f_1(u)\, f_2(v)$$

This separability allows one to precalculate $f_1(u)$ and $f_2(v)$ so that $\bar{g}_{mn}$ may be calculated using a table look-up algorithm, greatly reducing the numbers of operations and function calculations. Since all subarray sections are identical except for orientation, the same f_1 and f_2 tables may be used for each. The total far-field radiation pattern is then obtained by vectorally summing the contributions from each subarray.

3.2 Antenna Position and Orientation

The spacecraft position and orientation are specified by its altitude and three angles. These angles (YAW, TILT, are TWIST) are defined by Figure 5. While it is true that only two angles are needed to specify any possible (static) orientation of the antenna, three angles are used to enable the user to picture clearly the antenna pointing direction. The antenna subsatellite point is assumed here to be 0° Longitude, 0° Latitude as shown in Figure 6.

The matrices for the three rotations are:

$$\text{YAW:}\quad \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos(\text{YAW}) & \sin(\text{YAW}) & 0 \\ -\sin(\text{YAW}) & \cos(\text{YAW}) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} \tag{3-4}$$

$$\text{TILT:}\quad \begin{bmatrix} x'' \\ y'' \\ z'' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\text{TILT}) & -\sin(\text{TILT}) \\ 0 & \sin(\text{TILT}) & \cos(\text{TILT}) \end{bmatrix} \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} \tag{3-5}$$

$$\text{TWIST:}\quad \begin{bmatrix} x''' \\ y''' \\ z''' \end{bmatrix} = \begin{bmatrix} \cos(\text{TWIST}) & \sin(\text{TWIST}) & 0 \\ -\sin(\text{TWIST}) & \cos(\text{TWIST}) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x'' \\ y'' \\ z'' \end{bmatrix} \tag{3-6}$$

In practice, the YAW, TILT, and TWIST matrices would be multiplied together and stored as a single 3x3 matrix.

3.3 Coordinate Transformation To Produce The "Footprint" On The Earth's Surface

There are two transformations involved:

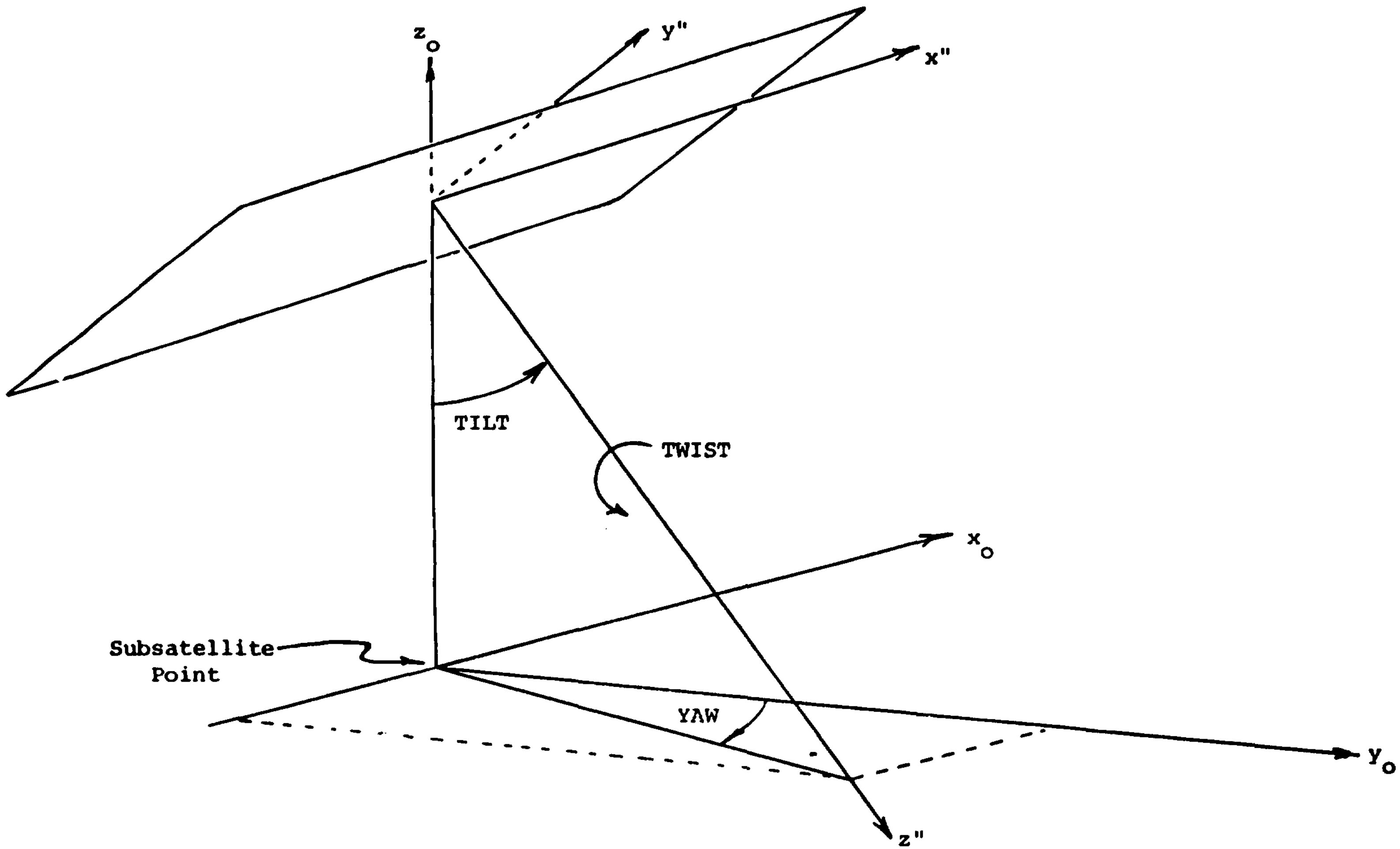


Figure 5. Orientation angles and geometry for the SMR antenna.

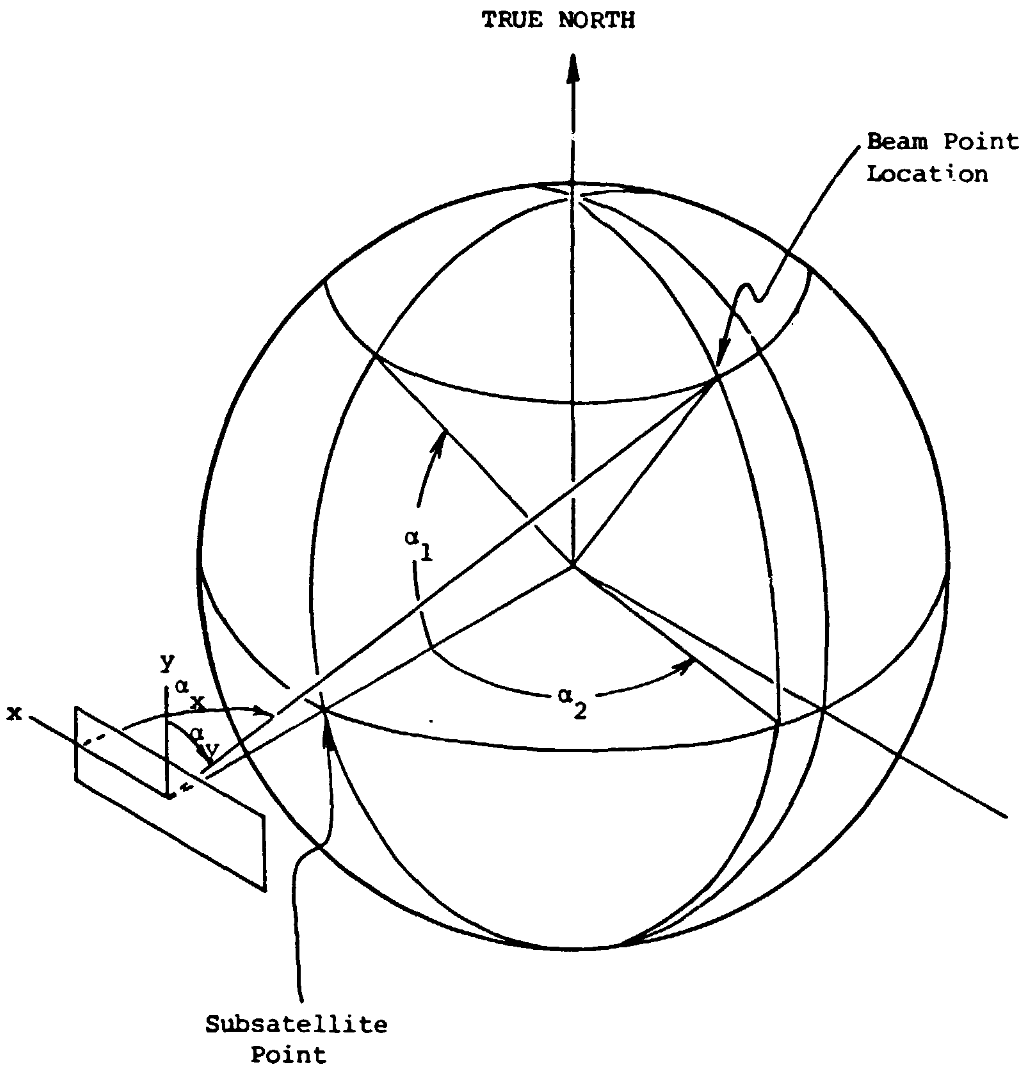


Figure 6. SMRA antenna above a spherical earth. The subsatellite point is at 0° latitude, 0° longitude. The beam is pointed at [α_1(latitude), α_2(longitude)].

(1) What point, i.e., with latitude (α_1) and longitude (α_2), on the earth's surface corresponds to a given beam direction (u,v)?

(2) What antenna beam direction (u,v,) corresponds to a specified latitude and longitude location?

The first transformation is used to predict the location of the beam center. The second is necessary to determine the "footprint" contours of the antenna.

3.3.1 Latitude and Longitude From Beam Direction

For an unrotated antenna pointing to a nadir of (0°, 0°), the following formulas may be derived:

$$\alpha_r = \sin^{-1}\left[\frac{R_e+\text{Alt}}{R_e}\right]\sin\theta - \theta \quad (\alpha_r>0)$$

$$\phi_r = \phi - \frac{\pi}{2} \tag{3-7}$$

$$\text{Range} = R_e \cdot \alpha_r$$

where: R_e = radius of the (spherical) earth.
Alt = antenna altitude in same units as R_e.
(θ,ϕ) = pointing direction of unrotated antenna.
α_r = range angle.
ϕ_r = heading angle.

Then:

$$\alpha_2 = \tan^{-1}(\sin\phi_r/\tan\alpha_r)$$
$$\alpha_1 = \cos^{-1}(\cos\alpha_r/\cos\alpha_2) \tag{3-7a}$$

If $\alpha_1>90^{\circ}$, $\alpha_1 = \alpha_1 - 180^{\circ}$.

Example, let R_e = 6400 km, Alt = 200 km, and (θ,ϕ) = (60°, 120°). Then:

$\alpha_r = 3.263975^{\circ}$ $\qquad$ $\phi_r = 30^{\circ}$
$\alpha_2 = 1.6333^{\circ}$ $\qquad$ $\alpha_1 = 2.8263^{\circ}$
Range = 364.56 km.

3.3.2 Beam Direction From Latitude and Longitude

Given α_1 and α_2 we may invert eqns. (3-7a) to find:

$$\alpha_r = \cos^{-1}(\cos\alpha_1 \cdot \cos\alpha_2)$$
$$\phi_r = \sin^{-1}(\cos\alpha_1 \cdot \cos\alpha_r \cdot \sin\alpha_2) \qquad (3\text{-}8)$$

Then:

$$\phi = \phi_r + 90^c$$
$$z = (R_e + \text{Alt}) - R_e \cos\alpha_1\cos\alpha_2$$
$$x = -R_e \cos\alpha_1\sin\alpha_2 \qquad (3\text{-}9)$$
$$y = R_e \sin\alpha_1$$
$$r = \sqrt{x^2+y^2+z^2}$$
$$\theta = \cos^{-1} (z/r)$$

Example, let R_e = 6400, Alt = 200 km, $\alpha_1 = 2.82631^\circ$, and $\alpha_2 = 1.6333^\circ$. Then:

$\alpha_r = 3.263975^\circ$	$x' = -182.19476$ km.
$\phi_r = 29.9997 \approx 30^\circ$	$y' = 315.5738$ km.
$\phi = 120^\circ$	$r' = 420.764$ km.
$z' = 210.382$ km.	$\theta = 60^\circ$

3.4 Data Handling Techniques and Data Reduction

With the vast amounts of data generated by this algorithm, it was clear that in order to obtain usable results, the data must be reduced to pictoral form. Five modes of presentation were developed. These are:

1. Printer profile plots of "principal planes."
2. Printer contour plot of the entire region of interest.
3. Plotter profile plots of "principle planes."
4. Plotter contour plots of the entire region.
5. Plotter three-dimensional plots of the entire region.

The printer plots provide a quick and inexpensive preview of the results of the simulation. If satisfactory results are obtained, then the Calcomp plotter is used to draw more detailed plots.

When the Tektronix 4051 interactive graphics terminal is made operational, many of the data presentation problems will be greatly simplified. It will be then possible to quickly draw a complete contour "footprint" from any data set. If a permanent copy is desired, a hard copy or photograph may be taken.

3.5 Areas For Further Development

The mathematical model discussed here is preliminary in nature and its algorithms will be refined and expanded during Phase II.

The most significant addition to the model will be the incorporation of data gathered from near-field and far-field electrical measurements, thermal measurements, and mechanical tests of the subarray panels. These data, to be taken during Phase IV, will be used by the model to predict the performance of the full-size SMR antenna. It is planned to add these modules to the algorithm during Phase III.

The other important addition to the model will be the inclusion of a module to accept arbitrary array elements and/or total antenna type. With this change, other antenna types, such as reflector antennas, other aperature antennas, and traveling wave antennas, can be simulated as well as arrays of antennas with arbitrary elements.

3.6 Summary and Block Diagram Of The Simulation Algorithm

The operation of the SMRA mathematical model can be summarized by the block diagram shown in Figure 7. Only those modules presently implemented are shown.

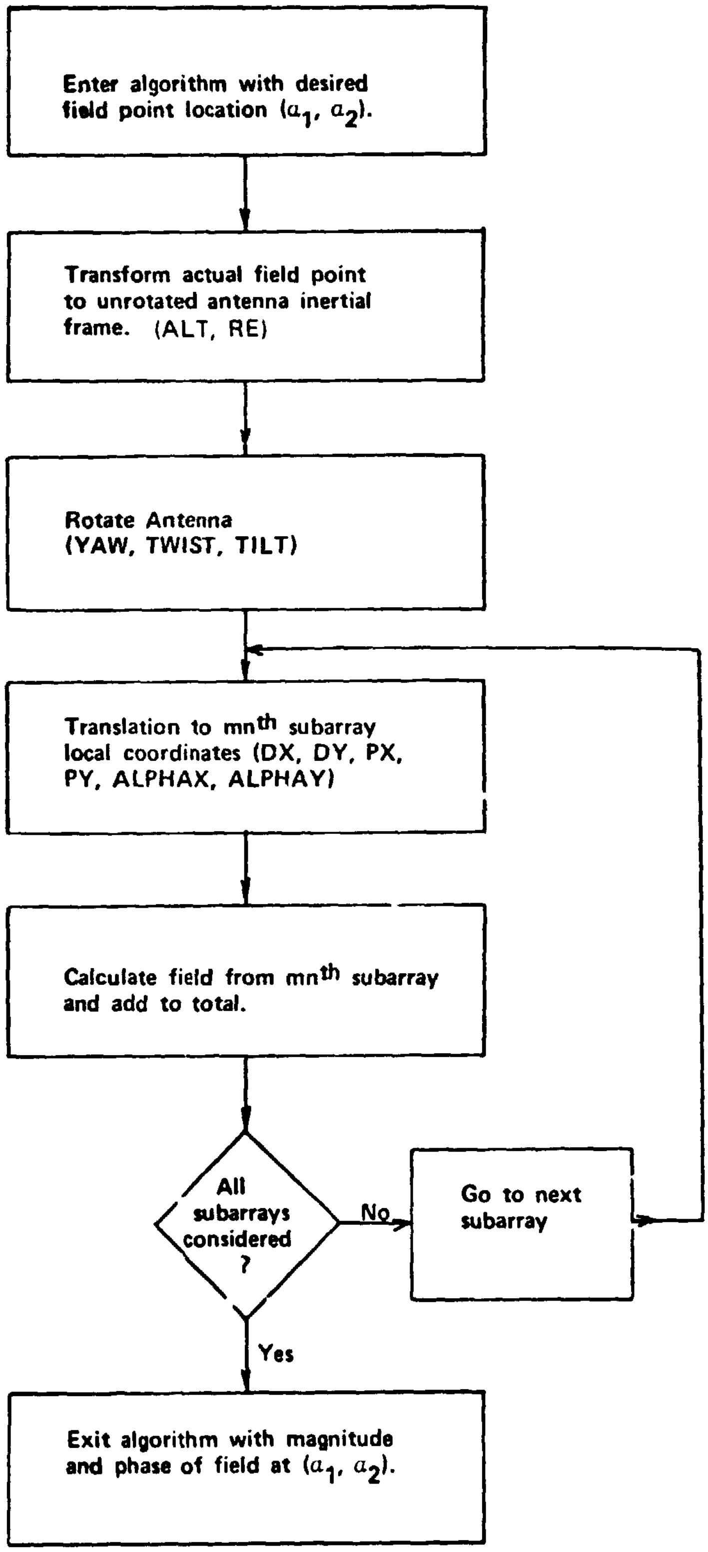


Figure 7. Operation of the SMRA mathematical model.

4.0 THE SMRA SIMULATION PROGRAM

A computer program was written to implement the simulation algorithms of Section 3. It produces line printer plots and Calcomp plotter plots of the anteann footprint on the earth's surface. The organization of the program is shown in Figure 8, and a description of each program segment is given in Section 4.1.

4.1 Program Description

MAINPGM - Performs mostly housekeeping chores and calls other routines according to user input commands. It calculates the "YAW-TILT-TWIST" array, predicted beam center location, plot normalization factor (pattern value at predicted beam center location), increments beam pointing angle to cover entire "footprint" region and initiates profiles along lines of constant latitude and longitude intersecting the predicted beam center.

ANTENA - Inputs and calculates appropriate antenna parameters: number of elements, spacing, phase shift, number of subarrays, polarization, and element type. After calculations have been performed, a summary is printed.

MECH - Calculates mechanical deformation data based on the inputs from STRESS, THERML, and MISC. For each subarray, MECH calculates the average displacement ZAVG, the tilt angles, ALPHAX and ALPHAY, and the error coefficient of the bilinear approximations. A summary is printed after execution.

STRESS - Determines the warpage of the array that is due to mechanical considerations.

THERML - Will determine the warpage of the array due to thermal gradients across and through the array structure. (Not Yet Implemented)

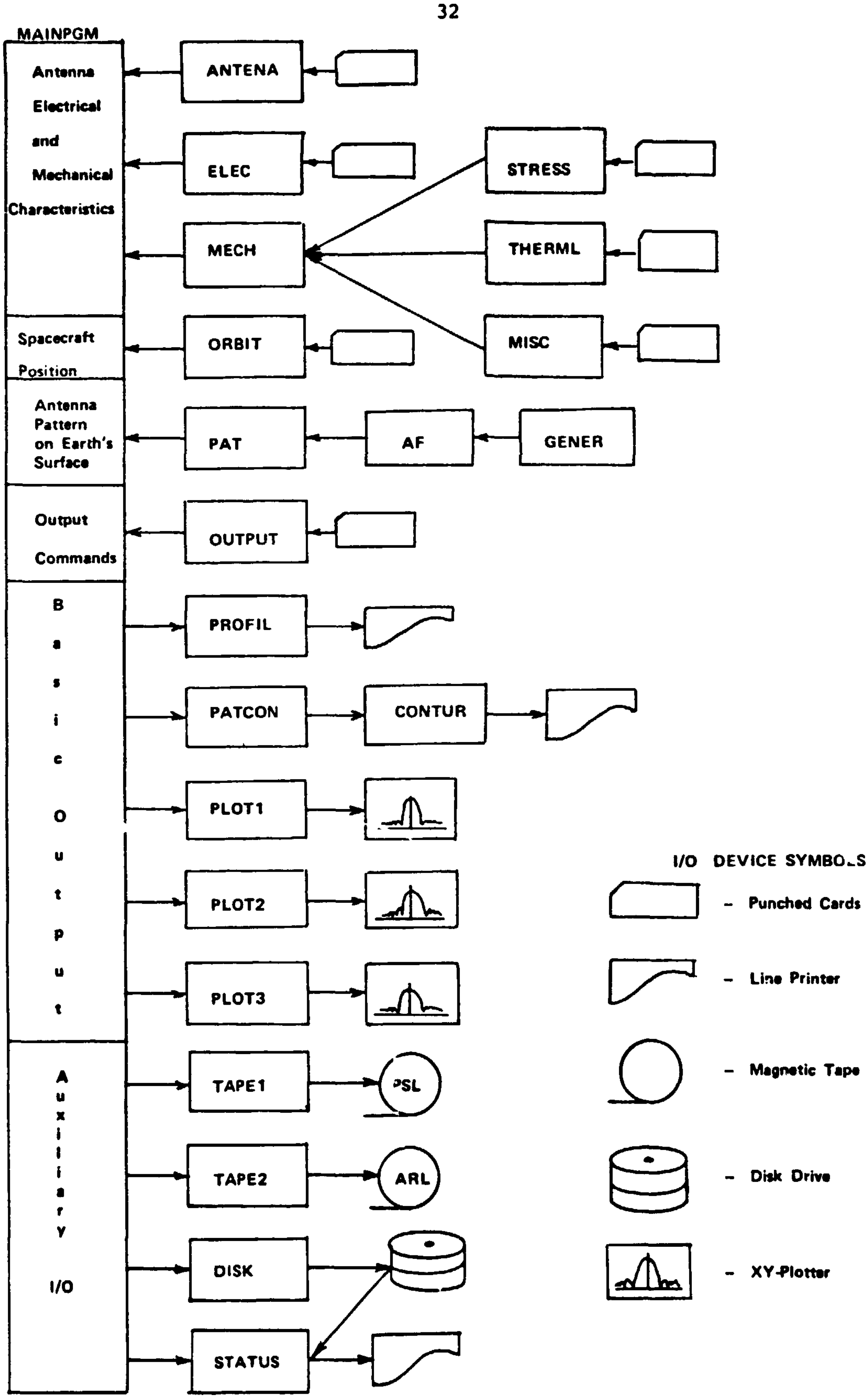


Figure 8. Organization of the SMRA Simulation Program.

MISC - Inputs any other deformation data not covered by STRESS and THERML.

ELEC - Inputs the amplitude, phase, and linear phase gradients of each subarray. This information is passed to PAT via common block ELCTRC, and a summary is printed.

ORBIT - Inputs orbital parameters and antenna YAW, TILT, and TWIST, then prints a summary.

PAT - Is the basic pattern subprogram. Given latitude-longitude coordinates on the earth's surface, it performs all translations and rotations to determine the beam pointing angle (u,v). It then calls AF to find the subarray factor and finally computes the sum of all subarrays.

AF - This function calculates the array factors of a subpanel by "table look-up" with linear interpolation if $|u| < \text{UMAX}$ and $|v| < \text{VMAX}$. Otherwise, the AF is computed in the usual way.

GENER - This routine generates the table used by AF. Table length is 1001 words: UMAX and VMAX are chosen to include the main beam plus the first three side lobes.

OUTPUT - Translates user commands for printer and pattern output into logical switches for the program.

PROFIL - Is the printer profile plot routine. It will print a one-dimensional plot down the page for up to 501 data points. The exact values of both the abscissa and ordinate are printed with each data point, the ordinate also being printed in dB.

PATCON - Is chiefly a "bookkeeping" subroutine for CONTUR. It calls subroutine CONTUR three times to generate a complete 151 x 151 two-dimensional contour map.

CONTUR - Prints a 51 x 151 contour plot of the footprint. To obtain a complete 151 x 151 plot, this routine is called three times by subroutine PATCON. Then the three separate plots are pasted together to make the composite.

PLOT1 - Is the Calcomp one-dimensional plot routine. It is called twice by the main program, and it is used to generate the profile plots of the principal planes through the main beam.

PLOT2 - Is the Calcomp contour map routine. From the data used to generate the printer contour map, it draws a continuous contour plot of the antenna ground footprint over the rectangular region specified by the user.

PLOT3 - Is the Calcomp three-dimensional plot routine. It plots the magnitude (in dB) of the footprint pattern over rectangular region specified by the user.

TAPE1 - Will be used to store the pattern matrices and other important variables so that additional plots may be generated by other programs without recomputing the data. (Not Yet Implemented)

TAPE2 - Is the ARL data tape routine. It stores the antenna pattern as a function of u and v and is used whenever ARL requires a new antenna pattern for their processor modeling program. (At present, TAPE2 is a separate computer program.)

DISK - Will be used to store pattern data on a disk drive at PSL. (Not Yet Implemented)

STATUS - Will be used to determine what data has been stored by TAPE1 and DISK, to selectively erase any simulation run, and to reinitialize the entire storage area. (Not Yet Implemented)

4.2 Input/Output and Flexibility To The User

The program input data has been structured so that user knowledge of computer fundamentals is not required. Consequently, the program can be used by anyone desiring information concerning the footprint of a particular antenna configuration.

The input has been divided into six modules. These are:

1. Simulation Information
2. Antenna Position and Orientation
3. Output Commands and Parameters
4. Antenna Configuration
5. Antenna Mechanical Parameters
6. Antenna Electrical Parameters

By including input parameters in these six categories, it is possible for the user to simulate a wide range of electrical, mechanical, and physical scenarios. Furthermore, a change in the simulation does not require that the complete input deck be repunched. When related scenarios are being studied, only one of the six modules need be changed.

Examples of different simulations are deferred to Section 5.

4.2.1 Simulation Information

The simulation information consists of three entries: 1) the simulation number, 2) the date of the simulation, and 3) a short narrative describing the simulation. The simulation number and date provide bookkeeping reference information. The narrative is printed at the beginning of the computer output to allow quick identification of the program output and future dates.

4.2.2 Antenna Position and Orientation

The parameters used as input for this category are antenna altitude, yaw, tilt, twist, and frequency. Altitude is expressed in kilometers, the angles are expressed in degrees, and frequency is expressed in GHz. These parameters are more fully described in Section 3.2.

4.2.3 Output Commands and Parameters

Five logical switches are used to control the five output categories of Section 3.4. If a particular output is desired, the associated command switch is set to logical "1". In addition to the output commands, it is necessary to specify parameters for those output devices which have been turned on by the output commands.

The parameters needed for a particular simulation are governed by which logical switches have been previously engaged. If any output command is entered, then the latitude and longitude limits of the footprint must be entered. If a plotter contour map is desired the contour level parameters are required. For a printer contour, the highest contour, lowest contour, and contour level interval must be entered. For any two- or three-dimensional plot, the plot resolution is necessary.

Some outputs do not require a command. The narrative described above and the summaries described in Section 3 have no command word; this information is always printed.

4.2.4 Antenna Configuration

This category contains all the parameters needed by subroutine ANTENA. These include the number of subarray sections, the number of elements, the interelement spacings in centimeters, the interelement phase shifts in degrees, the element type. and the element polarization.

4.2.5 Antenna Mechanical Information

Antenna mechanical information includes all the parameters needed by subroutines STRESS, THERML, and MISC. In this preliminary simulation model, the displacement of the antenna from nominal flatness (expressed in centimeters) is entered through subroutine MISC.

4.2.6 Antenna Electrical Parameters

All excitation information is entered through subroutine ELEC. The necessary parameters provide information concerning the excitation magnitude, phase, and any linear phase taper for each subarray section.

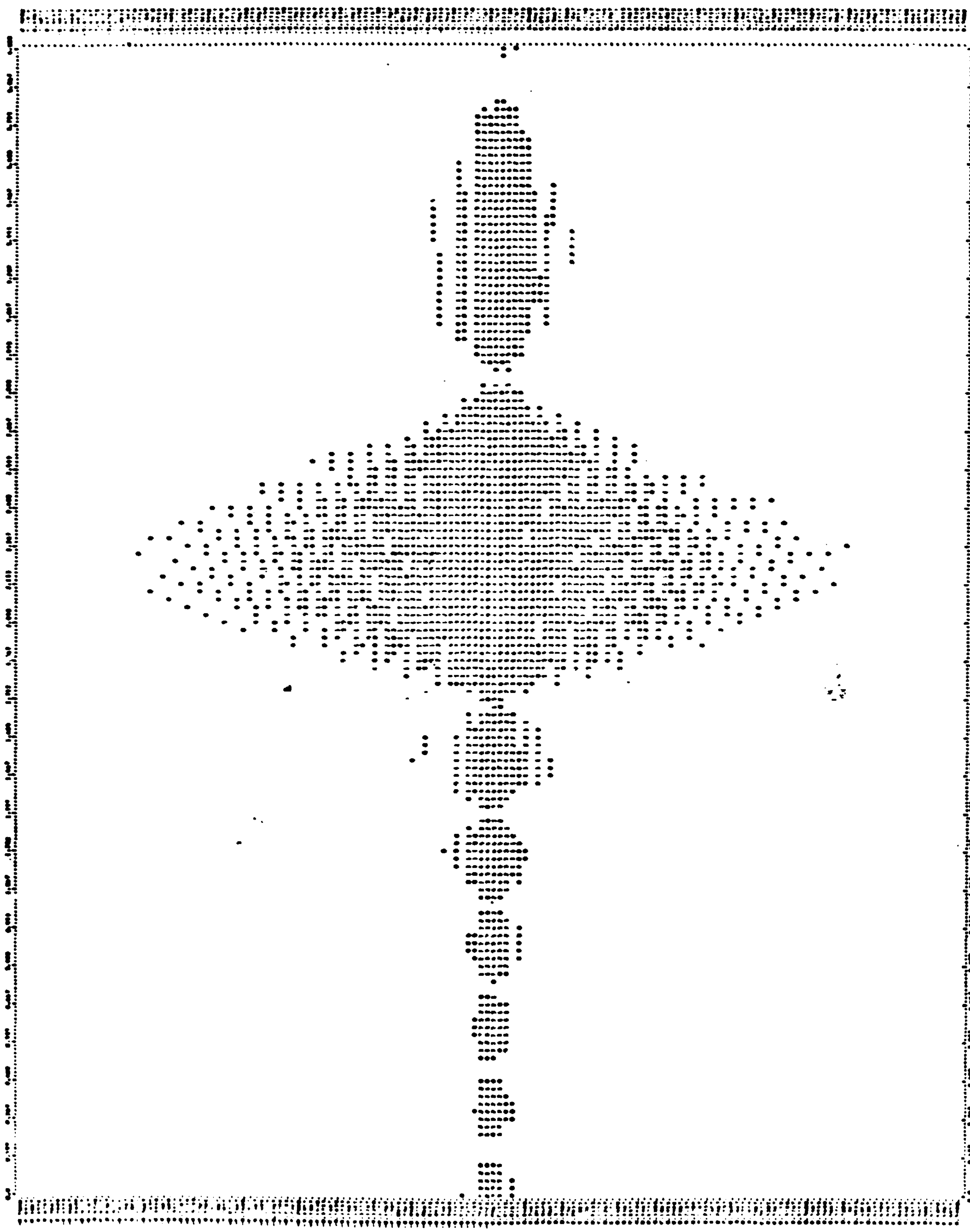
5.0 EXAMPLES OF COMPUTER SIMULATION RUNS

The following pages illustrate the actual line printer output from the Shuttle Multispectral Radar Antenna Simulation Program. The pages run in sequence; no attempt has been made to join the profile plot or contour map pages together. However, a photo-reduction of a typical composite contour map is shown in Figure 9.

The comments printed with the pattern output provide all the necessary information to visualize each scenario being simulated. All antennas have the following characteristics in common:

1. Frequency = 9.0 GHz
2. Tilt Angle = 50^{o}
3. Altitude = 200 km
4. Polarization: Horizontal
5. Configuration: Both modules excited for minimum beam width
6. Number of elements: 504 x 12
7. Element spacing: 2.2966 x 2.3550 cm
8. Phase Shift: 0^{o}

Pattern 100 is the simulation of the baseline design, with no electrical or mechanical errors. Pattern 101 illustrates pattern errors due to misalignment of the three panels. Pattern 102 shows the effect of a spherical bow in the antenna which might be induced by thermal gradients through the antenna surface. A systematic phase error is simulated by Pattern 103, and Pattern 104 provides information on errors caused by Shuttle attitude errors.



```
EXAMPLE 1:
   BASELINE DESIGN FOR X-BAND SPACE SHUTTLE IMAGING RADAR (BOTH PANELS).


SYSTEM INFORMATION:
     FREQUENCY =  9.000 GHZ.
     YAW =    0.0   DEGREES
     TILT =   50.000 DEGREES
     TWIST =    0.0   DEGREES
     ALTITUDE =  200.000 KM.


ANTENNA PARAMETERS FOR SIMULATION NUMBER 100
     ELEMENT TYPE: HORIZONTAL DIPOLE
     NUMBER OF ELEMENTS (X,Y) = (504 ,  12)
     INTERELEMENT SPACING (CM.): 2.2966 ,  2.3550
     INTERELEMENT PHASE SHIFT (DEG.):  0.0    ,  0.0


DEFORMATION DATA FOR SIMULATION 100:

0.0        0.0

0.0        0.0


ELECTRICAL DATA FOR SIMULATION 100:

        ( 1, 1)   (
PHSX:     0.0
PHSY:     0.0
AMAG:     1.00
APHS:     0.0


PRINT/PLOT INFORMATION:
     REQUESTED OUTPUT:
          PRINTER PROFILE
          PRINTER CONTOUR
     PLOT RESOLUTION: 151 X 151 POINTS

     STARTX =   -0.500
     STOPX =     0.500
     DELTAX =     0.007

     STARTY =     0.0
     STOPY =     4.000
     DELTAY =     0.027

SUBARRAY DATA SUMMARY FOR PATTERN100:
```

AREA	XCENT	YCENT	ZAVG	ALPHAX	ALPHAY	AMAG	APHS	PHSX	PHSY
1	0.0	0.0	0.0	0.0	0.0	1.0000	0.0	0.0	0.0

```
PREDICTED BEAM CENTER:
     LATITUDE =    2.1945
     LONGITUDE =     0.0
     RANGE = [illegible]
     HEADING =     0.0
```

PLOT NORMALIZATION FACTOR = -35.011 09.

PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 100

```
          0.0       0.133     0.267     0.400     0.533     0.667     0.800     0.933     1.067     1.200     1.333
          I.........I.........I.........I.........I.........I.........I.........I.........I.........I.........I
-0.5000.
-0.4933.
-0.4867.
-0.4800.
-0.4733.
-0.4667.
-0.4600.
-0.4533.
-0.4467.
-0.4400.
-0.4333.
-0.4267.
-0.4200.
-0.4133.
-0.4067.
-0.4000.
-0.3933.
-0.3867.
-0.3800.
-0.3733.
-0.3667.
-0.3600.
-0.3533.
-0.3467.
-0.3400.
-0.3333.
-0.3267.
-0.3200.
-0.3133.
-0.3067.
-0.3000.
-0.2933.
-0.2867.
-0.2800.
-0.2733.
-0.2667.
-0.2600.
-0.2533.
-0.2467.
-0.2400.
-0.2333.
-0.2267.
-0.2200.
-0.2133.
-0.2067.
-0.2000.
-0.1933.
-0.1867.
-0.1800.
-0.1733.
-0.1667.
-0.1600.
-0.1533.
-0.1467.
-0.1400.
-0.1333.
-0.1267.
-0.1200.
-0.1133.
-0.1067.
-0.1000.
-0.0933.
-0.0867.
-0.0800.
-0.0733.
-0.0667.
-0.0600.
-0.0533.
-0.0467.
-0.0400.
-0.0333.
-0.0267.
-0.0200.
-0.0133.
-0.0067.
-0.0000.2 3 3 2 1   0 1 2 3 3 3 3 2 1   0 2 2 2 3 3 3 2 0   2 3 3 3 3 3 3 2 0   0 2 3 4 4 4 4 4 3 2 1
 0.0067.
 0.0133.
 0.0200.
 0.0267.
 0.0333.
 0.0400.
 0.0467.
 0.0533.
 0.0600.
 0.0667.
 0.0733.
 0.0800.
 0.0867.
```

```
0.0933.
0.1000.
0.1067.
0.1133.
0.1200.
0.1267.
0.1333.
0.1400.
0.1467.
0.1533.
0.1600.
0.1667.
0.1733.
0.1800.
0.1867.
0.1933.
0.2000.
0.2067.
0.2133.
0.2200.
0.2267.
0.2333.
0.2400.
0.2467.
0.2533.
0.2600.
0.2667.
0.2733.
0.2800.
0.2867.
0.2933.
0.3000.
0.3067.
0.3133.
0.3200.
0.3267.
0.3333.
0.3400.
0.3467.
0.3533.
0.3600.
0.3667.
0.3733.
0.3800.
0.3867.
0.3933.
0.4000.
0.4067.
0.4133.
0.4200.
0.4267.
0.4333.
0.4400.
0.4467.
0.4533.
0.4600.
0.4667.
0.4733.
0.4800.
0.4867.
0.4933.
0.5000.
       I.........I.........I.........I.........I.........I.........I.........I.........I.........I.........I
      0.0      0.133     0.267     0.400     0.533     0.667     0.800     0.933     1.067     1.200     1.333
```

PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 100

```
1.333     1.467     1.600     1.733     1.867     2.000     2.133     2.267     2.400     2.533     2.667
|.........|.........|.........|.........|.........|.........|.........|.........|.........|.........|
```

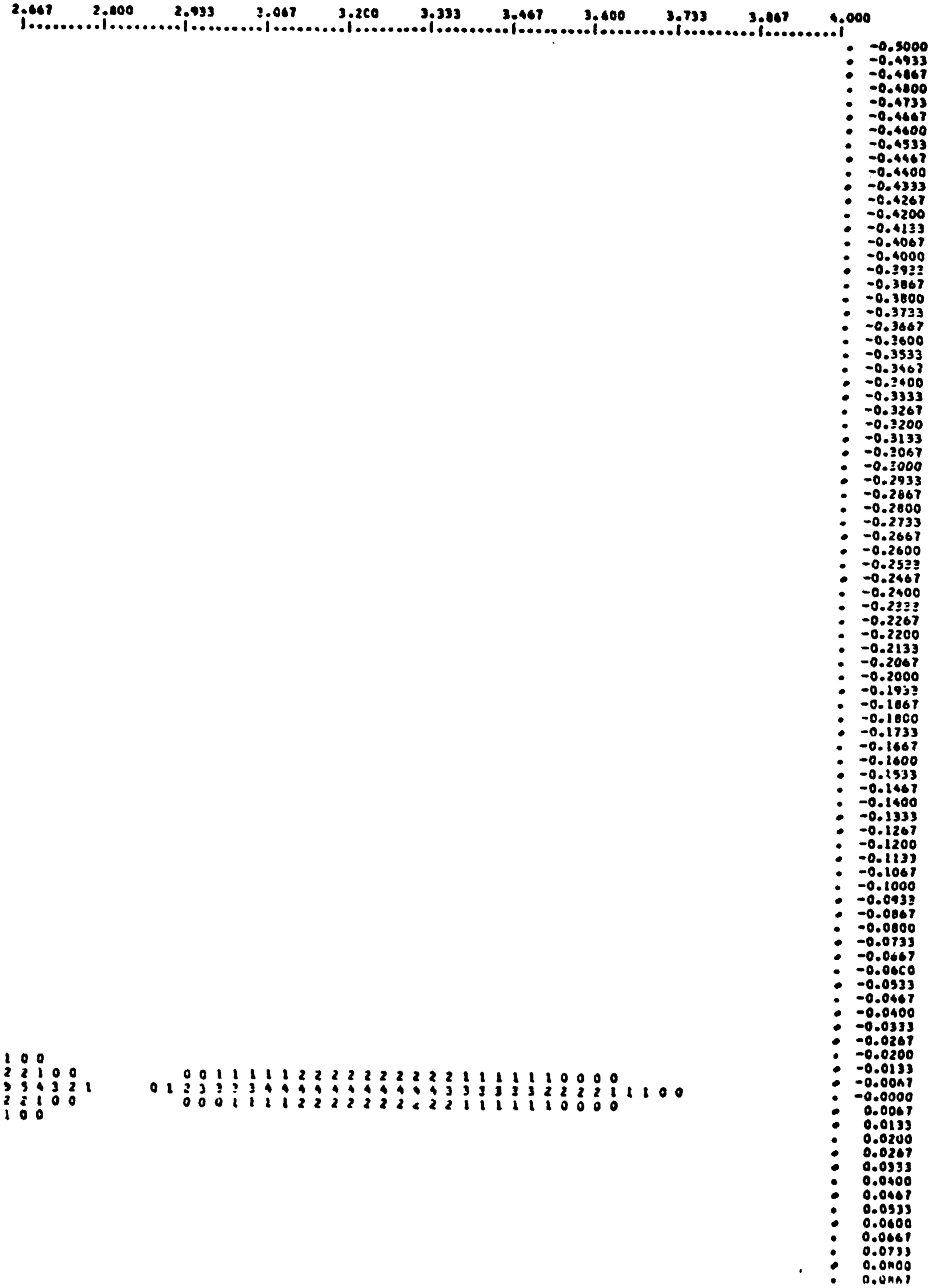
```
                                                    0 0 0 0 0
                                                      0 C 0 0 C C 0 0
                                                          0 0 C 0 1 1 1 0 0 0 0
                                                                  0 0 0 0 0 0 0 0 0 0 0
                                        C C 0 0 0 0 0                             0 0 0
                                      C 0 1 1 1 1 2 2 2 2 2 1 1 1 1 0 0
                                    0 C 1 1 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 2 2 2 2 1 1 C 0 0
                                    0 1 1 2 2 3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 2 2 2 1 1
                                    0 1 1 2 3 3 3 4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 4 4 4 4 4 4 3 3 3 2
0 2 3 4 5 5 5 5 5 5 4 3 2   0 3 5 6 6 7 7 8 8 8 8 9 9 9 9 9 9 9 9 9 9 9 9 9 8 8 8 8 8 7 7 7 6 6 6 5
                                    0 1 1 2 3 3 3 4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 4 4 4 4 4 3 3 3 2 2
                                    0 1 1 2 2 3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 2 2 2 1 1
                                    0 0 1 1 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 2 2 2 2 1 1 0 0 0
                                      C 0 1 1 1 1 2 2 2 2 2 1 1 1 1 0 0
                                        0 0 0 0 0 0 0                             0 0 0
                                                                  0 0 0 0 0 0 0 0 0 0 0
                                                          0 0 0 0 1 1 1 0 0 0 0
                                                      0 0 0 0 0 0 0 0
                                                    0 0 0 0 0
```

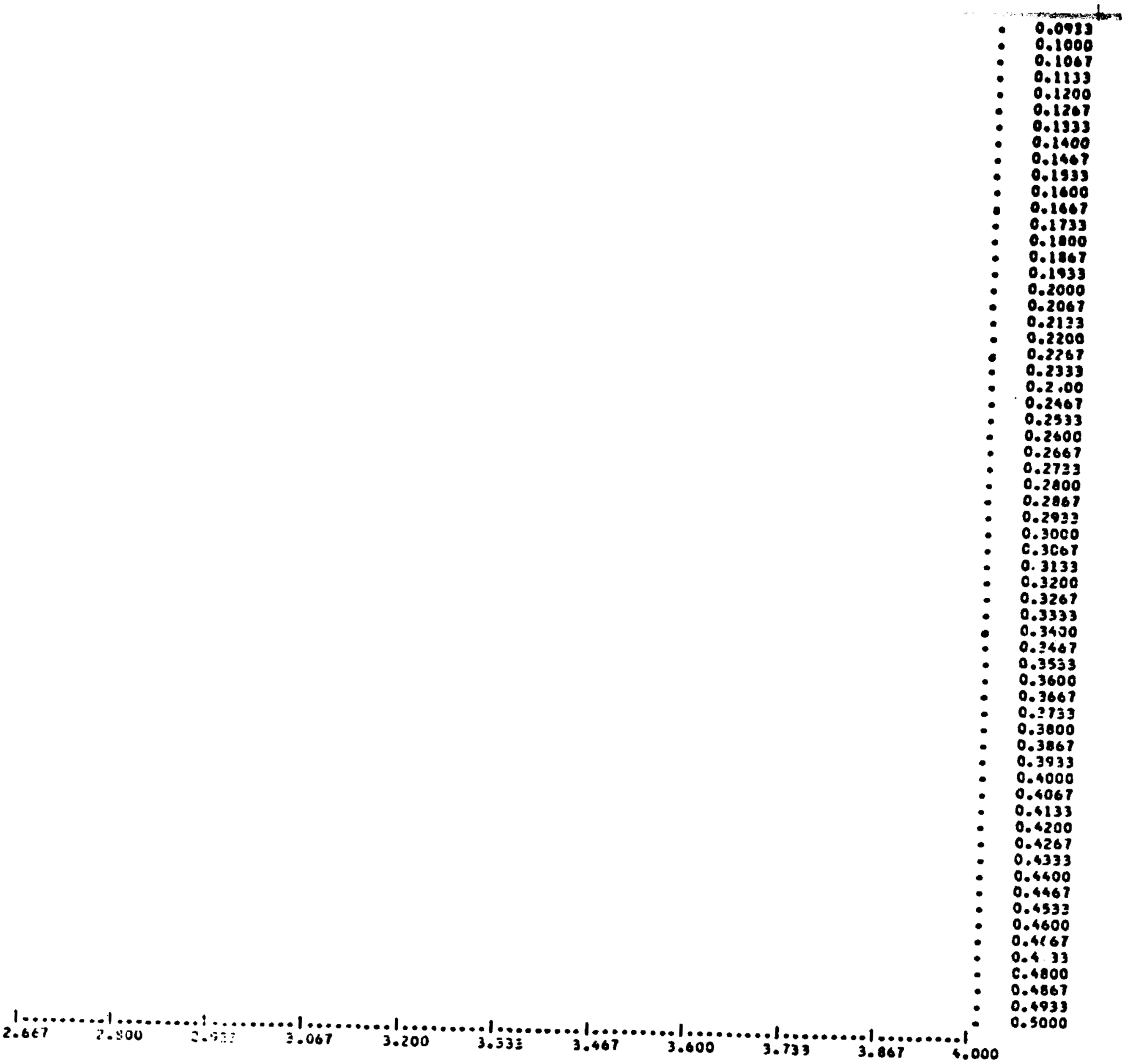
```
|.........|.........|.........|.........|.........|.........|.........|.........|.........|.........|
1.333     1.467     1.600     1.733     1.867     2.000     2.123     2.267     2.400     2.533     2.667
```

CCNTCUR LEVEL KEY

```
C: -0.2850000E 02 TO -0.2549998E 02   4: -0.1650000E 02 TC -0.1349999E C2   8: -C.4500000E C1 TO -0.1499990E 01
1: -0.2550000E 02 TO -0.2249998E C2   5: -0.1350000E C2 TC -0.1049999E 02   9: -0.1500000E 01 TO  0.1500010E 01
2: -0.2250000E 02 TO -0.1949998E 02   6: -0.1050000E C2 TO -0.7499990E 01    : -0.1000000E 51 TO -0.2850000E 02
3: -0.1950000E 02 TO -0.1649998E 02   7: -C.7500000E 01 TO -0.4499993E 01   +:  0.1500010E 01 TO  C.1000000E 51
```

PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 100




0.0933
0.1000
0.1067
0.1133
0.1200
0.1267
0.1333
0.1400
0.1467
0.1533
0.1600
0.1667
0.1733
0.1800
0.1867
0.1933
0.2000
0.2067
0.2133
0.2200
0.2267
0.2333
0.2.00
0.2467
0.2533
0.2600
0.2667
0.2733
0.2800
0.2867
0.2933
0.3000
C.3067
0.3133
0.3200
0.3267
0.3333
0.3400
0.3467
0.3533
0.3600
0.3667
0.2733
0.3800
0.3867
0.3933
0.4000
0.4067
0.4133
0.4200
0.4267
0.4333
0.4400
0.4467
0.4533
0.4600
0.4(67
0.4 33
C.4800
0.4867
0.4933
0.5000
2.667
2.800
2.?33
3.067
3.200
3.333
3.467
3.600
3.733
3.867
4.000

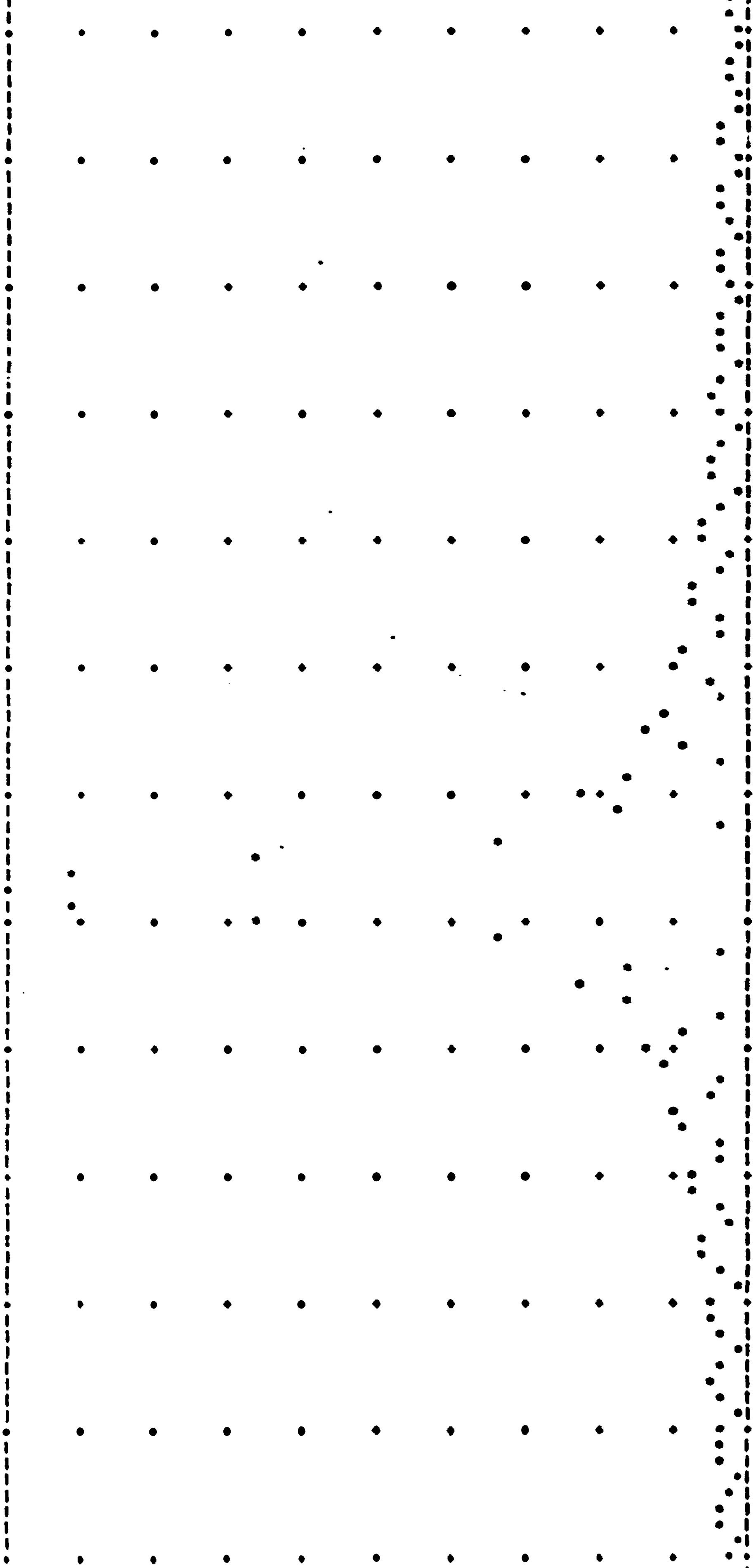
X-AXIS PROFILE PLOT ALONG 2.194 DEGREES LATITUDE.
PATTERN NUMBER 100

SCALE FACTOR IS 10**-2

Plot scale: 99.9983 79.9988 59.9993 39.9958 20.0003 0.0008

DB.	REAL	
-46.59	0.468	0.5000
-45.83	0.511	0.4980
-50.60	0.295	0.4960
-62.74	0.073	0.4940
-47.81	0.407	0.4920
-45.41	0.537	0.4900
-48.08	0.394	0.4880
-65.99	0.050	0.4860
-49.82	0.323	0.4840
-45.45	0.534	0.4820
-46.47	0.475	0.4800
-55.30	0.172	0.4780
-53.10	0.221	0.4760
-45.94	0.505	0.4740
-45.48	0.522	0.4720
-50.84	0.287	0.4700
-59.39	0.107	0.4680
-46.94	0.450	0.4660
-44.96	0.565	0.4640
-48.17	0.390	0.4620
-77.03	0.014	0.4600
-48.56	0.373	0.4580
-44.86	0.572	0.4560
-46.42	0.478	0.4540
-57.29	0.137	0.4520
-51.12	0.278	0.4500
-45.15	0.553	0.4480
-45.27	0.545	0.4460
-51.87	0.255	0.4440
-55.44	0.169	0.4420
-45.85	0.510	0.4400
-44.58	0.590	0.4380
-48.76	0.365	0.4360
-65.79	0.051	0.4340
-47.03	0.445	0.4320
-44.27	0.611	0.4300
-46.72	0.462	0.4280
-62.98	0.071	0.4260
-48.85	0.361	0.4240
-44.31	0.609	0.4220
-45.31	0.542	0.4200
-54.21	0.193	0.4180
-51.66	0.261	0.4160
-44.68	0.583	0.4140
-44.38	0.604	0.4120
-50.19	0.310	0.4100
-56.48	0.150	0.4080
-45.43	0.535	0.4060
-43.82	0.644	0.4040
-47.59	0.417	0.4020
-70.25	0.031	0.4000
-46.61	0.467	0.3980
-43.57	0.663	0.3960
-45.79	0.514	0.3940
-60.65	0.092	0.3920
-48.36	0.382	0.3900
-43.61	0.660	0.3880
-44.52	0.594	0.3860
-53.34	0.215	0.3840
-51.00	0.282	0.3820
-43.95	0.635	0.3800
-43.64	0.657	0.3780
-49.54	0.334	0.3760
-55.39	0.170	0.3740
-44.59	0.589	0.3720
-42.08	0.702	0.3700
-47.04	0.445	0.3680
-65.81	0.051	0.3660
-45.60	0.525	0.3640
-42.78	0.726	0.3620
-45.27	0.545	0.3600
-62.73	0.073	0.3580
-47.07	0.443	0.3560
-42.73	0.730	0.3540
-43.97	0.633	0.3520
-54.07	0.198	0.3500
-49.20	0.347	0.3480
-42.93	0.714	0.3460
-43.03	0.705	0.3440
-49.86	0.321	0.3420
-52.45	0.238	0.3400
-43.37	0.678	0.3380
-42.37	0.761	0.3360
-47.14	0.439	0.3340
-58.31	0.121	0.3320
-44.10	0.674	0.3300
-41.95	0.799	0.3280
-45.70	0.550	0.3260
-90.01	0.031	0.3240
-45.16	0.552	0.3220

-41.74	0.819	0.3200
-43.74	0.650	0.3180
-57.66	0.131	0.3160
-46.66	0.465	0.3140
-41.73	0.819	0.3120
-42.63	0.739	0.3100
-51.70	0.260	0.3080
-48.77	0.365	0.3060
-41.92	0.801	0.3040
-41.79	0.813	0.3020
-48.21	0.388	0.3000
-51.[illegible]	0.252	0.2980
-42.33	0.765	0.2960
-41.18	0.873	0.2940
-45.82	0.512	0.2920
-57.76	0.129	0.2900
-42.97	0.711	0.2880
-40.76	0.917	0.2860
-44.01	0.630	0.2840
******	0.001	0.2820
-42.87	0.640	0.2800
-40.51	0.943	0.2780
-42.61	0.740	0.2760
-57.48	0.124	0.2740
-45.13	0.554	0.2720
-40.43	0.952	0.2700
-41.51	0.840	0.2680
-51.35	0.271	0.2660
-46.86	0.454	0.2640
-40.51	0.943	0.2620
-40.64	0.[illegible]29	0.2600
-47.76	0.409	0.2580
-49.35	0.341	0.2560
-40.75	0.918	0.2540
-39.96	1.005	0.2520
-45.25	0.547	0.2500
-53.30	0.216	0.2480
-41.17	0.874	0.2460
-39.44	1.066	0.2440
-43.33	0.681	0.2420
-61.68	0.082	0.2400
-41.79	0.813	0.2380
-39.07	1.113	0.2360
-41.82	0.811	0.2340
-64.42	0.060	0.2320
-42.65	0.737	0.2300
-38.83	1.143	0.2280
-40.59	0.935	0.2260
-53.61	0.209	0.2240
-43.84	0.643	0.2220
-38.71	1.160	0.2200
-39.57	1.050	0.2180
-48.78	0.364	0.2160
-45.42	0.536	0.2140
-38.73	1.158	0.2120
-38.73	1.157	0.2100
-45.64	0.522	0.2090
-47.70	0.412	0.2060
-38.87	1.139	0.2040
-38.03	1.254	0.2020
-43.32	0.682	0.2000
-51.18	0.276	0.1980
-39.15	1.102	0.1960
-37.46	1.339	0.1940
-41.47	0.845	0.1920
-57.96	0.127	0.1900
-39.60	1.048	0.1880
-37.00	1.412	0.1860
-39.95	1.006	0.1840
-68.60	0.037	0.1920
-40.22	0.975	0.1800
-36.65	1.471	0.1780
-38.67	1.166	0.1760
-53.50	0.211	0.1740
-41.09	0.883	0.1720
-36.39	1.515	0.1700
-37.56	1.225	0.1680
-48.05	0.396	0.1660
-42.22	0.774	0.1640
-36.22	1.545	0.1620
-36.60	1.480	0.1600
[illegible]4.55	0.593	0.1580
[illegible].81	0.645	0.1560
[illegible].15	1.557	0.1540
[illegible]5.75	1.631	0.1520
-41.94	0.800	0.1900
-46.10	0.495	0.1480
-36.18	1.553	0.1460
-35.01	1.777	0.1440
-39.84	1.019	0.1420
-49.75	0.325	0.1400
-36.31	1.529	0.1380
-34.24	1.918	0.1360
-38.06	1.250	0.1340
-57.49	0.134	0.1320
-36.96	1.445	0.1300
-33.76	2.052	0.1280
-36.51	1.492	0.1260
-61.76	0.032	0.1240
-36.95	1.420	0.1220
-33.22	2.180	0.1200
-35.15	1.748	0.1180



-49.81	0.322	0.1160
-37.51	1.221	0.1140
-37.74	2.301	0.1120
-33.49	2.018	0.11C0
-44.52	0.594	0.1080
-38.31	1.214	0.1060
-32.35	2.414	0.1040
-37.74	2.306	0.1020
-40.90	C.902	0.1000
-39.42	1.067	0.0980
-31.98	2.519	0.0960
-31.65	2.616	0.0940
-38.09	1.244	0.0920
-41.05	0.886	0.0900
-31.65	2.616	0.0880
-30.59	2.953	0.0860
-35.69	1.642	0.0840
-43.61	0.460	0.0820
-31.36	2.704	0.08C0
-29.56	3.326	0.0780
-33.55	2.101	0.0760
-48.45	0.378	0.0740
-31.11	2.753	0.0720
-28.53	3.746	0.07C0
-31.56	2.641	0.0680
-49.55	0.033	0.0660
-30.89	2.853	0.0640
-27.47	4.232	0.0620
-29.65	3.292	0.06C0
-47.73	0.411	0.0580
-30.72	2.910	0.0560
-26.35	4.815	0.0540
-27.73	4.108	0.0520
-40.12	0.586	0.0500
-30.58	2.959	0.0480
-25.12	5.547	0.0460
-25.73	5.171	0.0440
-35.05	1.768	0.C420
-30.48	2.994	0.04C0
-23.71	6.523	0.0380
-23.55	6.644	0.0360
-30.76	2.896	0.0340
-30.40	3.C20	0.0320
-22.00	7.941	0.0300
-21.04	8.674	0.0280
-26.61	4.672	0.0260
-30.41	3.015	0.0240
-19.75	10.291	0.0220
-17.38	12.769	0.02C0
-21.97	7.970	0.0180
-30.51	2.581	0.C160
-16.38	15.174	0.0140
-13.29	21.646	0.0120
-15.72	16.376	0.01C0
-30.98	2.824	0.0080
-9.72	32.650	0.0060
-3.72	65.179	0.0040
-0.89	90.368	0.0020
-0.00	99.598	0.00C0
-0.83	90.849	-0.0020
-3.61	65.581	-0.0040
-9.4[illegible]	33.517	-0.C060
-29.[illegible]	3.467	-0.0080
-15.89	16.046	-0.01C0
-13.28	21.678	-0.0120
-16.23	15.436	-0.0140
-29.59	3.315	-0.C160
-22.22	7.746	-C.0180
-17.90	12.741	-0.02C0
-19.63	1C 436	-0.0220
-29.81	3.232	-0.C240
-26.92	4.509	-0.0260
-21.08	8.828	-0.0280
-21.91	8.027	-0.0300
-29.98	3.170	-0.0320
-31.19	2.756	-0.0340
-23.62	6.592	-0.C360
-23.64	6.574	-0.0380
-30.13	.115	-0.0400
-35.62	1.656	-0.0420
-25.92	5.116	-0.0440
-25.07	5.578	-0.0460
-30.30	3.054	-0.0480
-41.02	0.849	-0.0500
-27.84	4.053	-0.0520
-26.32	4.832	-0.0540
-30.50	2.986	-0.0560
-49.76	0.325	-0.0580
-29.79	3.239	-0.0600
-27.46	4.238	-0.C620
-30.72	2.911	-0.0640
-59.25	0.109	-0.0660
-31.75	2.586	-0.C680
-28.53	3.744	-0.07C0
-30.96	2.820	-0.0720
-48.95	0.449	-0.0740
-33.78	2.047	-0.0760
-29.57	3.21[illegible]	-0.C780
-31.24	2.742	-0.0800
-42.86	0.7[illegible]	-0.0820
-35.[illegible]	1.5[illegible]	-0.C840
-30.81	[illegible]	-0.0860

-31.45	2.645	-0.0880
-40.55	0.937	-0.0900
-37.41	1.178	-0.0920
-31.71	2.599	-0.0940
-31.93	2.541	-0.0960
-39.06	1.117	-0.0980
-41.38	0.853	-0.1000
-32.92	2.785	-0.1020
-32.79	2.427	-0.1040
-38.01	1.258	-0.1060
-45.70	0.550	-0.1080
-34.00	1.974	-0.1100
-32.73	2.310	-0.1120
-37.28	1.247	-0.1140
-51.96	0.280	-0.1160
-35.28	1.722	-0.1180
-33.71	2.184	-0.1200
-36.76	1.453	-0.1220
-67.66	0.041	-0.1240
-36.69	1.464	-0.1260
-33.76	2.052	-0.1280
-36.40	1.513	-0.1300
-55.22	0.173	-0.1320
-38.27	1.220	-0.1340
-34.36	1.913	-0.1360
-36.18	1.552	-0.1380
-48.81	0.363	-0.1400
-40.09	0.990	-0.1420
-35.04	1.769	-0.1440
-36.08	1.571	-0.1460
-45.52	0.530	-0.1480
-42.26	0.771	-0.1500
-35.81	1.620	-0.1520
-36.07	1.571	-0.1540
-43.42	0.674	-0.1560
-44.99	0.563	-0.1580
-36.68	1.466	-0.1600
-36.17	1.554	-0.1620
-41.93	0.801	-0.1640
-48.72	0.367	-0.1660
-37.66	1.309	-0.1680
-36.35	1.522	-0.1700
-40.94	0.903	-0.1720
-54.82	0.182	-0.1740
-38.80	1.149	-0.1760
-36.63	1.473	-0.1780
-40.04	0.995	-0.1800
-81.66	0.003	-0.1820
-40.12	0.957	-0.1840
-37.01	1.411	-0.1860
-39.45	1.065	-0.1880
-56.32	0.152	-0.1900
-41.68	0.624	-0.1920
-37.49	1.335	-0.1940
-39.04	1.117	-0.1960
-50.44	0.301	-0.1980
-43.60	0.661	-0.2000
-38.08	1.247	-0.2020
-38.78	1.159	-0.2040
-47.23	0.435	-0.2060
-46.01	0.501	-0.2080
-36.80	1.149	-0.2100
-38.66	1.165	-0.2120
-45.09	0.557	-0.2140
-49.22	0.342	-0.2160
-39.67	1.039	-0.2180
-38.67	1.165	-0.2200
-43.55	0.662	-0.2220
-54.57	0.187	-0.2240
-40.71	0.922	-0.2260
-38.81	1.147	-0.2280
-42.47	0.752	-0.2300
-68.23	0.029	-0.2320
-41.98	0.796	-0.2340
-39.07	1.113	-0.2360
-41.64	0.829	-0.2380
-59.82	0.102	-0.2400
-43.54	0.665	-0.2420
-39.46	1.064	-0.2440
-41.06	0.885	-0.2460
-52.58	0.735	-0.2480
-45.50	0.531	-0.2500
-40.00	1.000	-0.2520
-40.67	0.926	-0.2540
-48.91	0.358	-0.2560
-48.12	0.293	-0.2580
-40.71	0.922	-0.2600
-40.45	0.950	-0.2620
-46.56	0.470	-0.2640
-51.88	0.755	-0.2660
-41.60	0.832	-0.2680
-40.39	0.956	-0.2700
-44.92	0.568	-0.2720
-58.99	0.118	-0.2740
-42.73	0.720	-0.2760
-43.50	0.744	-0.2780
-43.72	0.657	-0.2800
-75.66	0.017	-0.2820
-44.16	0.619	-0.2840
-40.77	0.910	-0.2860
[illegible]	0.720	-0.2880
[illegible]	[illegible]	[illegible]

-46.02	0.500	-0.2920
-41.21	0.870	-0.2940
-42.25	0.772	-0.2960
-51.92	0.765	-0.2980
-48.50	0.376	-0.3000
-41.85	0.809	-0.3020
-41.87	0.807	-0.3040
-48.50	0.376	-0.3060
-52.11	0.248	-0.3080
-42.70	0.732	-0.3100
-41.70	0.822	-0.3120
-46.45	0.476	-0.3140
-58.50	0.119	-0.3160
-43.84	0.642	-0.3180
-41.73	0.820	-0.3200
-45.02	0.561	-0.3220
-80.83	0.009	-0.3240
-45.34	0.541	-0.3260
-41.96	0.798	-0.3280
-44.00	0.631	-0.3300
-57.58	0.132	-0.3320
-47.24	0.430	-0.3340
-42.46	0.759	-0.3360
-43.31	0.683	-0.3380
-52.07	0.249	-0.3400
-50.14	0.311	-0.3420
-43.08	0.701	-0.3440
-42.88	0.718	-0.3460
-48.97	0.356	-0.3480
-54.52	0.188	-0.3500
-44.05	0.627	-0.3520
-42.71	0.732	-0.3540
-46.91	0.451	-0.3560
-64.00	0.063	-0.3580
-45.28	0.539	-0.3600
-42.78	0.726	-0.3620
-45.50	0.531	-0.3640
-64.39	0.060	-0.3640
-47.18	0.437	-0.3680
-43.05	0.700	-0.3700
-44.52	0.594	-0.3720
-54.95	0.179	-0.3740
-49.74	0.326	-0.3760
-43.68	0.655	-0.3780
-43.90	0.638	-0.3800
-50.78	0.283	-0.3820
-53.66	0.207	-0.3840
-44.59	0.590	-0.3860
-43.59	0.662	-0.3880
-48.22	0.348	-0.3900
-61.45	0.085	-0.3920
-45.88	0.508	-0.3940
-43.55	0.664	-0.3960
-46.51	0.473	-0.3980
-68.47	0.038	-0.4000
-47.70	0.412	-0.4020
-43.83	0.643	-0.4040
-45.36	0.539	-0.4060
-56.10	0.157	-0.4080
-50.37	0.303	-0.4100
-44.41	0.602	-0.4120
-44.64	0.586	-0.4140
-51.46	0.267	-0.4160
-54.60	0.186	-0.4180
-45.37	0.539	-0.4200
-44.29	0.610	-0.4220
-48.72	0.367	-0.4240
-63.81	0.065	-0.4260
-46.79	0.458	-0.4280
-44.27	0.612	-0.4300
-46.94	0.450	-0.4320
-64.77	0.058	-0.4340
-48.87	0.360	-0.4360
-44.60	0.569	-0.4380
-45.79	0.513	-0.4400
-55.13	0.175	-0.4420
-52.05	0.250	-0.4440
-45.31	0.543	0.4460
-45.11	0.555	-0.4480
-50.97	0.233	-0.4500
-57.64	0.131	-0.4520
-46.47	0.473	-0.4540
-44.84	0.572	-0.4560
-48.47	0.377	-0.4580
-81.30	0.009	-0.4600
-48.25	0.387	-0.4620
-44.97	0.564	-0.4640
-46.88	0.452	-0.4660
-59.07	0.112	-0.4680
-50.96	0.283	-0.4700
-45.50	0.531	-0.4720
-45.91	0.507	-0.4740
-52.93	0.226	-0.4760
-55.53	0.167	-0.4780
-46.52	0.472	-0.4800
-45.45	0.535	-0.4820
-49.72	0.327	-0.4840
-66.81	0.046	-0.4860
-48.15	0.391	-0.4880
-45.41	0.517	-0.4900
-47.75	0.410	-0.4920
-62.26	0.077	-0.4940

DP.	REAL		
-50.71	0.292		-0.4960
-45.84	0.510		-0.4980
-46.?	0.470		-0.5000

DP	REAL	99.9983	79.9988	59.9993	39.9998	20.0003	0.0008

Y-AXIS PROFILE PLOT ALONG 0.0 LONGITUDE.
PATTERN NUMBER 100

DP.	REAL	1.0035	0.8028	0.6022	0.4015	0.2009	0.0002	
-32.99	0.022							3.9999
-33.67	0.021							3.9918
-34.42	0.019							3.9833
-35.26	0.017							3.9759
-36.19	0.015							3.9679
-37.26	0.014							3.9599
-38.50	0.012							3.9519
-39.97	0.010							3.9439
-41.76	0.008							3.9359
-44.06	0.006							3.9279
-47.24	0.004							3.9199
-52.42	0.002							3.9119
-67.60	0.000							3.9039
-56.02	0.002							3.8959
-48.86	0.004							3.8879
-44.95	0.006							3.8799
-42.23	0.008							3.8719
-40.15	0.010							3.8639
-38.45	0.012							3.8559
-37.02	0.014							3.8479
-35.78	0.016							3.8399
-34.68	0.018							3.8319
-33.70	0.021							3.8239
-32.81	0.023							3.8159
-31.99	0.025							3.8079
-31.24	0.027							3.7999
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-29.89	0.032							3.7839
-29.28	0.034							3.7759
-28.71	0.037							3.7679
-28.16	0.039							3.7599
-27.65	0.041							3.7519
-27.16	0.044							3.7439
-26.70	0.046							3.7359
-26.25	0.049							3.7279
-25.83	0.051							3.7199
-25.42	0.054							3.7119
-25.03	0.056							3.7039
-24.65	0.059							3.6959
-24.29	0.061							3.6879
-23.94	0.064							3.6799

-23.41	0.066	3.6719
-23.24	0.069	3.6629
-22.97	0.071	3.6559
-22.67	0.074	3.6479
-22.38	0.076	3.6399
-22.09	0.079	3.6319
-21.82	0.081	3.6239
-21.55	0.084	3.6159
-21.29	0.086	3.6079
-21.04	0.089	3.5999
-20.80	0.091	3.5919
-20.56	0.094	3.5839
-20.33	0.096	3.5759
-20.11	0.099	3.5679
-19.89	0.101	3.5599
-19.68	0.104	3.5519
-19.48	0.106	3.5439
-19.28	0.109	3.5359
-19.09	0.111	3.5279
-18.90	0.113	3.5199
-18.72	0.116	3.5119
-18.55	0.118	3.5039
-18.37	0.121	3.4959
-18.21	0.123	3.4879
-18.05	0.125	3.4799
-17.89	0.127	3.4719
-17.74	0.130	3.4639
-17.59	0.132	3.4559
-17.45	0.134	3.4479
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-17.18	0.138	3.4319
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-16.82	0.144	3.4079
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-16.39	0.152	3.3759
-16.29	0.153	3.3679
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-16.11	0.156	3.3519
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-15.69	0.164	3.3039
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-15.41	0.170	3.1919
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-15.51	0.168	3.1679
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-15.61	0.166	3.1519
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-15.74	0.163	3.1359
-15.82	0.162	3.1279
-15.90	0.160	3.1199
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-16.35	0.152	3.0879
-16.49	0.150	3.0800
-16.65	0.147	3.0719
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-17.00	0.141	3.0560
-17.19	0.138	3.0480
-17.41	0.135	3.0400
-17.64	0.131	3.0320
-17.89	0.128	3.0240
-18.16	0.124	3.0160
-18.46	0.119	3.0080
-18.78	0.115	3.0000
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-21.44	0.085	2.9520
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-22.75	0.073	2.9360
-23.53	0.067	2.9280
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-25.46	0.053	2.9120
-26.67	0.046	2.9040
-28.11	0.039	2.8960
-29.95	0.032	2.8880
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-35.74	0.016	2.8720
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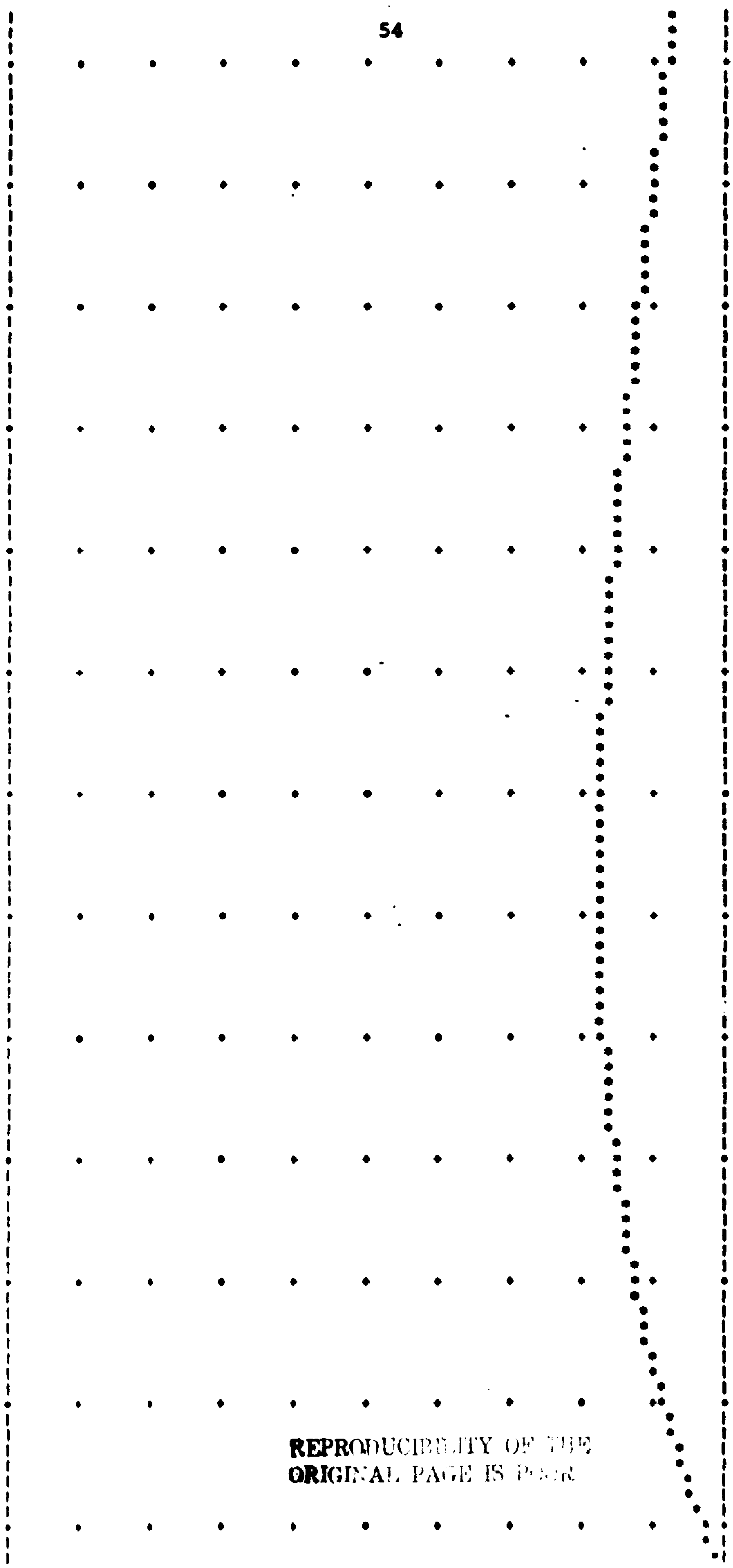

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-26.83	0.046	2.8160
-25.14	0.055	2.8080
-23.70	0.065	2.8000
-22.43	0.076	2.7920
-21.30	0.086	2.7840
-20.28	0.097	2.7760
-19.35	0.108	2.7680
-18.50	0.119	2.7600
-17.70	0.130	2.7520
-16.96	0.142	2.7440
-16.26	0.154	2.7360
-15.61	0.166	2.7280
-14.98	0.178	2.7200
-14.40	0.191	2.7120
-13.84	0.203	2.7040
-13.30	0.216	2.6960
-12.79	0.229	2.6880
-12.30	0.243	2.6800
-11.83	0.256	2.6720
-11.38	0.270	2.6640
-10.94	0.284	2.6560
-10.53	0.298	2.6480
-10.12	0.312	2.6400
-9.73	0.326	2.6320
-9.35	0.341	2.6240
-8.99	0.355	2.6160
-8.63	0.370	2.6080
-8.29	0.385	2.6000
-7.96	0.400	2.5920
-7.64	0.415	2.5840
-7.32	0.430	2.5760
-7.02	0.446	2.5680
-6.73	0.461	2.5600
-6.44	0.476	2.5520
-6.16	0.492	2.5440
-5.89	0.508	2.5360
-5.62	0.523	2.5280
-5.37	0.539	2.5200
-5.12	0.554	2.5120
-4.88	0.570	2.5040
-4.65	0.586	2.4960
-4.42	0.601	2.4880
-4.20	0.617	2.4800
-3.99	0.632	2.4720
-3.78	0.647	2.4640
-3.57	0.663	2.4560
-3.38	0.678	2.4480
-3.19	0.693	2.4400
-3.00	0.709	2.4320
-2.82	0.722	2.4240
-2.65	0.737	2.4160
-2.48	0.751	2.4080
-2.32	0.766	2.4000
-2.16	0.780	2.3920
-2.01	0.793	2.3840
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-1.73	0.820	2.3680
-1.59	0.833	2.3600
-1.46	0.845	2.3520
-1.34	0.857	2.3440
-1.22	0.869	2.3360
-1.10	0.881	2.3280
-0.99	0.892	2.3200
-0.89	0.902	2.3120
-0.79	0.913	2.3040
-0.70	0.922	2.2960
-0.61	0.932	2.2880
-0.53	0.941	2.2800
-0.45	0.949	2.2720
-0.38	0.957	2.2640
-0.32	0.964	2.2560
-0.26	0.971	2.2480
-0.20	0.977	2.2400
-0.15	0.982	2.2320
-0.11	0.987	2.2240
-0.07	0.992	2.2160
-0.04	0.995	2.2080
-0.01	0.998	2.2000
0.01	1.001	2.1920
0.02	1.002	2.1840
0.03	1.003	2.1760
0.03	1.003	2.1680
0.03	1.003	2.1600
0.02	1.002	2.1520
-0.00	1.000	2.1440
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-0.19	0.978	2.1040
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-0.31	0.964	2.0880
-0.39	0.956	2.0800
-0.47	0.947	2.0720
-0.56	0.937	2.0640
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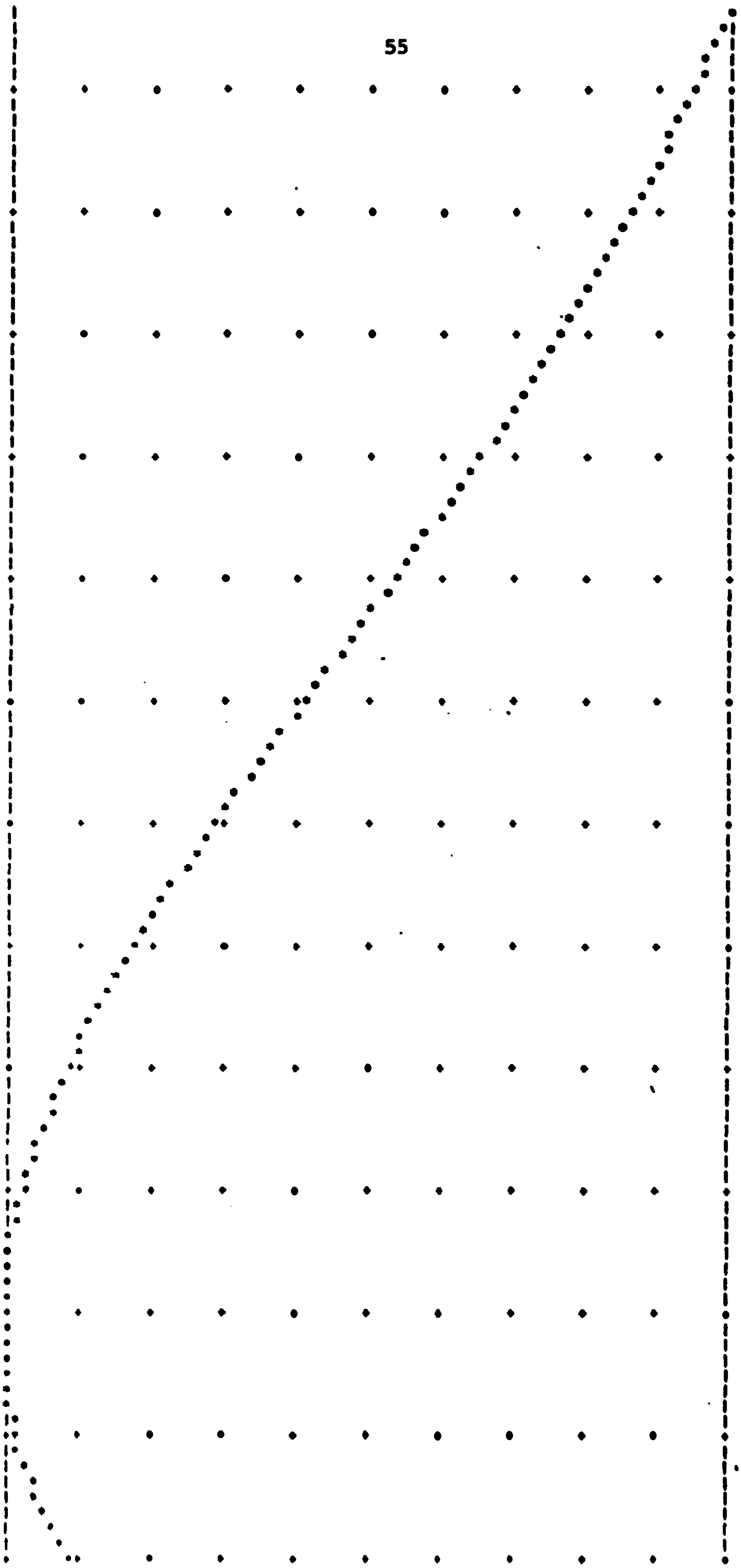
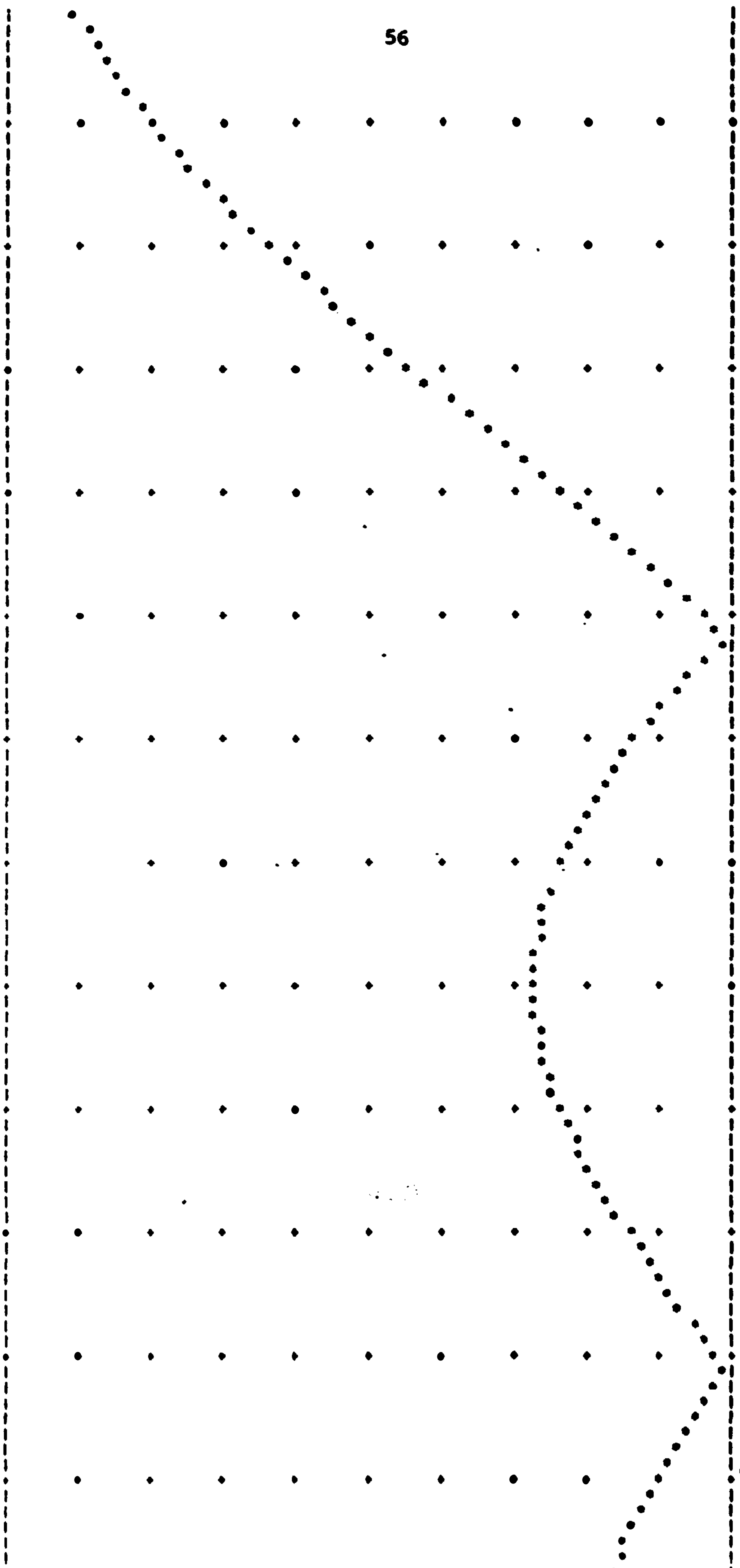
-0.77	0.915	2.0480





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-1.44	0.847	2.0080
-1.61	0.831	2.0000
-1.79	0.814	1.9920
-1.97	0.797	1.9840
-2.17	0.779	1.9760
-2.38	0.760	1.9680
-2.61	0.740	1.9600
-2.85	0.720	1.9520
-3.10	0.700	1.9440
-3.37	0.678	1.9360
-3.65	0.657	1.9280
-3.95	0.634	1.9200
-4.27	0.611	1.9120
-4.61	0.588	1.9040
-4.97	0.564	1.8960
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-5.75	0.516	1.8800
-6.18	0.491	1.8720
-6.64	0.466	1.8640
-7.13	0.440	1.8560
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-9.45	0.337	1.8240
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-10.91	0.285	1.8080
-11.74	0.259	1.8000
-12.66	0.233	1.7920
-13.67	0.207	1.7940
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-16.11	0.156	1.7680
-17.62	0.132	1.7600
-19.41	0.107	1.7520
-21.64	0.083	1.7440
-24.57	0.059	1.7360
-28.91	0.036	1.7280
-37.61	0.013	1.7200
-41.00	0.009	1.7120
-30.36	0.030	1.7040
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-20.88	0.090	1.6800
-19.27	0.107	1.6720
-17.97	0.126	1.6640
-16.89	0.143	1.6560
-15.98	0.159	1.6480
-15.21	0.174	1.6400
-14.55	0.187	1.6329
-13.98	0.200	1.6240
-13.48	0.212	1.6160
-13.06	0.222	1.6080
-12.69	0.232	1.6050
-12.38	0.240	1.5920
-12.12	0.248	1.5840
-11.91	0.254	1.5760
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-11.61	0.263	1.5600
-11.52	0.265	1.5520
-11.47	0.267	1.5440
-11.46	0.267	1.5360
-11.49	0.267	1.5280
-11.55	0.265	1.5200
-11.64	0.262	1.5120
-11.78	0.258	1.5040
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-12.72	0.231	1.4720
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-14.41	0.190	1.4400
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-16.36	0.152	1.4160
-17.20	0.139	1.4080
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-19.25	0.109	1.3920
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-24.01	0.063	1.3680
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-29.98	0.032	1.3520
-35.88	0.016	1.3440
-64.90	0.001	1.3360
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-16.48	0.150	1.2400
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-14.98	C.178	1.2000
-14.86	0.181	1.1920
-14.79	0.182	1.1840
-14.78	C.182	1.1760
-14.81	0.182	1.1680
-14.91	C.180	1.1600
-15.05	0.177	1.1520
-15.25	0.173	1.1440
-15.51	C.168	1.1360
-15.83	0.162	1.1280
-16.21	0.155	1.1200
-16.67	C.147	1.1120
-17.20	0.138	1.1040
-17.83	C.128	1.0960
-18.56	0.118	1.0880
-19.41	0.107	1.0800
-20.40	0.095	1.0720
-21.58	0.083	1.0640
-23.01	0.071	1.0560
-24.76	0.058	1.0480
-27.02	0.045	1.0400
-30.14	C.031	1.0320
-35.11	0.018	1.0240
-47.97	0.004	1.0160
-40.45	0.009	1.0080
-32.83	0.023	1.0000
-28.89	0.036	0.9920
-26.26	C.C49	0.9840
-24.30	0.061	0.9760
-22.76	0.073	0.9680
-21.51	C.084	C.9600
-20.49	0.095	0.9520
-19.63	C.104	0.9440
-18.91	C.113	0.9360
-18.31	0.122	0.9280
-17.80	C.129	C.9200
-17.39	0.135	0.9120
-17.06	C.140	0.9040
-16.81	0.144	0.8960
-16.63	C.147	0.8880
-16.51	C.149	0.8800
-16.46	0.150	0.8720
-16.47	0.150	0.8640
-16.55	0.149	0.8560
-16.70	0.146	0.8480
-16.91	C.143	C.8400
-17.20	0.138	0.8320
-17.56	0.132	0.8240
-18.00	0.126	0.8160
-18.54	0.118	0.8080
-19.18	C.110	0.8000
-19.94	0.101	0.7920
-20.84	0.091	0.7840
-21.92	C.C80	0.776C
-23.23	0.069	0.7680
-24.83	C.C57	C.7600
-26.88	0.045	0.7520
-29.65	0.033	0.7440
-33.82	0.020	0.7360
-42.26	C.009	0.7280
-46.10	0.005	0.7200
-35.13	C.018	0.7120
-30.49	C.030	0.7040
-27.54	C.042	0.6960
-25.40	0.054	0.6880
-23.75	0.065	0.68C0
-22.43	0.076	0.6720
-21.35	0.C86	0.6640
-20.45	0.095	0.6560
-19.71	C.103	0.6480
-19.09	0.111	0.6400
-18.58	C.118	0.6320
-18.16	C.124	0.6240
-17.84	0.128	0.6160
-17.59	0.132	0.6080
-17.42	C.135	0.60C0
-17.33	0.136	0.5920
-17.30	0.136	0.5840
-17.35	0.136	0.5760
-17.47	0.134	0.5680
-17.66	0.131	0.56C0
-17.92	0.127	0.5520
-18.27	C.122	0.5440
-18.70	C.116	0.5360
-19.23	0.109	0.5280
-19.87	C.102	0.5200
-20.63	0.093	0.5120
-21.54	C.084	0.5040
-22.64	0.074	0.4960
-23.97	0.063	0.4880
-25.62	0.052	0.4800
-27.74	0.041	0.4720
-30.64	0.029	0.4640
-35.13	0.018	0.4560
-45.09	0.006	0.4480
-42.87	0.006	0.4400
-34.75	C.018	0.4320
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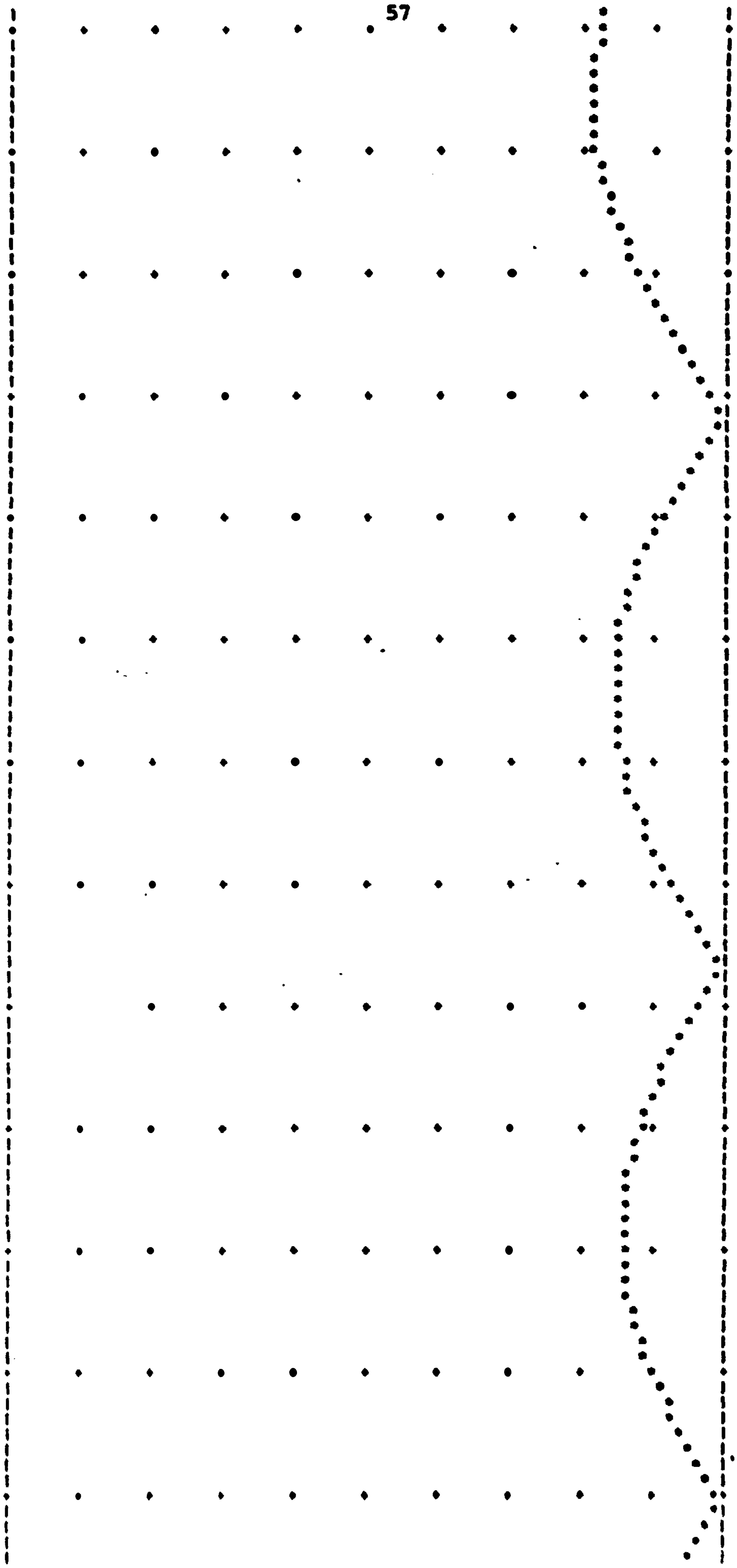

CB.	REAL	
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-20.77	0.092	0.3760
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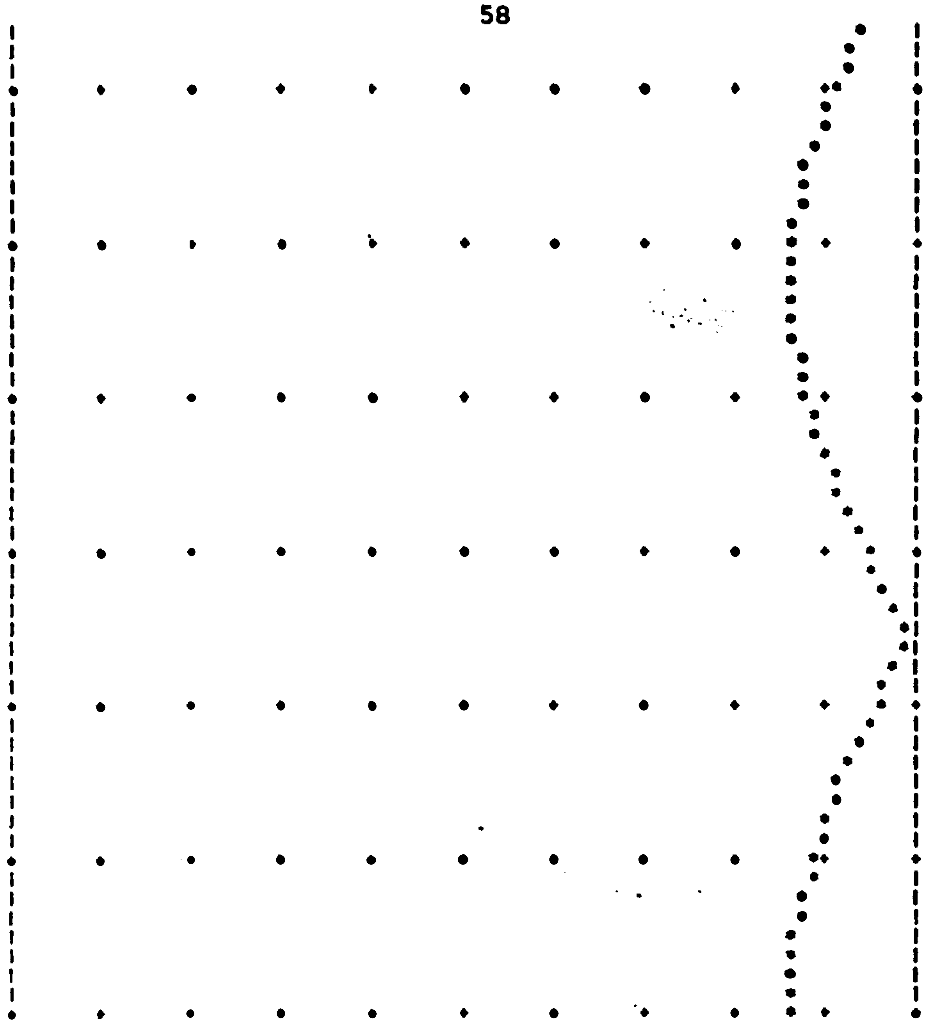
-19.42	0.107	0.3600
-18.91	0.113	0.3520
-18.50	C.119	0.3440
-18.17	0.123	0.3360
-17.92	0.127	0.3280
-17.74	0.130	0.3200
-17.64	0.131	0.3120
-17.60	0.132	0.3040
-17.62	0.132	0.2960
-17.71	0.130	0.2880
-17.87	C.128	0.2800
-18.10	0.124	0.2720
-18.40	C.120	0.2640
-18.78	0.115	0.2560
-19.24	0.109	0.2480
-19.80	0.102	0.2400
-20.46	0.095	0.2320
-21.24	0.087	0.2240
-22.16	C.078	0.2160
-23.27	0.069	0.2080
-24.60	C.C59	0.2000
-26.24	0.049	0.1920
-28.35	0.039	0.1840
-31.20	0.028	0.1760
-35.56	0.017	0.1680
-44.87	0.006	0.1600
-45.57	0.005	0.1520
-35.83	0.016	0.1440
-31.39	C.C27	0.1360
-28.52	0.C37	0.1280
-26.42	C.C48	0.1200
-24.78	C.C59	0.1120
-23.45	0.067	0.1040
-22.36	0.076	0.0960
-21.44	C.085	0.0880
-20.66	0.093	0.0800
-19.95	C.100	0.0720
-19.43	0.107	0.0640
-18.96	0.113	0.0560
-18.55	0.118	0.0480
-18.23	0.123	0.0400
-17.97	0.126	0.0320
-17.76	0.129	0.0240
-17.61	0.132	0.0160
-17.52	C.133	0.0080
-17.47	0.134	0.0



EXAMPLE 2:
DEMONSTRATION OF FOOTPRINT DEGRADATION DUE TO ANTENNA PANEL UNFOLDING ERRORS.

SYSTEM INFORMATION:
FREQUENCY = 9.000 GHZ.
YAW = 0.0 DEGREES
TILT = 50.000 DEGREES
TWIST = 0.0 DEGREES
ALTITUDE = 200.000 KM.

ANTENNA PARAMETERS FOR SIMULATION NUMBER 101
ELEMENT TYPE: HORIZONTAL DIPOLE
NUMBER OF ELEMENTS (X,Y) = (504 , 12)
INTERELEMENT SPACING (CM.): 2.2966 , 2.3550
INTERELEMENT PHASE SHIFT (DEG.): 0.0 , 0.0

DEFORMATION DATA FOR SIMULATION 101:

-1.00	0.0	0.0	2.00
-1.00	0.0	0.0	2.00

ELECTRICAL DATA FOR SIMULATION 101:

	(1, 1)	(2, 1)	(3, 1)	(
PHSX:	0.0	0.0	0.0	
PHSY:	0.0	0.0	0.0	
AMAG:	1.00	1.00	1.00	
APHS:	0.0	0.0	0.0	

PRINT/PLOT INFORMATION:
REQUESTED OUTPUT:
PRINTER PROFILE
PRINTER CONTOUR
PLOT RESOLUTION: 151 X 151 POINTS

STARTX = -0.500
STOPX = 0.500
DELTAX = 0.007

STARTY = 0.0
STOPY = 4.000
DELTAY = 0.027

SUBARRAY DATA SUMMARY FOR PATTERN101:

AREA	XCENT	YCENT	ZAVG	ALPHAX	ALPHAY	AMAG	APHS	PHSX	PHSY
1	-385.83	0.0	-0.50	0.148	0.0	1.0000	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	1.0000	0.0	0.0	0.0
3	385.83	0.0	1.00	0.297	0.0	1.0000	0.0	0.0	0.0

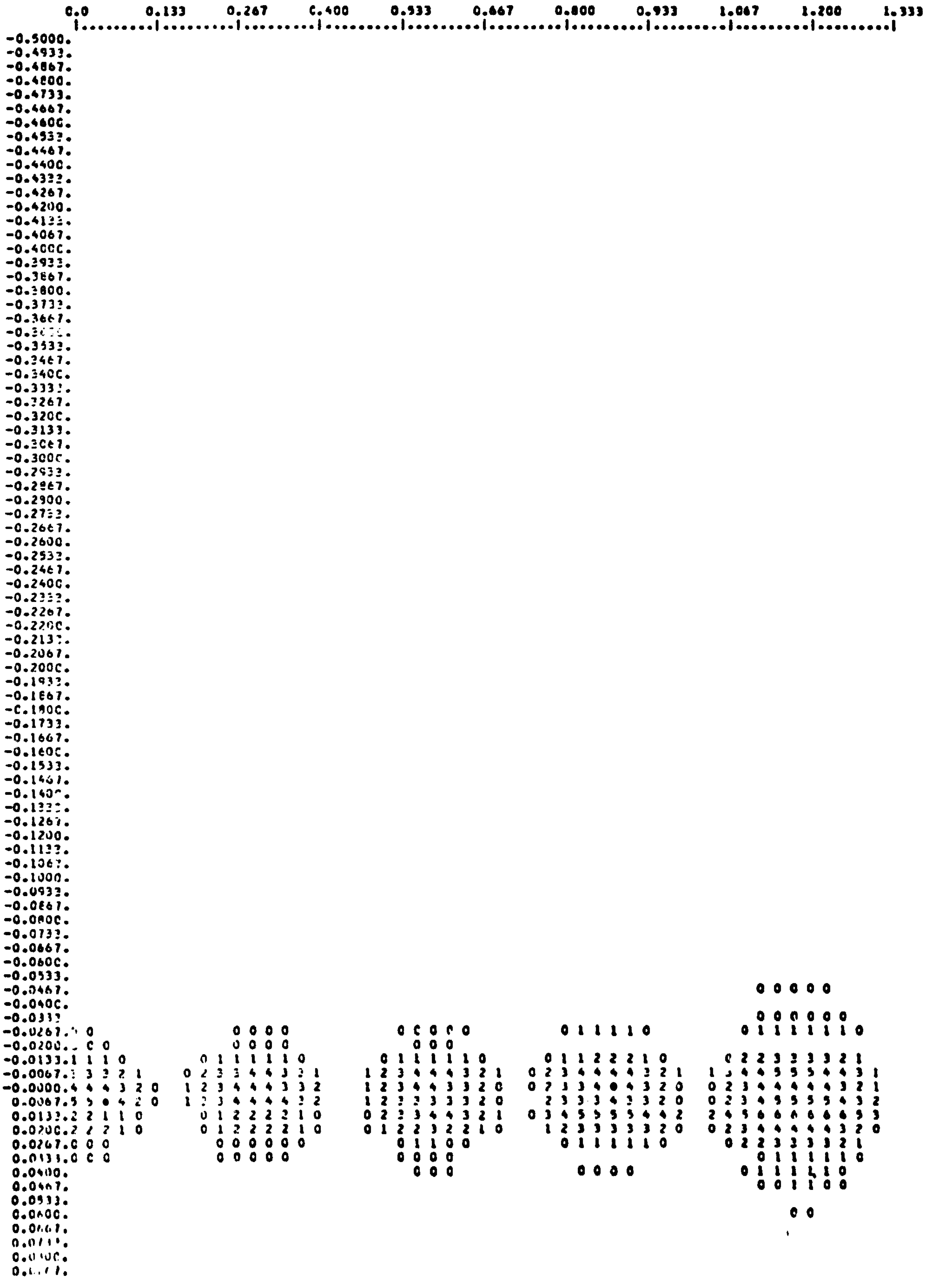
PREDICTED BEAM CENTER:
LATITUDE = 2.1545
LONGITUDE = 0.0
RANGE = 2[illegible]

HEADING =   0.0

60

PLOT NORMALIZATION FACTOR = -46.325 DB.

PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 101



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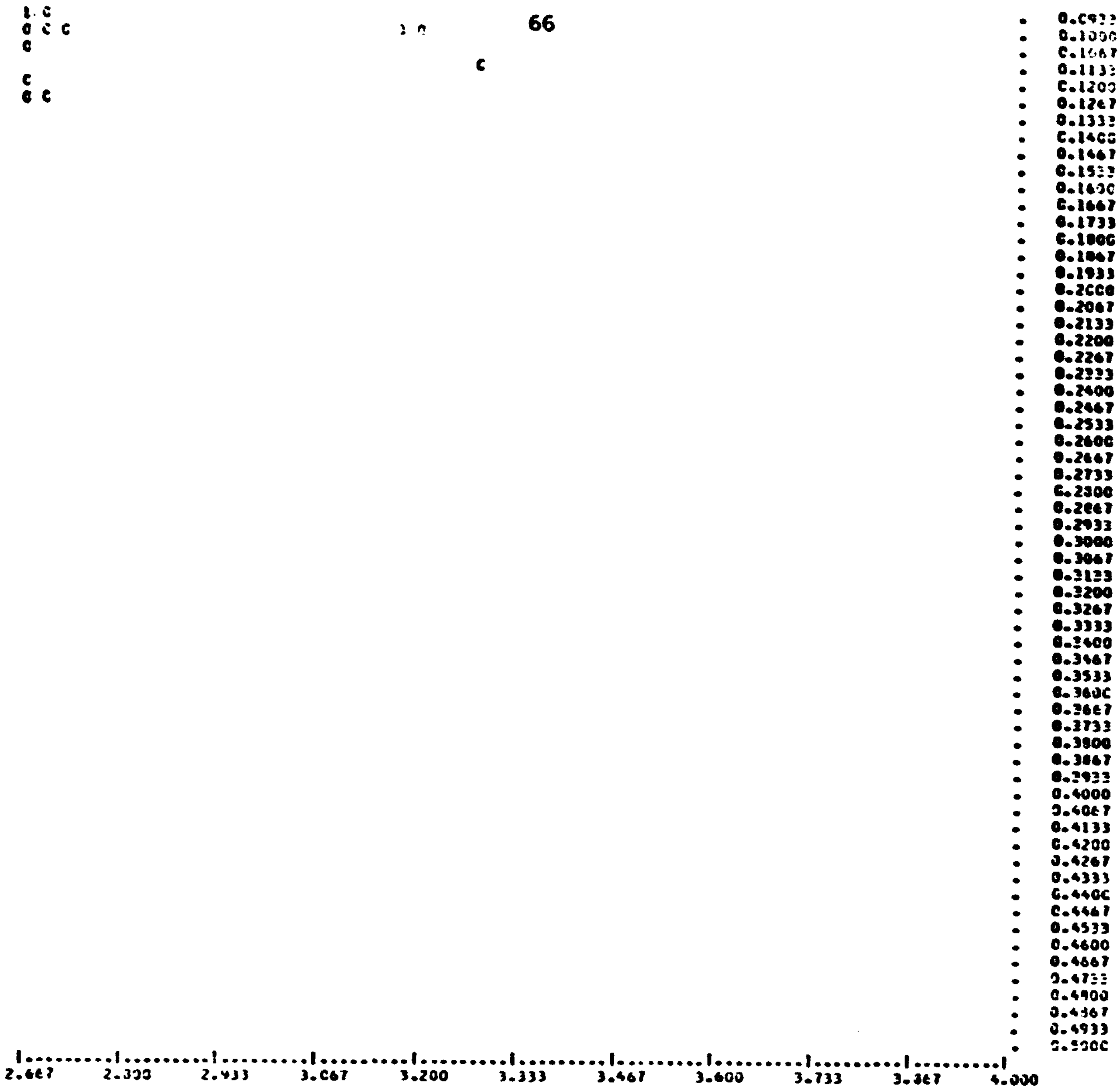
0.1000.
0.1067.
0.1133.
0.1200.
0.1267.
0.1333.
0.1400.
0.1467.
0.1533.
0.1600.
0.1667.
0.1733.
0.1800.
0.1867.
0.1933.
0.2000.
0.2067.
0.2133.
0.2200.
0.2267.
0.2333.
0.2400.
0.2467.
0.2533.
0.2600.
0.2667.
0.2733.
0.2800.
0.2867.
0.2933.
0.3000.
0.3067.
0.3133.
0.3200.
0.3267.
0.3333.
0.3400.
0.3467.
0.3533.
0.3600.
0.3667.
0.3733.
0.3800.
0.3867.
0.3933.
0.4000.
0.4067.
0.4133.
0.4200.
0.4267.
0.4333.
0.4400.
0.4467.
0.4533.
0.4600.
0.4667.
0.4733.
0.4800.
0.4867.
0.4933.
0.5000.
        I.........I.........I.........I.........I.........I.........I.........I.........I.........I.........I
       0.0      0.133     0.267     0.400     0.533     0.667     0.800     0.933     1.067     1.200     1.333
```

PRINTER CONTCUR PLOT FOR SIMULATICN NUMBER 101

CONTOUR LEVEL KEY

0: -0.2850000E 02 TO -0.2549999E 02
1: -0.2550000E 02 TO -0.2249999E 02
2: -0.2250000E 02 TO -0.1949999E 02
3: -0.1950000E 02 TO -0.1649999E 02
4: -0.1650000E 02 TO -0.1349999E 02
5: -0.1350000E 02 TO -0.1049999E 02
6: -0.1050000E 02 TO -0.7499999E 01
7: -0.7500000E 01 TO -0.4499999E 01
8: -0.4500000E 01 TO -0.1499990E 01
9: -0.1500000E 01 TO 0.1500010E 01
 : -0.1000000E 51 TO -0.2850000E 02
*: 0.1500010E 01 TO 0.1000000E 51

PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 101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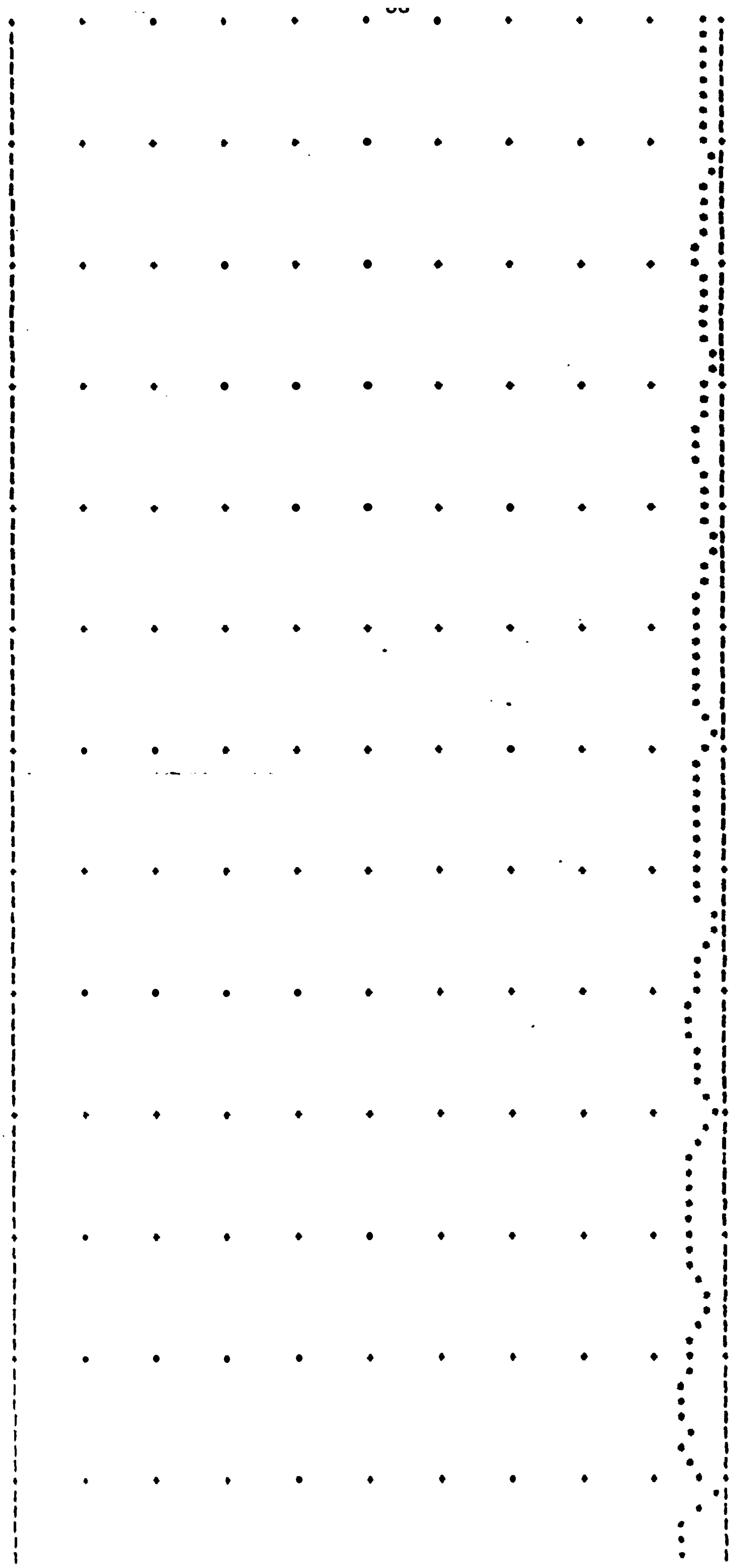
0.1133
0.1200
0.1267
0.1333
0.1400
0.1467
0.1533
0.1600
0.1667
0.1733
0.1800
0.1867
0.1933
0.2000
0.2067
0.2133
0.2200
0.2267
0.2333
0.2400
0.2467
0.2533
0.2600
0.2667
0.2733
0.2800
0.2867
0.2933
0.3000
0.3067
0.3133
0.3200
0.3267
0.3333
0.3400
0.3467
0.3533
0.3600
0.3667
0.3733
0.3800
0.3867
0.3933
0.4000
0.4067
0.4133
0.4200
0.4267
0.4333
0.4400
0.4467
0.4533
0.4600
0.4667
0.4733
0.4800
0.4867
0.4933
0.5000
2.667
2.800
2.933
3.067
3.200
3.333
3.467
3.600
3.733
3.867
4.000

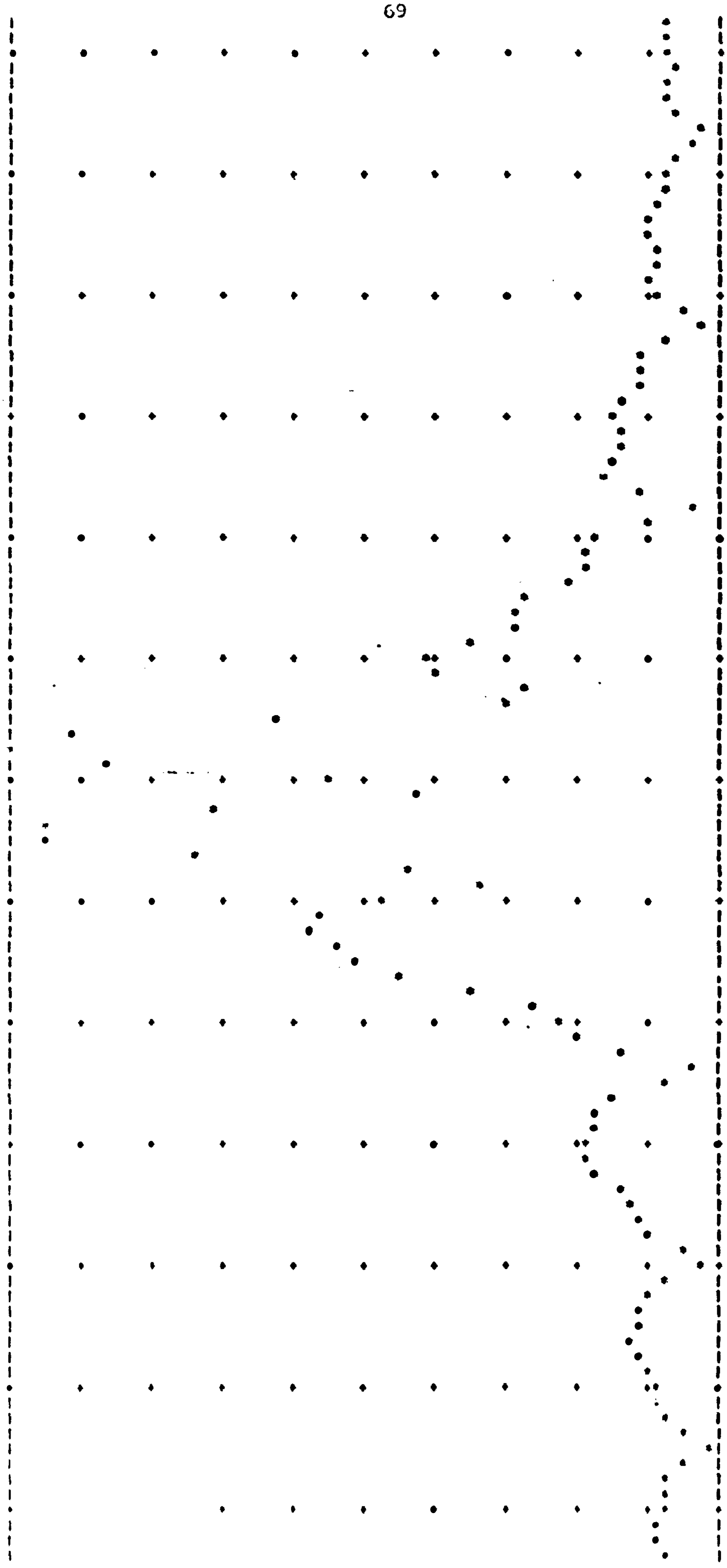
X-AXIS PROFILE PLOT ALONG 2.194 DEGREES LATITUDE.
PATTERN NUMBER 101

DB. REAL 2.3224 1.8588 1.3951 0.9314 0.4678 0.0041

DB.	REAL	
-40.95	0.009	0.5000
-32.78	0.023	0.4980
-30.47	0.030	0.4960
-30.29	0.031	0.4940
-29.9[illegible]	0.032	0.4920
-28.59	0.036	0.4900
-28.59	0.037	0.4880
-29.39	0.034	0.4860
-30.43	0.030	0.4840
-30.17	0.031	0.4820
-30.03	0.032	0.4800
-32.24	0.024	0.4780
-40.42	0.010	0.4760
-39.46	0.011	0.4740
-32.01	0.025	0.4720
-29.94	0.032	0.4700
-29.79	0.032	0.4680
-29.44	0.034	0.4660
-28.43	0.038	0.4640
-28.13	0.039	0.4620
-29.03	0.035	0.4600
-29.92	0.032	0.4580
-29.62	0.033	0.4560
-29.65	0.033	0.4540
-32.30	0.024	0.4520
-42.05	0.008	0.4500
-37.28	0.014	0.4480
-31.05	0.028	0.4460
-29.37	0.034	0.4440
-29.31	0.034	0.4420
-28.81	0.036	0.4400
-27.60	0.041	0.4380
-27.68	0.041	0.4360
-28.72	0.037	0.4340
-29.49	0.03[illegible]	0.4320
-29.02	0.035	0.4300
-29.35	0.034	0.4280
-32.72	0.023	0.4260
-45.29	0.005	0.4240
-35.03	0.018	0.4220
-29.59	0.032	0.4200
-29.78	0.036	0.4180
-26.78	0.036	0.4160
-28.07	0.039	0.4140
-27.14	0.044	0.4120
-27.29	0.043	0.4100
-28.44	0.038	0.4080
-28.91	0.036	0.4060
-28.40	0.039	0.4040
-29.22	0.035	0.4020
-32.75	0.021	0.4000
-46.25	0.005	0.3980
-32.69	0.023	0.3960
-28.92	0.036	0.3940
-28.21	0.039	0.3920
-28.15	0.037	0.3900
-27.23	0.044	0.3880
-26.48	0.047	0.3860
-26.95	0.045	0.3840
-28.14	0.039	0.3820
-28.21	0.039	0.3800
-27.82	0.041	0.3780
-29.37	0.034	0.3760
-35.01	0.016	0.3740
-40.08	0.010	0.3720
-30.53	0.030	0.3700
-27.93	0.040	0.3680
-27.64	0.041	0.3660
-27.37	0.043	0.3640
-26.31	0.048	0.3620
-25.67	0.051	0.3600
-26.70	0.046	0.3580
-27.72	0.041	0.3560
-27.40	0.043	0.3540
-27.38	0.043	0.3520
-30.03	0.032	0.3500
-40.03	0.010	0.3480
-34.82	0.019	0.3460
-28.64	0.037	0.3440
-27.06	0.044	0.3420
-27.03	0.045	0.3400
-26.41	0.04[illegible]	0.3380
-25.38	0.054	0.3360
-25.38	0.054	0.3340
-25.49	0.047	0.3320
-27.09	0.044	0.3300
-26.[illegible]	0.047	0.3280
-27.[illegible]	0.0[illegible]	0.3260
-31.55	0.0[illegible]	0.3240
[illegible]	0.0[illegible]	0.3220
[illegible]	[illegible]	0.3200
-27.[illegible]	0.0[illegible]	0.3180

-26.32	0.048	0.3160
-26.26	0.049	0.3140
-25.29	0.054	0.3120
-24.52	0.059	0.3100
-25.02	0.056	0.3080
-26.19	0.049	0.3060
-26.15	0.047	0.3040
-25.84	0.051	0.3020
-27.62	0.042	0.3000
-34.83	0.018	0.2980
-36.45	0.015	0.2960
-28.05	0.040	0.2940
-25.79	0.051	0.2920
-25.62	0.052	0.2900
-25.22	0.055	0.2880
-24.10	0.062	0.2860
-23.81	0.064	0.2840
-24.77	0.058	0.2820
-25.62	0.052	0.2800
-25.15	0.055	0.2780
-25.44	0.053	0.2760
-28.89	0.036	0.2740
-42.06	0.008	0.2720
-30.62	0.029	0.2700
-25.84	0.051	0.2680
-24.80	0.053	0.2660
-24.79	0.058	0.2640
-23.90	0.064	0.2620
-22.98	0.071	0.2600
-23.30	0.068	0.2580
-24.47	0.060	0.2560
-24.64	0.059	0.2540
-24.18	0.062	0.2520
-25.62	0.052	0.2500
-31.93	0.025	0.2480
-36.44	0.015	0.2460
-26.78	0.046	0.2440
-24.19	0.062	0.2420
-23.95	0.063	0.2400
-23.61	0.066	0.2380
-22.46	0.075	0.2360
-22.05	0.079	0.2340
-22.94	0.071	0.2320
-23.83	0.064	0.2300
-23.38	0.068	0.2280
-23.56	0.065	0.2260
-26.81	0.046	0.2240
-39.25	0.011	0.2220
-29.05	0.035	0.2200
-24.05	0.062	0.2180
-22.95	0.071	0.2160
-22.94	0.071	0.2140
-22.05	0.079	0.2120
-21.08	0.088	0.2100
-21.36	0.086	0.2080
-22.51	0.075	0.2060
-22.65	0.074	0.2040
-22.17	0.078	0.2020
-23.61	0.066	0.2000
-30.03	0.032	0.1980
-34.00	0.020	0.1960
-24.59	0.059	0.1940
-22.09	0.079	0.1920
-21.88	0.081	0.1900
-21.50	0.084	0.1880
-20.20	0.097	0.1860
-19.91	0.101	0.1840
-20.91	0.091	0.1820
-21.61	0.083	0.1800
-21.08	0.088	0.1780
-21.35	0.086	0.1760
-24.84	0.057	0.1740
-38.08	0.012	0.1720
-26.13	0.049	0.1700
-21.53	0.084	0.1680
-20.59	0.093	0.1660
-20.57	0.094	0.1640
-19.56	0.105	0.1620
-18.61	0.117	0.1600
-18.96	0.113	0.1580
-20.07	0.099	0.1560
-20.00	0.100	0.1540
-19.56	0.105	0.1520
-21.29	0.086	0.1500
-28.60	0.037	0.1480
-29.47	0.034	0.1460
-21.38	0.085	0.1440
-19.26	0.109	0.1420
-19.17	0.110	0.1400
-18.64	0.11[illegible]	0.1380
-17.39	0.135	0.1360
-17.10	0.140	0.1340
-16.04	0.1[illegible]5	0.1320
-18.59	0.113	0.1300
-17.95	0.127	0.1280
-18.45	0.120	0.1260
-22.61	0.074	0.1240
-35.02	0.013	0.1220
-21.81	0.081	0.1200
-17.99	0.126	0.1180
-17.[illegible]5	0.1[illegible]6	0.1160
-17.26	0.1[illegible]	0.1140





-16.06	0.157	0.1120
-15.13	0.174	0.1100
-15.65	0.165	0.1080
-16.59	0.148	0.1060
-16.17	0.155	0.1040
-15.84	0.162	0.1020
-18.08	0.125	0.1000
-27.09	0.044	0.0980
-23.16	0.069	0.0960
-16.74	0.146	0.0940
-15.15	0.175	0.0920
-15.19	0.174	0.0900
-14.39	0.151	0.0880
-13.05	0.223	0.0860
-12.88	0.227	0.0[illegible]
-13.77	0.205	0.0820
-13.82	0.203	0.0800
-13.02	0.223	0.0780
-13.88	0.202	0.0760
-19.02	0.112	0.0740
-25.89	0.051	0.0720
-15.38	0.170	0.0700
-12.40	0.240	0.0680
-12.15	0.247	0.0660
-11.89	0.254	0.0640
-10.35	0.304	0.0620
-9.43	0.339	0.0600
-9.87	0.321	0.0580
-10.25	0.307	0.0560
-9.26	0.344	0.0540
-9.00	0.355	0.0520
-11.77	0.258	0.0500
-21.40	0.085	0.0480
-13.28	0.217	0.0460
-8.35	0.382	0.0440
-7.34	0.430	0.0420
-7.58	0.418	0.0400
-6.15	0.493	0.0380
-4.21	0.616	0.0360
-3.60	0.661	0.0340
-3.52	0.665	0.0320
-2.07	0.789	0.0300
-0.42	0.953	0.0280
-0.69	0.923	0.0260
-3.97	0.635	0.0240
-3.20	0.692	0.0220
3.07	1.425	0.0200
6.41	2.091	0.0180
7.22	2.322	0.0160
5.96	1.986	0.0140
1.97	1.255	0.0120
-0.72	0.975	0.0100
4.36	1.651	0.0080
6.79	2.186	0.0060
6.81	2.191	0.0040
4.60	1.658	0.0020
0.07	1.008	0.0000
-2.33	0.765	-0.0020
0.71	1.085	-0.0040
2.29	1.301	-0.0060
2.37	1.314	-0.0080
1.90	1.245	-0.0100
1.37	1.164	-0.0120
0.22	1.026	-0.0140
-1.81	0.811	-0.0160
-4.34	0.697	-0.0180
-5.31	0.512	-0.0200
-6.92	0.451	-0.0220
-10.41	0.332	-0.0240
-23.34	0.069	-0.0260
-15.19	0.174	-0.0280
-9.55	0.333	-0.0300
-8.16	0.391	-0.0320
-7.99	0.399	-0.0340
-7.59	0.417	-0.0360
-7.38	0.427	-0.0380
-8.27	0.386	-0.0400
-10.13	0.312	-0.0420
-11.32	0.272	-0.0440
-11.53	0.264	-0.0460
-13.42	0.213	-0.0480
-20.26	0.057	-0.0500
-25.56	0.053	-0.0520
-15.37	0.171	-0.0540
-12.84	0.228	-0.0560
-12.47	0.238	-0.0580
-12.15	0.247	-0.0600
-11.51	0.266	-0.0620
-11.69	0.260	-0.0640
-13.10	0.221	-0.0660
-14.55	0.187	-0.0680
-14.69	0.184	-0.0700
-15.45	0.169	-0.0720
-19.52	0.104	-0.0740
-37.21	0.014	-0.0760
-20.63	0.094	-0.0780
-16.57	0.152	-0.0800
-15.41	0.170	-0.0820
-15.27	0.172	-0.0840
[illegible]	[illegible]	-0.0860
-14.1[illegible]	0.175	-0.0880
[illegible]	0.177	-0.0900

-16.64	0.147	-0.0920
-17.12	0.139	-0.0940
-17.20	0.138	-0.0960
-19.52	0.106	-0.0980
-23.31	0.039	-0.1000
-26.59	0.045	-0.1020
-19.59	0.105	-0.1040
-17.72	0.130	-0.1060
-17.54	0.133	-0.1080
-17.05	0.141	-0.1100
-16.30	0.152	-0.1120
-16.57	0.148	-0.1140
-17.99	0.126	-0.1160
-19.02	0.112	-0.1180
-18.87	0.114	-0.1200
-19.93	0.101	-0.1220
-24.97	0.056	-0.1240
-37.83	0.013	-0.1260
-23.28	0.069	-0.1280
-19.89	0.101	-0.1300
-19.29	0.108	-0.1320
-19.09	0.111	-0.1340
-18.25	0.122	-0.1360
-17.95	0.127	-0.1380
-18.94	0.113	-0.1400
-20.35	0.096	-0.1420
-20.48	0.095	-0.1440
-20.67	0.093	-0.1460
-23.52	0.067	-0.1480
-34.62	0.019	-0.1500
-28.22	0.039	-0.1520
-22.26	0.077	-0.1540
-20.80	0.091	-0.1560
-20.71	0.092	-0.1580
-20.08	0.099	-0.1600
-19.34	0.108	-0.1620
-19.74	0.103	-0.1640
-21.17	0.087	-0.1660
-21.90	0.080	-0.1680
-21.68	0.082	-0.1700
-23.05	0.071	-0.1720
-28.87	0.036	-0.1740
-36.66	0.014	-0.1760
-25.28	0.054	-0.1780
-22.38	0.076	-0.1800
-21.97	0.080	-0.1820
-21.70	0.082	-0.1840
-20.81	0.091	-0.1860
-20.59	0.093	-0.1880
-21.65	0.083	-0.1900
-22.93	0.071	-0.1920
-22.87	0.072	-0.1940
-23.17	0.069	-0.1960
-26.36	0.048	-0.1980
-38.99	0.011	-0.2000
-29.70	0.033	-0.2020
-24.25	0.061	-0.2040
-23.10	0.070	-0.2060
-23.02	0.071	-0.2080
-22.32	0.077	-0.2100
-21.60	0.083	-0.2120
-22.05	0.079	-0.2140
-23.46	0.067	-0.2160
-24.04	0.063	-0.2180
-23.80	0.065	-0.2200
-25.26	0.055	-0.2220
-31.38	0.027	-0.2240
-37.90	0.013	-0.2260
-27.14	0.044	-0.2280
-24.38	0.060	-0.2300
-24.02	0.063	-0.2320
-23.74	0.065	-0.2340
-22.83	0.072	-0.2360
-22.60	0.074	-0.2380
-23.65	0.066	-0.2400
-24.83	0.057	-0.2420
-24.77	0.058	-0.2440
-25.04	0.056	-0.2460
-28.18	0.039	-0.2480
-40.44	0.009	-0.2500
-31.65	0.026	-0.2520
-26.22	0.049	-0.2540
-24.93	0.057	-0.2560
-24.85	0.057	-0.2580
-24.19	0.062	-0.2600
-23.43	0.067	-0.2620
-23.80	0.065	-0.2640
-25.17	0.055	-0.2660
-25.78	0.051	-0.2680
-25.49	0.053	-0.2700
-26.77	0.046	-0.2720
-32.39	0.024	-0.2740
-41.07	0.009	-0.2760
-29.17	0.035	-0.2780
-26.17	0.049	-0.2800
-25.[illegible]	0.052	-0.2820
-25.46	0.053	-0.2840
-24.56	0.059	-0.2860
-24.21	0.062	-0.2880
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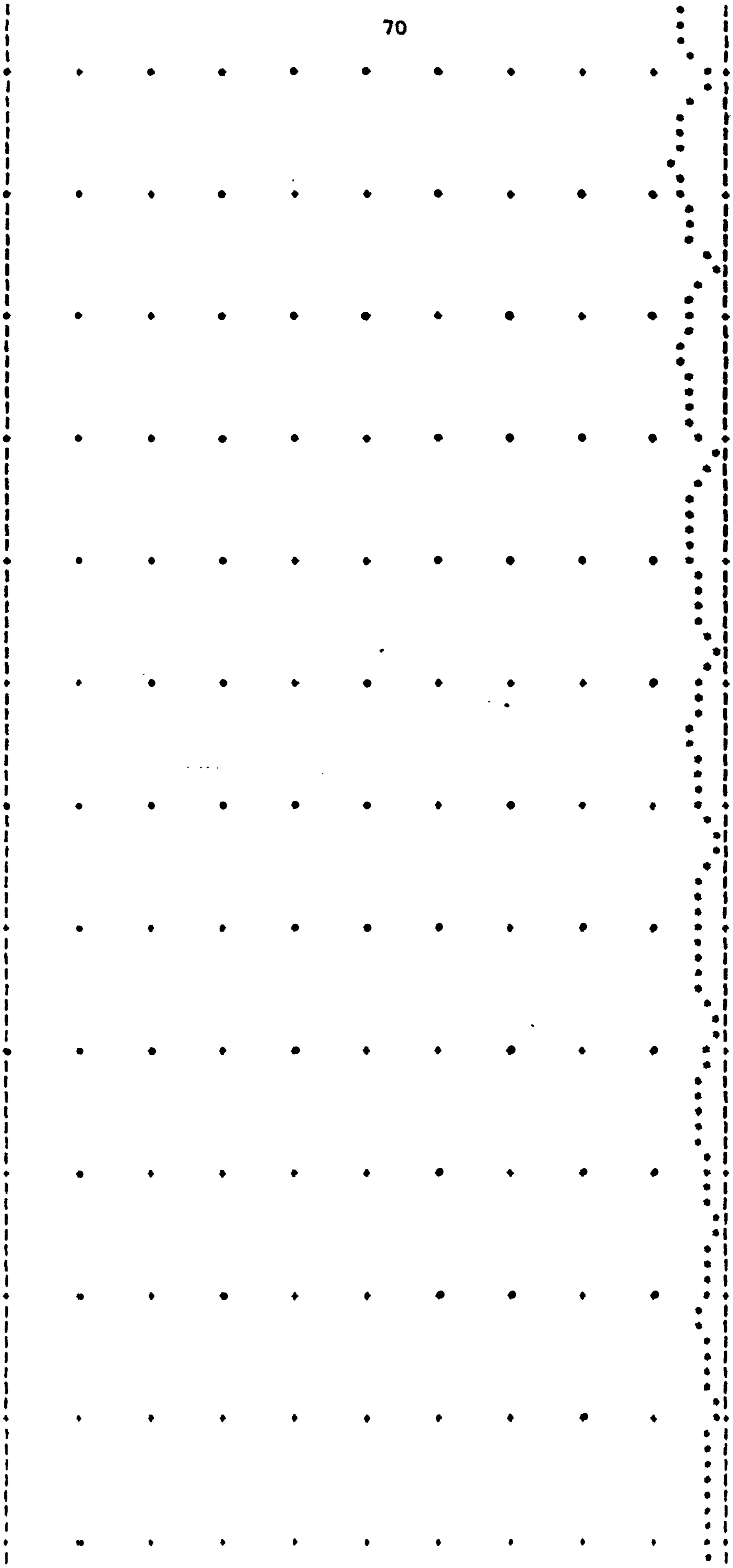
-26.[illegible]	[illegible]	-0.2920
-26.[illegible]	0.048	-0.2940



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-28.14	0.039	-0.3040
-26.49	0.047	-0.3060
-26.40	0.048	-0.3080
-25.86	0.051	-0.3100
-25.00	0.056	-0.3120
-25.15	0.055	-0.3140
-26.42	0.048	-0.3160
-27.25	0.043	-0.3180
-26.93	0.045	-0.3200
-27.72	0.041	-0.3220
-32.10	0.025	-0.3240
-46.83	0.005	-0.3260
-31.81	0.026	-0.3280
-27.86	0.040	-0.3300
-27.07	0.044	-0.3320
-26.98	0.045	-0.3340
-26.17	0.049	-0.3360
-25.57	0.053	-0.3380
-26.19	0.049	-0.3400
-27.54	0.042	-0.3420
-27.82	0.041	-0.3440
-27.59	0.042	-0.3460
-29.30	0.034	-0.3480
-36.07	0.016	-0.3500
-39.94	0.010	-0.3520
-30.52	0.030	-0.3540
-27.99	0.040	-0.3560
-27.69	0.041	-0.3580
-27.42	0.043	-0.3600
-26.50	0.047	-0.3620
-26.25	0.049	-0.3640
-27.23	0.043	-0.3660
-28.41	0.038	-0.3680
-28.27	0.039	-0.3700
-28.40	0.033	-0.3720
-31.15	0.028	-0.3740
-41.46	0.008	-0.3760
-36.18	0.016	-0.3780
-29.97	0.032	-0.3800
-28.36	0.038	-0.3820
-28.28	0.039	-0.3840
-27.76	0.041	-0.3860
-26.90	0.045	-0.3880
-26.99	0.045	-0.3900
-28.21	0.039	-0.3920
-29.07	0.035	-0.3940
-28.72	0.037	-0.3960
-29.33	0.034	-0.3980
-33.21	0.022	-0.4000
-47.75	0.004	-0.4020
-34.37	0.019	-0.4040
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-28.82	0.036	-0.4080
-28.79	0.036	-0.4100
-28.09	0.039	-0.4120
-27.36	0.043	-0.4140
-27.75	0.041	-0.4160
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-29.58	0.033	-0.4200
-29.21	0.035	-0.4220
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-29.58	0.032	-0.4320
-29.32	0.034	-0.4340
-29.24	0.035	-0.4360
-28.43	0.038	-0.4380
-27.26	0.040	-0.4400
-28.47	0.034	-0.4420
-29.77	0.032	-0.4440
-30.02	0.032	-0.4460
-29.73	0.033	-0.4480
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Y-AXIS PROFILE PLOT ALONG 0.0 LONGITUDE.
PATTERN NUMBER 101

DB.	REAL	1.0035 0.8028 0.6022 0.4015 0.2009 0.0002	
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-41.50	0.008		3.9359
-43.81	0.006		3.9279
-46.99	0.004		3.9199
-52.16	0.002		3.9119
-67.35	0.000		3.9039
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-44.70	0.006		3.8799
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-34.44	0.019		3.8319
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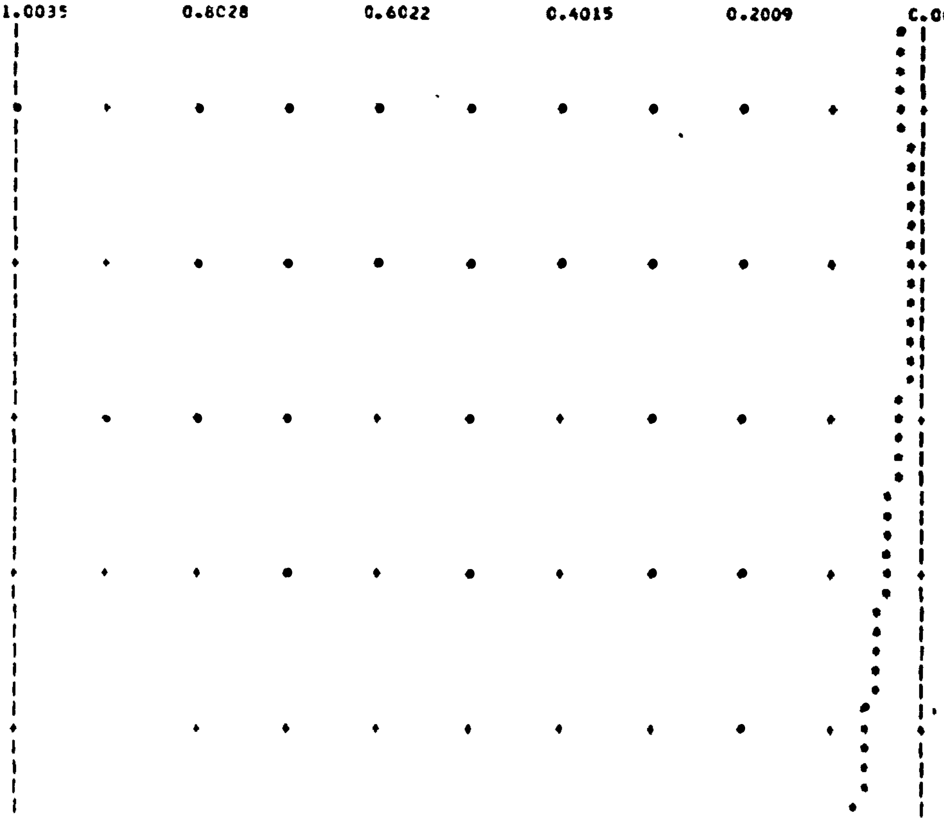

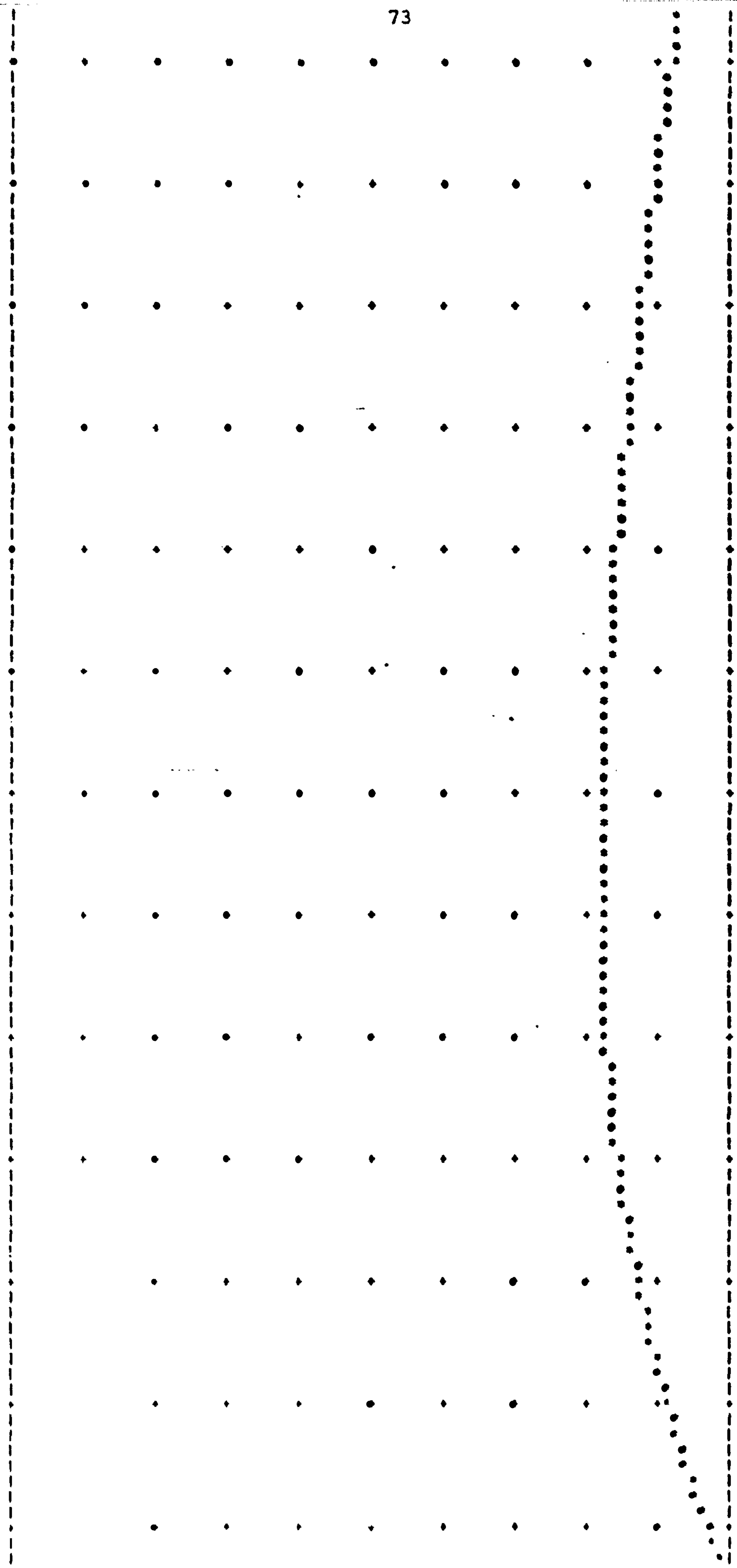

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-19.92	0.101	3.5679
-19.71	0.103	3.5599
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-19.30	0.108	3.5439
-19.10	0.111	3.5359
-18.91	0.113	3.5279
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-17.72	0.130	3.4719
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-17.43	0.134	3.4559
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-17.15	0.139	3.4359
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-15.67	0.165	3.3199
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-15.39	0.170	3.1679
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-20.30	0.097	2.9680
-20.81	0.091	2.9600
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-22.68	0.073	2.9360
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-19.30	0.108	2.7680
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-16.91	C.143	2.7440
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-14.35	0.192	2.7120
-13.80	0.204	2.7040
-13.26	C.217	2.6960
-12.75	C.230	2.6880
-12.26	0.244	2.6800
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-10.91	0.285	2.6560
-10.49	C.299	2.6480
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-8.96	0.357	2.6160
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-7.61	C.416	2.5840
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-6.70	0.462	2.5600
-6.42	0.478	2.5520
-6.14	C.493	2.5440
-5.87	0.509	2.5360
-5.61	0.574	2.5280
-5.35	0.540	2.5200
-5.11	0.555	2.5120
-4.87	C.571	2.5040
-4.63	C.587	2.4960
-4.41	C.602	2.4880
-4.19	0.618	2.4800
-3.97	0.633	2.4720
-3.76	0.643	2.4640
-3.56	0.664	2.4560
-3.37	0.679	2.4480
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-2.64	C.738	[illegible]
-2.47	0.752	[illegible]
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-1.33	C.858	2.3440
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0.02	1.002	2.1520
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-0.14	C.984	2.1120
-0.19	C.979	2.1040
-0.25	C.972	2.0960
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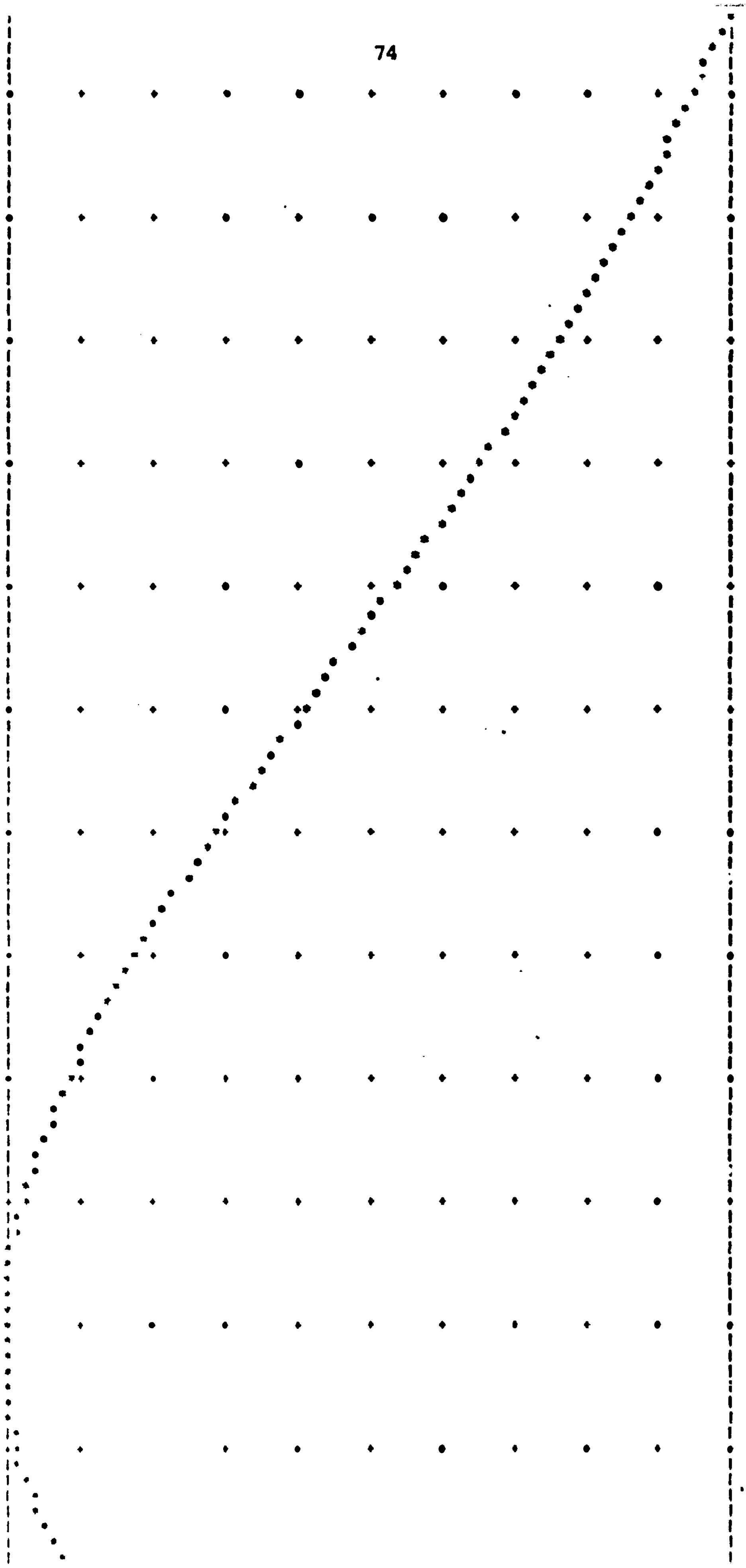

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-1.60	0.832	2.0000
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-1.96	0.798	1.9840
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-3.09	0.701	1.9440
-3.35	0.680	1.9360
-3.64	0.658	1.9280
-3.94	0.636	1.9200
-4.25	0.613	1.9120
-4.59	0.589	1.9040
-4.95	0.566	1.8960
-5.33	0.542	1.8880
-5.73	0.517	1.8800
-6.16	0.492	1.8720
-6.61	0.467	1.8640
-7.10	0.442	1.8560
-7.62	0.416	1.8480
-8.18	0.390	1.8400
-8.77	0.364	1.8320
-9.42	0.338	1.8240
-10.12	0.312	1.8160
-10.87	0.286	1.8080
-11.70	0.260	1.8000
-12.61	0.234	1.7920
-13.63	0.208	1.7840
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-16.06	0.157	1.7680
-17.57	0.132	1.7600
-19.36	0.108	1.7520
-21.59	0.083	1.7440
-24.52	0.059	1.7360
-28.85	0.036	1.7280
-37.55	0.013	1.7200
-40.94	0.009	1.7120
-30.29	0.031	1.7040
-25.76	0.052	1.6960
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-20.81	0.091	1.6800
-19.19	0.110	1.6720
-17.89	0.128	1.6640
-16.81	0.144	1.6560
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-15.12	0.175	1.6400
-14.46	0.189	1.6320
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-13.39	0.214	1.6160
-12.96	0.225	1.6080
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-12.28	0.243	1.5920
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-11.40	0.269	1.5520
-11.35	0.271	1.5440
-11.33	0.271	1.5360
-11.35	0.271	1.5280
-11.41	0.269	1.5200
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-14.23	0.194	1.4400
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-15.44	0.169	1.4240
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-21.88	0.081	1.3760
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-29.74	0.033	1.3520
-35.63	0.017	1.3440
-64.65	0.001	1.3360
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-26.77	0.046	1.3120
-24.35	0.061	1.3040
-22.51	0.075	1.2960
-21.05	0.089	1.2880
-19.85	0.102	1.2800
-18.85	0.114	1.2720
-18.00	0.126	1.2640
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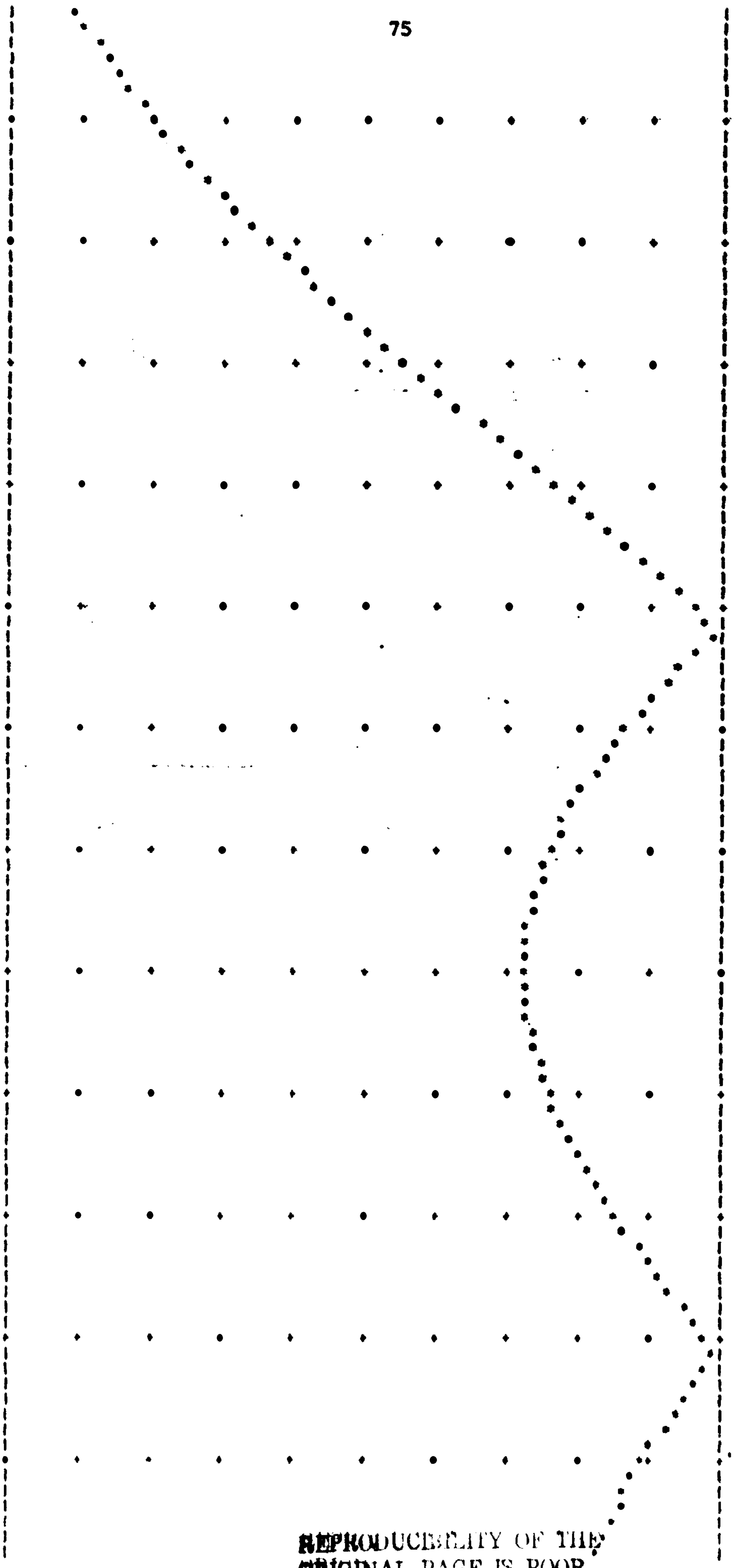

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-15.29	0.170	1.1280
-15.77	0.163	1.1200
-16.22	0.155	1.1120
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-17.36	0.136	1.0960
-18.08	0.125	1.0880
-18.92	0.113	1.0800
-19.91	0.101	1.0720
-21.08	0.088	1.0640
-22.49	0.075	1.0560
-24.24	0.061	1.0480
-26.49	0.047	1.0400
-29.60	0.033	1.0 20
-34.55	0.019	1.0240
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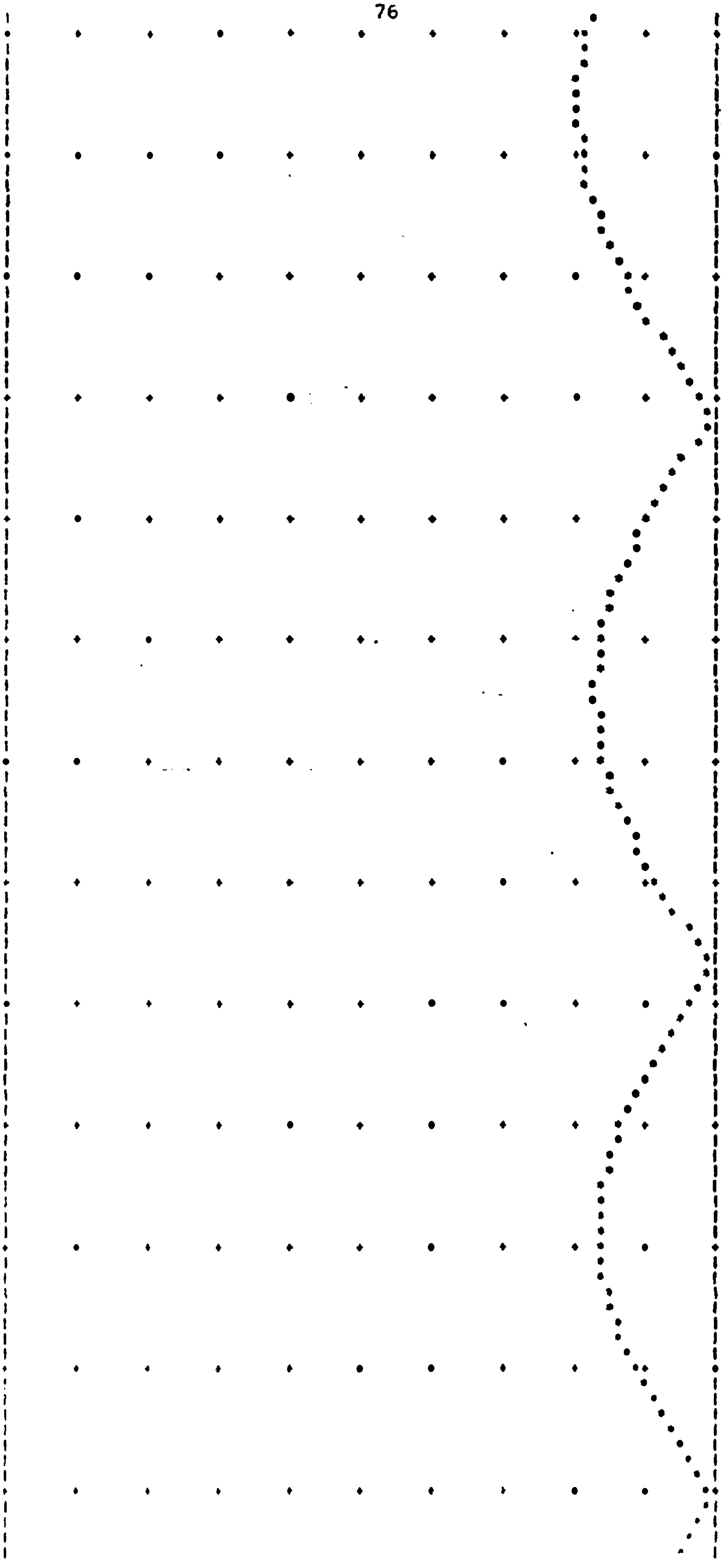
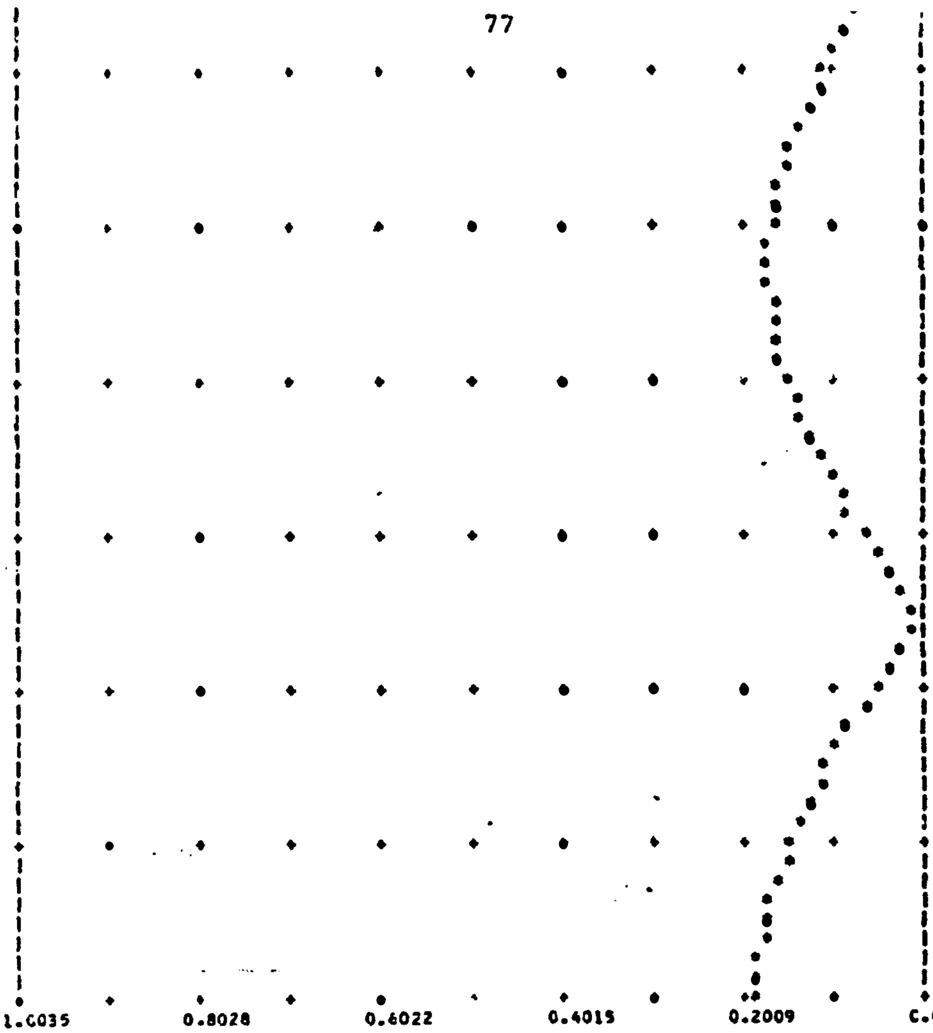
-32.24	0.024	1.0000
-28.30	0.038	0.9920
-25.65	0.052	0.9840
-23.68	0.065	0.9760
-22.13	0.078	0.9680
-20.87	0.090	0.9600
-19.84	0.102	0.9520
-18.97	0.113	0.9440
-18.24	0.123	0.9360
-17.62	0.131	0.9280
-17.11	0.139	0.9200
-16.69	0.146	0.9170
-16.34	0.152	0.9040
-16.08	0.157	0.8960
-15.98	0.161	0.8880
-15.75	0.163	0.8800
-15.69	0.164	0.8720
-15.69	0.164	0.8640
-15.76	0.163	0.8560
-15.39	0.160	0.8480
-16.09	0.157	0.8400
-16.37	0.152	0.8320
-16.71	0.145	0.8240
-17.15	0.139	0.8160
-17.67	0.131	0.8080
-18.20	0.122	0.8000
-19.04	0.112	0.7920
-19.93	0.101	0.7840
-21.00	0.089	0.7760
-22.29	0.077	0.7680
-23.88	0.064	0.7600
-25.92	0.051	0.7520
-28.67	0.037	0.7440
-32.83	0.023	0.7360
-41.25	0.009	0.7280
-45.08	0.006	0.7200
-34.09	0.020	0.7120
-29.43	0.034	0.7040
-26.47	0.047	0.6960
-24.32	0.061	0.6880
-22.65	0.074	0.6800
-21.31	0.086	0.6720
-20.22	0.098	0.6640
-19.31	0.108	0.6560
-18.54	0.118	0.6480
-17.91	0.127	0.6400
-17.38	0.135	0.6320
-16.95	0.142	0.6240
-16.61	0.148	0.6160
-16.35	0.152	0.6080
-16.17	0.155	0.6000
-16.05	0.158	0.5920
-16.01	0.158	0.5840
-16.04	0.159	0.5760
-16.14	0.156	0.5680
-16.32	0.153	0.5600
-16.56	0.149	0.5520
-16.89	0.143	0.5440
-17.31	0.136	0.5360
-17.82	0.128	0.5280
-18.44	0.120	0.5200
-19.19	0.110	0.5120
-20.08	0.099	0.5040
-21.16	[illegible]	0.4960
-22.47	0.075	0..880
-24.10	0.062	0.4800
-26.21	0.049	0.4720
-29.09	0.035	0.4640
-33.56	0.021	0.4560
-41.50	0.007	0.4480
-42.27	[illegible]	[illegible]
[illegible]	[illegible]	0.4320
[illegible]	[illegible]	0.4240
[illegible]	[illegible]	0.4160





DB.	REAL	
-23.92	0.06[illegible]	
-22.30	0.077	0.4000
-20.99	0.089	0.3923
-19.91	0.101	0.3840
-19.02	0.112	0.3760
-18.26	0.122	0.3680
-17.63	0.131	0.3600
-17.11	0.140	0.3520
-16.68	0.147	0.3440
-16.33	0.153	0.3360
-16.06	0.157	0.3280
-15.86	0.161	0.3200
-15.74	0.163	0.3120
-15.68	0.164	0.3040
-15.68	0.164	0.2960
-15.76	0.163	0.2880
-15.90	0.160	0.2800
-16.11	0.15[illegible]	0.2720
-16.39	0.152	0.2640
-16.75	0.145	0.2560
-17.19	0.138	0.2480
-17.73	0.130	0.7400
-18.37	0.121	0.2320
-19.13	0.111	0.2240
-20.04	0.100	0.2160
-21.12	0.088	0.2080
-22.44	0.076	0.2000
-24.06	0.063	0.1920
-26.14	0.049	0.1840
-28.98	0.036	0.1760
-33.33	0.022	0.1680
-42.62	0.007	0.1600
-43.29	0.007	0.1520
-33.53	0.021	0.1440
-29.08	0.035	0.1360
-26.19	0.049	0.1280
-24.07	0.063	0.1200
-22.41	0.076	0.1120
-21.07	0.088	0.1040
-19.95	0.101	0.0960
-19.01	0.112	0.0880
-18.21	0.123	0.0800
-17.53	0.133	0.0720
-16.95	0.142	0.0640
-16.46	0.150	0.0560
-16.05	0.158	0.0480
-15.70	0.164	0.0400
-15.42	0.169	0.0320
-15.19	0.174	0.0240
-15.03	0.177	0.0160
-14.92	0.180	0.0080
-14.85	0.181	0.0

EXAMPLE 3:
DEMONSTRATION OF THERMALLY INDUCED MECHANICAL DEFORMATIONS
(SPHERICAL) ON THE FULL X-BAND HORIZONTAL ARRAY.
6

SYSTEM INFORMATION:
FREQUENCY = 5.000 GHZ.
YAW = 0.0 DEGREES
TILT = 50.000 DEGREES
TWIST = 0.0 DEGREES
ALTITUDE = 200.000 KM.

ANTENNA PARAMETERS FOR SIMULATION NUMBER 102
ELEMENT TYPE: HORIZONTAL DIPOLE
NUMBER OF ELEMENTS (X,Y) = (504 , 12)
INTERELEMENT SPACING (CM.): 2.2966 , 2.3550
INTERELEMENT PHASE SHIFT (DEG.): 0.0 , 0.0

DEFORMATION DATA FOR SIMULATION 102:

5.00	3.47	2.22	1.25	0.55	0.14	0.0	0.14	0.55	1.25
2.22	3.47	5.00							
5.00	3.47	2.22	1.25	0.55	0.14	0.0	0.14	0.55	1.25
2.22	3.47	5.00							

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

ELECTRICAL DATA FOR SIMULATION 102:

	(1, 1)	(2, 1)	(3, 1)	(4, 1)	(5, 1)	(6, 1)	(7, 1)	(8, 1)	(9, 1)	(10, 1)
(11, 1)	(12, 1)	(								
PHSX:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0									
PHSY:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0									
AMAG:	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00									
APHS:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0									

PRINT/PLOT INFORMATION:
REQUESTED OUTPUT:
PRINTER PROFILE
PRINTER CONTOUR
PLOT RESOLUTION: 151 X 151 POINTS

STARTX = -0.500
STOPX = 0.500
DELTAX = 0.007

STARTY = 0.0
STOPY = 4.000
DELTAY = 0.027

SUBARRAY DATA SUMMARY FOR PATTERN 102:

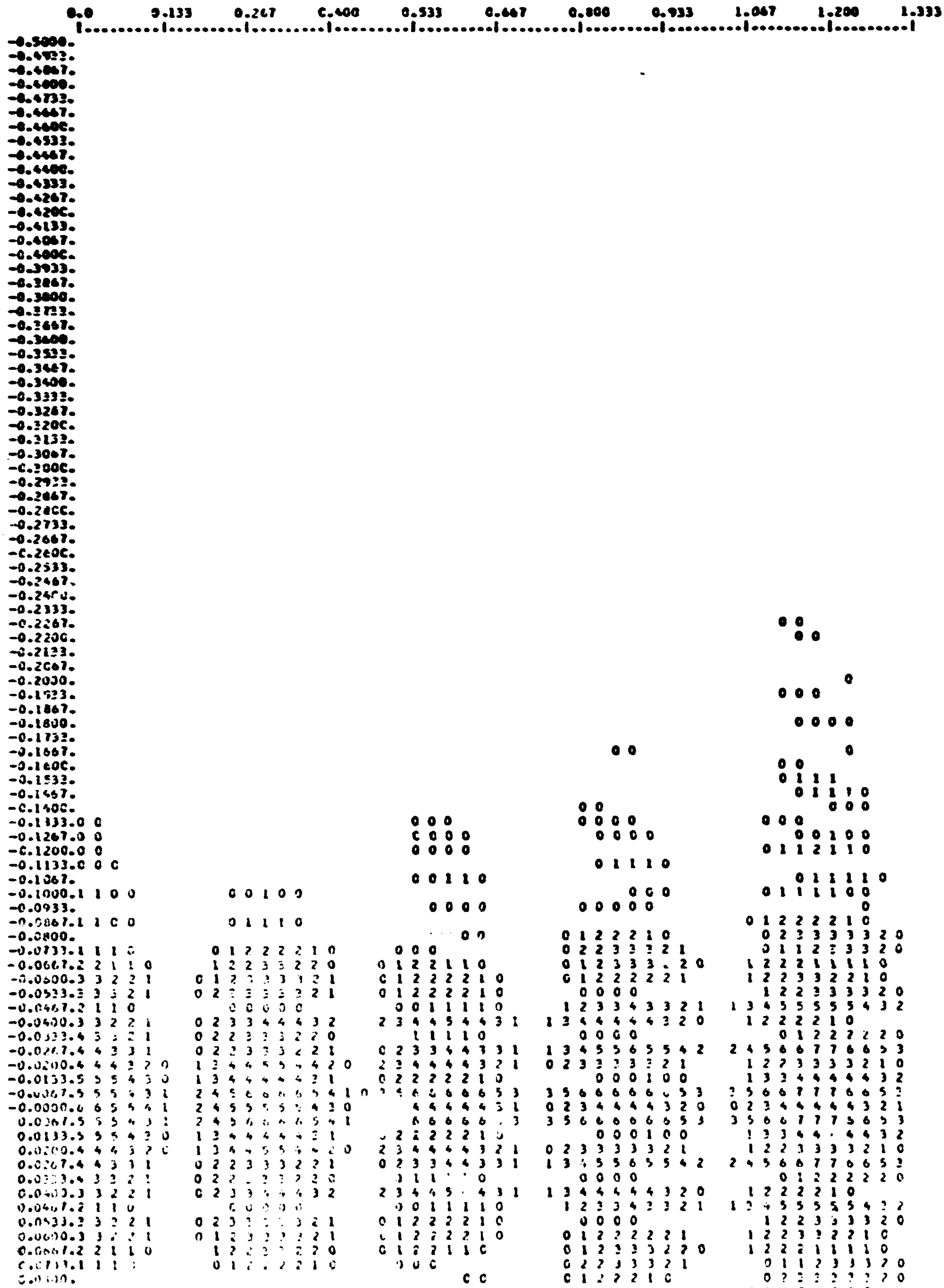
AREA	XPOINT	YPOINT	ZAVG	ALPHAX	ALPHAY	AMAG	APHS	PHSX	PHSY
1	[illegible]	0.0	4.29	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0
2	[illegible]	0.0	[illegible]	-0.7[illegible]		1.0000	0.0	0.0	0.[illegible]

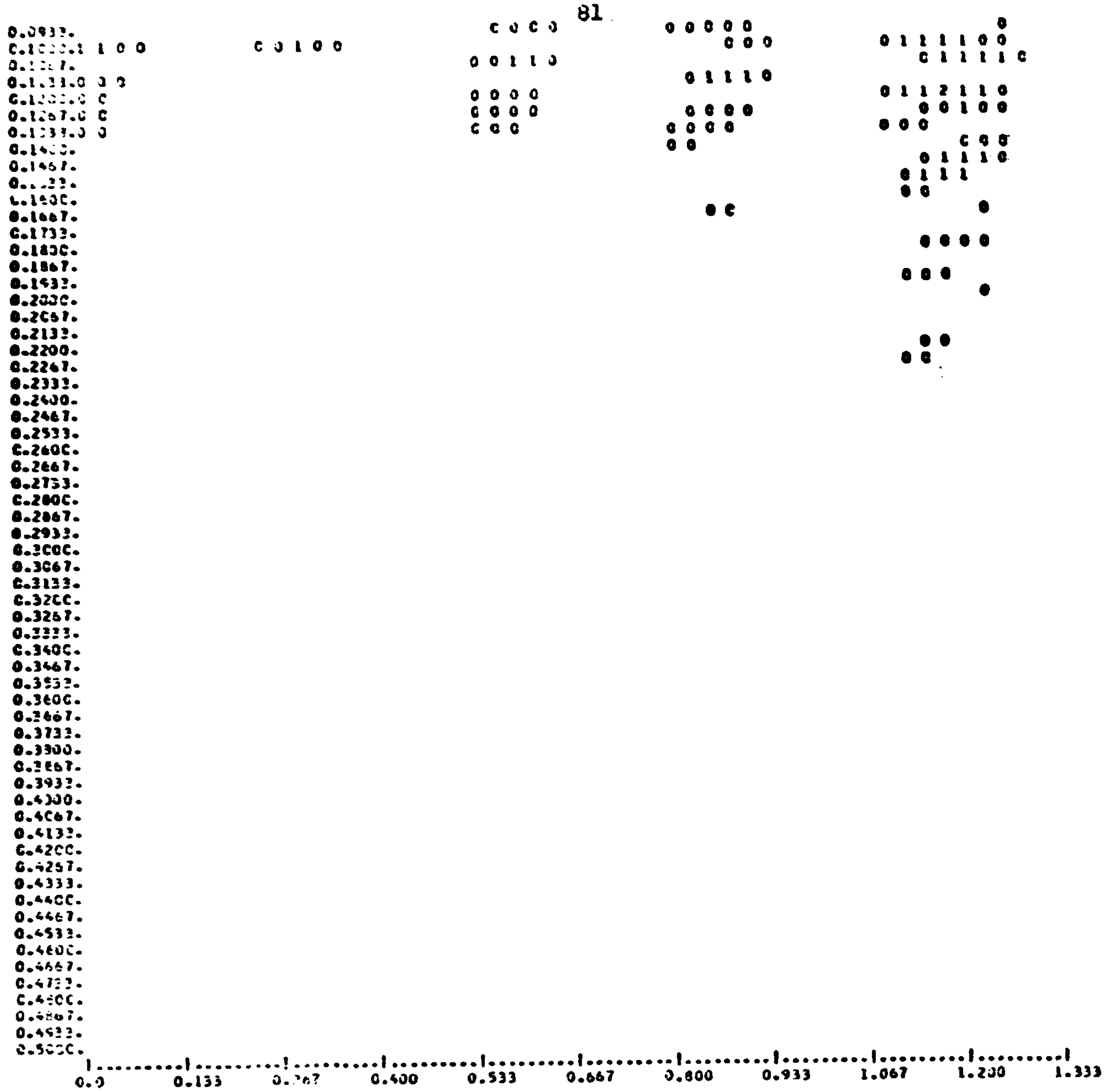
3	-337.60	0.0	1.74	-0.577	0.0	1.0000	0.0	0.0	0.
4	-241.14	0.0	0.90	-0.413	0.000	1.0000	0.0	0.0	0.
5	-144.65	0.0	0.35	-0.247	0.0	1.0000	0.0	0.0	0.
6	-48.23	0.0	0.07	-0.082	0.0	1.0000	0.0	0.0	0.
7	48.23	0.0	0.07	0.082	0.0	1.0000	0.0	0.0	0.
8	144.65	0.0	0.35	0.247	0.0	1.0000	0.0	0.0	0.
9	241.14	0.0	0.90	0.413	0.000	1.0000	0.0	0.0	0.
10	337.60	0.0	1.74	0.577	0.0	1.0000	0.0	0.0	0.
11	434.06	0.0	2.05	0.742	0.0	1.0000	0.0	0.0	0.
12	530.51	0.0	4.24	0.908	0.0	1.0000	0.0	0.0	0.

PREDICTED BEAM CENTER:
LATITUDE = 2.1945
LONGITUDE = 0.0
RANGE = 243.978
HEADING = 0.0

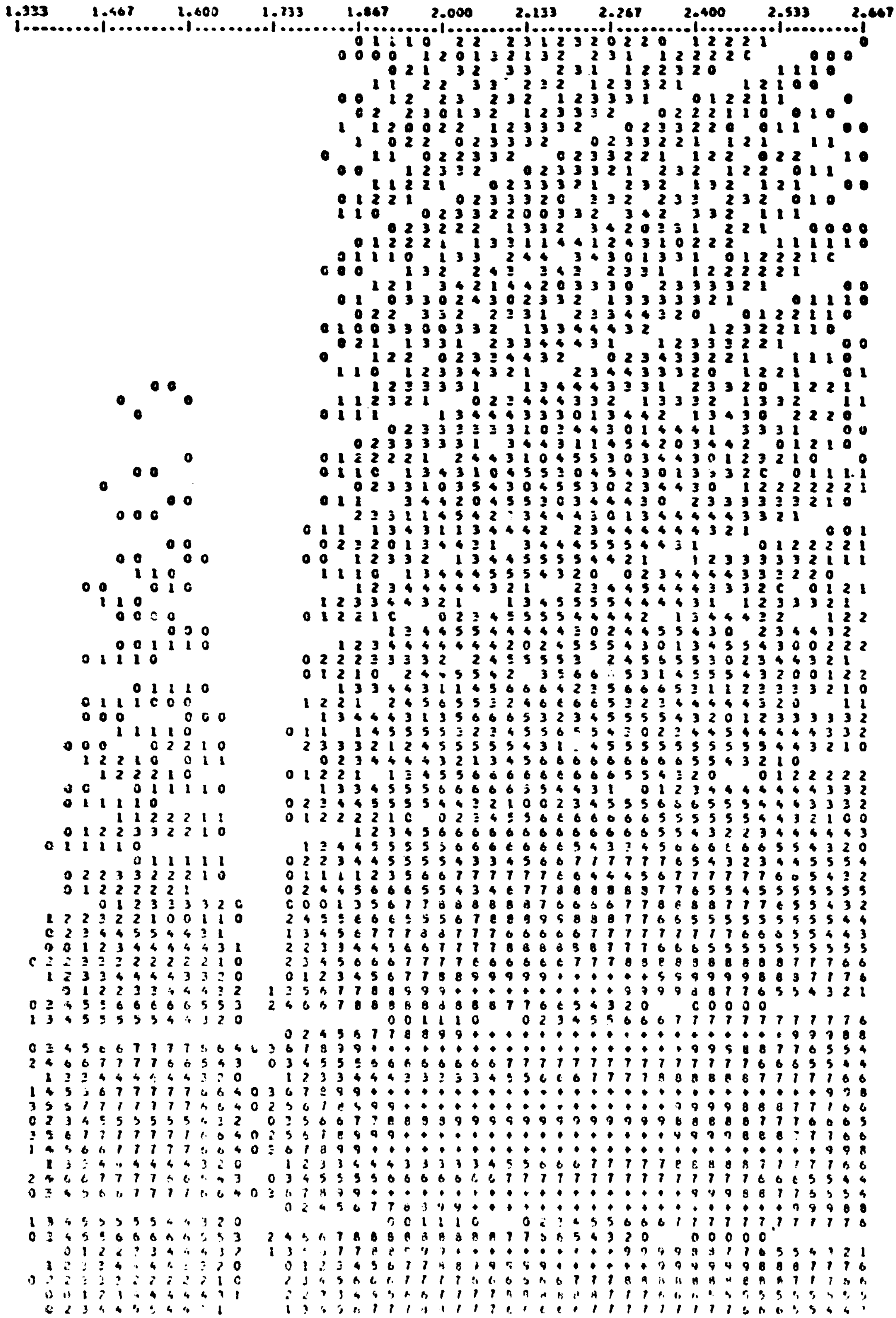
PLOT NORMALIZATION FACTOR = -51.369 DB.

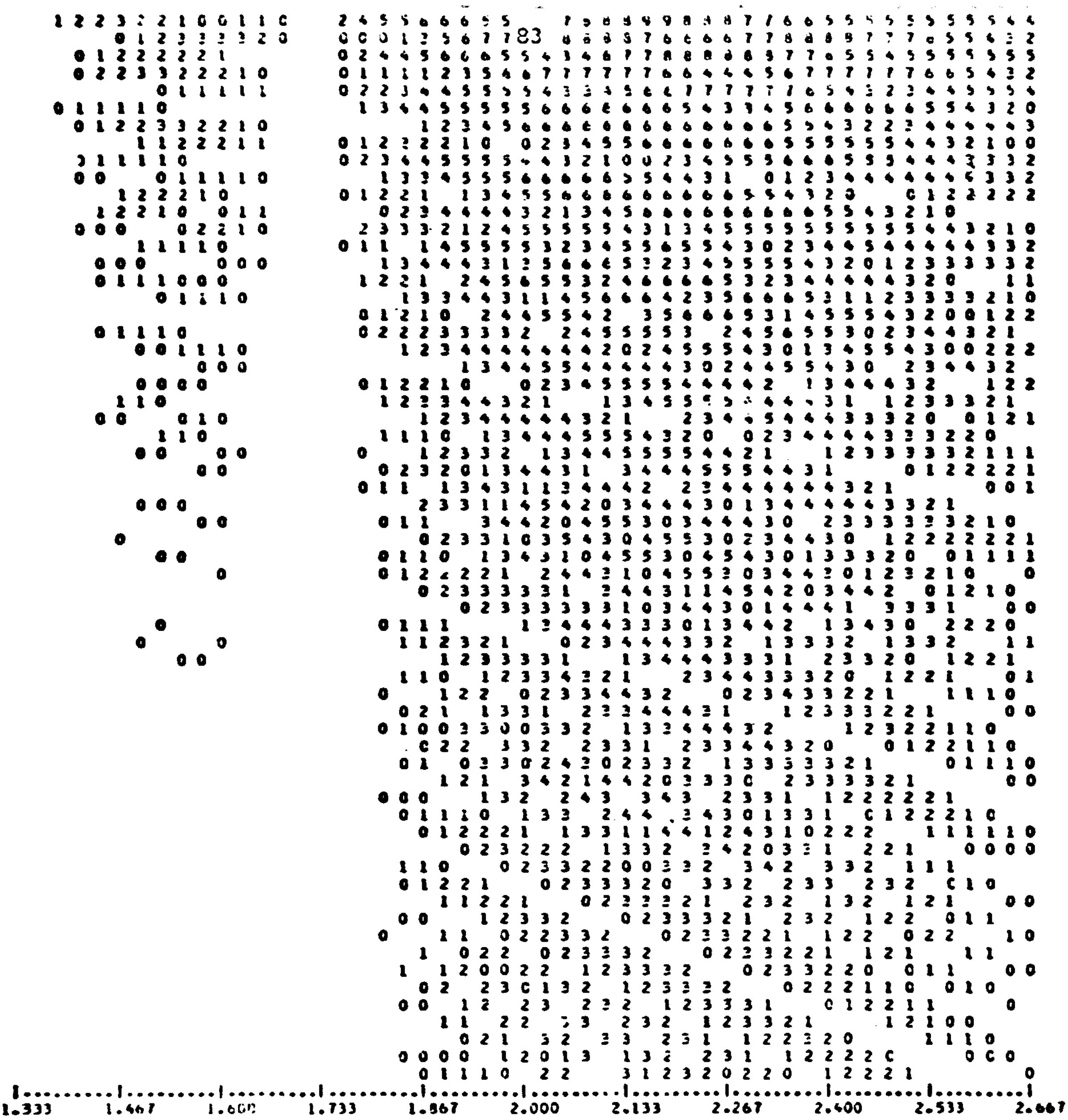
PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 102




0.0
0.133
0.400
0.533
0.667
0.800
0.933
1.067
1.200
1.333

PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 102





CONTOUR LEVEL KEY

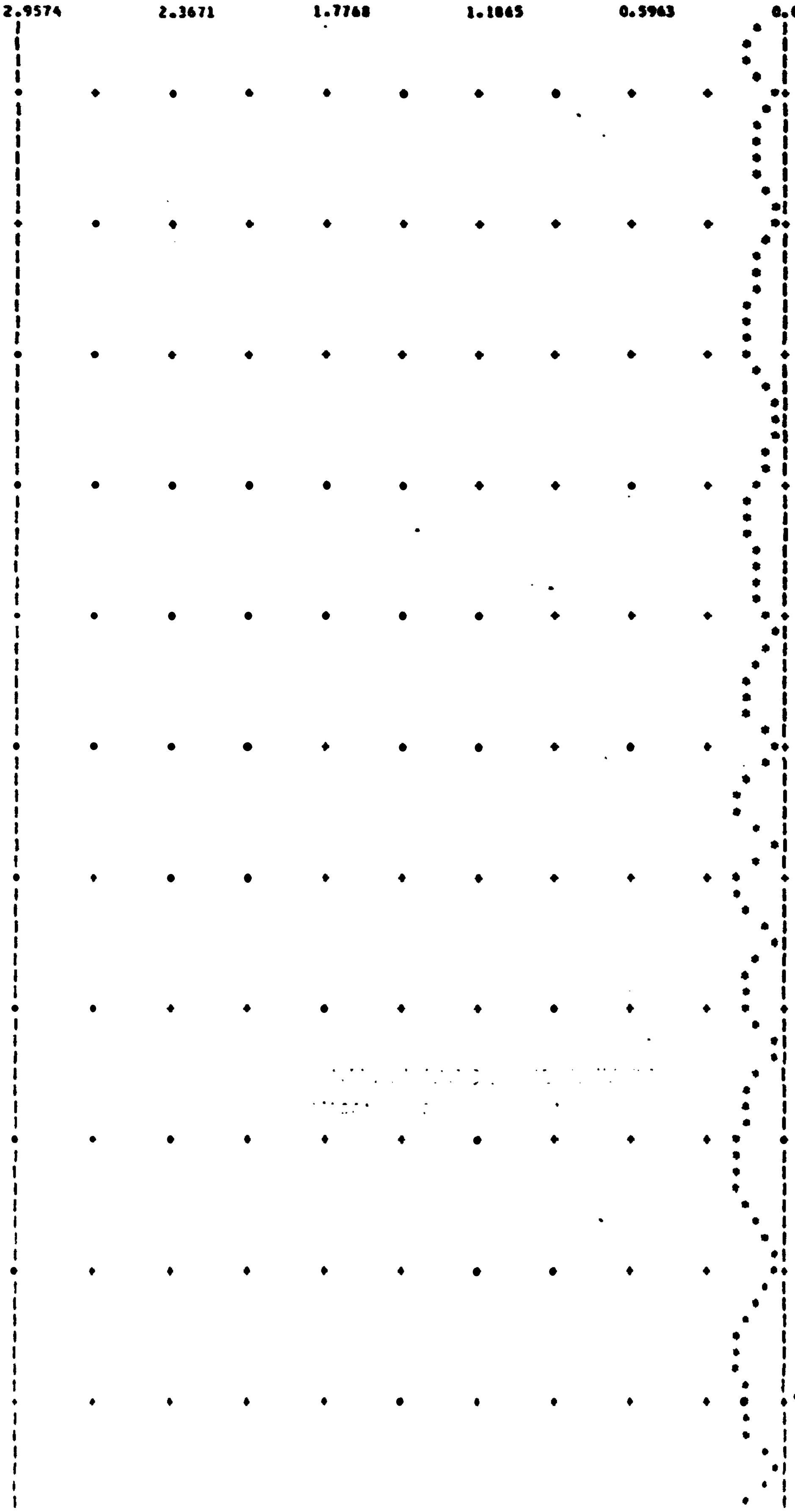
0: -0.2850000E 02 TO -0.2549998E 02	4: -0.1650000E 02 TO -0.1349999E 02	8: -0.4500000E 01 TO -0.1499990E 01
1: -0.2550000E 02 TO -0.2249998E 02	5: -0.1350000E 02 TO -0.1049999E 02	9: -0.1500000E 01 TO 0.1500010E 01
2: -0.2250000E 02 TO -0.1949998E 02	6: -0.1050000E 02 TO -0.7499990E 01	: -0.1000000E 51 TO -0.2850000E 02
3: -0.1950000E 02 TO -0.1649998E 02	7: -0.7500000E 01 TO -0.4499990E 01	+: 0.1500010E 01 TO 0.1000000E 51

PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 102

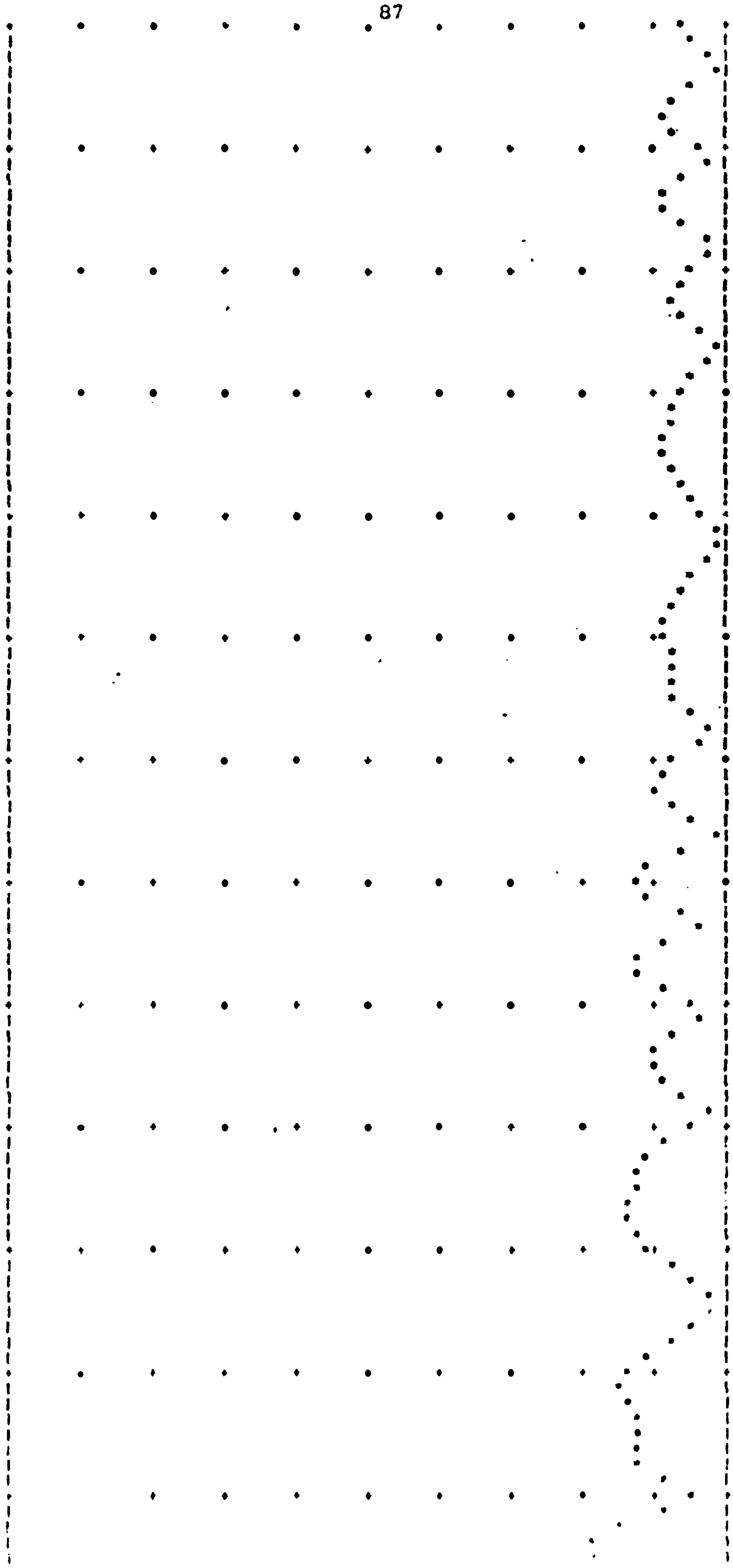

2.667
2.800
2.933
3.067
3.200
3.333
3.467
3.600
3.733
3.867
4.000

X-AXIS PROFILE PLOT ALONG 2.194 DEGREES LATITUDE.
PATTERN NUMBER 102

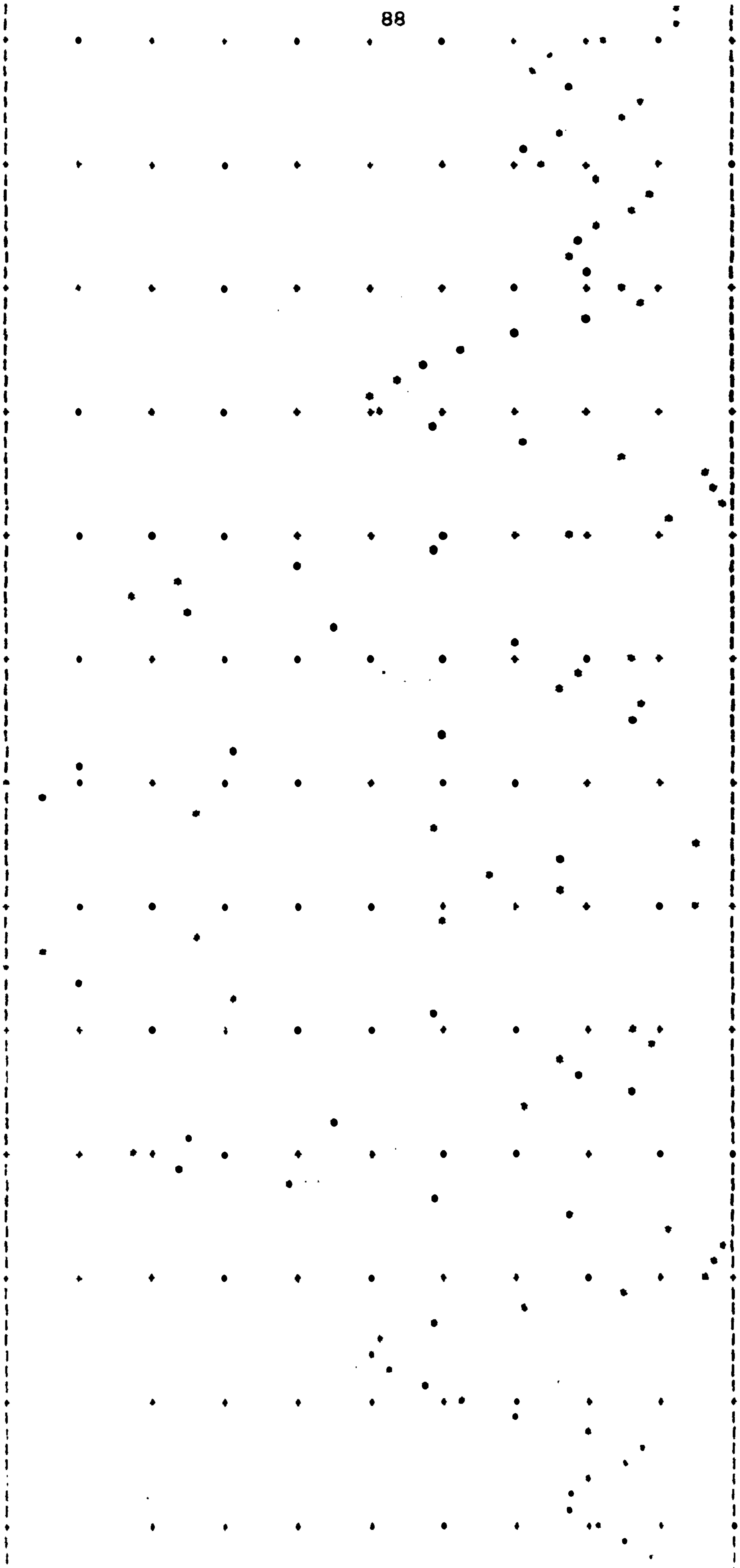
2.9574 2.3671 1.7768 1.1865 0.5963 0.0060



DB.	REAL	
-19.08	0.111	0.5000
-16.90	0.143	0.4980
-17.52	0.133	0.4960
-21.07	0.088	0.4940
-29.89	0.032	0.4920
-26.43	0.048	0.4900
-20.90	0.090	0.4880
-18.99	0.112	0.4860
-18.93	0.113	0.4840
-20.45	0.095	0.4820
-24.28	0.061	0.4800
-35.26	0.017	0.4780
-29.79	0.032	0.4760
-23.03	0.071	0.4740
-20.60	0.093	0.4720
-19.73	0.103	0.4700
-19.07	0.111	0.4680
-18.07	0.125	0.4660
-17.36	0.136	0.4640
-17.37	0.135	0.4620
-18.52	0.119	0.4600
-20.82	0.091	0.4580
-24.34	0.061	0.4560
-29.64	0.033	0.4540
-41.03	0.009	0.4520
-35.48	0.017	0.4500
-27.20	0.044	0.4480
-22.57	0.074	0.4460
-19.53	0.106	0.4440
-17.75	0.130	0.4420
-17.16	0.139	0.4400
-17.63	0.131	0.4380
-18.67	0.117	0.4360
-19.34	0.108	0.4340
-19.56	0.105	0.4320
-20.62	0.093	0.4300
-24.29	0.061	0.4280
-36.78	0.014	0.4260
-26.57	0.047	0.4240
-20.41	0.095	0.4220
-17.88	0.123	0.4200
-17.25	0.137	0.4180
-18.42	0.120	0.4160
-22.65	0.074	0.4140
-44.05	0.006	0.4120
-22.00	0.079	0.4100
-16.60	0.148	0.4080
-14.94	0.179	0.4060
-15.99	0.159	0.4040
-20.96	0.090	.4020
-34.11	0.020	0.4000
-19.40	0.107	0.3980
-15.48	0.168	0.3960
-14.97	0.178	0.3940
-17.17	0.139	0.3920
-23.28	0.069	0.3900
-29.67	0.037	0.3880
-20.68	0.093	0.2860
-17.61	0.132	0.3840
-16.83	0.144	0.3820
-17.66	0.131	0.3800
-20.50	0.094	0.3780
-27.96	0.040	0.3760
-30.99	0.028	0.3740
-21.60	0.083	0.3720
-18.41	0.120	0.3700
-17.30	0.136	0.3680
-16.77	0.145	0.3660
-15.99	0.159	0.3640
-15.24	0.173	0.3620
-15.24	0.173	0.3600
-16.27	0.154	0.3580
-18.44	0.120	0.3560
-21.82	0.081	0.3540
-26.85	0.045	0.3520
-37.42	0.013	0.3500
-33.14	0.022	0.3460
-24.84	0.057	0.3460
-20.28	0.097	0.3440
-17.31	0.136	0.3420
-15.60	0.166	0.3400
-15.07	0.176	0.3380
-15.57	0.166	0.3360
-16.50	0.150	0.3340
-16.90	0.143	0.3320
-16.99	0.141	0.3300
-18.24	0.122	0.3280
-22.55	0.075	0.3260
[illegible]	0.017	0.3240
[illegible]	[illegible]	0.3220
-17.10	0.140	0.3200
-15.11	0.176	0.3180



-14.97	0.170	0.3160
-16.85	0.144	0.3140
-22.91	0.072	0.3120
-30.65	0.029	0.3100
-17.22	0.136	0.3080
-13.29	0.216	0.3060
-12.42	0.239	0.3040
-14.37	0.171	0.3020
-21.43	0.085	0.3000
-23.79	0.065	0.2980
-15.81	0.178	0.2960
-12.44	0.239	0.2940
-12.83	0.228	0.2920
-16.09	0.157	0.2900
-23.59	0.063	0.2880
-22.39	0.076	0.2860
-16.65	0.146	0.2840
-14.59	0.187	0.2820
-14.35	0.192	0.2800
-15.79	0.162	0.2780
-19.89	0.101	0.2760
-31.68	0.026	0.2740
-22.30	0.079	0.2720
-16.56	0.149	0.2700
-14.54	0.187	0.2680
-13.86	0.203	0.2660
-13.32	0.216	0.2640
-12.61	0.234	0.2620
-12.29	0.243	0.2600
-12.87	0.227	0.2580
-14.57	0.187	0.2560
-17.41	0.135	0.2540
-21.61	0.083	0.2520
-28.76	0.036	0.2500
-34.75	0.018	0.2480
-23.82	0.054	0.2460
-18.52	0.119	0.2440
-15.15	0.175	0.2420
-13.03	0.222	0.2400
-12.22	0.245	0.2380
-12.43	0.238	0.2360
-13.37	0.215	0.2340
-13.79	0.204	0.2320
-13.62	0.208	0.2300
-14.33	0.193	0.2280
-17.49	0.134	0.2260
-26.09	0.045	0.2240
-20.26	0.097	0.2220
-14.26	0.195	0.2200
-11.81	0.257	0.2180
-11.43	0.266	0.2160
-12.00	0.224	0.2140
-18.17	0.124	0.2120
-29.79	0.032	0.2100
-14.52	0.198	0.2080
-9.93	0.317	0.2060
-8.73	0.366	0.2040
-10.23	0.308	0.2020
-15.95	0.160	0.2000
-20.52	0.094	0.1980
-11.76	0.259	0.1960
-8.34	0.362	0.1940
-8.96	0.357	0.1920
-11.03	0.256	0.1900
-18.53	0.118	0.1880
-18.67	0.117	0.1860
-13.19	0.219	0.1840
-10.96	0.283	0.1820
-10.54	0.297	0.1800
-11.74	0.259	0.1780
-15.45	0.169	0.1760
-24.22	0.061	0.1740
-17.42	0.135	0.1720
-12.10	0.248	0.1700
-9.97	0.317	0.1680
-9.14	0.347	0.1660
-8.66	0.369	0.1640
-8.03	0.396	0.1620
-7.86	0.405	0.1600
-8.57	0.373	0.1580
-10.34	0.302	0.1560
-13.32	0.216	0.1540
-17.56	0.132	0.1520
-24.18	0.060	0.1500
-26.44	0.048	0.1480
-18.10	0.125	0.1460
-13.24	0.218	0.1440
-10.11	0.312	0.1420
-6.27	0.336	0.1400
-7.67	0.413	0.1380
-8.24	[illegible]	0.1360
-9.23	[illegible]	0.1340
-9.21	0.346	0.1320
[illegible]	0.374	0.1300
-9.12	[illegible]	0.1280
[illegible]	[illegible]	0.1260
-17.88	0.128	0.1240
[illegible]	[illegible]	0.1220
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]



[illegible]	[illegible]	0.1120
-13.22	[illegible]	0.1100
-5.23	[illegible]	0.1080
-2.60	[illegible]	0.1060
-1.45	[illegible]	0.1040
-3.84	[illegible]	0.1020
-8.58	0.372	0.1000
-7.70	0.412	0.0980
-3.07	0.702	0.0960
-1.40	0.851	0.0940
-2.23	0.774	0.0920
-5.53	0.529	0.0900
-9.78	0.324	0.0880
-7.79	0.408	0.0860
-5.09	0.557	0.0840
-3.97	0.643	0.0820
-3.83	0.644	0.0800
-4.74	0.579	0.0780
-7.33	0.430	0.0760
-9.19	0.347	0.0740
-4.92	0.567	0.0720
-1.26	0.865	0.0700
0.74	1.089	0.0680
1.88	1.241	0.0660
2.72	1.368	0.0640
3.26	1.456	0.0620
3.05	1.421	0.0600
1.62	1.205	0.0580
-1.55	0.836	0.0560
-7.48	0.423	0.0540
-20.13	0.099	0.0520
-23.06	0.070	0.0500
-30.30	0.031	0.0480
-12.63	0.234	0.0460
-3.81	0.645	0.0440
1.50	1.189	0.0420
4.96	1.771	0.0400
7.00	2.238	0.0380
7.67	2.417	0.0360
6.87	2.205	0.0340
4.23	1.628	0.0320
-1.20	0.871	0.0300
-8.23	0.358	0.0280
-4.14	0.621	0.0260
-3.43	0.674	0.0240
-9.29	0.345	0.0220
-3.52	[illegible]	0.0200
1.47	1.144	0.0180
6.03	2.002	0.0160
8.45	2.646	0.0140
9.41	2.955	0.0120
8.97	[illegible]	0.0100
6.78	[illegible]	0.0080
1.62	1.205	0.0060
-16.83	0.144	0.0040
-3.28	0.665	0.0020
-0.00	1.000	0.0000
-3.10	0.700	-0.0020
-13.42	0.120	-0.0040
1.42	1.178	-0.0060
6.70	2.162	-0.0080
8.94	[illegible]	-0.0100
9.42	2.957	-0.0120
8.49	2.658	-0.0140
6.11	2.021	-0.0160
1.62	1.205	-0.0180
-8.13	[illegible]	-0.0200
-9.60	0.331	-0.0220
-3.47	0.670	-0.0240
-4.06	0.627	-0.0260
-8.23	[illegible]	-0.0280
-1.38	0.853	-0.0300
4.14	1.611	-0.0320
6.83	2.195	-0.0340
7.67	[illegible]	-0.0360
7.03	2.246	-0.0380
5.03	1.785	-0.0400
1.66	[illegible]	-0.0420
-3.64	0.657	-0.0440
-12.34	0.241	-0.0460
-30.67	0.029	-0.0480
-22.94	0.071	-0.0500
-20.66	0.093	-0.0520
-7.67	0.414	-0.0540
-1.66	0.826	-0.0560
1.57	1.197	-0.0580
3.04	[illegible]	-0.0600
3.27	[illegible]	-0.0620
2.74	[illegible]	-0.0640
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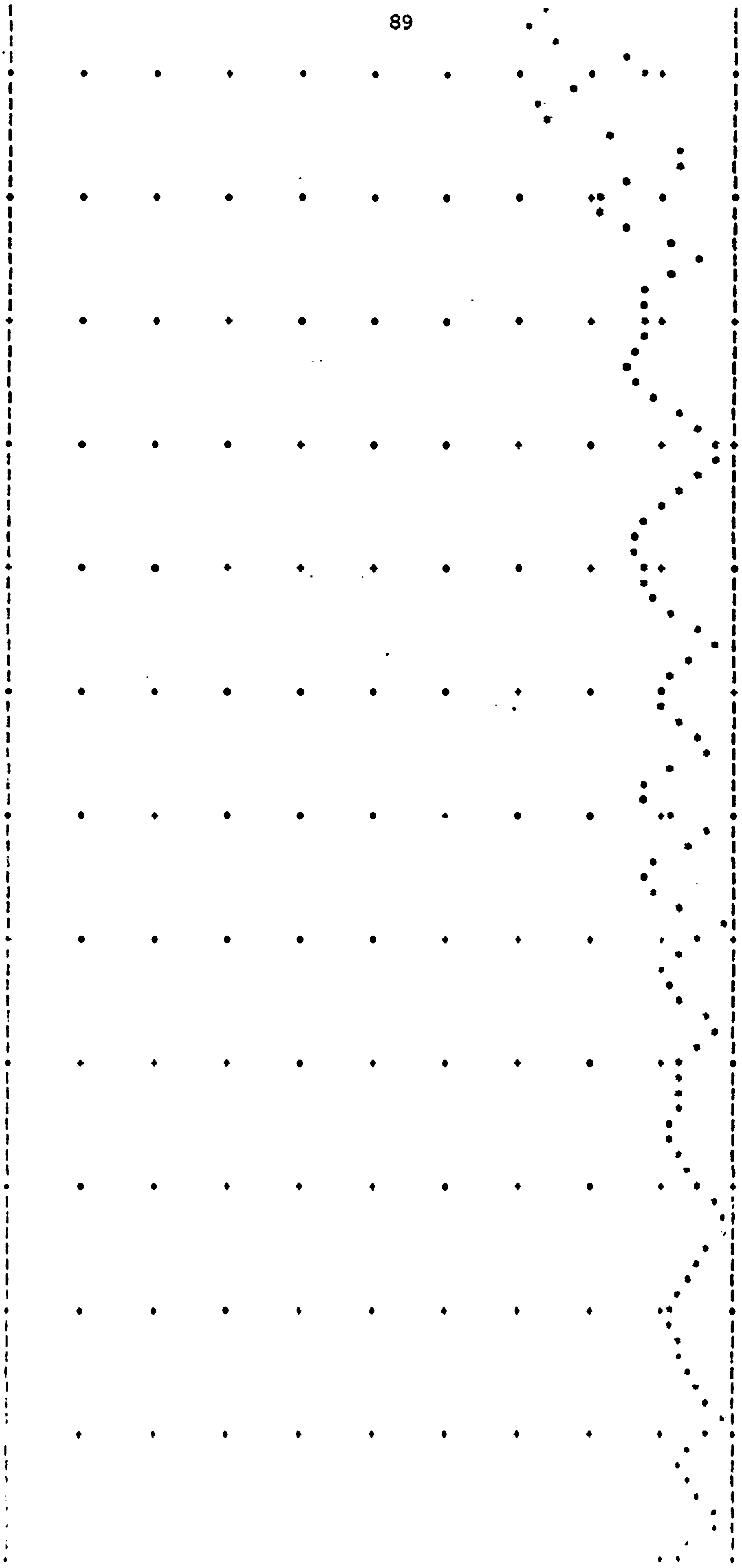

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-8.71	0.367	-0.1000
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-7.52	0.421	-0.1140
-5.45	0.534	-0.1160
-5.41	0.536	-0.1180
-7.23	0.435	-0.1200
-11.68	0.261	-0.1220
-17.84	0.129	-0.1240
-12.47	0.238	-0.1260
-9.16	0.349	-0.1280
-8.54	0.374	-0.1300
-9.19	0.347	-0.1320
-9.25	0.345	-0.1340
-8.26	0.386	-0.1360
-7.67	0.413	-0.1380
-8.23	0.387	-0.1400
-10.05	0.315	-0.1420
-13.15	0.220	-0.1440
-17.95	0.127	-0.1460
-26.15	0.049	-0.1480
-24.60	0.059	-0.1500
-17.68	0.131	-0.1520
-13.42	0.213	-0.1540
-10.44	0.301	-0.1560
-8.60	0.372	-0.1580
-7.86	0.404	-0.1600
-8.04	0.396	-0.1620
-8.65	0.369	-0.1640
-9.18	0.347	-0.1660
-9.94	0.318	-0.1680
-12.01	0.251	-0.1700
-17.21	0.138	-0.1720
-24.42	0.060	-0.1740
-15.59	0.166	-0.1760
-11.80	0.257	-0.1780
-10.55	0.297	-0.1800
-10.93	0.284	-0.1820
-13.11	0.221	-0.1840
-18.48	0.119	-0.1860
-18.77	0.116	-0.1880
-11.94	0.253	-0.1900
-8.99	0.355	-0.1920
-8.81	0.363	-0.1940
-11.62	0.262	-0.1960
-20.21	0.098	-0.1980
-16.17	0.155	-0.2000
-10.30	0.305	-0.2020
-8.74	0.366	-0.2040
-9.92	0.319	-0.2060
-14.36	0.192	-0.2080
-29.6	0.035	-0.2100
-18.38	0.121	-0.2120
-13.07	0.222	-0.2140
-11.44	0.268	-0.2160
-11.76	0.258	-0.2180
-14.11	0.197	-0.2200
-20.04	0.100	-0.2220
-27.30	0.044	-0.2240
-17.61	0.132	-0.2260
-14.34	0.192	-0.2280
-13.62	0.209	-0.2300
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-13.34	0.214	-0.2340
-12.50	0.237	-0.2360
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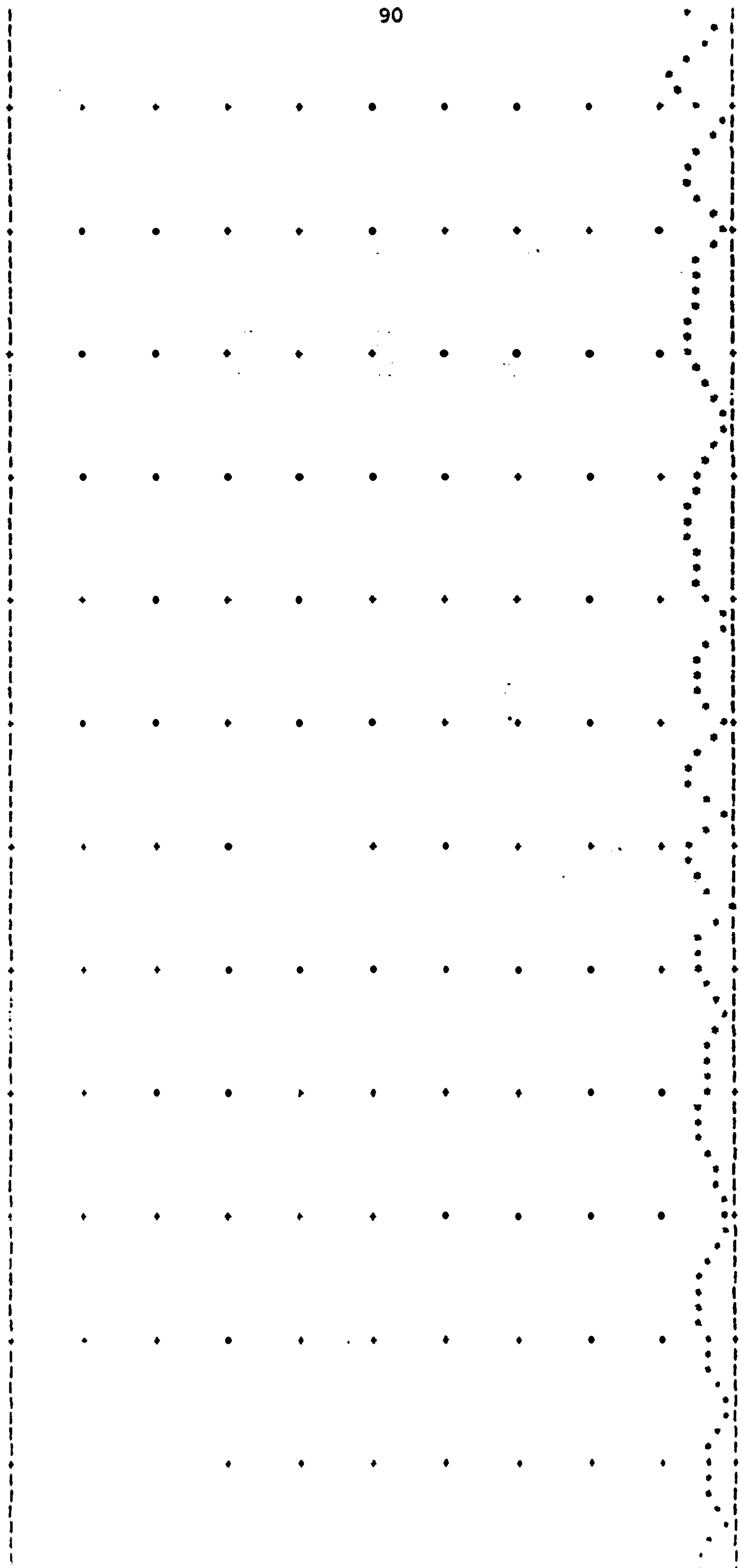

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-13.25	0.217	-0.3060
-17.20	0.138	-0.3080
-30.08	0.021	-0.3100
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-16.51	0.143	-0.3140
-14.99	0.178	-0.3160
-15.09	0.176	-0.3180
-17.04	0.141	-0.3200
-22.06	0.079	-0.3220
-35.25	0.017	-0.3240
-22.68	0.073	-0.3260
-18.29	0.122	-0.3280
-17.00	0.141	-0.3300
-16.90	0.143	-0.3320
-16.52	0.149	-0.3340
-15.59	0.166	-0.3360
-15.07	0.176	-0.3380
-15.58	0.166	-0.3400
-17.27	0.137	-0.3420
-20.22	0.098	-0.3440
-24.75	0.058	-0.3460
-32.92	0.023	-0.3480
-37.74	0.013	-0.3500
-27.00	0.045	-0.3520
-21.89	0.080	-0.3540
-18.49	0.119	-0.3560
-16.30	0.153	-0.3580
-15.25	0.173	-0.3600
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-15.98	0.159	-0.3640
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-17.29	0.137	-0.3680
-18.39	0.120	-0.3700
-21.52	0.084	-0.3720
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-20.56	0.094	-0.3780
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-16.83	0.144	-0.38[illegible]
-17.58	0.137	-0.3840
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-44.47	0.006	-0.4120
-22.74	0.073	-0.4140
-18.45	0.120	-0.4160
-17.25	0.137	-0.4180
-17.86	0.128	-0.4200
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-17.64	0.121	-0.4380
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?-AXIS PROFILE PLOT ALONG 0.0 LONGITUDE.
PATTERN NUMBER 102

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-32.71	0.023	3.8159
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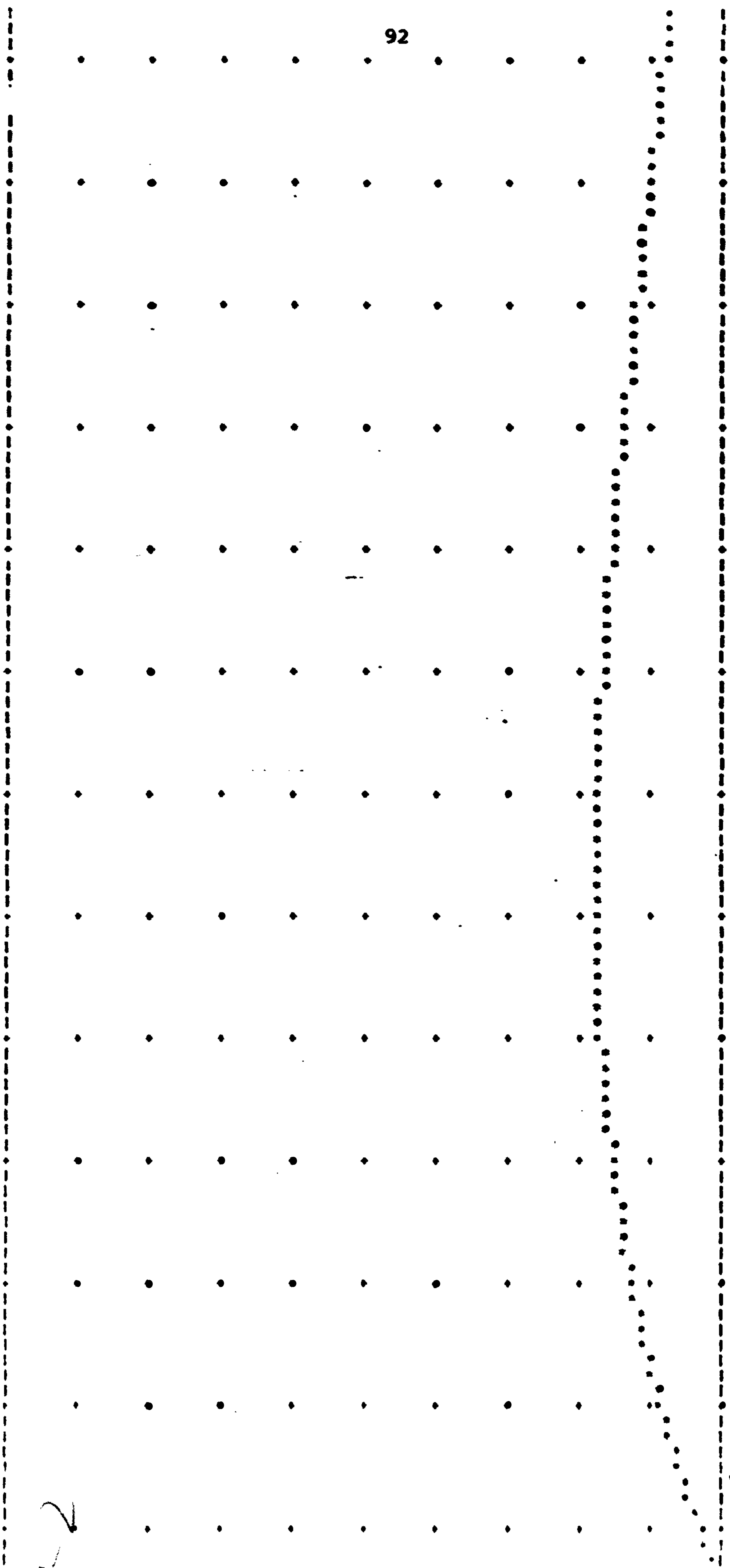

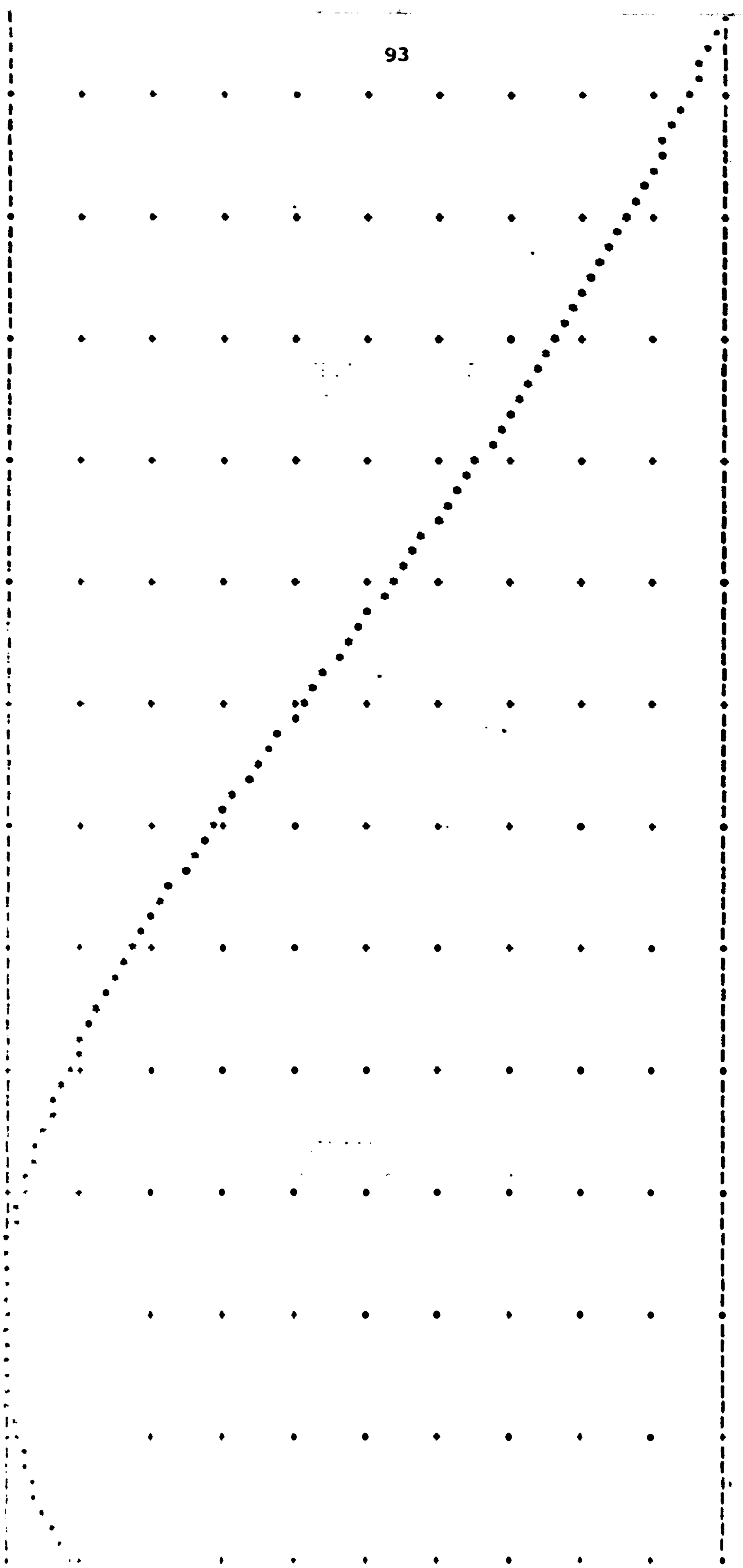

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-18.53	0.119	2.7600
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-16.27	0.154	2.7360
-15.61	0.166	2.7280
-14.99	0.178	2.7200
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-12.80	0.229	2.6880
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-10.53	0.297	2.6480
-10.13	0.312	2.6400
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-9.36	0.340	2.6240
-8.99	0.355	2.6160
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-6.17	0.492	2.5440
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-5.38	0.538	2.5200
-5.13	0.554	2.5120
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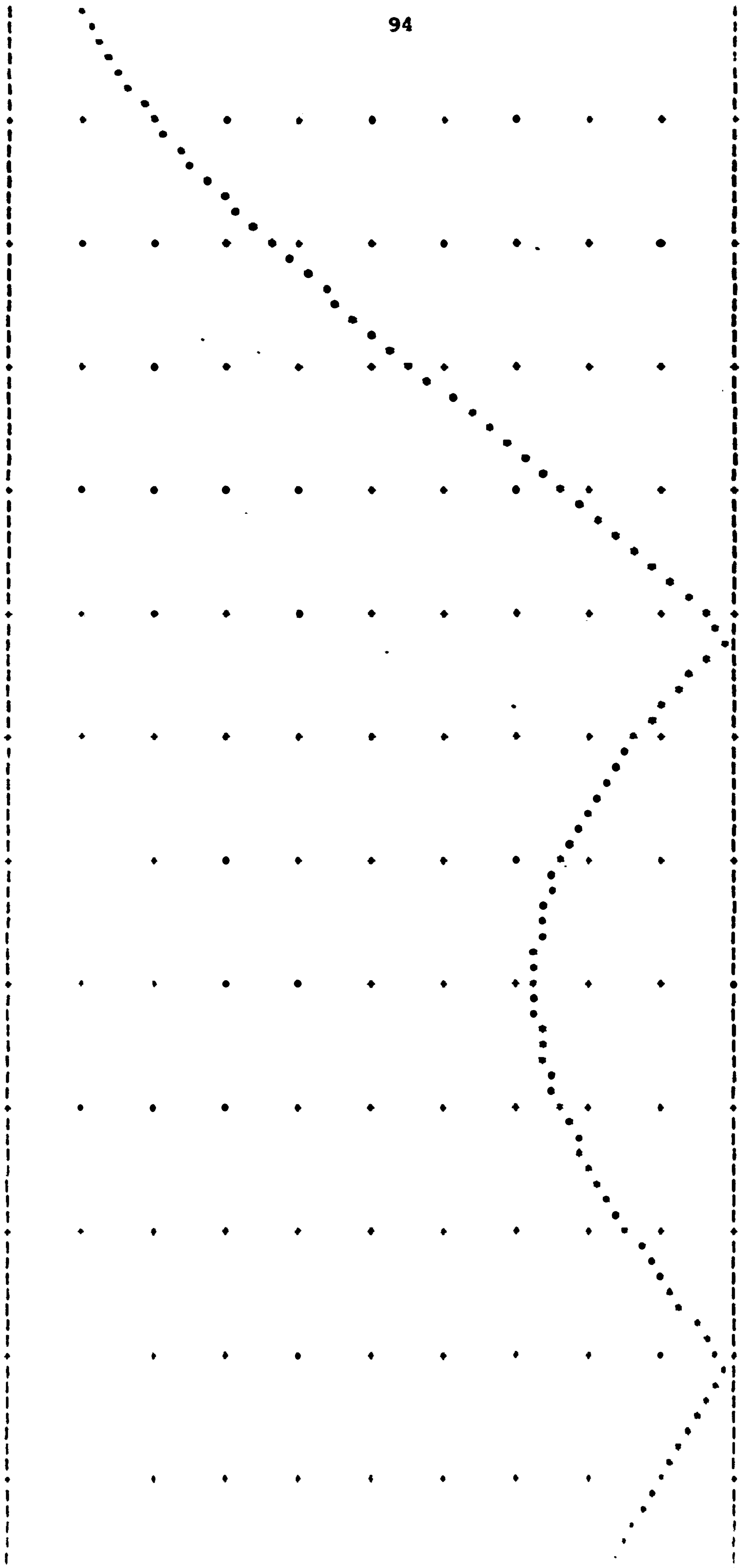
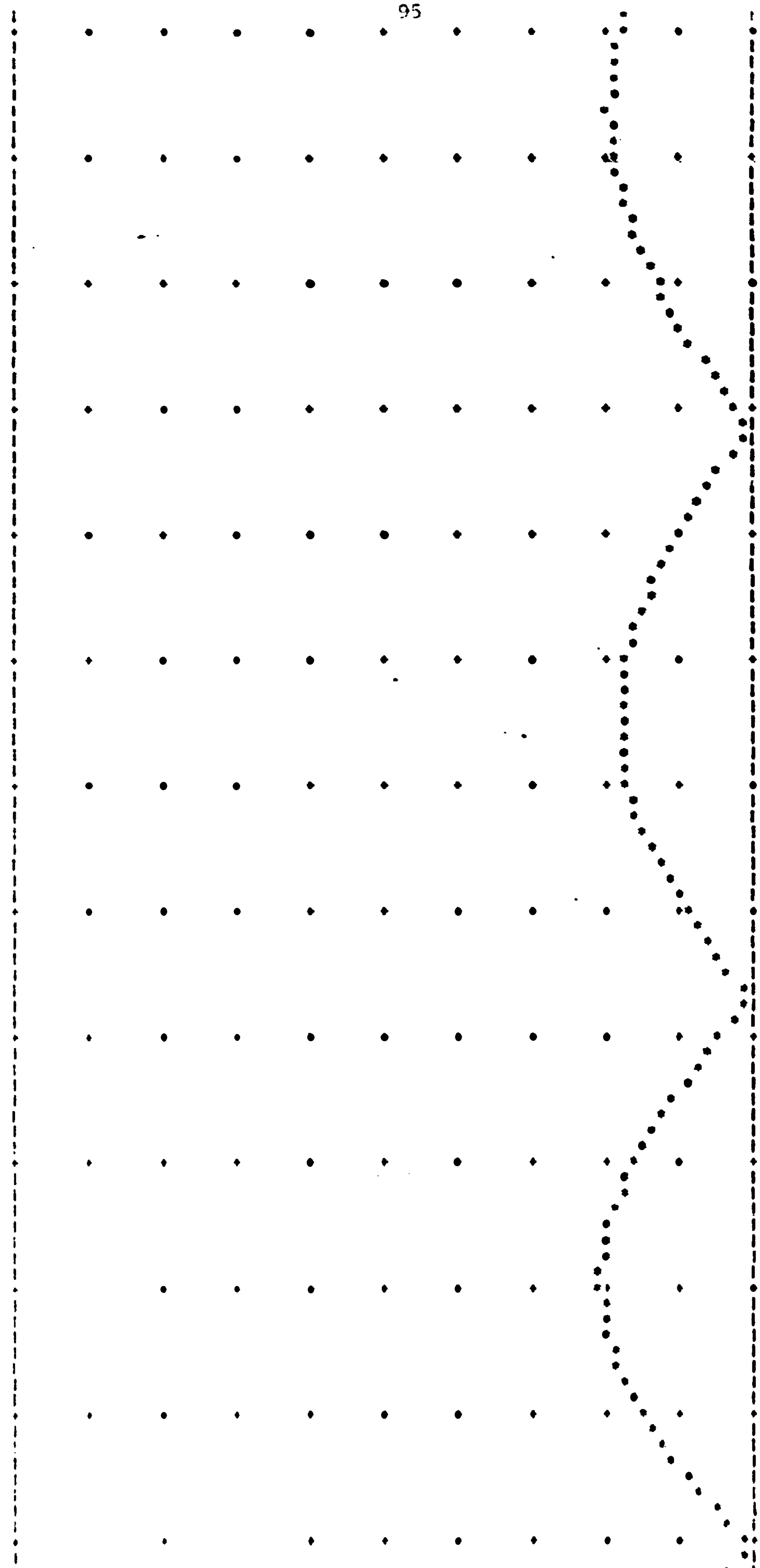
-1.73	0.820	2.3680
-1.59	0.833	2.3600
-1.46	0.845	2.3520
-1.34	0.857	2.3440
-1.22	0.869	2.3360
-1.10	0.881	2.3280
-1.00	0.892	2.3200
-0.89	0.902	2.3120
-0.79	0.913	2.3040
-0.70	0.922	2.2960
-0.61	0.932	2.2880
-0.52	0.941	2.2800
-0.46	0.949	2.2720
-0.38	0.957	2.2640
-0.32	0.964	2.2560
-0.26	0.971	2.2480
-0.20	0.977	2.2400
-0.15	0.982	2.2320
-0.11	0.987	2.2240
-0.07	0.992	2.2160
-0.04	0.995	2.2080
-0.01	0.998	2.2000
0.01	1.001	2.1920
0.02	1.002	2.1840
0.03	1.003	2.1760
0.03	1.003	2.1680
0.03	1.003	2.1600
0.02	1.002	2.1520
-0.00	1.000	2.1440
-0.03	0.997	2.1360
-0.06	0.994	2.1280
-0.0[illegible]	0.989	2.1200
-0.14	0.986	2.1120
-0.19	0.978	2.1040
-0.25	0.972	2.0960
-0.3[illegible]	0.964	2.0880
-0.39	0.95[illegible]	2.0800
-0.47	0.947	2.0720
-0.5[illegible]	0.9[illegible]7	2.0640
[illegible]	0.9[illegible]	2.0560
[illegible]	0.9[illegible]	2.0480

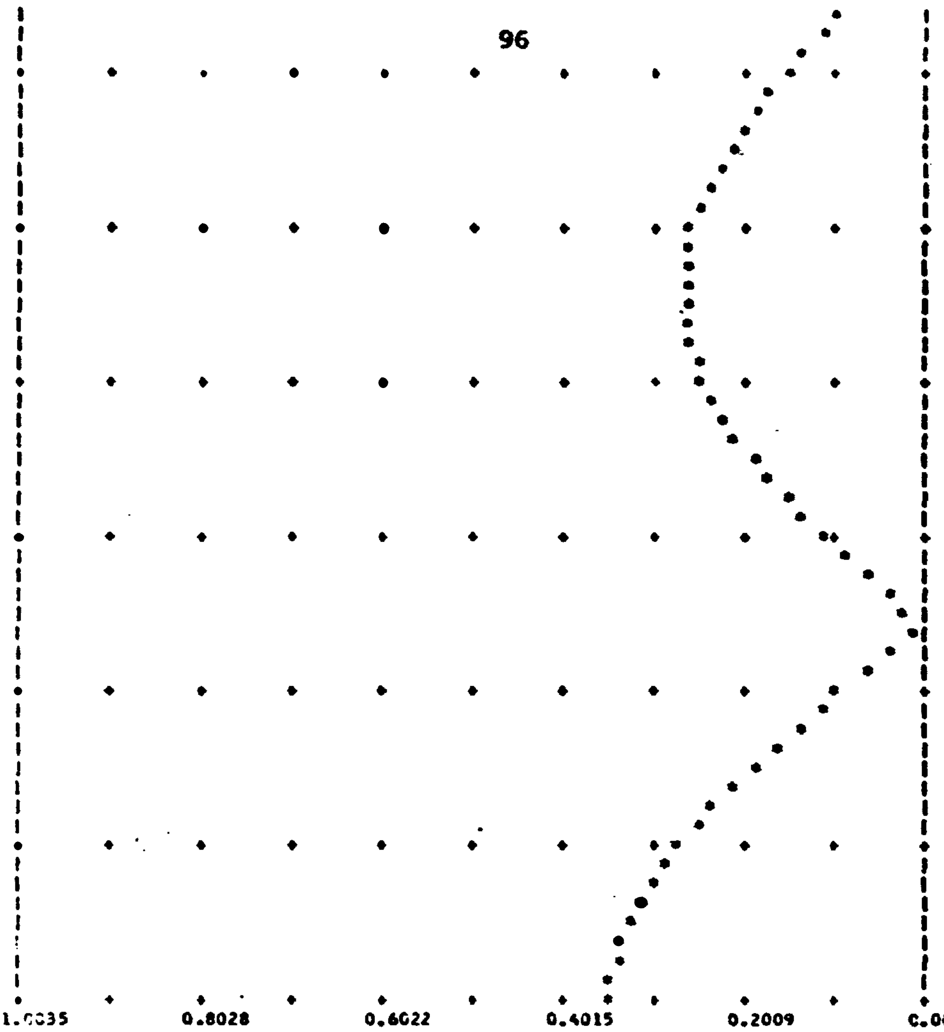


-0.89	0.903	2.0400
-1.01	0.890	2.0320
-1.15	0.876	2.0240
-1.29	0.862	2.0160
-1.45	0.847	2.0080
-1.61	0.831	2.0000
-1.79	0.814	1.9920
-1.94	0.797	1.9840
-2.18	0.778	1.9760
-2.39	0.760	1.9680
-2.61	0.740	1.9600
-2.85	0.720	1.9520
-3.11	0.699	1.9440
-3.37	0.678	1.9360
-3.66	0.656	1.9280
-3.96	0.634	1.9200
-4.28	0.611	1.9120
-4.62	0.588	1.9040
-4.98	0.564	1.8960
-5.36	0.540	1.8880
-5.76	0.515	1.8800
-6.19	0.490	1.8720
-6.65	0.465	1.8640
-7.14	0.440	1.8560
-7.66	0.414	1.8480
-8.22	0.388	1.8400
-8.81	0.362	1.8320
-9.46	0.336	1.8240
-10.16	0.310	1.8160
-10.92	0.284	1.8080
-11.75	0.259	1.8000
-12.66	0.233	1.7920
-13.68	0.207	1.7840
-14.82	0.182	1.7760
-16.12	0.155	1.7680
-17.63	0.131	1.7600
-19.42	0.107	1.7520
-21.65	0.083	1.7440
-24.58	0.059	1.7360
-28.92	0.035	1.7280
-37.62	0.013	1.7200
-41.01	0.009	1.7120
-30.37	0.030	1.7040
-25.84	0.051	1.6960
-22.97	0.071	1.6880
-20.89	0.090	1.6800
-19.29	0.109	1.6720
-17.98	0.126	1.6640
-16.90	0.143	1.6560
-15.99	0.159	1.6480
-15.22	0.173	1.6400
-14.55	0.187	1.6320
-13.98	0.200	1.6240
-13.49	0.212	1.6160
-13.06	0.222	1.6080
-12.70	0.232	1.6000
-12.38	0.240	1.5920
-12.12	0.248	1.5840
-11.91	0.254	1.5760
-11.74	0.259	1.5680
-11.61	0.263	1.5600
-11.52	0.265	1.5520
-11.47	0.267	1.5440
-11.46	0.267	1.5360
-11.48	0.267	1.5280
-11.54	0.265	1.5200
-11.63	0.262	1.5120
-11.77	0.258	1.5040
-11.94	0.253	1.4960
-12.15	0.247	1.4880
-12.40	0.240	1.4800
-12.70	0.232	1.4720
-13.04	0.223	1.4640
-13.43	0.213	1.4560
-13.87	0.202	1.4480
-14.38	0.191	1.4400
-14.94	0.179	1.4320
-15.59	0.166	1.4240
-16.32	0.153	1.4160
-17.15	0.139	1.4080
-18.10	0.124	1.4000
-19.20	0.110	1.3920
-20.49	0.095	1.3840
-22.03	0.079	1.3760
-23.94	0.064	1.3680
-26.42	0.048	1.3600
-29.93	0.032	1.3520
-35.79	0.016	1.3440
-64.81	0.001	1.3360
-36.53	0.015	1.3280
-30.42	0.030	1.3200
-26.93	0.045	1.3120
-24.50	0.060	1.3040
-22.66	0.074	1.2960
-21.20	0.087	1.2880
-20.01	0.100	1.2800
-19.00	0.112	1.2720
-18.15	0.124	1.2640
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]



[illegible]	[illegible]	1.2240
-15.16	0.175	1.2160
-14.92	0.180	1.2080
-14.73	0.183	1.2000
-14.59	0.186	1.1920
-14.51	0.188	1.1840
-14.49	0.189	1.1760
-14.51	0.188	1.1680
-14.59	0.186	1.1600
-14.72	0.184	1.1520
-14.90	0.180	1.1440
-15.14	0.175	1.1360
-15.44	0.169	1.1280
-15.81	0.162	1.1200
-16.25	0.154	1.1120
-16.76	0.145	1.1040
-17.37	0.135	1.0960
-18.08	0.125	1.0880
-18.91	0.113	1.0800
-19.88	0.101	1.0720
-21.04	0.089	1.0640
-22.44	0.076	1.0560
-24.17	0.062	1.0480
-26.41	0.048	1.0400
-29.50	0.033	1.0320
-34.44	0.019	1.0240
-47.27	0.004	1.0160
-39.73	0.010	1.0080
-32.08	0.025	1.0000
-28.12	0.039	0.9920
-25.45	0.053	0.9840
-23.46	0.067	0.9760
-21.89	0.080	0.9680
-20.61	0.093	0.9600
-19.55	0.105	0.9520
-18.66	0.117	0.9440
-17.90	0.127	0.9360
-17.27	0.137	0.9280
-16.73	0.145	0.9200
-16.28	0.153	0.9120
-15.91	0.160	0.9040
-15.62	0.166	0.8960
-15.39	0.170	0.8880
-15.24	0.173	0.8800
-15.14	0.175	0.8720
-15.11	0.175	0.8640
-15.15	0.175	0.8560
-15.25	0.173	0.8480
-15.42	0.169	0.8400
-15.66	0.165	0.8320
-15.97	0.159	0.8240
-16.37	0.152	0.8160
-16.86	0.144	0.8080
-17.45	0.134	0.8000
-18.16	0.124	0.7920
-19.01	0.112	0.7840
-20.04	0.100	0.7760
-21.29	0.086	0.7680
-22.84	0.072	0.7600
-24.84	0.057	0.7520
-27.55	0.042	0.7440
-31.66	0.026	0.7360
-40.04	0.010	0.7280
-43.83	0.006	0.7200
-32.79	0.023	0.7120
-28.09	0.039	0.7040
-25.08	0.056	0.6960
-22.88	0.072	0.6880
-21.17	0.087	0.6800
-19.79	0.102	0.6720
-18.64	0.117	0.6640
-17.69	0.131	0.6560
-16.87	0.143	0.6480
-16.19	0.155	0.6400
-15.61	0.166	0.6320
-15.13	0.175	0.6240
-14.74	0.183	0.6160
-14.43	0.190	0.6080
-14.19	0.195	0.6000
-14.02	0.199	0.5920
-13.93	0.201	0.5840
-13.91	0.202	0.5760
-13.95	0.201	0.5680
-14.07	0.198	0.5600
-14.27	0.193	0.5520
-14.54	0.187	0.5440
-14.91	0.180	0.5360
-15.36	0.171	0.5280
-15.93	0.160	0.5200
-16.62	[illegible]	0.5120
-17.46	[illegible]	0.5040
-18.48	[illegible]	0.4960
-19.72	[illegible]	0.4880
-21.21	[illegible]	0.4800
[illegible]	[illegible]	0.4720
-26.10	[illegible]	0.4640
[illegible]	[illegible]	0.4560
[illegible]	[illegible]	0.4480
[illegible]	[illegible]	0.4400
[illegible]	[illegible]	0.4320
[illegible]	[illegible]	0.4240
[illegible]	[illegible]	0.4160

DB.	REAL	
-23.62	0.093	0.4080
-18.44	0.113	0.4000
-17.58	0.132	0.3920
-16.45	0.151	0.3840
-15.45	0.164	0.3760
-14.63	0.184	0.3680
-14.00	0.206	0.3600
-13.42	0.213	0.3520
-12.93	0.226	0.3440
-12.53	0.236	0.3360
-12.21	0.245	0.3280
-11.95	0.253	0.3200
-11.77	0.258	0.3120
-11.66	0.261	0.3040
-11.61	0.263	0.2960
-11.63	0.262	0.2880
-11.72	0.259	0.2800
-11.83	0.255	0.2720
-12.11	0.248	0.2640
-12.42	0.239	0.2560
-12.81	0.229	0.2480
-13.33	0.216	0.2400
-13.89	0.202	0.2320
-14.60	0.186	0.2240
-15.46	0.169	0.2160
-16.49	0.150	0.2080
-17.76	0.129	0.2000
-19.34	0.108	0.1920
-21.37	0.085	0.1840
-24.16	0.062	0.1760
-28.46	0.038	0.1680
-37.71	0.013	0.1600
-38.34	0.012	0.1520
-28.53	0.037	0.1440
-24.04	0.063	0.1360
-21.11	0.088	0.1280
-18.94	0.113	0.1200
-17.24	0.137	0.1120
-15.86	0.161	0.1040
-14.70	0.184	0.0960
-13.72	0.206	0.0880
-12.89	0.227	0.0800
-12.17	0.246	0.0720
-11.55	0.264	0.0640
-11.02	0.281	0.0560
-10.57	0.296	0.0480
-10.19	0.309	0.0400
-9.87	0.321	0.0320
-9.62	0.330	0.0240
-9.42	0.338	0.0160
-9.27	0.344	0.0080
-9.18	0.347	0.0



NORMAL TERMINATION

EXAMPLE 4:
DEMONSTRATION OF SYSTEMATIC ELECTRICAL ERRORS IN THE FULL X-BAND
HORIZONTAL ARRAY.

SYSTEM INFORMATION:
FREQUENCY = 9.000 GHZ.
YAW = 0.0 DEGREES
TILT = 50.000 DEGREES
TWIST = 0.0 DEGREES
ALTITUDE = 200.000 KM.

ANTENNA PARAMETERS FOR SIMULATION NUMBER 103
ELEMENT TYPE: HORIZONTAL DIPOLE
NUMBER OF ELEMENTS (X,Y) = (504 , 12)
INTERELEMENT SPACING (CM.): 2.2966 , 2.3550
INTERELEMENT PHASE SHIFT (DEG.): 0.0 , 0.0

DEFORMATION DATA FOR SIMULATION 103:

0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0

ELECTRICAL DATA FOR SIMULATION 103:

	(1, 2)	(2, 2)	(3, 2)	(4, 2)	(5, 2)	(6, 2)	(
PHSX:	0.0	0.0	0.0	0.0	0.0	0.0	
PHSY:	0.0	0.0	0.0	0.0	0.0	0.0	
AMAG:	1.00	1.00	1.00	1.00	1.00	1.00	
APHS:	15.00	10.00	5.00	0.0	0.0	0.0	

	(1, 1)	(2, 1)	(3, 1)	(4, 1)	(5, 1)	(6, 1)	(
PHSX:	0.0	0.0	0.0	0.0	0.0	0.0	
PHSY:	0.0	0.0	0.0	0.0	0.0	0.0	
AMAG:	1.00	1.00	1.00	1.00	1.00	1.00	
APHS:	0.0	0.0	0.0	-5.00	-10.00	-15.00	

PRINT/PLOT INFORMATION:
REQUESTED OUTPUT:
PRINTER PROFILE
PRINTER CONTOUR
PLOT RESOLUTION: 151 X 151 POINTS

STARTX = -0.500
STOPX = 0.500
DELTAX = 0.007

STARTY = [illegible]
[illegible]
[illegible]

SUBARRAY DATA SUMMARY FOR PATTERN 103:

AREA	XCENT	YCENT	ZAVG	ALPHAX	ALPHAY	AMPS	APHS	PHSX	PHSY
1	-482.29	-7.06	0.0	0.0	0.0	1.0000	0.0	0.0	0.0
2	-289.37	-7.06	0.0	0.0	0.0	1.0000	0.0	0.0	0.0
3	-96.46	-7.06	0.0	0.0	0.0	1.0000	0.0	0.0	0.0
4	96.46	-7.06	0.0	0.0	0.0	1.0000	-5.00	0.0	0.0
5	289.37	-7.06	0.0	0.0	0.0	1.0000	-10.00	0.0	0.0
6	482.29	-7.06	0.0	0.0	0.0	1.0000	-15.00	0.0	0.0
7	-482.29	7.06	0.0	0.0	0.0	1.0000	15.00	0.0	0.0
8	-289.37	7.06	0.0	0.0	0.0	1.0000	10.00	0.0	0.0
9	-96.46	7.06	0.0	0.0	0.0	1.0000	5.00	0.0	0.0
10	96.46	7.06	0.0	0.0	0.0	1.0000	0.0	0.0	0.0
11	289.37	7.06	0.0	0.0	0.0	1.0000	0.0	0.0	0.0
12	482.29	7.06	0.0	0.0	0.0	1.0000	0.0	0.0	0.0

PREDICTED BEAM CENTER:
LATITUDE = 2.1945
LONGITUDE = 0.0
RANGE = 243.578
HEADING = 0.0

PLOT NORMALIZATION FACTOR = -35.088 DB.

PRINTED CONTOUR PLOT FOR SIMULATION NUMBER 103

```
        0.0        0.133      0.267      0.400      0.533      0.667      0.800      0.933      1.067      1.200      1.333
         I..........I..........I..........I..........I..........I..........I..........I..........I..........I..........I
-0.5000.
-0.4933.
-0.4867.
-0.4800.
-0.4733.
-0.4667.
-0.4600.
-0.4533.
-0.4467.
-0.4400.
-0.4333.
-0.4267.
-0.4200.
-0.4133.
-0.4067.
-0.4000.
-0.3933.
-0.3867.
-0.3800.
-0.3733.
-0.3667.
-0.3600.
-0.3533.
-0.3467.
-0.3400.
-0.3333.
-0.3267.
-0.3200.
-0.3133.
-0.3067.
-0.3000.
-0.2933.
-0.2867.
-0.2800.
-0.2733.
-0.2667.
-0.2600.
-0.2533.
-0.2467.
-0.2400.
-0.2333.
-0.2267.
-0.2200.
-0.2133.
-0.2067.
-0.2000.
-0.1933.
-0.1867.
-0.1800.
-0.1733.
-0.1667.
-0.1600.
-0.1533.
-0.1467.
-0.1400.
-0.1333.
-0.1267.
-0.1200.
-0.1133.
-0.1067.
-0.1000.
-0.0933.
-0.0867.
-0.0800.
-0.0733.
-0.0667.
-0.0600.
-0.0533.
-0.0467.
-0.0400.
-0.0333.
-0.0267.
-0.0200.
-0.0133.
-0.0067.
-0.0000.1 3 3 2 1     0 1 2 3 3 3 2 1 0     1 3 3 3 3 3 3 2 0     1 2 3 3 3 3 2 1     1 3 4 4 4 4 4 4 3 2 1
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 0.0133.
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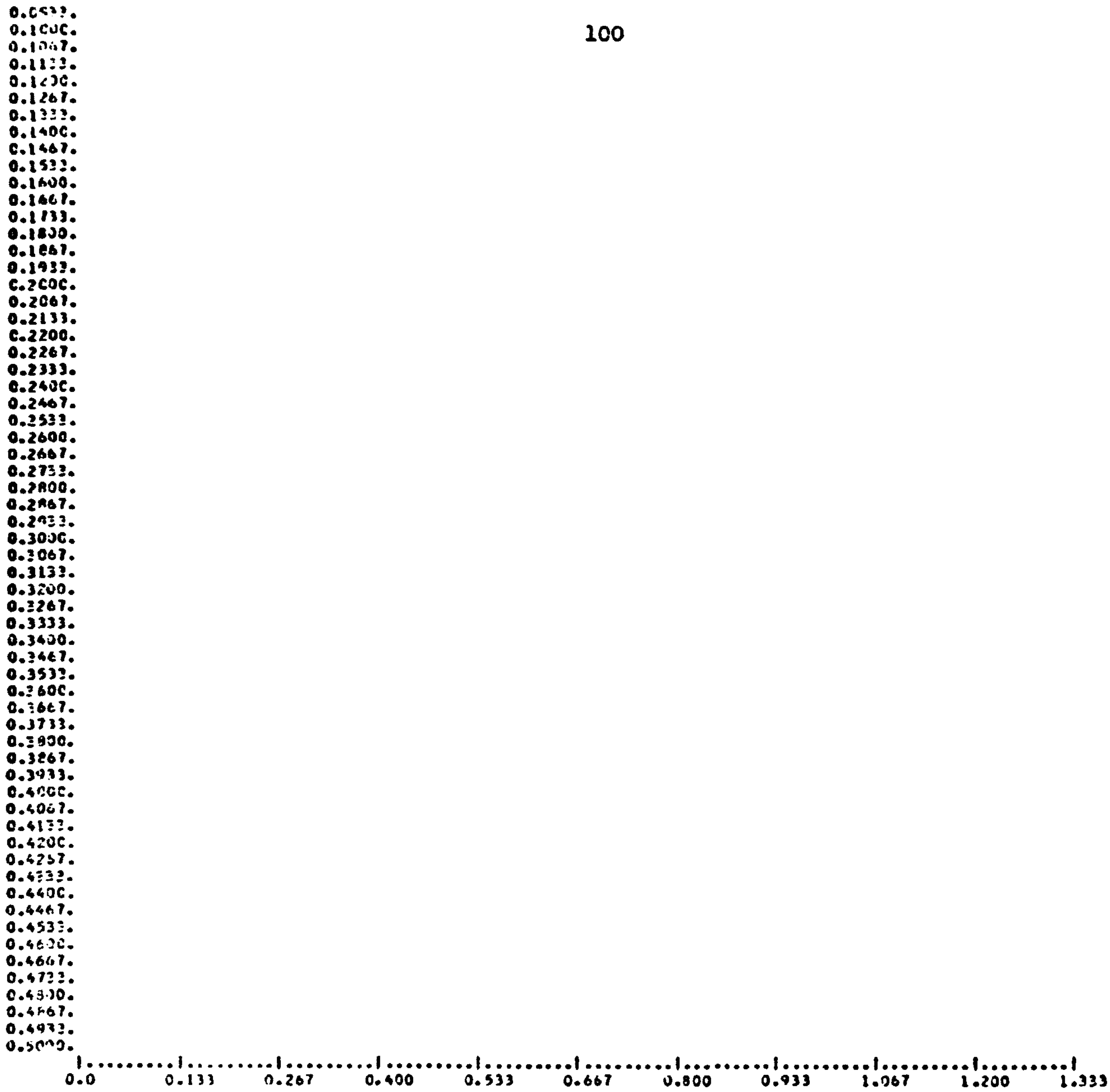
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0.5000.
0.0
0.133
0.267
0.400
0.533
0.667
0.800
0.933
1.067
1.200
1.333

PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 103

```
1.333     1.467     1.600     1.733     1.867     2.000     2.133     2.267     2.400     2.533     2.667
|.........|.........|.........|.........|.........|.........|.........|.........|.........|.........|
                                                    0 0 0 0 0
                                                      0 0 0 1 1 1 0 0 0 0
                                                            0 0 0 0 0 0 0 0 0
                                                                  0 0 0 0 0 0 0 0 0 0
                                        0 0 0 C 0 0 0
                                      0 0 1 1 1 1 2 2 1 1 1 1 1 0 0 0
                                    0 1 1 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 2 2 2 2 1 1 0 0 0
                                  0 1 1 2 2 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 2 2 1 1 0 0
                                    0 1 2 3 3 4 4 4 5 5 5 5 5 5 5 6 6 6 6 5 5 5 5 5 5 5 4 4 4 4 3 3 2
  0 2 3 4 5 5 5 5 5 4 3 2   0 2 4 5 5 7 7 8 8 8 8 9 9 9 9 5 9 9 5 9 9 9 9 9 8 8 8 8 8 7 7 7 6 6 6 5 4
                                            0 0 1 2 2 2 3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 2 2 2 1
                                      0 1 1 2 2 3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 2 2 2 1 1 0
                                      0 1 1 2 2 2 2 3 3 3 3 3 3 3 3 3 3 3 2 2 2 2 1 1 1 0 0
                                      0 0 1 1 2 2 2 2 2 2 2 2 2 2 1 1 1 1 0 0
                                      0 0 0 0 1 1 1 1 0 0 0
                                                                        0 0 0 0 0 0 0
                                                            0 0 0 1 1 1 1 1 1 0 0 0
                                                          0 0 0 0 0 0 0
                                                      0 0 C 0 0 C
```

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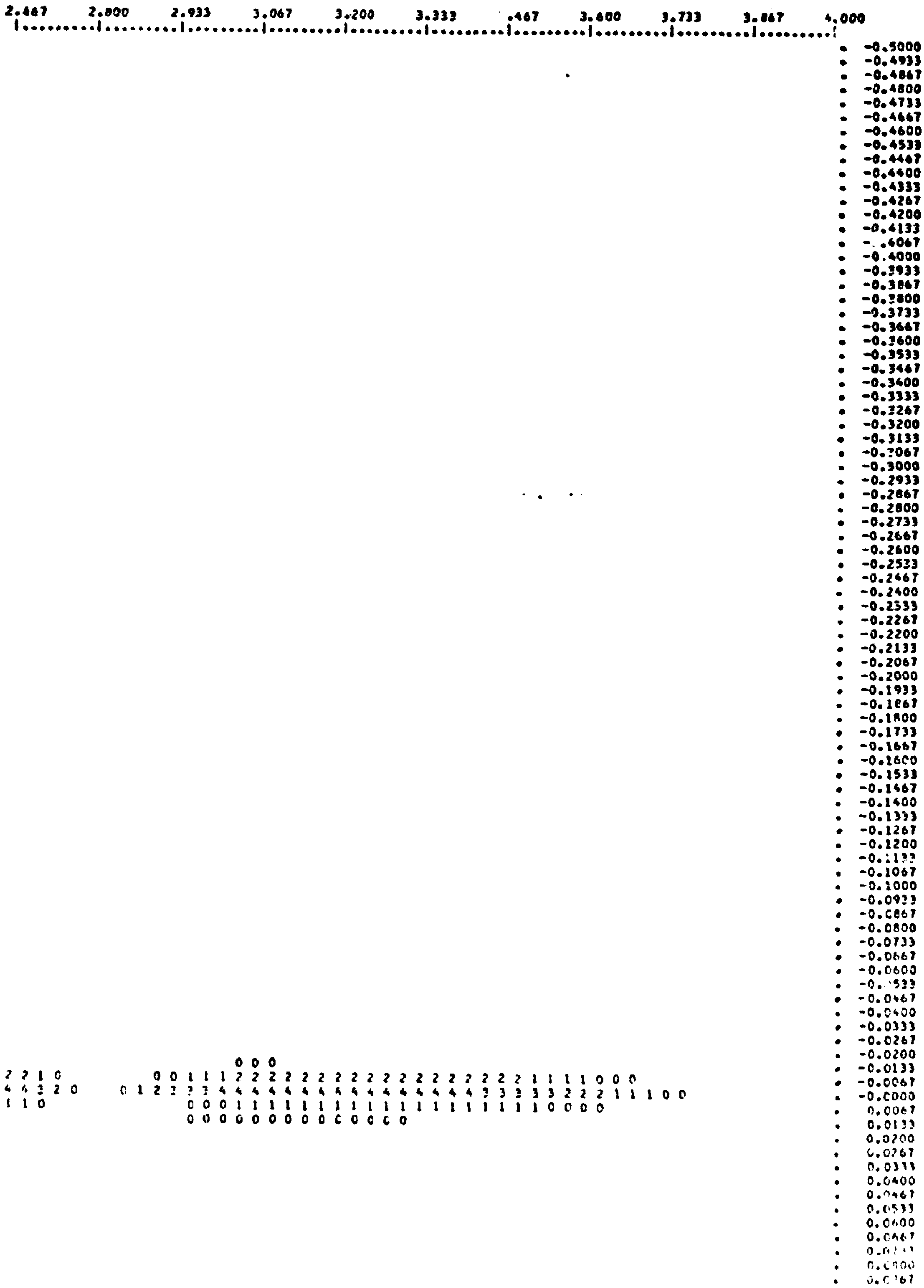
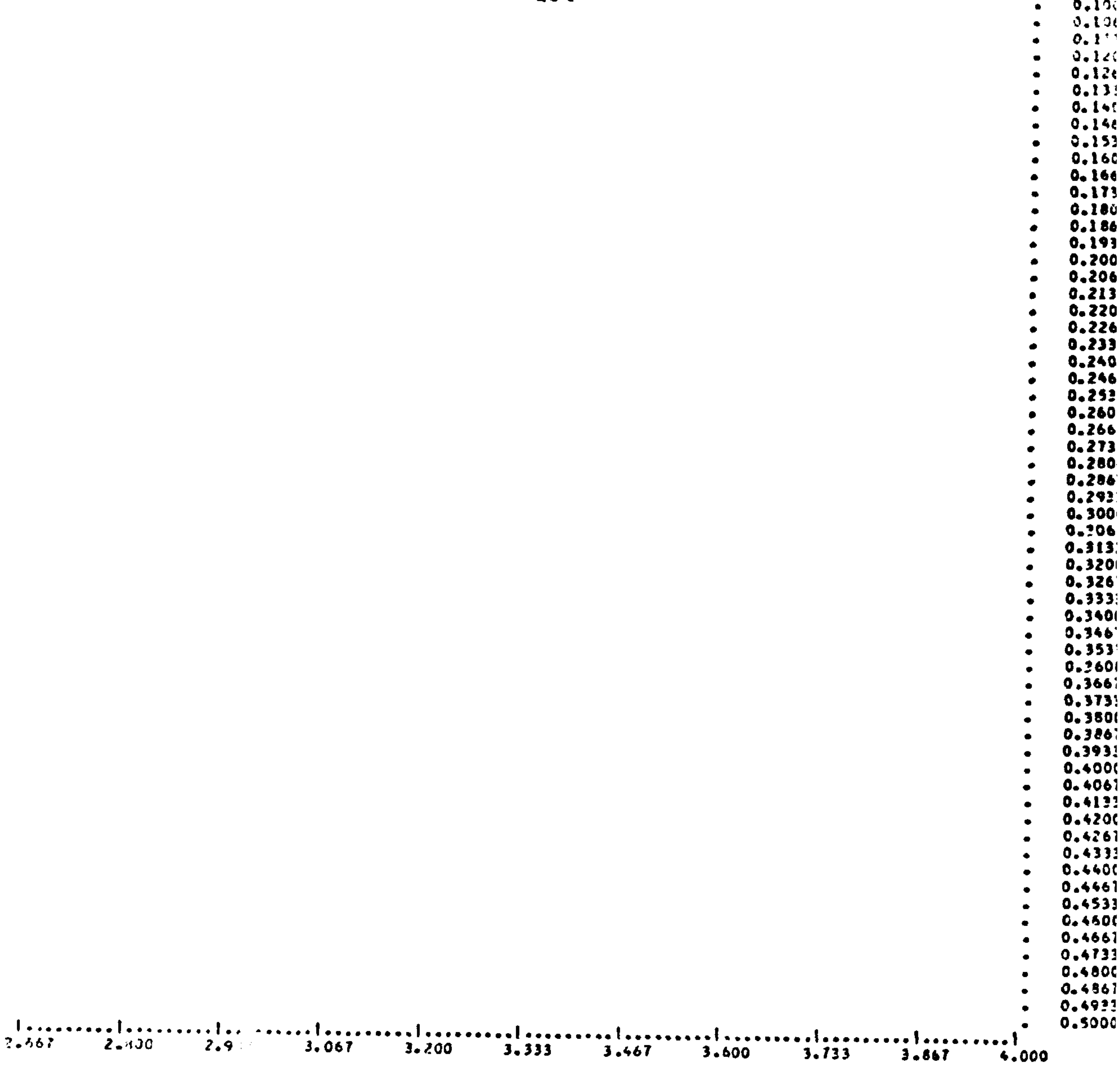
I.........I.........I.........I.........I.........I.........I.........I.........I.........I.........I
1.333     1.467     1.600     1.733     1.867     2.000     2.133     2.267     2.400     2.533     2.667
```

CONTOUR LEVEL KEY

```
0: -0.2850000E 02 TO -0.2549998E 02    4: -0.1650000E 02 TC -0.1349999E 02    8: -C.4500000E 01 TO -C.1499950E 01
1: -0.2550000E 02 TO -0.2249998E 02    5: -0.1350000E 02 TO -0.1049999E 02    9: -0.1500000E 01 TO  0.1500010E 01
2: -0.2250000E 02 TO -0.1949998E 02    6: -0.1050000E 02 TO -0.7499990E 01     : -0.1000000E 51 TO -0.2850000E 02
3: -0.1950000E 02 TO -0.1649998E 02    7: -C.7500000E 01 TO -0.4499990E 01    +:  0.1500010E 01 TO  0.1000000E 51
```

PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 103




3.067
3.200
3.333
3.467
3.600
3.733
3.867
4.000

X-AXIS PROFILE PLOT ALONG 2.144 DEGREES LATITUDE.
PATTERN NUMBER 103

SCALE FACTOR IS 1.0**-2

REAL 99.9427 79.9560 59.9653 39.9826 19.9959 0.0392

CR.	REAL	
-44.02	C.449	0.5000
-44.71	C.591	0.4980
-44.11	0.293	0.4960
-72.41	C.024	0.4940
-49.24	0.345	0.4920
-45.50	C.531	0.4900
-47.10	C.442	0.4880
-58.27	0.122	0.4860
-51.49	0.256	0.4840
-45.58	0.576	0.4820
-45.61	0.524	0.4800
-51.65	C.262	0.4780
-57.77	0.129	0.4760
-46.95	C.449	0.4740
-45.44	C.534	0.4720
-45.37	0.340	^.4700
-69.13	0.035	0.4680
-47.99	C.399	0.4660
-44.76	C.565	0.4640
-47.00	C.447	0.4620
-59.49	0.106	0.4600
-51.06	0.280	0.4580
-45.90	C.507	0.4560
-46.90	0.452	0.4540
-57.40	C.135	0.4520
-50.88	0.286	0.4500
-44.51	0.595	0.4480
-44.01	C.620	0.4460
-48.70	C.367	0.4440
-63.60	C.066	0.4420
-46.87	C.453	0.4400
-44.46	0.596	0.4380
-47.38	C.426	0.4360
-70.73	C.029	0.4340
-48.12	0.293	0.4320
-44.16	C.619	0.4300
-45.47	0.533	0.4280
-55.04	C.177	0.4260
-51.51	C.266	0.4240
-44.97	0.565	0.4220
-44.97	C.564	0.4200
-51.59	C.463	0.4180
-54.76	C.193	0.4160
-45.32	C.542	0.4140
-44.07	C.626	0.4120
-48.17	C.390	0.4100
-67.71	C.041	0.4080
-47.16	C.439	0.4060
-44.61	C.565	0.4040
-47.92	C.407	0.4020
-70.21	0.031	0.4000
-46.23	C.485	0.3980
-42.72	C.731	0.3960
-44.06	0.626	0.3940
-53.14	C.230	0.3920
-50.96	0.233	0.3900
-44.C4	C.627	0.3880
43.95	0.634	C.3860
-50.41	0.302	0.3840
-54.C2	0.199	0.3820
-44.38	0.604	0.3800
-47.08	C.702	0.3780
-47.15	C.439	0.3760
-66.24	0.049	0.3740
-45.52	C.505	0.3720
-43.23	C.686	0.3700
-45.98	0.533	0.3680
-67.79	C.041	0.3660
-46.90	0.452	0.3640
-47.91	C.716	0.3620
-44.30	C.609	0.3600
-59.50	C.189	0.3580
-49.84	0.321	0.3560
-43.63	[illegible]	0.3540
[illegible]	[illegible]	0.3520
-54.20	0.175	0.3500
[illegible]	[illegible]	0.3480
[illegible]	0.768	0.3460
-41.76	C.616	0.3440
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[illegible]	[illegible]	0.3400
[illegible]	[illegible]	0.3380
[illegible]	C.777	0.3360
[illegible]	[illegible]	0.3340
[illegible]	[illegible]	0.3320
-45.01	[illegible]	[illegible]
-61.7	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

-42.21	0.775	0.3200
-43.17	0.695	0.3180
-53.78	0.232	0.3160
-44.71	0.347	0.3140
-42.13	0.782	0.3120
-42.36	0.789	0.3100
-44.36	0.382	0.3080
-53.19	0.219	0.3060
-43.28	0.686	0.3040
-42.43	0.756	0.3020
-48.43	0.379	0.3000
-51.83	0.255	0.2980
-41.81	0.812	0.2960
-43.11	0.548	0.2940
-42.28	0.678	0.2920
-68.99	0.036	0.2900
-44.32	0.608	0.2880
-40.79	0.913	0.2860
-42.89	0.717	0.2840
-58.17	0.123	0.2820
-45.16	0.552	0.2800
-40.47	0.947	0.2780
-41.46	0.845	0.2760
-50.53	0.258	0.2740
-47.86	0.405	0.2720
-41.08	0.883	0.2700
-41.14	0.977	0.2680
-45.31	0.384	0.2660
-49.58	0.332	0.2640
-41.06	0.885	0.2620
-40.23	0.974	0.2600
-45.26	0.546	0.2580
-55.55	0.167	0.2560
-42.25	0.772	0.2540
-40.66	0.527	0.2520
-45.50	0.531	0.2500
-53.20	0.219	0.2480
-40.70	0.923	0.2460
-38.44	1.196	0.2440
-41.13	0.878	0.2420
-58.39	0.120	0.2400
-43.35	0.680	0.2380
-39.14	1.059	0.2360
-40.82	0.910	0.2340
-53.52	0.211	0.2320
-44.10	0.674	0.2300
-39.85	1.141	0.2280
-39.52	1.057	0.2260
-47.80	0.407	0.2240
-46.81	0.456	0.2220
-37.42	1.069	0.2200
-39.25	1.095	0.2180
-46.00	0.501	0.2160
-48.31	0.384	0.2140
-39.31	1.083	0.2120
-34.34	1.210	0.2100
-43.72	0.690	0.2080
-54.15	0.195	0.2060
-40.39	0.956	0.2040
-38.74	1.157	0.2020
-42.59	0.652	0.2000
-51.08	0.279	0.1980
-34.68	1.164	0.1960
-30.46	1.504	0.1940
-39.23	1.093	0.1920
-57.81	0.129	0.1900
-41.09	0.832	0.1880
-37.09	1.393	0.1860
-32.60	1.135	0.1840
-52.79	0.279	0.1820
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[illegible]	1.474	0.1780
-37.53	1.329	0.1760
-46.57	0.469	0.1740
-43.78	0.647	0.1720
-37.02	1.408	0.1700
-37.16	1.387	0.1680
-44.74	0.579	0.1660
-44.73	0.580	0.1640
-35.73	1.458	0.1620
-36.13	1.562	0.1600
-41.70	0.922	0.1580
-49.89	0.259	0.1560
-37.56	1.324	0.1540
-36.41	1.512	0.1520
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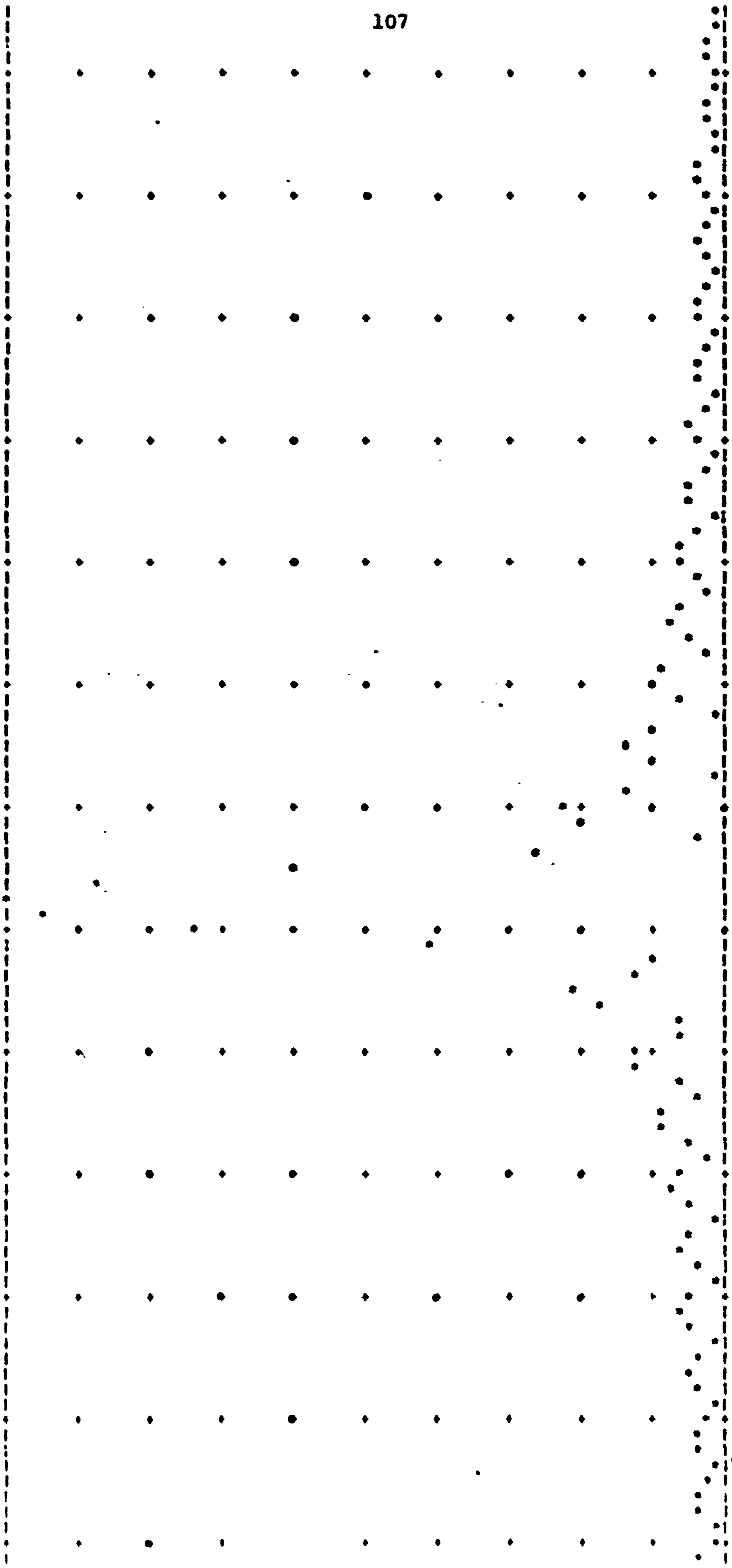
-45.97	0.502	0.1480
[illegible]	1.648	0.1460
-33.62	2.011	0.1440
[illegible]	[illegible]	0.1420
[illegible]	0.014	0.1400
[illegible]	1.374	0.1380
-34.22	1.924	0.1360
[illegible]	1.665	0.1340
-52.67	0.131	0.1320
[illegible]	1.311	0.1300
-33.62	2.066	0.1280
-35.17	1.754	0.1260
[illegible]	0.459	0.1240
[illegible]	1.105	0.1220
[illegible]	[illegible]	0.1200
[illegible]	[illegible]	0.1180



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-33.75	2.175	0.1100
-40.42	0.953	0.1080
-41.97	0.797	0.1060
-33.58	2.093	0.1040
-33.32	2.159	0.1020
-41.06	0.885	0.1000
-39.24	1.091	0.0980
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-34.96	1.787	0.0920
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-32.58	2.349	0.0880
-30.39	3.024	0.0860
-34.02	1.990	0.0840
-52.29	0.243	0.0820
-32.13	2.474	0.0800
-29.24	3.452	0.0780
-31.80	2.572	0.0760
-52.37	0.241	0.0740
-32.76	2.301	0.0720
-28.82	3.622	0.0700
-30.70	2.918	0.0680
-46.53	0.471	0.0660
-32.31	2.423	0.0640
-27.63	4.152	0.0620
-29.71	3.669	0.0600
-39.00	1.123	0.0580
-33.39	2.141	0.0560
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-40.21	0.576	0.0500
-30.31	3.052	0.0480
-24.42	6.013	0.0460
-24.29	6.162	0.0440
-30.55	2.967	0.0420
-34.21	1.949	0.0400
-24.34	6.070	0.0380
-23.12	6.985	0.0360
-28.31	3.842	0.0340
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-22.48	7.518	0.0300
-20.43	9.461	0.0280
-24.15	6.201	0.0260
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-20.97	8.941	0.0220
-17.94	12.674	0.0200
-20.64	9.286	0.0180
-41.21	0.878	0.0160
-17.39	13.501	0.0140
-13.24	21.772	0.0120
-14.34	19.192	0.0100
-31.78	2.575	0.0080
-11.75	25.635	0.0060
-4.60	58.261	0.0040
-1.26	86.531	0.0020
-0.01	99.943	0.0000
-0.47	94.690	-0.0020
-2.78	72.596	-0.0040
-7.75	40.974	-0.0060
-20.22	9.747	-0.0080
-18.19	12.322	-0.0100
-13.62	20.835	-0.0120
-15.52	16.755	-0.0140
-25.26	5.455	-0.0160
-24.26	6.122	-0.0180
-18.10	12.439	-0.0200
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-30.91	2.847	-0.0260
-21.56	7.979	-0.0280
-21.73	8.194	-0.0300
-27.87	4.043	-0.0320
-34.59	1.760	-0.0340
-24.32	6.080	-0.0360
-23.36	6.793	-0.0380
-28.04	3.945	-0.0400
-44.47	0.549	-0.0420
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-25.81	5.123	-0.0460
-30.59	2.956	-0.0480
-40.95	0.896	-0.0500
-27.39	4.270	-0.0520
-25.34	5.408	-0.0540
-24.33	3.812	-0.0560
-45.76	0.515	-0.0580
-31.26	2.710	-0.0600
-27.55	4.199	-0.0620
-29.64	3.260	-0.0640
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[illegible]	[illegible]	-0.0820
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[illegible]	2.717	-0.0860

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-35.25	1.727	-0.1220
-49.65	0.328	-0.1240
-38.64	1.170	-0.1260
-34.17	1.957	-0.1280
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-47.53	0.420	-0.1320
-39.99	1.001	-0.1340
-34.65	1.851	-0.1360
-35.44	1.691	-0.1380
-43.79	0.646	-0.1400
-43.35	0.680	-0.1420
-36.22	1.545	-0.1440
-36.62	1.476	-0.1460
-45.66	0.521	-0.1480
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-35.19	1.740	-0.1520
-34.80	1.829	-0.1540
-40.04	0.955	-0.1560
-51.03	0.281	-0.1580
-37.54	1.327	-0.1600
-35.92	1.600	-0.1620
-40.15	0.982	-0.1640
-55.81	0.162	-0.1660
-38.35	1.204	-0.1680
-36.99	1.594	-0.1700
-39.02	1.119	-0.1720
-61.76	0.022	-0.1740
-40.42	0.952	-0.1760
-36.91	1.427	-0.1780
-39.17	1.101	-0.1800
-55.15	0.175	-0.1820
-41.55	0.826	-0.1840
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-39.54	1.183	-0.1880
-48.66	0.369	-0.1900
-44.46	0.593	-0.1920
-38.57	1.178	-0.1940
-39.54	1.055	-0.1960
-50.54	0.297	-0.1980
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-37.42	1.345	[illegible]2040
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-38.34	1.211	-0.2120
-43.09	0.701	-0.2140
-54.55	0.187	-0.2160
-40.32	0.966	-0.2180
-38.26	1.222	-0.2200
-41.62	0.930	-0.2220
-75.18	0.017	-0.2240
-42.23	0.774	-0.2260
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-41.53	0.839	-0.2300
-59.52	0.106	-0.2320
-43.34	0.693	-0.2340
-39.21	1.095	-0.2360
-40.65	0.924	-0.2380
-51.23	0.274	-0.2400
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-41.55	0.836	-0.2460
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-45.25	0.546	-0.2500
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-39.31	1.092	-0.2540
-45.12	0.555	-0.2560
-52.00	0.224	-0.2580
-41.49	0.843	-0.2600
-40.15	0.983	-0.2620
-44.65	0.545	-0.2640
-57.85	0.128	-0.2660
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-40.07	0.997	-0.2700
-43.07	0.7[illegible]7	-0.2720
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-50.[illegible]	[illegible]	[illegible]

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-42.74	0.724	-0.2960
-51.04	0.261	-0.2980
-46.99	0.385	-0.3000
-41.24	0.867	-0.3020
-43.51	0.930	-0.3040
-45.27	0.539	-0.3060
-59.58	0.104	-0.3080
-43.67	0.554	-0.3100
-41.54	0.828	-0.3120
-44.95	0.566	-0.3140
-30.71	0.009	-0.3160
-44.77	0.577	-0.3180
-41.52	0.840	-0.3200
-43.56	0.664	-0.3220
-56.47	0.150	-0.3240
-47.45	0.424	-0.3260
-42.44	0.755	-0.3280
-43.44	0.673	-0.3300
-52.85	0.229	-0.3320
-49.44	0.337	-0.3340
-42.92	0.723	-0.3360
-42.76	0.729	-0.3380
-48.90	0.259	-0.3400
-54.86	0.181	-0.3420
-44.48	0.597	-0.3440
-43.54	0.666	-0.3460
-49.20	0.347	-0.3480
-54.41	0.193	-0.3500
-43.55	0.664	-0.3520
-41.68	0.824	-0.3540
-44.65	0.586	-0.3560
-62.78	0.073	-0.3580
-46.93	0.450	-0.3600
-42.90	0.716	-0.3620
-44.53	0.594	-0.3640
-56.15	0.156	-0.3660
-48.77	0.364	-0.3680
-42.15	0.693	-0.3700
-43.57	0.663	-0.3720
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-45.04	0.560	-0.4120
-44.24	0.614	-0.4140
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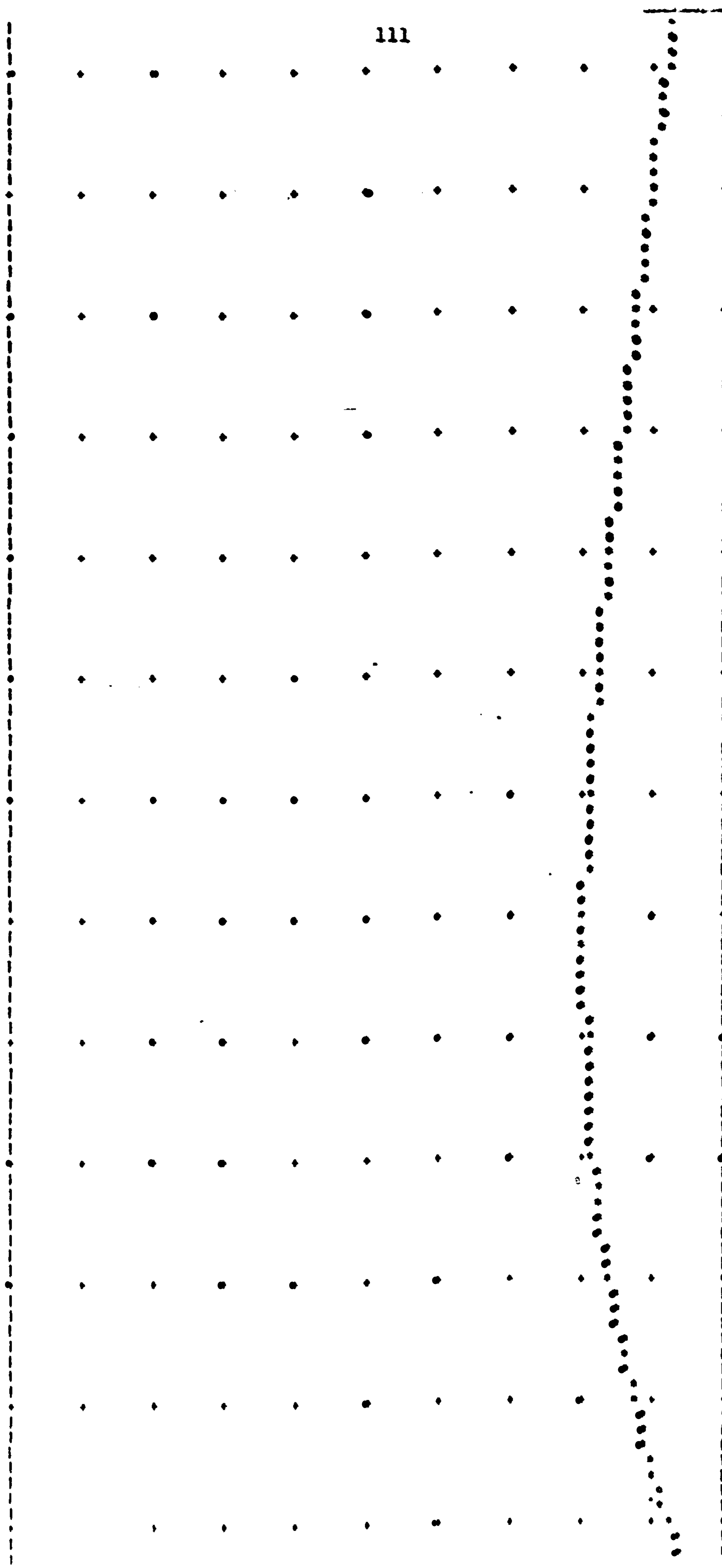
-59.45	0.107	-0.4180
-46.01	0.501	-0.4200
-43.90	0.638	-0.4220
-45.59	0.452	-0.4240
-67.30	0.043	-0.4260
-48.52	0.375	-0.4280
-44.62	0.587	-0.4300
-46.23	0.488	-0.4320
-57.55	0.133	-0.4340
-50.70	0.292	-0.4360
-45.45	0.566	-0.4380
-45.17	0.551	-0.4400
-51.67	0.251	-0.4420
-56.51	0.149	-0.4440
-46.69	0.463	-0.4460
-45.77	0.515	-0.4480
-51.20	0.275	-0.4500
-57.53	0.133	-0.4520
-46.00	0.501	-0.4540
-43.86	0.641	-0.4560
-46.38	0.480	-0.4580
-60.14	0.097	-0.4600
-50.09	[illegible]	-0.4620
-45.21	0.349	-0.4640
-46.10	0.495	-0.4660
-54.55	0.195	-0.4680
-51.15	0.220	-0.4700
-45.74	0.514	-0.4720
-45.11	0.544	-0.4740
-50.31	0.312	-0.4760
-62.09	0.073	-0.4780
-47.7	0.410	-0.4800
[illegible]	[illegible]	-0.4820
[illegible]	[illegible]	-0.4840
-72.[illegible]	0.024	-0.4860
[illegible]	[illegible]	-0.4880
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

-53.[illegible]	0.203	-0.4960
-47.[illegible]	0.445	-0.4980
-47.12	0.440	-0.5000

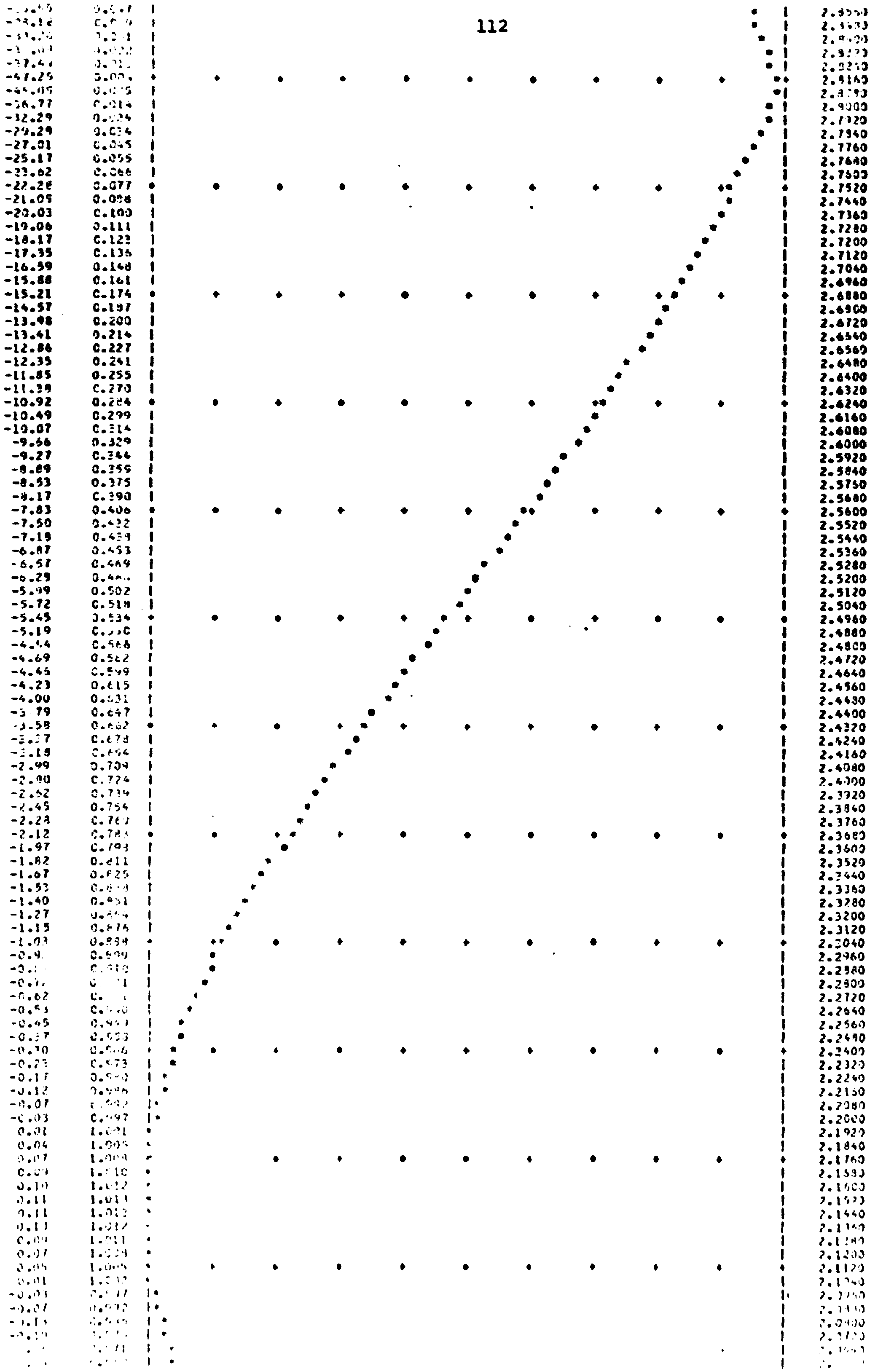
DB.	REAL	99.9427	79.9560	59.9673	39.9826	19.9959	0.0072

Y-AXIS PROFILE PLOT ALONG 0.0 LONGITUDE.
PATTERN NUMBER 103

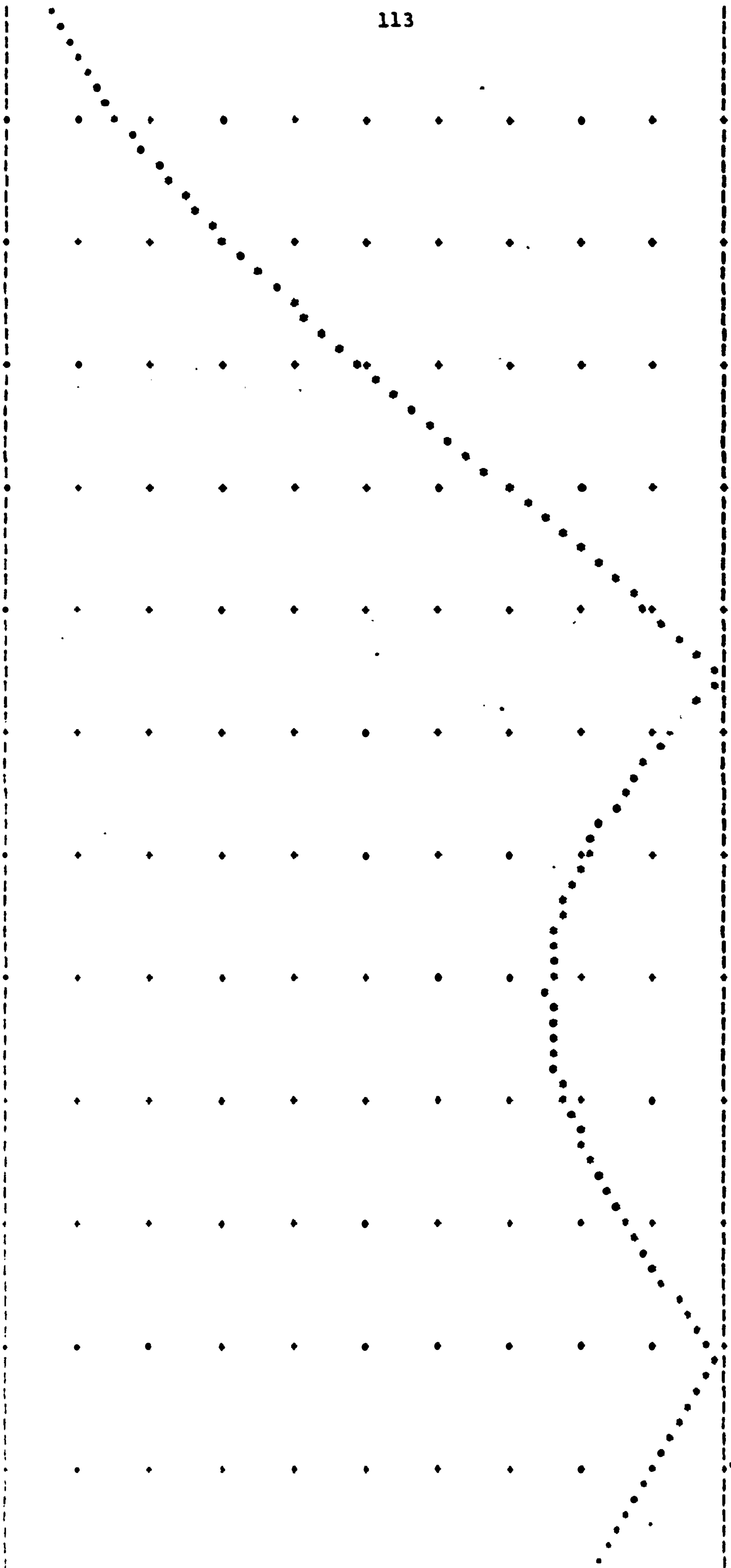
DB.	REAL	1.0126	C.8102	0.6077	0.4053	0.2029	0.0004
-33.08	0.022						3.9998
-33.75	0.021						3.9918
-34.49	0.019						3.9838
-35.32	0.C17						3.9759
-35.25	0.015						3.9679
-37.31	0.014						2.9599
-38.54	0.012						3.9519
-40.00	C.010						3.9439
-41.79	0.008						3.9359
-44.05	C.006						3.9279
-47.26	0.C04						3.9199
-52.43	C.002						3.9119
-67.64	0.000						3.9039
-54.01	0.002						3.8959
-48.84	C.004						3.8879
-44.92	0.006						3.8799
-42.21	C.008						3.8719
-40.12	C.010						3.8639
-38.41	0.012						3.8559
-36.97	0.014						3.8479
-35.72	C.C16						3.8399
-34.62	C.C19						3.8319
-33.65	C.021						3.8239
-32.[illegible]	0.023						3.8159
-31.91	0.025						3.8079
-31.15	C.028						3.7999
[illegible]	0.030						3.7919
[illegible]	0.032						3.7839
[illegible].17	0.035						3.7759
[illegible]	0.037						[illegible]
[illegible]	0.040						3.7559
[illegible]	0.042						3.7519
[illegible]	C.045						[illegible]
[illegible]	0.047						[illegible]
[illegible]	0.050						[illegible]
[illegible]	[illegible]						[illegible]
[illegible]	[illegible]						[illegible]
[illegible]	[illegible]						[illegible]
[illegible]	[illegible]						[illegible]
[illegible]	[illegible]						[illegible]
[illegible]	[illegible]						[illegible]

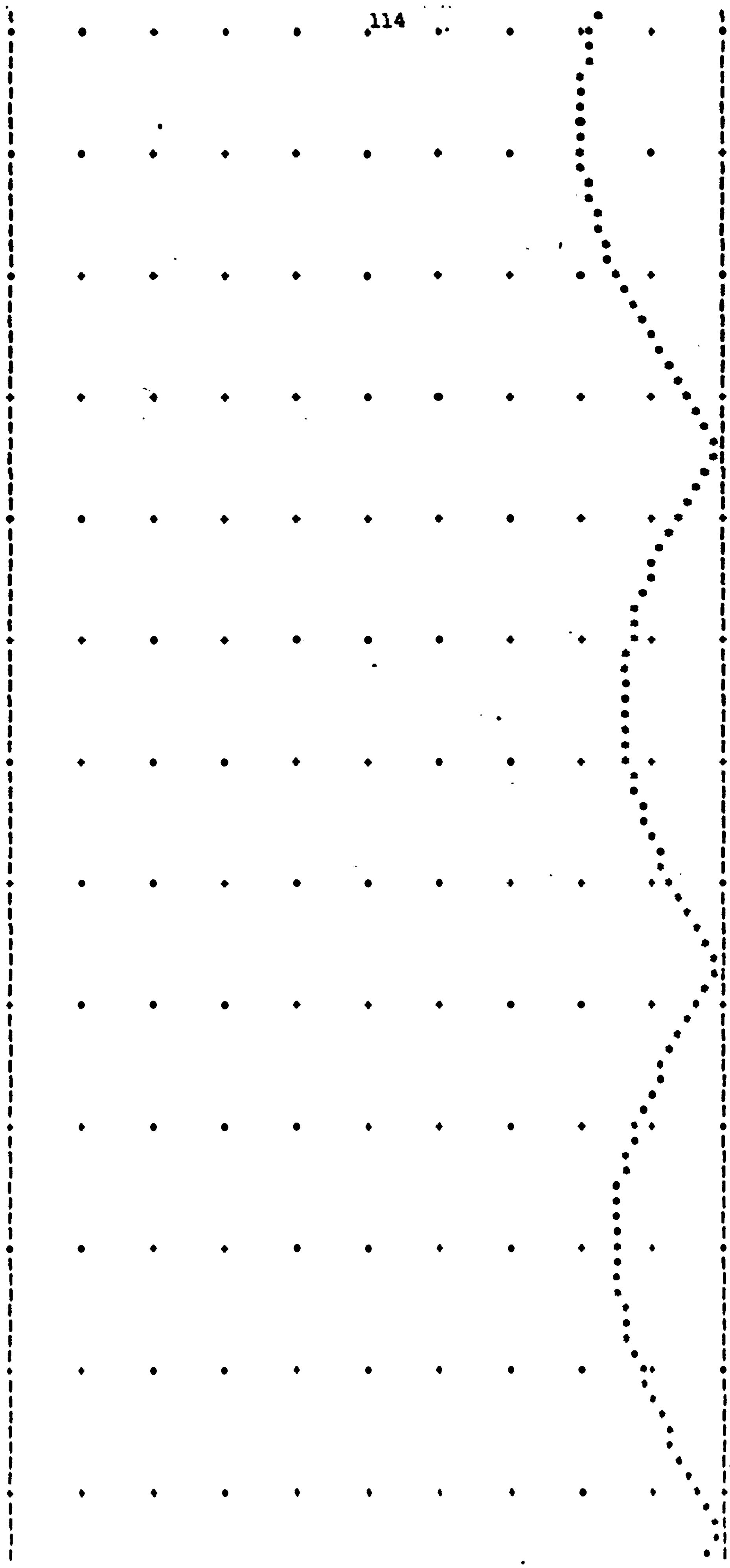


-23.40	0.068	3.6719
-23.04	0.070	3.6639
-22.74	0.072	3.6559
-22.43	0.076	3.6479
-22.13	0.078	3.6399
-21.84	0.081	3.6319
-21.55	0.084	3.6239
-21.28	0.086	3.6159
-21.01	0.089	3.6079
-20.75	0.092	3.5999
-20.50	0.094	3.5919
-20.25	0.097	3.5839
-20.02	0.100	3.5759
-19.78	0.103	3.5679
-19.56	0.105	3.5599
-19.34	0.108	3.5519
-19.13	0.111	3.5439
-18.92	0.113	3.5359
-18.72	0.116	3.5279
-18.52	0.119	3.5199
-18.33	0.121	3.5119
-18.14	0.124	3.5039
-17.96	0.126	3.4959
-17.78	0.129	3.4879
-17.61	0.132	3.4799
-17.44	0.134	3.4719
-17.28	0.137	3.4639
-17.12	0.139	3.4559
-16.97	0.142	3.4479
-16.82	0.144	3.4399
-16.67	0.147	3.4319
-16.54	0.149	3.4239
-16.40	0.151	3.4159
-16.27	0.154	3.4079
-16.14	0.156	3.3999
-16.02	0.158	3.3919
-15.90	0.160	3.3839
-15.79	0.162	3.3759
-15.68	0.164	3.3679
-15.57	0.166	3.3599
-15.47	0.168	3.3519
-15.37	0.170	3.3439
-15.28	0.172	3.3359
-15.19	0.174	3.3279
-15.11	0.176	3.3199
-15.02	0.177	3.3119
-14.95	0.179	3.3039
-14.88	0.180	3.2959
-14.81	0.182	3.2879
-14.75	0.183	3.2799
-14.69	0.184	3.2719
-14.64	0.185	3.2639
-14.59	0.186	3.2559
-14.54	0.187	3.2479
-14.50	0.188	3.2399
-14.47	0.189	3.2319
-14.44	0.190	3.2239
-14.41	0.190	3.2159
-14.39	0.191	3.2079
-14.38	0.191	3.1999
-14.37	0.191	3.1919
-14.37	0.191	3.1839
-14.37	0.191	3.1759
-14.38	0.191	3.1679
-14.39	0.191	3.1599
-14.41	0.190	3.1519
-14.44	0.190	3.1439
-14.47	0.189	3.1359
-14.51	0.188	3.1279
-14.56	0.187	3.1199
-14.61	0.186	3.1119
-14.68	0.185	3.1039
-14.75	0.183	3.0959
-14.83	0.181	3.0879
-14.91	0.180	3.0800
-15.01	0.178	3.0719
-15.12	0.175	3.0640
-15.23	0.173	3.0560
-15.36	0.171	3.0480
-15.50	0.168	3.0400
-15.65	0.165	3.0320
-15.82	0.162	3.0240
-16.00	0.159	3.0160
-16.19	0.155	3.0080
-16.40	0.151	3.0000
-16.6[illegible]	0.147	2.9920
-16.87	0.143	2.9840
-17.14	0.1[illegible]	2.9760
-17.43	0.134	2.9680
-17.74	0.130	2.9600
-18.08	0.125	2.9520
-18.45	0.120	2.9440
[illegible]	0.114	2.9360
[illegible]	0.109	2.9280
-19.74	0.103	2.9200
-20.71	0.096	2.9120
[illegible]	[illegible]	2.9040
[illegible]	[illegible]	2.8960
[illegible]	0.077	2.8880
[illegible]	0.070	2.8800
[illegible]	[illegible]	2.8720
[illegible]	[illegible]	2.8640



-0.57	0.942	2.0400
-0.67	0.931	2.0320
-0.73	0.920	2.0240
-0.85	0.907	2.0160
-0.98	0.893	2.0080
-1.12	0.879	2.0000
-1.27	0.864	1.9920
-1.43	0.848	1.9840
-1.60	0.832	1.9760
-1.78	0.815	1.9680
-1.97	0.797	1.9600
-2.18	0.778	1.9520
-2.40	0.759	1.9440
-2.63	0.739	1.9360
-2.88	0.718	1.9280
-3.14	0.697	1.9200
-3.41	0.675	1.9120
-3.70	0.653	1.9040
-4.01	0.630	1.8960
-4.34	0.607	1.8880
-4.69	0.583	1.8800
-5.05	0.559	1.8720
-5.44	0.534	1.8640
-5.86	0.509	1.8560
-6.30	0.484	1.8480
-6.77	0.459	1.8400
-7.27	0.433	1.9320
-7.80	0.407	1.8240
-8.37	0.381	1.8160
-8.98	0.355	1.8080
-9.64	0.329	1.8000
-10.36	0.303	1.7920
-11.14	0.277	1.7840
-11.98	0.252	1.7760
-12.92	0.226	1.7680
-12.96	0.200	1.7600
-15.13	0.175	1.7520
-16.46	0.150	1.7440
-18.00	0.126	1.7360
-19.85	0.102	1.7280
-22.14	0.078	1.7200
-25.19	0.055	1.7120
-29.73	0.032	1.7040
-39.58	0.010	1.6960
-39.34	0.011	1.6880
-30.07	0.031	1.6800
-25.81	0.051	1.6720
-23.07	0.070	1.6640
-21.07	0.088	1.6560
-19.51	0.106	1.6480
-18.26	0.122	1.6400
-17.22	0.138	1.6320
-16.35	0.152	1.6240
-15.62	0.165	1.6160
-14.99	0.178	1.6080
-14.45	0.189	1.6000
-13.99	0.200	1.5920
-13.60	0.209	1.5840
-13.28	0.217	1.5760
-13.00	0.224	1.5680
-12.79	0.229	1.5600
-12.61	0.234	1.5520
-12.45	0.237	1.5440
-12.41	0.240	1.5360
-12.37	0.241	1.5280
-12.37	0.241	1.5200
-12.41	0.240	1.5120
-12.49	0.237	1.5040
-12.62	0.234	1.4960
-12.79	0.229	1.4880
-13.00	0.224	1.4800
-13.25	0.217	1.4720
-13.56	0.210	1.4640
-13.91	0.202	1.4560
-14.32	0.192	1.4480
-14.80	0.182	1.4400
-15.33	0.171	1.4320
-15.95	0.159	1.4240
-16.65	0.147	1.4160
-17.45	0.134	1.4080
-18.38	0.121	1.4000
-19.43	0.107	1.3920
-20.72	0.092	1.3840
-22.24	0.077	1.3760
-24.13	0.062	1.3680
-26.58	0.047	1.3600
-30.04	0.031	1.3520
-35.91	0.016	1.3440
-64.39	0.001	1.3360
-36.61	0.015	1.3280
-30.47	0.030	1.3200
-26.95	0.045	1.3120
-24.51	0.059	1.3040
-22.65	0.074	1.2960
-21.11	0.087	1.2880
[illegible]	0.101	1.2800
-18.92	0.112	1.2720
-18.05	0.125	1.2640
-17.31	0.136	1.2560
-16.67	0.147	1.2480
-16.12	0.156	1.2400
[illegible]	0.165	1.2320





-15.26	0.173	1.2240
-14.92	0.179	1.2160
-14.65	0.185	1.2080
-14.41	0.190	1.2000
-14.27	0.193	1.1920
-14.16	0.196	1.1840
-14.09	0.197	1.1760
-14.08	0.198	1.1680
-14.11	0.197	1.1600
-14.19	0.195	1.1520
-14.32	0.192	1.1440
-14.51	0.188	1.1360
-14.74	0.183	1.1280
-15.03	0.177	1.1200
-15.38	0.170	1.1120
-15.80	0.162	1.1040
-16.28	0.153	1.0960
-16.84	0.144	1.0880
-17.49	0.133	1.0800
-18.24	0.122	1.0720
-19.11	0.111	1.0640
-20.12	0.099	1.0560
-21.31	0.086	1.0480
-22.74	0.073	1.0400
-24.49	0.060	1.0320
-26.72	0.046	1.0240
-29.76	0.032	1.0160
-34.50	0.019	1.0080
-45.60	0.005	1.0000
-41.74	0.008	0.9920
-33.41	0.021	0.9840
-29.32	0.034	0.9760
-26.62	0.047	0.9680
-24.65	0.059	0.9600
-23.11	0.070	0.9520
-21.88	0.081	0.9440
-20.87	0.090	0.9360
-20.04	0.100	0.9280
-19.25	0.108	0.9200
-18.78	0.115	0.9120
-18.31	0.121	0.9040
-17.94	0.127	0.8960
-17.65	0.131	0.8880
-17.44	0.134	0.8800
-17.31	0.136	0.8720
-17.25	0.137	0.8640
-17.26	0.137	0.8560
-17.35	0.136	0.8480
-17.50	0.133	0.8400
-17.73	0.130	0.8320
-18.05	0.125	0.8240
-18.44	0.120	0.8160
-18.94	0.113	0.8080
-19.53	0.106	0.8000
-20.25	0.097	0.7920
-21.12	0.088	0.7840
-22.16	0.078	0.7760
-23.42	0.067	0.7680
-24.99	0.056	0.7600
-27.01	0.045	0.7520
-29.74	0.033	0.7440
-33.88	0.020	0.7360
-42.28	0.008	0.7280
-46.09	0.005	0.7200
-35.09	0.018	0.7120
-30.41	0.030	0.7040
-27.42	0.043	0.6960
-25.25	0.055	0.6880
-23.57	0.066	0.6800
-22.21	0.078	0.6720
-21.09	0.089	0.6640
-20.16	0.098	0.6560
-19.37	0.107	0.6480
-18.71	0.116	0.6400
-18.16	0.124	0.6320
-17.70	0.130	0.6240
-17.33	0.136	0.6160
-17.04	0.141	0.6080
-16.82	0.144	0.6000
-16.67	0.147	0.5920
-16.58	0.148	0.5840
-16.56	0.149	0.5760
-16.61	0.148	0.5680
-16.72	0.146	0.5600
-16.89	0.143	0.5520
-17.14	0.139	0.5440
-17.46	0.134	0.5360
-17.86	0.128	0.5280
-18.34	0.121	0.5200
-18.92	0.113	0.5120
-19.61	0.105	0.5040
-20.42	0.095	0.4960
-21.37	0.085	0.4880
-22.52	0.075	0.4800
-23.90	0.064	0.4720
-25.61	0.052	0.4640
-27.80	0.041	0.4560
-30.90	0.029	0.4480
-35.47	0.017	0.4400
[illegible]	0.005	0.4320
[illegible]	0.007	0.4240
[illegible]	0.019	0.4160

DB.	REAL	
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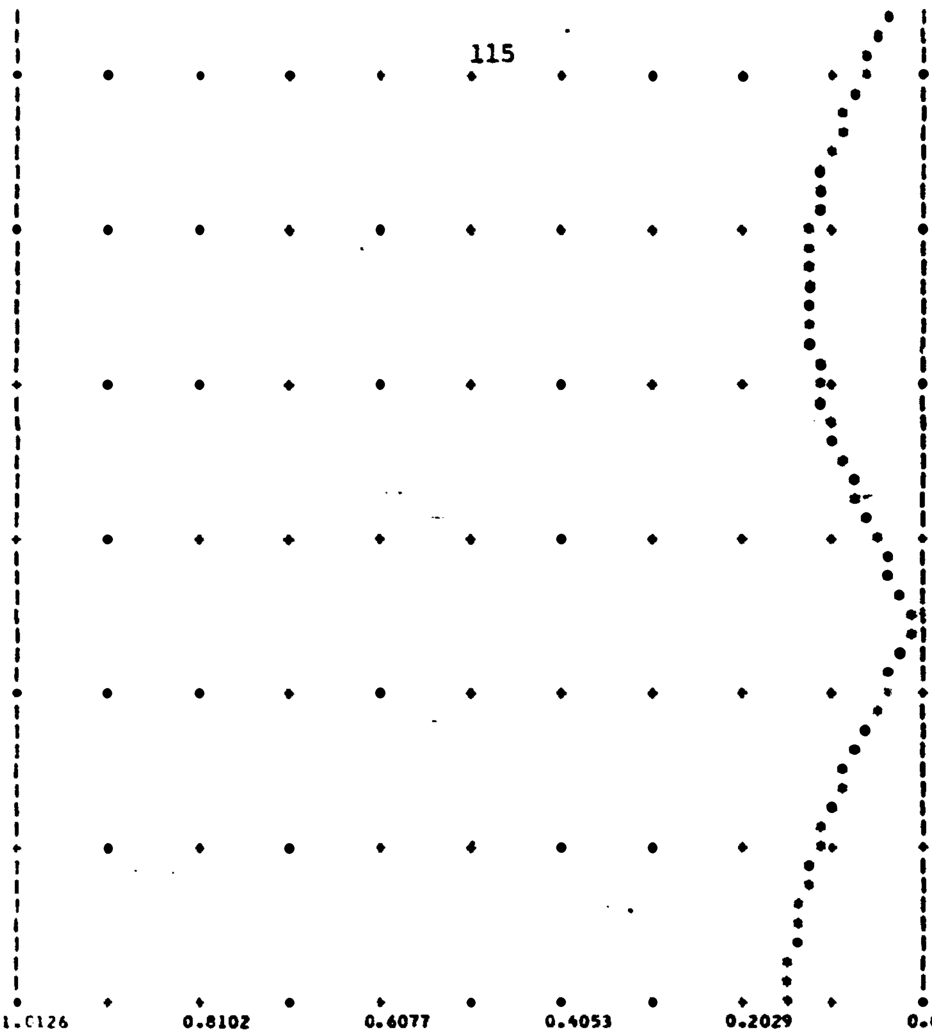
-27.47	0.041	0.4000
-25.69	0.052	0.3920
-24.13	0.062	0.3840
-22.90	0.072	0.3760
-21.89	0.080	0.3680
-21.06	0.089	0.3600
-20.37	0.096	0.3520
-19.81	0.102	0.3440
-19.35	0.108	0.3360
-18.99	0.112	0.3280
-18.71	0.116	0.3200
-18.52	0.119	0.3120
-18.40	0.120	0.3040
-18.36	0.121	0.2960
-18.38	0.120	0.2880
-18.48	0.119	0.2800
-18.66	0.117	0.2720
-18.91	0.113	0.2640
-19.24	0.109	0.2560
-19.66	0.104	0.2480
-20.17	0.098	0.2400
-20.79	0.091	0.2320
-21.53	0.084	0.2240
-22.42	0.076	0.2160
-23.48	0.067	0.2080
-24.78	0.058	0.2000
-26.35	0.048	0.1920
-28.46	0.038	0.1840
-31.28	0.027	0.1760
-35.61	0.017	0.1680
-44.89	0.006	0.1600
-45.55	0.005	0.1520
-35.78	0.016	0.1440
-31.32	0.027	0.1360
-28.41	0.038	0.1280
-26.23	0.049	0.1200
-24.61	0.059	0.1120
-23.25	0.069	0.1040
-22.12	0.078	0.0960
-21.17	0.087	0.0880
-20.35	0.096	0.0800
-19.66	0.104	0.0720
-19.06	0.111	0.0640
-18.55	0.118	0.0560
-18.11	0.124	0.0480
-17.74	0.130	0.0400
-17.44	0.134	0.0320
-17.19	0.138	0.0240
-17.00	0.141	0.0160
-16.85	0.144	0.0080
-16.76	0.145	0.0



NORMAL TERMINATION

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EXAMPLE 5:
   DEMONSTRATION OF THE EFFECT OF SHUTTLE ATTITUDE ERRORS ON FULL X-BAND
   HORIZONTAL ARRAY PERFORMANCE.



SYSTEM INFORMATION:
     FREQUENCY =  9.000 GHZ.
     YAW =    2.000 DEGREES
     TILT =   52.000 DEGREES
     TWIST =    5.000 DEGREES
     ALTITUDE =  200.000 KM.


ANTENNA PARAMETERS FOR SIMULATION NUMBER 104
     ELEMENT TYPE: HORIZONTAL DIPOLE
     NUMBER OF ELEMENTS (X,Y) = (504 ,  12)
     INTERELEMENT SPACING (CM.):  2.2966 ,  2.3550
     INTERELEMENT PHASE SHIFT (DEG.):  0.0    ,  0.0


DEFORMATION DATA FOR SIMULATION 104:

0.0        0.0

0.0        0.0



ELECTRICAL DATA FOR SIMULATION 104:

          ( 1, 1)    (
PHSX:      0.0
PHSY:      0.0
AMAG:      1.00
APHS:      0.0



PRINT/PLOT INFORMATION:
     REQUESTED OUTPUT:
          PRINTER PROFILE
          PRINTER CONTOUR
     PLOT RESOLUTION: 151 X 151 POINTS

     STARTX =   -0.500
     STOPX =    0.500
     DELTAX =    0.007

     STARTY =    0.0
     STOPY =    4.000
     DELTAY =    0.027

SUBARRAY DATA SUMMARY FOR PATTERN104:
AREA   XCENT   YCENT   ZAVG   ALPHAX   ALPHAY   AMAG     APHS   PHSX   PHS
  1     0.0     0.0     0.0    0.0      0.0     1.0000   0.0    0.0    0.


PREDICTED BEAM CENTER:
     LATITUDE =   2.3[illegible]47
     LONGITUDE =    0.0026
     RANGE = [illegible].612
     HEADING =    2.000
```
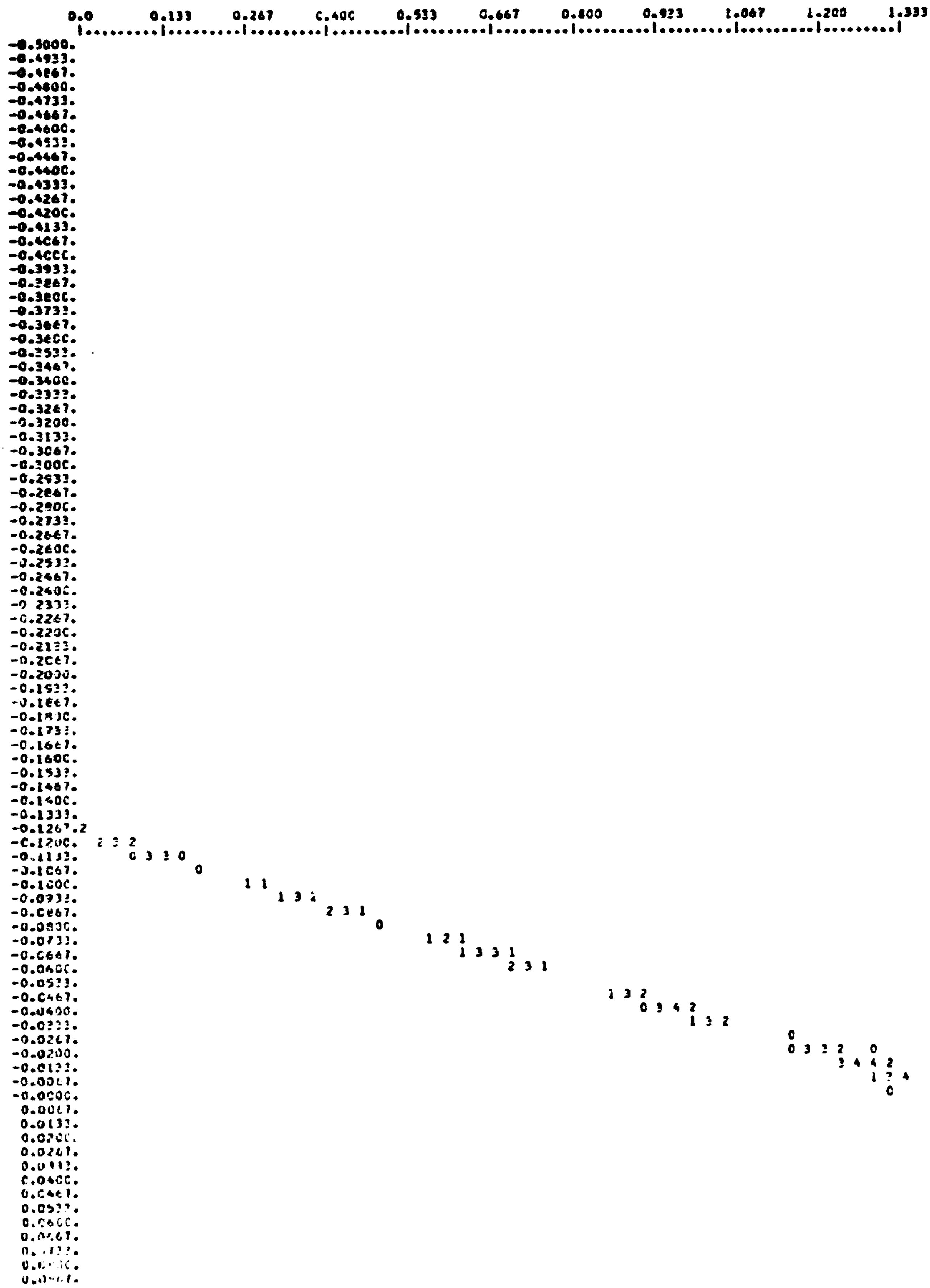
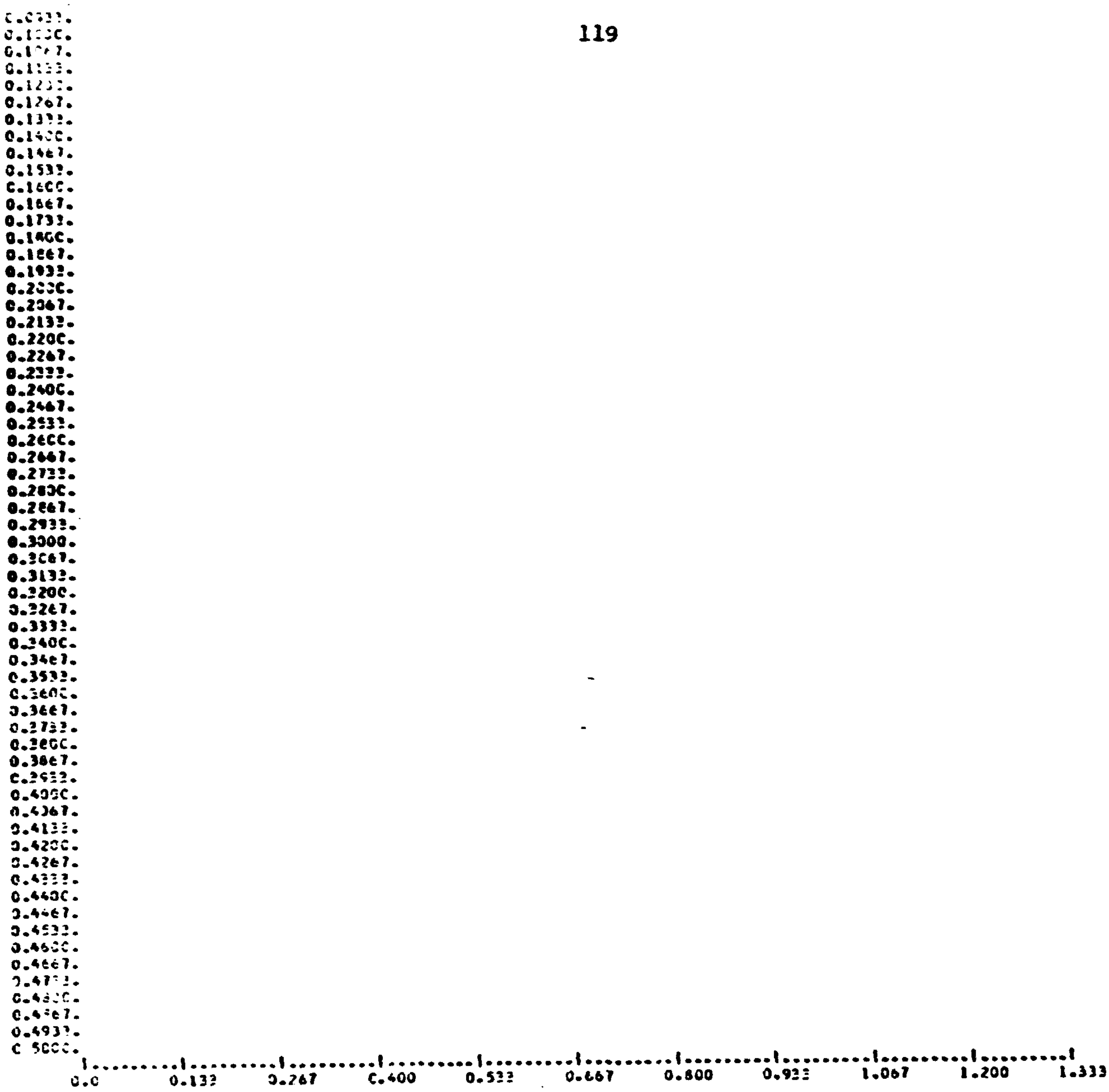

PLCT NCRMALIZATICN FACTCR = -35.418 DB.

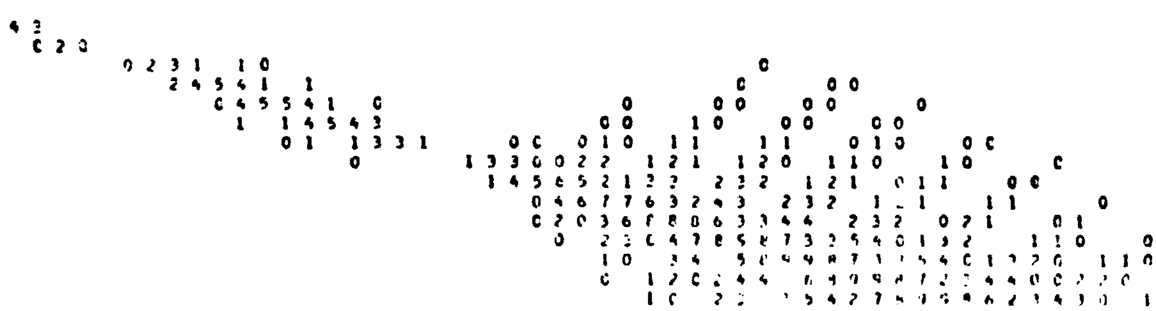
PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 104




0.0
0.133
0.267
0.400
0.533
0.667
0.800
0.933
1.067
1.200
1.333
0.5000.

PRINTEF CONTOUR PLCT FCR SIMULATION NUMBER 104

1.333 1.467 1.600 1.733 1.867 2.000 2.133 2.267 2.400 2.533 2.667



CONTOUR LEVEL KEY

0: -0.2850000E 02 TO -0.2549999E 02	4: -0.1650000E 02 TO -0.1349999E 02	8: -0.4500000E 01 TO -0.1499990E 01
1: -0.2550000E 02 TO -0.2249999E 02	5: -0.1350000E 02 TO -0.1049999E 02	9: -0.1500000E 01 TO 0.1500010E 01
2: -0.2250000E 02 TO -0.1949998E 02	6: -0.1050000E 02 TO -0.7499990E 01	: -0.1000000E 51 TO -0.2850000E 02
3: -0.1950000E 02 TO -0.1649998E 02	7: -0.7500000E 01 TO -0.4499990E 01	+: 0.1500010E 01 TO 0.1000000E 51

PRINTER CONTOUR PLOT FOR SIMULATION NUMBER 104

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2.667     2.800     2.933     3.067     3.200     3.333     3.467     3.600     3.733     3.867     4.000
|.........|.........|.........|.........|.........|.........|.........|.........|.........|..... ...|
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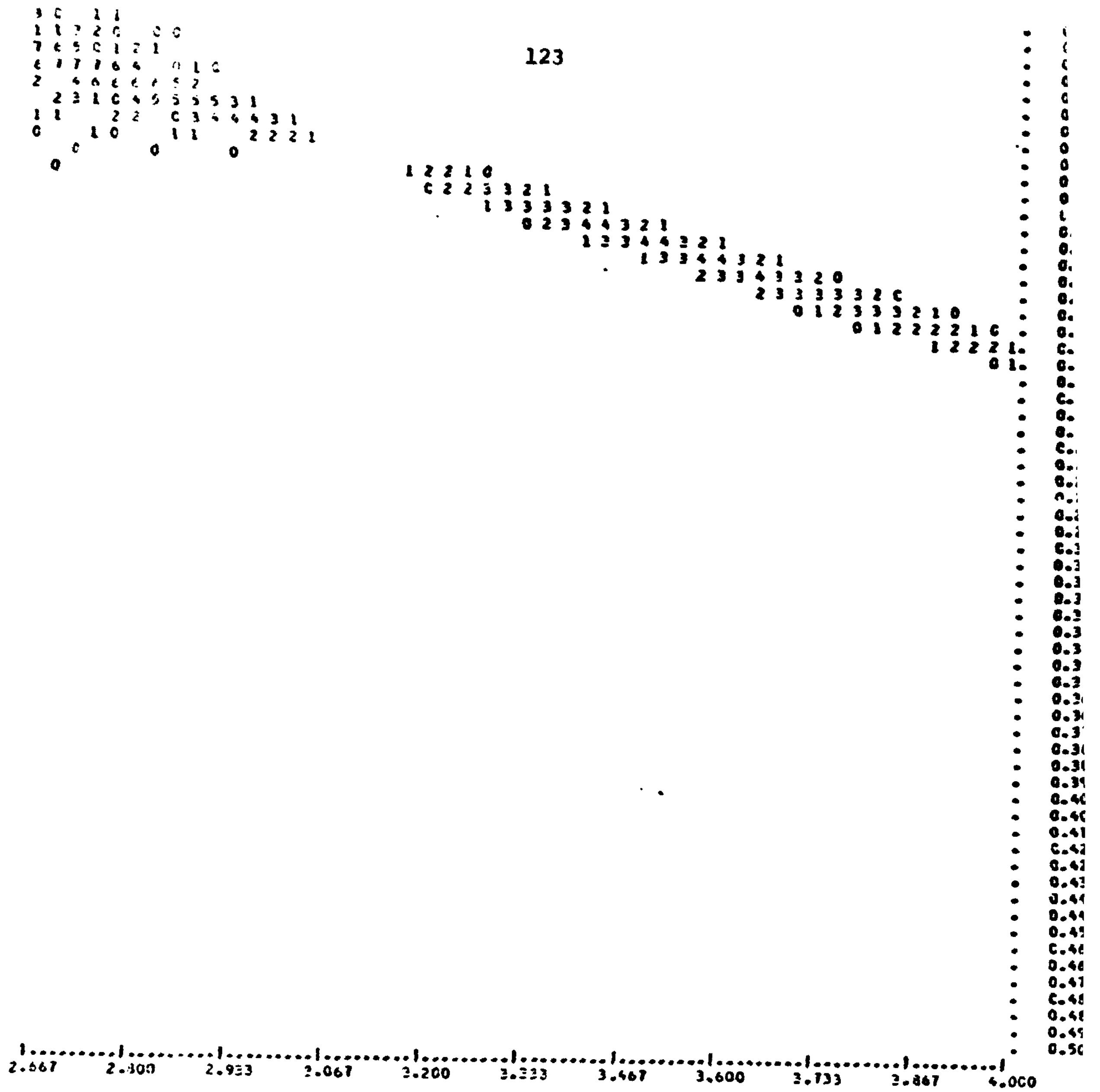
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3.200
3.333
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3.600
3.733
3.867
4.000

X-AXIS PROFILE PLOT ALONG 2.364 DEGREES LATITUDE.
PATTERN NUMBER 104

SCALE FACTOR IS 10**-2

REAL 99.2487 79.3996 59.5506 39.7015 19.8525 0.0035

DB.	REAL	
-45.38	C.538	0.5000
-54.79	0.182	0.4980
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-44.59	0.589	0.4940
-43.83	0.643	0.4920
-48.03	C.357	0.4900
-68.28	0.039	0.4880
-46.74	C.460	0.4860
-43.47	C.670	0.4840
-44.91	0.568	0.4820
-54.08	0.198	0.4800
-51.38	C.270	0.4780
-44.22	0.615	0.4760
-43.42	C.675	0.4740
-47.55	0.417	0.4720
-67.99	C.040	0.4700
-46.32	C.483	0.4680
-43.05	0.704	0.4660
-44.52	C.594	0.4640
-53.85	0.203	0.4620
-50.79	0.289	0.4600
-43.75	C.649	0.4580
-43.01	0.707	0.4560
-47.32	C.430	0.4540
-65.49	C.055	0.4520
-45.73	0.517	0.4500
-42.60	0.741	0.4480
-44.21	C.616	0.4460
-54.13	0.157	0.4440
-45.87	C.321	0.4420
-43.20	C.692	0.4400
-42.63	0.758	0.4380
-47.25	C.434	0.4360
-61.86	0.081	0.4340
-44.95	0.583	0.4320
-42.13	C.783	C.4300
-43.99	0.632	0.4280
-55.00	C.178	0.4260
-48.71	C.367	0.4240
-42.58	C.743	0.4220
-42.28	C.769	0.4200
-47.39	C.427	0.4180
-58.19	C.123	0.4160
-44.13	C.622	0.4140
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-43.87	C.641	C.4100
-56.65	C.144	0.4080
-47.36	C.429	0.4060
-41.90	0.803	0.4040
-41.98	0.796	0.4020
-47.81	C.407	0.4000
-54.73	C.133	0.3980
-43.18	0.693	0.3960
-41.15	C.876	0.3940
-43.88	C.640	0.3920
-60.70	C.092	C.3900
-45.89	0.529	0.3880
-41.20	0.871	0.3860
-41.72	C.819	0.3840
-48.61	C.371	0.3820
-51.64	0.262	0.3800
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-44.06	C.627	0.3740
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-54.19	0.195	0.3360
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-41.75	C.818	C.3300
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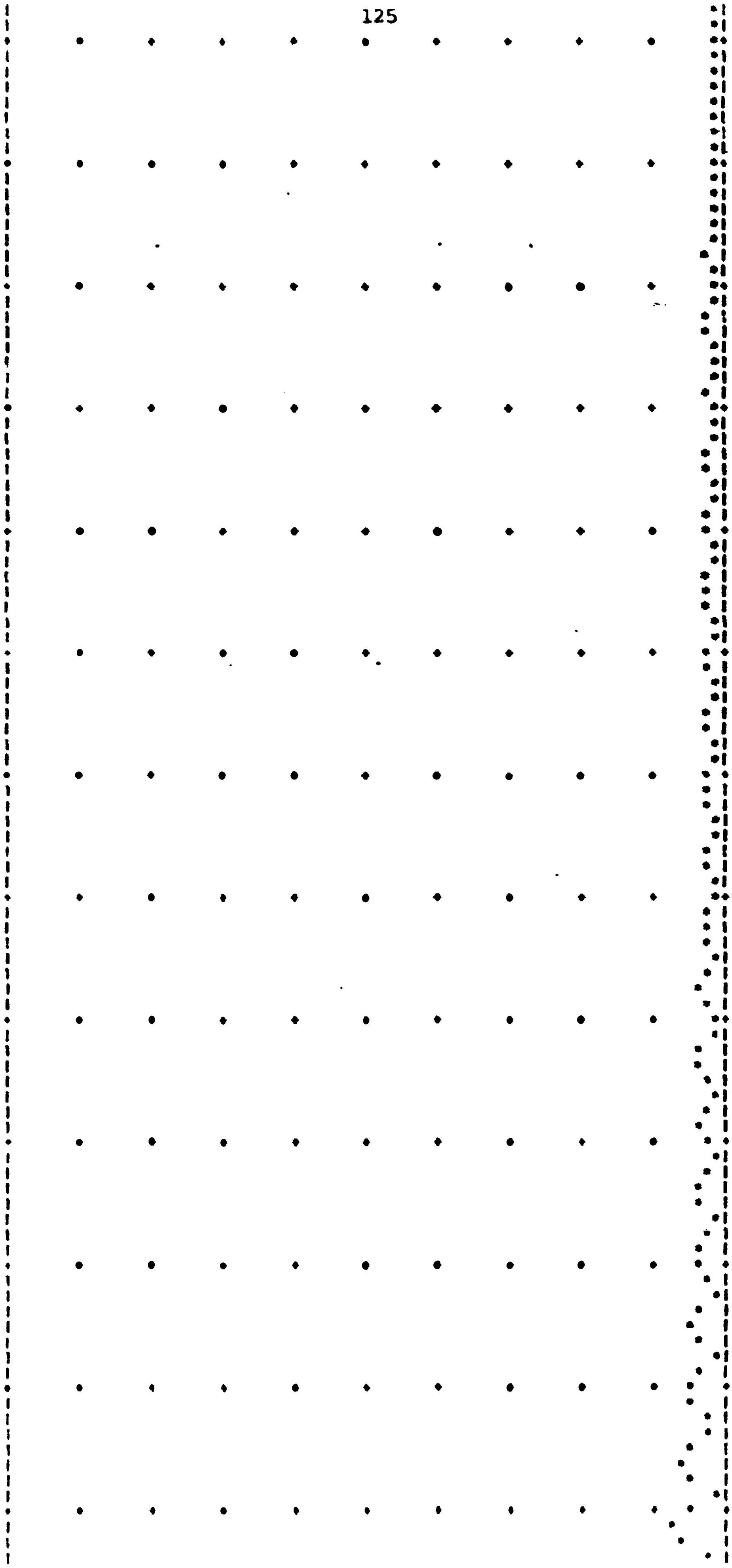

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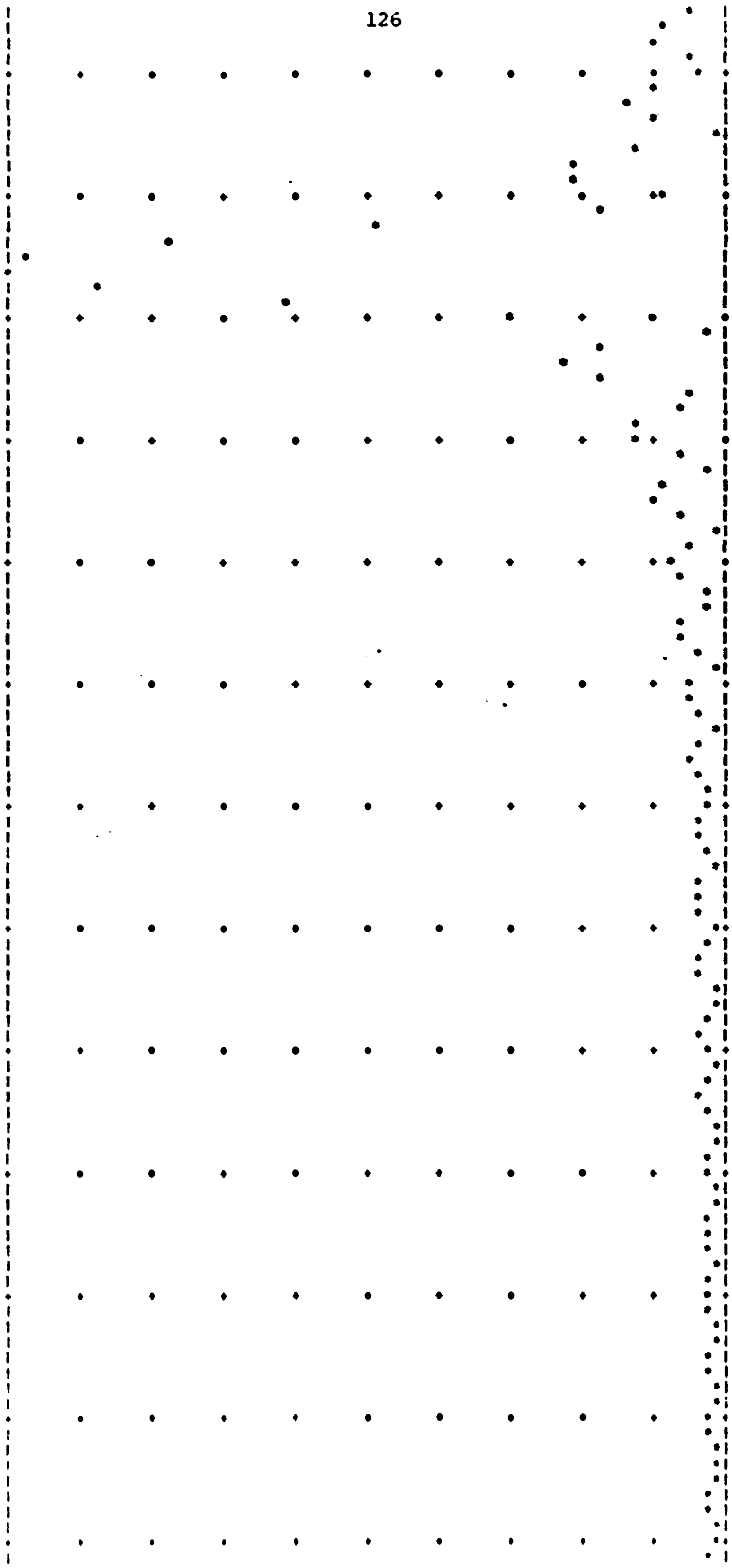

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-50.86	0.286	-0.2680
-43.71	0.664	-0.2700
-42.54	0.747	-0.2720
-46.95	0.449	-0.2740
-64.26	0.061	-0.2760
-45.42	0.536	-0.2780
-42.51	0.747	-0.2800
-44.44	0.597	-0.2820
-55.87	0.162	-0.2840
-40.29	0.947	-0.2860
-42.31	[illegible]	-0.2880
[illegible]	[illegible]	-0.2900

-49.94	0.361	-0.2920
-57.46	0.134	-0.2940
-45.05	0.559	-0.2960
-42.55	0.712	-0.2980
-45.66	0.521	-0.3000
-61.62	0.053	-0.3020
-48.18	0.390	-0.3040
-43.46	0.67[illegible]	-0.3060
-44.03	0.62[illegible]	-0.3080
-50.90	0.265	-0.3100
-54.40	0.190	-0.3120
-44.88	0.570	-0.3140
-43.44	0.673	-0.3160
-46.86	0.454	-0.3180
-72.09	0.020	-0.3200
-47.56	0.419	-0.3220
-43.70	0.653	-0.3240
-44.82	0.574	-0.3260
-53.06	0.222	-0.3280
-52.71	0.232	-0.3300
-44.88	0.570	-0.3320
-43.55	0.625	-0.3340
-48.05	0.396	-0.3360
-71.07	0.028	-0.3380
-47.24	0.425	-0.3400
-44.06	0.631	-0.3420
-45.59	0.525	-0.3440
-55.31	0.172	-0.3460
-51.71	0.260	-0.3480
-44.98	0.564	-0.3500
-44.43	0.598	-0.3520
-49.16	0.348	-0.3540
-63.93	0.064	-0.3560
-47.10	0.441	-0.3580
-44.34	0.607	-0.3600
-46.21	0.484	-0.3620
-57.49	0.133	-0.3640
-51.15	0.277	-0.3660
-45.16	0.552	-0.3680
-44.97	0.564	-0.3700
-50.16	0.310	-0.3720
-61.16	0.088	-0.3740
-47.13	0.440	-0.3760
-44.70	0.582	-0.3780
-46.95	0.449	-0.3800
-59.50	0.106	-0.3820
-50.54	0.2[illegible]	-0.3840
-45.41	0.537	-0.3860
-45.43	0.535	-0.3880
-50.98	0.293	-0.3900
-60.01	0.100	-0.3920
-47.28	0.422	-0.3940
-45.05	0.559	-0.3960
-47.48	0.423	-0.3980
-60.94	0.090	-0.4000
-50.99	0.282	-0.4020
-45.70	0.519	-0.4040
-45.83	0.511	-0.4060
-51.55	0.265	-0.4080
-59.72	0.103	-0.4100
-47.54	0.420	-0.4120
-45.40	0.527	-0.4140
-47.88	0.404	-0.4160
-61.59	0.083	-0.4180
-51.27	0.272	-0.4200
-46.03	0.499	-0.4220
-46.17	0.491	-0.4240
-51.87	0.255	-0.4260
-60.23	0.097	-0.4280
-47.92	0.402	-0.4300
-45.73	0.517	-0.4320
-48.14	0.392	-0.4340
-61.31	0.086	-0.4360
-51.86	0.257	-0.4380
-46.41	0.478	-0.4400
-46.45	0.476	-0.4420
-51.93	0.254	-0.4440
-61.53	0.083	-0.4460
-48.41	0.380	-0.4480
-46.05	0.493	-0.4500
-48.27	0.386	-0.4520
-60.27	0.097	-0.4540
-52.59	0.235	-0.4560
-46.84	0.455	-0.4580
-46.66	0.465	-0.4600
-51.69	0.260	-0.4620
-64.12	0.062	-0.4640
-49.05	0.353	-0.4660
-46.38	0.480	-0.4680
-48.23	0.386	-0.4700
-58.76	0.115	-0.4720
-53.75	0.205	-0.4740
-47.34	0.429	-0.4760
-46.83	0.455	-0.4780
-51.27	0.273	-0.4800
-69.83	0.0[illegible]	-0.4820
-49.87	0.321	-0.4840
-46.74	0.46[illegible]	-0.4860
-49.20	0.339	-0.4880
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-47.[illegible]	[illegible]	-0.4940

[illegible]	[illegible]	-0.4960
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[illegible]	[illegible]	-0.5000

DB. REAL 99.9437 79.3996 59.5506 39.7015 19.8525 0.0035

Y-AXIS PROFILE PLOT ALONG 0.083LONGITUDE.
PATTERN NUMBER 104

SCALE FACTOR IS 10**-2

DB. REAL 99.8009 79.8408 59.8806 39.9204 19.9603 0.0001

DB.	REAL	
-56.81	0.144	3.9998
-55.40	0.170	3.9918
-54.21	0.195	3.9838
-53.22	0.213	3.9759
-52.39	0.240	3.9679
-51.69	0.260	3.9559
-51.12	0.278	3.9519
-50.67	0.293	3.9439
-50.33	0.304	3.9359
-50.11	0.312	2.9279
-49.99	0.317	3.9159
-49.99	0.317	3.9119
-50.10	0.312	2.9039
-50.35	0.304	3.8959
-50.74	0.290	3.8879
-51.30	0.272	3.8799
-52.05	0.250	3.8719
-53.05	0.222	2.8639
-54.39	0.191	3.8559
-56.17	0.155	3.8479
-59.79	0.116	2.8399
-62.79	0.072	3.8319
-71.11	0.028	3.8239
-74.15	0.020	3.8159
-63.79	0.069	3.8079
-58.53	0.113	3.7949
-55.45	0.169	3.7919
-53.27	0.218	3.7839
-51.59	0.267	3.7759
-50.12	0.312	3.7679
-49.01	0.354	3.7559
-48.11	0.393	3.7519
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[illegible]	[illegible]	3.7359
[illegible]	[illegible]	3.7279
[illegible]	[illegible]	3.7159
[illegible]	[illegible]	2.7119
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

-46.41	0.478	3.6879
-46.65	0.455	3.6799
-47.43	0.422	3.6719
-48.34	0.383	3.6639
-49.47	0.336	3.6559
-50.99	0.232	3.6479
-53.07	0.222	3.6399
-56.09	0.157	3.6319
-61.16	0.088	3.6239
-76.20	0.015	3.6159
-64.63	0.059	3.6079
-57.47	0.134	3.5999
-53.65	0.208	3.5919
-51.08	0.279	3.5839
-49.18	0.347	3.5759
-47.73	0.411	3.5679
-46.60	0.468	3.5599
-45.73	0.517	3.5519
-45.07	0.558	3.5439
-44.60	0.589	3.5359
-44.30	0.609	3.5279
-44.17	0.619	3.5199
-44.20	0.617	3.5119
-44.39	0.603	3.5039
-44.77	0.578	3.4959
-45.34	0.541	3.4879
-46.13	0.494	3.4799
-47.21	0.436	3.4719
-48.65	0.370	3.4639
-50.59	0.295	3.4559
-53.34	0.215	3.4479
-57.69	0.131	3.4399
-67.27	0.043	3.4319
-66.94	0.045	3.4239
-57.60	0.132	3.4159
-53.32	0.216	3.4079
-50.60	0.295	3.3999
-48.70	0.367	3.3919
-47.32	0.431	3.3839
-46.30	0.484	3.3759
-45.57	0.527	3.3679
-45.09	0.557	3.3599
-44.82	0.574	3.3519
-44.76	0.578	3.3439
-44.91	0.569	3.3359
-45.25	0.546	3.3279
-45.82	0.512	3.3199
-46.63	0.466	3.3119
-47.72	0.411	3.3039
-49.17	0.348	3.2959
-51.10	0.279	3.2879
-53.74	0.206	3.2799
-57.65	0.131	3.2719
-64.97	0.056	3.2639
-75.44	0.015	3.2559
-61.80	0.081	3.2479
-57.04	0.141	3.2399
-54.35	0.192	3.2319
-52.63	0.232	3.2239
-51.64	0.262	3.2159
-51.06	0.280	3.2079
-50.86	0.286	3.1999
-51.01	0.281	3.1919
-51.50	0.266	3.1839
-52.33	0.242	3.1759
-53.53	0.211	3.1679
-55.18	0.174	3.1599
-57.37	0.135	3.1519
-60.31	0.097	3.1439
-64.34	0.061	3.1359
-70.34	0.030	3.1279
-81.66	0.008	3.1199
-88.94	0.004	3.1119
-89.27	0.003	3.1039
-80.09	0.010	3.0959
-69.61	0.033	3.0879
-62.20	0.078	3.0800
-57.79	0.130	3.0719
-54.26	0.194	3.0640
-51.55	0.265	3.0560
-49.39	0.340	3.0480
-47.65	0.414	3.0400
-46.30	0.484	3.0320
-45.29	0.544	3.0240
-44.62	0.588	3.0160
-44.29	0.611	3.0080
-44.32	0.608	3.0000
-44.80	0.575	2.9920
-45.87	0.509	2.9840
-47.81	0.407	2.9760
-51.38	0.270	2.9680
-60.34	0.095	2.9600
-59.29	0.109	2.9520
-49.35	0.341	2.9440
-44.52	0.594	2.9360
-41.33	0.855	2.9280
-36.99	1.12[illegible]	2.9200
-37.21	1.373	2.9120
-35.06	1.610	2.9040
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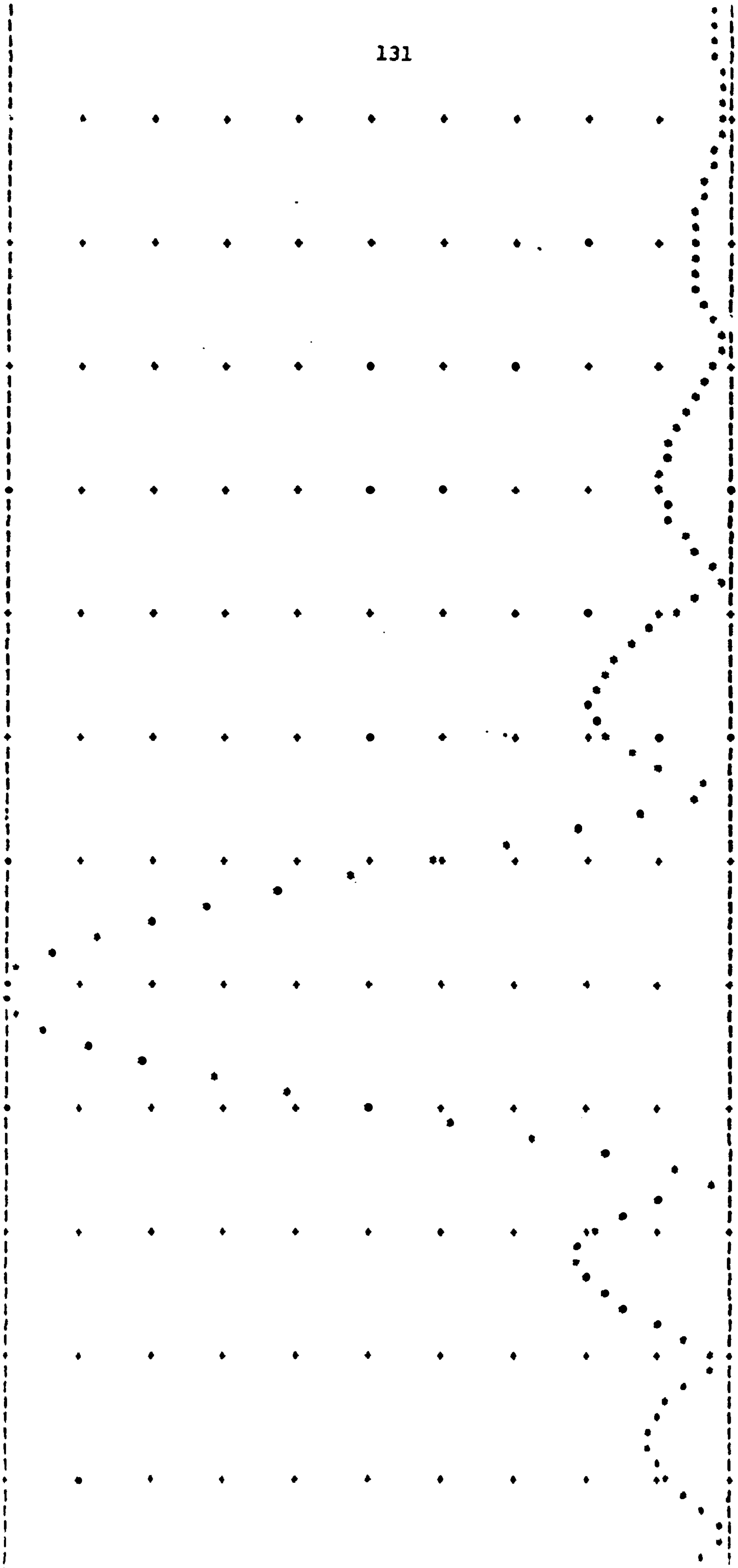
[illegible]	[illegible]	2.8880
[illegible]	2.0[illegible]	2.8800



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-34.97	1.784	2.8560
-36.37	1.518	2.8480
-38.73	1.157	2.8400
-43.02	0.706	2.8320
-53.02	0.177	2.8240
-47.51	0.421	2.8160
-39.47	1.065	2.8080
-35.26	1.726	2.8000
-32.44	2.387	2.7920
-30.41	3.017	2.7840
-28.93	3.575	2.7760
-27.88	4.035	2.7680
-27.21	4.362	2.7600
-26.88	4.528	2.7520
-26.92	4.509	2.7440
-27.37	4.280	2.7360
-28.32	3.837	2.7280
-29.97	3.173	2.7200
-32.80	2.291	2.7120
-38.24	1.224	2.7040
-79.35	0.012	2.6960
-37.25	1.372	2.6880
-31.67	2.795	2.6800
-27.47	4.234	2.6720
-25.03	5.605	2.6640
-23.30	6.842	2.6560
-22.09	7.868	2.6480
-21.30	8.610	2.6400
-20.92	8.997	2.6320
-20.94	8.972	2.6240
-21.43	8.489	2.6160
-22.47	7.526	2.6080
-24.34	6.065	2.6000
-27.66	4.141	2.5920
-35.00	1.779	2.5840
-40.67	0.926	2.5760
-22.21	3.867	2.5680
-23.13	6.977	2.5600
-19.96	10.050	2.5520
-17.76	12.939	2.5440
-16.21	15.466	2.5360
-15.17	17.445	2.5280
-14.57	18.692	2.5200
-14.41	19.037	2.5120
-14.74	18.332	2.5040
-15.68	16.446	2.4960
-17.53	13.292	2.4880
-21.08	8.830	2.4800
-30.18	3.095	2.4720
-28.18	3.901	2.4640
-18.40	12.019	2.4560
-13.52	21.080	2.4480
-10.22	30.819	2.4400
-7.34	41.044	2.4320
-5.75	51.403	2.4240
-4.21	61.560	2.4160
-2.95	71.167	2.4080
-1.95	79.839	2.4000
-1.18	7.323	2.3920
-0.60	93.278	2.3840
-0.22	97.459	2.3760
-0.03	99.676	2.3680
-0.02	99.801	2.3600
-0.19	97.801	2.3520
-0.56	93.722	2.3440
-1.14	87.697	2.3360
-1.94	79.959	2.3280
-3.01	70.741	2.3200
-4.37	60.461	2.3120
-6.12	49.428	2.3040
-8.38	38.099	2.2960
-11.41	26.697	2.2880
-15.79	16.229	2.2800
-23.23	6.469	2.2720
-33.71	2.064	2.2640
-20.90	9.121	2.2560
-16.74	14.550	2.2480
-14.77	18.238	2.2400
-13.90	20.190	2.2320
-13.76	20.519	2.2240
-14.25	19.347	2.2160
-15.39	17.027	2.2080
-17.24	13.747	2.2000
-20.13	9.447	2.1920
-24.90	5.686	2.1840
-36.19	1.553	2.1760
-32.96	2.248	2.1680
-25.71	5.486	2.1600
-21.98	7.958	2.1520
-20.38	9.572	2.1440
-19.76	10.290	2.1360
-19.59	10.115	2.1280
-20.75	9.174	2.1200
-22.39	[illegible]	2.1120
-25.07	5.570	2.1040
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-39.75	1.020	2.0880
[illegible]	[illegible]	2.0800
[illegible]	2.618	[illegible]
[illegible]	[illegible]	[illegible]

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-28.72	3.666	2.0240
-32.08	2.490	2.0160
-38.17	1.234	2.0080
-70.82	0.029	2.0000
-39.82	1.021	1.9920
-34.[illegible]7	1.827	1.9840
-32.55	2.346	1.9760
-31.82	2.564	1.9680
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-33.18	2.193	1.9520
-35.29	1.719	1.9440
-38.74	1.156	1.9360
-44.78	0.577	1.9280
-65.78	0.051	1.9200
-48.76	0.365	1.9120
-43.83	0.644	1.9040
-42.20	0.776	1.8960
-42.23	0.774	1.8880
-43.51	0.668	1.8800
-46.04	0.499	1.8720
-50.13	0.311	1.8640
-56.64	0.147	1.8560
-68.62	0.037	1.8480
-91.79	0.003	1.8400
-70.72	0.029	1.8320
-58.61	0.117	1.8240
-52.55	0.236	1.8160
-49.10	0.351	1.8080
-47.35	0.429	1.8000
-47.08	0.443	1.7920
-48.50	0.376	1.7840
-52.89	0.227	1.7760
-80.66	0.009	1.7680
-52.12	0.248	1.7600
-45.91	0.507	1.7520
-42.78	0.726	1.7440
-41.22	0.869	1.7360
-40.87	0.905	1.7280
-41.71	0.821	1.7200
-44.13	0.622	1.7120
-49.62	0.330	1.7040
-75.62	0.017	1.6960
-48.67	0.370	1.6880
-43.34	0.681	1.6800
-40.69	0.903	1.6720
-39.96	1.005	1.6640
-40.27	0.970	1.6560
-41.90	0.804	1.6480
-45.45	0.532	1.6400
-54.22	0.195	1.6320
-56.00	0.158	1.6240
-46.47	0.475	1.6160
-42.97	0.711	1.6080
-41.58	0.834	1.6000
-41.60	0.832	1.5920
-42.96	0.713	1.5840
-46.02	0.500	1.5760
-52.61	0.234	1.5680
-67.63	0.042	1.5600
-50.97	0.283	1.5520
-46.84	0.455	1.5440
-45.37	0.539	1.5360
-45.51	0.530	1.5280
-47.09	0.442	1.5200
-50.45	0.300	1.5120
-57.35	0.136	1.5040
-75.14	0.017	1.4960
-57.42	0.135	1.4980
-54.00	0.200	1.4800
-53.52	0.211	1.4720
-54.98	0.178	1.4640
-58.40	0.120	1.4560
-64.57	0.059	1.4480
-75.93	0.016	1.4400
-94.62	0.002	1.4320
-77.66	0.013	1.4240
-65.73	0.051	1.4160
-60.31	0.096	1.4080
-57.77	0.129	1.4000
-57.57	0.132	1.3920
-60.37	0.096	1.3840
-73.71	0.021	1.3760
-61.79	0.081	1.3680
-55.44	0.169	1.3600
-51.19	0.276	1.3520
-49.93	0.317	1.3440
-50.41	0.302	1.3360
-51.09	[illegible]	1.3280
-62.66	0.07[illegible]	1.3200
-73.11	0.070	1.3120
-52.[illegible]	0.225	1.3040
-49.2[illegible]	[illegible]	1.2960
-48.01	[illegible]	1.2880
-48.[illegible]	[illegible]	1.2800
-51.09	0.279	1.2720
-57.8[illegible]	0.12[illegible]	1.2640
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

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-52.23	0.24[illegible]	1.2160
-59.29	0.107	1.2080
-63.53	0.034	1.2000
-55.65	0.161	1.1920
-52.47	0.233	1.1840
-51.83	0.256	1.1760
-53.20	0.219	1.1680
-56.92	0.143	1.1600
-65.91	0.051	1.1520
-69.76	0.033	1.1440
-61.11	0.088	1.1360
-59.35	0.108	1.1280
-60.45	0.095	1.1200
-64.12	0.062	1.1120
-71.53	0.027	1.1040
-90.35	0.003	1.0960
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-75.27	0.017	1.0800
-67.09	0.044	1.0720
-62.59	0.066	1.0640
-63.26	0.069	1.0560
-67.26	0.043	1.0480
-81.57	0.008	1.0400
-62.52	0.075	1.0320
-57.27	0.137	1.0240
-55.20	0.174	1.0160
-55.40	0.170	1.0080
-58.45	0.120	1.0000
-69.52	0.033	0.9920
-63.05	0.079	0.9840
-55.70	0.164	0.9760
-53.07	0.222	0.9680
-52.68	0.227	0.9600
-55.12	0.175	0.9520
-61.56	0.080	0.9440
-69.05	0.035	0.9360
-57.09	0.140	0.9280
-53.67	0.207	0.9200
-53.11	0.221	0.9120
-54.91	0.180	0.9040
-60.25	0.097	0.8960
-55.[illegible]9	0.0[illegible]2	0.8880
-60.81	0.091	0.8800
-56.53	0.147	0.8720
-55.93	0.160	0.8640
-57.68	0.131	0.8560
-62.58	0.074	0.8480
-79.31	0.011	0.8400
-67.91	0.040	0.8320
-63.54	0.067	0.8240
-63.60	0.066	0.8160
-65.69	0.045	0.8080
-73.69	0.021	0.8000
-91.45	0.003	0.7920
******	0.000	0.7840
-77.67	0.013	0.7760
-69.71	0.033	0.7680
-66.67	0.046	0.7600
-67.37	0.043	0.7520
-75.42	0.017	0.7440
-71.41	0.027	0.7360
-62.42	0.076	0.7280
-59.00	0.112	0.7200
-58.35	0.121	0.7120
-60.53	0.094	0.7040
-69.03	0.035	0.6960
-67.[illegible]	0.040	0.6880
-59.08	0.111	0.6800
-56.16	0.156	0.6720
-56.00	0.159	0.6640
-58.59	0.118	0.6560
-67.19	0.044	0.6480
-67.46	0.042	0.6400
-58.74	0.116	0.6320
-56.1[illegible]	0.156	0.6240
-56.25	0.152	0.6160
-59.29	0.109	0.6080
-67.14	0.039	0.6000
-69.32	0.034	0.5920
-60.85	0.091	0.5840
-58.70	0.116	0.5760
-59.38	0.107	0.5680
-62.[illegible]7	0.072	0.5600
-72.[illegible]5	0.024	0.5520
-74.65	0.019	0.5440
-66.95	0.045	0.5360
-65.59	0.050	0.5280
-68.31	0.019	0.5200
-76.[illegible]	0.017	0.5120
-89.1[illegible]	0.004	0.5040
******	0.000	0.4960
-81.[illegible]	0.009	0.4880
-72.[illegible]1	0.025	0.4800
-69.31	0.035	0.4720
-68.[illegible]	0.0[illegible]	0.4640
-74.72	0.019	0.4560
-77.[illegible]	0.0[illegible]	0.4480
[illegible].61	0.[illegible]	0.4400
-61.[illegible]	[illegible]	0.4320

DB.	REAL	
-60.39	0.096	0.4240
-62.38	0.081	0.4160
-64.06	0.039	0.4080
-74.58	0.018	0.4000
-62.44	0.076	0.3920
-58.66	0.117	0.3840
-57.83	0.128	0.3760
-59.47	0.106	0.3680
-65.07	0.056	0.3600
-80.23	0.010	0.3520
-62.84	0.072	0.3440
-58.79	0.115	0.3360
-57.92	0.127	0.3280
-59.41	0.107	0.3200
-64.19	0.062	0.3120
-66.13	0.065	0.3040
-66.41	0.048	0.2960
-61.62	0.082	0.2880
-60.57	0.094	0.2800
-61.89	0.080	0.2720
-65.98	0.050	0.2640
-77.00	0.014	0.2560
-75.30	0.017	0.2480
-68.92	0.036	0.2400
-68.06	0.040	0.2320
-70.15	0.031	0.2240
-75.37	0.017	0.2160
-86.41	0.005	0.2080
******	0.000	0.2000
-87.71	0.004	0.1920
-76.46	0.015	0.1840
-71.38	0.027	0.1760
-69.55	0.023	0.1680
-70.82	0.029	0.1600
-78.61	0.012	0.1520
-76.29	0.015	0.1440
-64.86	0.045	0.1360
-63.04	0.071	0.1280
-61.67	0.083	0.1200
-62.35	0.075	0.1120
-65.80	0.051	0.1040
-78.61	0.012	0.0960
-69.35	0.034	0.0830
-62.42	0.076	0.0300
-59.70	0.103	0.0720
-59.11	0.111	0.0640
-60.39	0.096	0.0560
-64.32	0.061	0.0480
-77.23	0.014	0.0400
-68.93	0.036	0.0320
-62.71	0.073	0.0240
-59.70	0.104	0.0160
-59.23	0.109	0.0080
-60.46	0.095	0.0

DB. REAL 99.8009 79.8408 59.8806 39.9204 19.9603 0.0001

NORMAL TERMINATION

6.0 A SUMMARY OF OTHER AREAS OF ENDEAVOR

6.1 The Need For Integration of Antenna Studies With Processor Studies

The University of Texas at Austin Applied Research Laboratory has been developing a computer model of the SMR radar processor with the goal of specifying hardware requirements, data rates, etc., for the SMR system. Communication lines between ARL and PSL have been set up during the latter part of the Phase I contract period in order to integrate PSL's antenna model and ARL's processor model into a more realistic total SMR system simulation model which will eventually be capable of accurately predicting the performance of the overall system. Prior to this interchange of information, both ARL and PSL were using well-developed models of their respective subsystems, but both teams had made somewhat unrealistic assumptions about the quality of the other group's components. Both groups were assuming "perfect", ideal performance characteristics from the other's subsystem.

It is felt that a continuing exchange of ideas, results, and data will yield two important benefits in the shuttle study effort. First, the very act of exchanging data demands some familiarity with the roles which the antenna, radar, and processor play and the way they interact with each other and the rest of the system. Too often this understanding is lacking, resulting in a poorly designed system composed of independently well-designed subsystems. By "closing the loop" with a free exchange of information, it will be possible to provide NASA/JSC with information that will be able to predict accurately the total system performance. The ARL or PSL models standing alone cannot do this.

Secondly, any constraints upon the antenna imposed by the rest of the system can be identified, and vice versa. This will allow bounds to be set on optimum design requirements based on errors and uncertainties within other system components. For example, a user may desire a 25 meter ground cell resolution over a 100 km swath, but because of filtering problems in the range compressor, it may not be feasible to implement so fine a resolution. As a consequence of this radar restriction, it may be possible to relax beam pointing accuracy requirements. By exploring all such constraints it should be possible to "box in" a feasible region of acceptable operation. By making hypothetical tradeoffs within this region, the most cost-effective system can be specified.

Passing large amounts of data between two widely separated locations can become a formidable task unless computer compatible magnetic tapes or disks are used as the medium of communications. An auxiliary computer program was written to create data tapes from the output of the PSL antenna simulation program. The contents of these tapes is discussed in the next section.

6.2 The ARL SMRA Performance Data Tape

The details of the data tape contents, format, etc., are described in the Interface Control Document entitled, "The Shuttle Imaging Radar Antenna Computer Simulation Data Tape" of August 27, 1976. Hence, only a brief description will be given here.

The (one-way) far-field radiation pattern of an array antenna may be written as the product of three terms.

$$\bar{E}(r,\theta,\phi) = E_0(r) f(\theta,\phi)\, \bar{g}(\theta,\phi) \qquad (6\text{-}1)$$

$$E_0(r) = \frac{-j\omega\mu e^{-jkr}}{4\pi r} \qquad (6\text{-}2)$$

where:

$f(\theta,\phi)$ = antenna array factor

$\bar{g}(\theta,\phi)$ = vector element pattern factor

Only data for $|f\bar{g}|$ has been stored, since the $E_0(r)$ term may be calculated without regard to θ and ϕ. If polarization information is needed, it may be added quite easily.

A coordinate transformation has been performed to simplify calculations. Rather than store $|f(\theta,\phi)\,\bar{g}(\theta,\phi)|$, let

$$\begin{aligned} u &= \sin\theta\cos\phi \\ v &= \sin\theta\cos\phi \end{aligned} \qquad (6\text{-}3)$$

The advantage of storing f and g as functions of u and v is that more data points are clustered within the main beam. However, even in the (u,v)-coordinate system, the narrow azimuth beam width of the SMR antenna demands rather dense discretization. To minimize interpolation errors, at least twenty points on either side of the main beam (in both u and v) are needed. This requirement makes storage of the entire (u,v,)-space or, equivalently, (θ,ϕ)-space prohibitive. Therefore, only the main beam and first two side lobes have been included. (All other side lobes are nominally 20 dB or more below the main beam maximum.) Data may be recovered quite easily by using the procedure described in the ICD.

6.3 SMRA Subarray Preliminary Specifications

The purpose of constructing subarray panels is two-fold:

1. To produce realistic simulation and measurement of reduced-size array behavior and to extend this to a prediction of full-size array behavior.
2. To verify the ability of near-field antenna pattern measurement techniques to measure full-scale SMRA characteristics, particularly in gain, beam coincidence, and cross-polarization levels at X-band.

The specifications on these test panels are based on an estimate of the tests and measurements that will be required to obtain the above results.

Objective (1) may be achieved by measurement of antenna characteristics (such as beam shape, footprint coincidence, etc.) under laboratory-simulated thermal and mechanical stress. Phase I studies have shown this to be critical, particularly at X-band. Once this baseline simulation has been done, systematic errors in the mechanical flatness of the subarray can be induced by mounting the subarray in a standard rigid jig; antenna pattern would then be measured for the subarray under these simulated stress conditions, which would be used to verify the ability of the computer simulation mode (developed under Phases I and II) to <u>predict</u> the actual measured antenna pattern distortions. Finally, from the measured data and the verified computer simulation, it should be possible to predict the performance of the full-scale SMR antenna, under response to space condition thermal stresses, panel unfolding mechanism accuracy, etc.

To check the above mentioned near-field measurements, the near-field antenna patterns (measured at NBS) will be compared with the far-field measurements taken at PSL.

The measurement specifications and their justifications that are listed here are based on data presently available, and as such are only preliminary requirements. As more information regarding antenna behavior is obtained through interactive graphics simulations of various space environmental conditions, these specifications will be refined. Final specifications for the subarrays will be delivered at the close of Phase II.

6.3.1 Measurements Necessary to Obtain Desired Data

Both near-field and far-field pattern measurements should be performed to verify the baseline electrical performance of each subarray. Near-field tests will be conducted by NBS (Boulder), while conventional far-field testing will be done using the 3000' PSL antenna range. A carefully defined set of electrical performance tests will be issued early in Phase III. The purposes of using two independent tests are: 1) to compare conventional far-field testing techniques to the near-field techniques for the subarray and 2) to establish the testing accuracy and capability of the near-field technique, when used for measuring the full-scale SMRA.

Thermal tests will be performed on the subarrays, with measurements of mechanical flatness performed simultaneously. Ideally, the goal of the thermal tests would be to determine the expected thermal response of the full-size antenna plus support structure. However, it has been indicated that the design of a support structure that would replicate the performance of the full-size structure will increase the subarray cost to a prohibitively high level. Consequently, at this time it is felt that it would be more cost-effective to determine the thermal gradient - mechanical deformation relationships between each subarray and a common support structure. After this data has been analyzed, separate specifications can be made for the support structure.

To provide data on the effects of mechanical deformation on antenna pattern parameters, an instrumented jig for the subarrays should be obtained so that simulated random and systematic mechanical errors may be induced into the subarray surface. To obtain pattern data, these tests should be performed simultaneously with the NBS near-field measurements. In this way, the effects of mechanical deformations on antenna performance which were predicted by the computer simulation can be verified, and an extrapolation can later be made to the performance of the full-size SMRA.

The results of these tests will be entered into a more advanced version of the SMRA simulation model as representative of space environmental thermal effects, with predictions made of pattern degradation, beam pointing inaccuracy, etc. Consequently, consideration should be given to the form of measurement data storage. It is our opinion that the most efficient method of managing large amounts of numerical information is to generate computer compatable digital and/or analog magnetic tapes for each test result.

6.3.2 Requirements Imposed By Measurement Facilities

In preliminary discussions with Hughes and Ball Brothers, a 6' x 6' area subarray was used as an approximate size. This size estimation was made using the following criteria: 1) the area was electrically large enough to allow meaningful electrical and thermal tests which could with a computer simulation model, be used to predict full-size array performance, and 2) the antenna effective aperature was small enough to conveniently make pattern tests using both near-field and far-field techniques.

The principal concern of (1) is to minimize the edge effects of the smaller subarray so that a better prediction can be made for the full-size SMRA. There are some guidelines in the literature[†], but even by following these suggestions, the subarrays would still be too large for meaningful far-field measurements. Therefore, criterion (2) is the most restrictive.

[†] c.f. N. Amitay, V. Galindo, and C.P. Wu, Theory and Analysis of Phased Array Antennas, John Wiley and Sons Inc., (New York): 1972, pp. 426-430.

The rule-of-thumb used by many antenna engineers for pattern testing is that the separation between the source and test antenna be greater than $2D^2/\lambda$, where D is the test antenna maximum dimensions. This criterion corresponds to a $\lambda/16$ path length difference between the source antenna and the extrema of the test antenna. For precise measurement of null depths and side lobe levels, several times this distance may be necessary. The longest leg of the PSL antenna range is 3000', which corresponds to a maximum antenna dimension of 35' at 1.2 GHz and 12.27' at 9.8 GHz. Using four times the rule-of-thumb distance corresponds to 17.5' at 1.2 GHz and 6.135' at 9.8 GHz. This criterion ($8D^2/\lambda$) should provide sufficient accuracy (equivalent to a 5.625° departure from planeness of the incident spherical wave) for all necessary measurements. Therefore, six feet is the upper bound on the maximum dimension (azimuth) of the X-band subarray.

Since the subarrays are to replicate the design approaches of the competing full-size arrays, the azimuth dimensions on the L-band section of the subarray should be 6' also. The elevation dimension of the arrays are open at this time, but for ease of handling, cost minimization, etc., it is proposed that it also be limited to six feet. This makes practical sense, because increasing the elevation dimension will not decrease the edge effects in the azimuth dimensions. Consequently, the most cost-effective design for the measurements which are necessary would be a square subarray.

The 6' x 6' subarray size can be accommodated by the other test facilities needed for the measurements described in Section 6.3.1. The near-field facility at NBS (Boulder, Colorado) can measure both gain and directivity of this size antenna with an uncertainty claim of better than 0.2 dB at the 3σ level, at both L- and X-bands. Facilities exist at NASA/JSC and elsewhere that can perform meaningful thermal and mechanical tests on a 6' x 6' structure.

6.3.3 A Summary of The Preliminary Specifications

The preliminary specifications for the SMRA test panels, based on the above considerations, are presented in Table 3.

TABLE 3. Preliminary specifications for the SMRA test panels.

1. The size shall not exceed 6' x 6'.

2. The weight shall not exceed 200 lbs.

3. The test panel shall operate at 1.5 GHz and 9.0 GHz.

4. Both horizontal and vertical polarization shall be available at each frequency.

5. The cross-polarized component shall not exceed -25 dB with respect to the principally-polarized component.

6. Two modules shall be present at both frequencies to demonstrate beamwidth switching.

7. This VSWR shall not exceed 1.3 in any mode of operation.

8. The maximum side lobe level shall not exceed 12 dB.

9. All array elements, feedlines, and the electrical design approach shall be the same as that which will be used on the full sized antenna.

APPENDIX

This appendix contains the computer listing of the Shuttle Multispectral Radar Antenna Simulation Program. This listing was obtained by compiling the program on the Physical Science Laboratory/New Mexico State University IBM 370/135 computer using DOS FORTRAN IV.

While the majority of this program can be run on any compatible IBM machine, the user is cautioned to examine all subprograms carefully for calls to functions and subroutines that may not be standard software items. Special attention is called to the subprograms PLOT, AXIS, LINE, and NUMBER.

```
DOS FORTRAN IV 360N-FO-479 3-9          MAINPGM            DATE   12/17/76     TIME    09.16.04

            C*************************************************************************
            C
            C        MAIN PROGRAM FOR SPACE SHUTTLE EARTH RESOURCES IMAGING RADAR ANTENNA
            C
            C        WRITTEN BY: E. L. COFFEY, SENIOR ENGINEER
            C                    PHYSICAL SCIENCE LABORATORY
            C                    ELECTROMAGNETICS SECTION
            C                    NEW MEXICO STATE UNIVERSITY
            C                    LAS CRUCES, NEW MEXICO  88001
            C                    PHONE: (505) 524 - 2851
            C
            C              DATE: 2 AUGUST 1976
            C           REVISED: 23 AUGUST 1976
            C
            C            VERSION 2.3
            C
            C*************************************************************************
            C
0001              REAL APLOT(151,151),CON(10),K,MU,XPRINT(501,2),YPRINT(501,2),
                 $XPLOT(501),YPLOT(501),ZAVG(24,12),ALPHAX(24,12),ALPHAY(24,12),
                 $ANGLE(3,3)
0002              REAL KX,KY
0003              REAL PHSX(24,12),AMAG(24,12),APHS(24,12),PHSY(24,12)
            C
0004              COMPLEX AF,AF1,PAT,CEXP,J
            C
0005              INTEGER NAM(80),DELIM,PR1,PR2,PR3,PL1,PL2,PL3,TP1,TP2
0006              INTEGER DATE(5)
0007              EQUIVALENCE (XPRINT(1,1),YPRINT(1,1)),(XPLOT(1),YPLOT(1))
            C
0008              COMMON /ANG/ YAW,TILT,TWIST,CTW,STW,CT,ST,CYAW,SYAW
0009              COMMON /IO/ PR1,PR2,PL1,PL2,PL3,TP1,TP2,NCON,CON,STARTX,STOPX,
                 $DELTAX,STARTY,STOPY,DELTAY,CONLOW,CONMAX,NPTSX,NPTSY,FLOOR,DASH
0010              COMMON /ARRAY/ APLOT
0011              COMMON /SYS/ REARTH,RE3,ALT,ALT3,ANGLE
0012              COMMON /ANT/ MSECT,NSECT,MEL,NEL,SX,SY,PX,PY,IHV,K,OMU4PI,ZAVG,
                 $ALPHAX,ALPHAY,KX.KY,PXSECT,PYSECT
0013              COMMON /ELCTRC/ PHSX,PHSY,AMAG,APHS
```

```
            C
0014              DATA J/(0.,1.)/
0015              DATA PI,MU,RADDEG/3.14159265E0,12.56637E-7,0.01745329E0/
0016              DATA DELIM /'&'/
0017              FLOOR=-30.0
            C
            C.........INPUT USER PARAMETERS
0018         1000 READ(1,1,END=9999) NUMPAT,DATE
0019            1 FORMAT(I5,1X,5A4)
0020              WRITE(3,2) NUMPAT,DATE
0021            2 FORMAT(1H1,12X,'PATTERN ',I3,15X,'SPACE SHUTTLE IMAGING RADAR ANTE
                 $NNA SIMULATION PROGRAM',14X,5A4////)
0022            9 IYES=0
0023              READ(1,3) NAR
0024            3 FORMAT(80A1)
            C.........CHECK FOR DELIMITER
0025              DO 10 I=1,80
0026              IF(NAR(I).EQ.DELIM) GO TO 11
0027           10 CONTINUE
0028              IYES=1
0029              I=81
0030           11 I=I-1
0031              WRITE(3,4) (NAR(JJ),JJ=1,I)
0032            4 FORMAT(20X,80A1)
0033              IF(IYES.EQ.1) GO TO 9
0034              WRITE(3,5)
0035            5 FORMAT(////)
            C.........END OF NARRATIVE
0036            6 FORMAT(8F10.0)
0037            7 FORMAT(2I5)
0038            9 FORMAT(5I1)
            C
            C          CALL SUBROUTINES FOR FURTHER OUTPUT CALCULATIONS
            C
0039              CALL ORBIT(NUMPAT,FREQ)
0040              CALL ANTENA(NUMPAT)
0041              CALL MECH(NUMPAT)
0042              CALL ELEC(MSECT,NSECT,NUMPAT)
```

```
DOS FORTRAN IV 360N-FO-479 3-9          MAINPGM            DATE   12/17/76     TIME    09.16.04

 0043                CALL OUTPUT(NUMPAT)
           C
           C........CALCULATE RUN PARAMETERS
           C
 0044                K=2.*PI*FREQ/30.0
 0045                OMEGA=2.*PI*FREQ 1E9
 0046                OMU4PI=OMEGA*MU/(4.*PI)
 0047                DXD=DELTAX/RADDEG
 0048                DYD=DELTAY/RADDEG
           C
 0049                WRITE(3,200) NUMPAT
 0050            200 FORMAT(20X,'SUBARRAY DATA SUMMARY FOR PATTERN ',I3,':'/
                    $1X,'AREA',8X,'XCENT',9X,'YCENT',9X,'ZAVG',8X,'ALPHAX',7X,
                    $'ALPHAY',8X,'AMAG',9X,'APHS',9X,'PHSX',9X,'PHSY')
 0051                IAREA=0
 0052                DO 201 N=1,NSECT
 0053                YCENT=SY*NEL*(N-FLOAT(NSECT+1)*0.5)
 0054                DO 201 M=1,MSECT
 0055                XCENT=SX*MEL*(M-FLOAT(MSECT+1)*0.5)
 0056                IAREA=IAREA+1
 0057                P1=ZAVG(M,N)
 0058                P2=ALPHAX(M,N)*57.295
 0059                P3=ALPHAY(M,N)*57.295
 0060                P4=AMAG(M,N)
 0061                P5=APHS(M,N)*57.295
 0062                P6=PHSX(M,N)*57.295
 0063                P7=PHSY(M,N)*57.295
 0064                WRITE(3,202) IAREA,XCENT,YCENT,P1,P2,P3,P4,P5,P6,P7
 0065            202 FORMAT(2X,I3,6X,F8.2,6X,F8.2,6X,F7.2,6X,F7.3,6X,F7.3,6X,F7.4,
                    $6X,F7.2,6X,F7.2,6X,F7.2)
 0066            201 CONTINUE
           C
           C........CALCULATE BEAM CENTER
           C
 0067                KX=K*SX
 0068                KY=K*SY
 0069                CALL GENER
 0070                UP=-PX/KX
```

```
0071              VP=-PY/KY
0072              IF(UP.EQ.0. .AND. VP.EQ.0.) GO TO 20
0073              PHIP=ATAN2(VP,UP)
0074              GO TO 21
0075           20 PHIP=0.
0076           21 CONTINUE
0077              WP=SQRT(1.0-(UP*UP+VP*VP))
0078              THETAP=ARCOS(WP)
          C
          C........UNTWIST
          C
0079              PHIP=PHIP+TWIST
0080              XP=SIN(THETAP)*COS(PHIP)
0081              YP=SIN(THETAP)*SIN(PHIP)
0082              ZP=COS(THETAP)
          C
          C........"UNTILT"
          C
0083              X=XP
0084              Y=CT*YP+ST*ZP
0085              Z=-ST*YP+CT*ZP
          C
          C........"UNYAW"
          C
0086              XP=CYAW*X-SYAW*Y
0087              YP=SYAW*X+CYAW*Y
0088              ZP=Z
          C
          C........CALCULATE ANGLES
          C
0089              RP=SQRT(XP*XP+YP*YP+ZP*ZP)
0090              THETAP=ARCOS(ZP/RP)
0091              IF(XP.EQ.0. .AND. YP.EQ.0.) GO TO 22
0092              PHIP=ATAN2(YP,XP)
0093              GO TO 23
0094           22 PHIP=0.0
0095           23 CONTINUE
          C
```

```
            C........PREDICT LATITUDE AND LONGITUDE ON EARTH ASSUMING SUBSATELLITE
            C        POINT IS AT (0,0).
            C
0096              ALPHAR=ARSIN(SIN(THETAP)/REARTH*(REARTH+ALT))-THETAP
0097              PHIR=PHIP-PI/2.0
0098              RANGE=REARTH*ALPHAR
            C
0099              FLONG=ATAN(SIN(PHIR)*TAN(ALPHAR))
0100              FLAT=ARCOS(COS(ALPHAR)/COS(FLONG))
0101              IF(FLAT.GT.PI/2.) FLAT=FLAT-PI
0102              FLATD=FLAT/RADDEG
0103              FLONGD=FLONG/RADDEG
0104              PHIRD=PHIR/RADDEG
0105              WRITE(3,102) FLATD,FLONGD,RANGE,PHIRD
0106          102 FORMAT(///20X,'PREDICTED BEAM CENTER:'/25X,'LATITUDE = ',F8.4/25X,
                 $'LONGITUDE = ',F9.4/25X,'RANGE = ',F7.3/25X,'HEADING = ',F8.3///)
            C
            C........NOW BEGIN POINT-BY-POINT CALCULATION OF PATTERN.
            C        FIRST CALCULATE AF AT BEAM CENTER.
            C
0107              AF=PAT(FLONG,FLAT)
0108              BIG1=CABS(AF)
0109              IF(BIG1.LT.1E-10) BIG1=1E-10
0110              BIG=20.0*ALOG10(BIG1)
            C
            C
0111              WRITE(3,113) BIG
0112          113 FORMAT(///20X,'PLOT NORMALIZATION FACTOR = ',F8.3,' DB.'////)
            C
            C
0113              IF(PR2+PL2+PL3.EQ.0) GO TO 50
0114              YR=STARTY-DELTAY
0115              DO 40 NN=1,NPTSY
0116              YR=YR+DELTAY
0117              XR=STARTX-DELTAX
0118              DO 40 MM=1,NPTSX
0119              XR=XR+DELTAX
0120              AF=PAT(XR,YR)
```

```
         IF(CABS(AF).LT.1E-10) AF=(1E-10,0.)
         APLOT(MM,NN)=20.*ALOG10(CABS(AF))-BIG
      40 CONTINUE
C
         IF(PL2.EQ.1) CALL PLOT2(NPTSX,NPTSY,CON,NCON,NUMPAT,-1000.)
         IF(PR2.EQ.1) CALL PATCON(APLOT,CONLOW,CONMAX,STARTX/RADDEG,
        $STOPX/RADDEG,STARTY/RADDEG,STOPY/RADDEG,NUMPAT)
         IF(PL3.NE.1) GO TO 50
         DO 45 M=1,NPTSX
         DO 45 N=1,NPTSY
         IF(APLOT(M,N).LT.FLOOR) APLOT(M,N)=FLOOR
      45 CONTINUE
         CALL PLOT3(NPTSX,NPTSY,NUMPAT)
C
C........ONE DIMENSIONAL PLOTS
C
      50 CONTINUE
         IF(PR1+PL1.EQ.0) GO TO 51
C
C           CALCULATE PROFILE ALONG X-AXIS AT Y=YC
C
         DX=(STOPX-STARTX)/500.0
         YR=FLAT
         XR=STARTX-DX
         DO 60 MM=1,501
         XR=XR+DX
         AF=PAT(XR,YR)
         XPRINT(MM,1)=XR/RADDEG
         XPRINT(MM,2)=CABS(AF)/BIG1
         IF(XPRINT(MM,2).LT.1E-10) XPRINT(MM,2)=1E-10
      60 XPLOT(MM)=20.*ALOG10(XPRINT(MM,2))
         IF(PR1.NE.1) GO TO 63
         WRITE(3,114) FLATD
     114 FORMAT(1H1,25X,'X-AXIS PROFILE PLOT ALONG ',F8.3,' DEGREES LATITUD
        $E.')
         CALL PROFIL(XPRINT,501,NUMPAT)
      63 CONTINUE
         IF(PL1.NE.1) GO TO 64
```

```
0150              CALL PLOT1(STARTX/RADDEG,STOPX/RADDEG,500,1,FLATD,NUMPAT,XPLOT)
0151           64 CONTINUE
             C
             C.........CALCULATE PROFILE ALONG Y-AXIS AT X=FLAT
0152              DY=(STOPY-STARTY)/500.0
0153              XR=FLONG
0154              YR=STARTY-DY
0155              DO 70 MM=1,501
0156              YR=YR+DY
0157              AF=PAT(XR,YR)
0158              YPRINT(MM,1)=YR/RADDEG
0159              YPRINT(MM,2)=CABS(AF)/BIG1
0160              IF(YPRINT(MM,2).LT.1E-10) YPRINT(MM,2)=1E-10
0161           70 YPLOT(MM)=20.*ALOG10(YPRINT(MM,2))
             C
             C.........OUTPUT SEQUENCE
0162              IF(PR1.NE.1) GO TO 80
0163              WRITE(3,115) FLONGD
0164          115 FORMAT(1H1,25X,'Y-AXIS PROFILE PLOT ALONG',F8.3,'LONGITUDE.')
0165              CALL PROFIL(YPRINT,501,NUMPAT)
             C.........PLOTTER PLOTS
0166           80 CONTINUE
0167              IF(PL1.NE.1) GO TO 90
0168              CALL PLOT1(STARTY/RADDEG,STOPY/RADDEG,500,2,FLONGD,NUMPAT,YPLOT)
0169           90 CONTINUE
0170           51 CONTINUE
0171           95 CONTINUE
             C.........NEW SEARCH CODE
0172              CALL PLOT(0.,0.,-3)
0173              GO TO 1000
             C
             C
             C
0174         9999 CONTINUE
0175              WRITE(3,117)
0176          117 FORMAT(20X,'NORMAL TERMINATION')
0177              CALL PLOT(0.,0.,999)
0178              STOP
```

```
DOS FORTRAN IV 360N-FO-479 3-9          ORBIT               DATE   12/17/76     TIME    09.16.34

0001              SUBROUTINE ORBIT(NUMPAT,FREQ)
0002              DATA RADDEG /0.01745329E0/
0003              REAL ANGLE(3,3)
0004              COMMON /ANG/ YAW,TILT,TWIST,CTW,STW,CT,ST,CYAW,SYAW
0005              COMMON /SYS/ REARTH,RE3,ALT,ALT3,ANGLE
0006              REARTH = 6370.0
0007              RE3=REARTH*1E3
0008              READ(1,6) FREQ
0009              READ(1,6) ALT
0010            6 FORMAT(8F10.0)
0011              ALT3=ALT*1E3
0012              READ(1,6) YAWD,TILTD,TWISTD
0013              TWIST=RADDEG*TWISTD
0014              TILT=RADDEG*TILTD
0015              YAW=RADDEG*YAWD
0016              CTW=COS(TWIST)
0017              STW=SIN(TWIST)
0018              CT=COS(TILT)
0019              ST=SIN(TILT)
0020              CYAW=COS(YAW)
0021              SYAW=SIN(YAW)
            C
0022              ANGLE(1,1)=CTW*CYAW-SYAW*CT*STW
0023              ANGLE(1,2)=SYAW*CTW+CYAW*CT*STW
0024              ANGLE(1,3)=-ST*STW
0025              ANGLE(2,1)=-STW*CYAW-SYAW*CT*CTW
0026              ANGLE(2,2)=CYAW*CT*CTW-SYAW*STW
0027              ANGLE(2,3)=-ST*CTW
0028              ANGLE(3,1)=-SYAW*ST
0029              ANGLE(3,2)=CYAW*ST
0030              ANGLE(3,3)=CT
            C
            C........OUTPUT SYSTEM INFORMATION
            C
0031              WRITE(3,100) FREQ
0032          100 FORMAT(20X,'SYSTEM INFORMATION:'/25X,'FREQUENCY = ',F6.3,' GHZ.')
0033              WRITE(3,101) YAWD,TILTD,TWISTD,ALT
0034          101 FORMAT(25X,'YAW = ',F8.3,' DEGREES'/25X,'TILT = ',F8.3,' DEGREES'/
```

```
                 $25X,'TWIST = ',F8.3,' DEGREES'/25X,'ALTITUDE = ',F8.3,' KM.'///)
            C
 0035             RETURN
 0036             END
```

```
0001              SUBROUTINE ANTENA(NUMPAT)
            C
            C      THIS ROUTINE INPUTS AND CALCULATES APPROPRIATE ANTENNA PARAMETERS
            C      FOR THE SPACE SHUTTLE SYNTHETIC IMAGING RADAR ANTENNA.
            C
            C      FINALLY, ALL ANTENNA PARAMETERS ARE OUTPUTTED.
            C
            C
            C...............ANTENNA CONFIGURATION -- TWO-DIMENSIONAL ARRAY................C
            C
0002              REAL ZAVG(24,12),ALPHAX(24,12),ALPHAY(24,12),K
0003              REAL KX,KY
0004              COMMON /ANT/ MSECT,NSECT,MEL,NEL,SX,SY,PX,PY,IHV,K,OMU4PI,ZAVG,
                 $ALPHAX,ALPHAY,KX,KY,PXSECT,PYSECT
            C
            C
0005              READ(1,1) MSECT,NSECT
0006              READ(1,1) NX,NY
0007            1 FORMAT(8I5)
0008              MEL=NX/MSECT
0009              NEL=NY/NSECT
0010              READ(1,2) SX,SY
0011            2 FORMAT(8F10.0)
0012              READ(1,2) PXD,PYD
0013              PX=PXD*0.01745329E0
0014              PY=PYD*0.01745329E0
0015              READ(1,1)IHV
0016              WRITE(3,3) NUMPAT
0017            3 FORMAT(20X,'ANTENNA PARAMETERS FOR SIMULATION NUMBER ',I3)
0018              IF(IHV.EQ.0) WRITE(3,100)
0019              IF(IHV.EQ.1) WRITE(3,101)
0020              IF(IHV.EQ.2) WRITE(3,102)
0021          100 FORMAT(25X,'ELEMENT TYPE: ISOTROPIC')
0022          101 FORMAT(25X,'ELEMENT TYPE: HORIZONTAL DIPOLE')
0023          102 FORMAT(25X,'ELEMENT TYPE: VERTICAL DIPOLE')
0024              WRITE(3,4) NX,NY
0025            4 FORMAT(25X,'NUMBER OF ELEMENTS (X,Y) = (',I3,' , ',I3,')')
0026              WRITE(3,5) SX,SY
```

```
    5 FORMAT(25X,'INTERELEMENT SPACING (CM.): ',F7.4,' , ',F7.4)
      WRITE(3,6) PXD,PYD
    6 FORMAT(25X,'INTERELEMENT PHASE SHIFT (DEG.): ',F7.4,' , ',F7.4///)
      RETURN
      END
```

DOS FORTRAN IV 360N-FO-479 3-9   MECH   DATE   12/17/76   TIME   09.16.56

```
      SUBROUTINE MECH(NUMPAT)
      REAL ZAVG(24,12),ALPHAX(24,12),ALPHAY(24,12),K
      REAL A(3,3)
      REAL KX,KY
      REAL WARP(201)
      COMMON /SYS/ RE,RE3,ALT,ALT3,A
      COMMON /ANT/ MSECT,NSECT,MEL,NEL,SX,SY,PX,PY,IHV,K,OMU4PI,ZAVG,
     $ALPHAX,ALPHAY,KX,KY,PXSECT,PYSECT
C
C
      CALL MISC(MSECT,NSECT,WARP)
      WRITE(3,100) NUMPAT
  100 FORMAT(20X,'DEFORMATION DATA FOR SIMULATION ',I3,':'/)
      NSECT1=NSECT+1
      MSECT1=MSECT+1
      DO 50 II=1,NSECT1
      I=NSECT1-II+1
      II=(I-1)*MSECT1+1
      III=I*MSECT1
      WRITE(3,101) (WARP(IJ),IJ=II,III)
  101 FORMAT(10(3X,F7.2))
      WRITE(3,105)
  105 FORMAT(/)
   50 CONTINUE
      WRITE(3,104)
C
C
      PXSECT=MEL*PX
      PYSECT=NEL*PY
      XLEN=SX*MEL
      YLEN=SY*NEL
      DX2=0.5/XLEN
      DY2=0.5/YLEN
C
C
  104 FORMAT(////)
      IAREA=0
      DO 30 N=1,NSECT
```

```
0032            YCENT=YLEN*(N-FLOAT(NSECT+1)*0.5)
0033            DO 30 M=1,MSECT
0034            XCENT=XLEN*(M-FLOAT(MSECT+1)*0.5)
0035            IAREA=IAREA+1
0036            NUM=(IAREA-1)+N
0037            A0=WARP(NUM)
0038            A1=WARP(NUM+1)
0039            A2=WARP(NUM+1+MSECT)
0040            A3=WARP(NUM+2+MSECT)
          C
0041            B0=(A0+A1+A2+A3)*0.25
0042            B1=DX2*(-A0+A1-A2+A3)
0043            B2=DY2*(-A0-A1+A2+A3)
0044            B3=DX2*DY2*4*(A0-A1-A2+A3)
          C
0045            ZAVG(M,N)=B0
0046            ALPHAX(M,N)=ATAN(B1)
0047            ALPHAY(M,N)=ATAN(B2)
0048         30 CONTINUE
0049            WRITE(3,104)
0050            RETURN
0051            END
```

```
DOS FORTRAN 1. 360N-FO-479 3-9          MISC                DATE   12/17/76     TIME     09.17.09

                  SUBROUTINE MISC(MSECT,NSECT,WARP)
                  REAL WARP(201)
                  NWARP=(MSECT+1)*(NSECT+1)
                  READ(1,2)  (WARP(I),I=1,NWARP)
                2 FORMAT(8F10.0)
                  RETURN
                  END
```

DOS FORTRAN IV 360N-FO-479 3-9 ELEC DATE 12/17/76 TIME 09.17.17

```
      SUBROUTINE ELEC(MSECT,NSECT,NUMPAT)
      REAL PHSX(24,12),AMAG(24,12),APHS(24,12),PHSY(24,12)
      COMMON /ELCTRC/ PHSX,PHSY,AMAG,APHS
      MNSECT=(MSECT+1)*(NSECT+1)
      DO 10 J=1,NSECT
      DO 10 I=1,MSECT
   10 READ(1,11) PHSX(I,J),PHSY(I,J),AMAG(I,J),APHS(I,J)
   11 FORMAT(8F10.0)
C
C
      WRITE(3,12) NUMPAT
   12 FORMAT(20X,'ELECTRICAL DATA FOR SIMULATION ',I3,':'/)
      J=NSECT+1
      DO 20 JJ=1,NSECT
      J=J-1
      WRITE(3,25) (I,J,I=1,MSECT)
      WRITE(3,21) (PHSX(I,J),I=1,MSECT)
      WRITE(3,22) (PHSY(I,J),I=1,MSECT)
      WRITE(3,23) (AMAG(I,J),I=1,MSECT)
      WRITE(3,24) (APHS(I,J),I=1,MSECT)
      WRITE(3,104)
   20 CONTINUE
   21 FORMAT(5X,'PHSX:',10(3X,F7.2))
   22 FORMAT(5X,'PHSY:',10(3X,F7.2))
   23 FORMAT(5X,'AMAG:',10(3X,F7.2))
   24 FORMAT(5X,'APHS:',10(3X,F7.2))
   25 FORMAT(10X,10(3X,'(',I2,',',I2,')'))
      DO 30 J=1,NSECT
      DO 30 I=1,MSECT
      PHSX(I,J)=PHSX(I,J)*0.017453293E0
      PHSY(I,J)=PHSY(I,J)*0.017453293E0
      APHS(I,J)=APHS(I,J)*0.017453293E0
   30 CONTINUE
      WRITE(3,104)
  104 FORMAT(////)
      RETURN
      END
```

```
DOS FORTRAN IV 360N-FO-479 3-9          PAT                    DATE   12/17/76     TIME    09.17.29

0001            FUNCTION PAT(XR,YR)
          C
          C        PAT COMPUTES THE COMPLEX-VALUED PATTERN FROM A PIECEWISE
          C        BILINEAR RECTANGULAR ARRAY.
          C
          C       ANTENNA PARAMETERS ARE PASSED BY COMMON BLOCK ANT.
          C        OTHER SYSTEM PARAMETERS ARE PASSED BY COMMON BLOCK SYS.
          C
          C
          C        WRITTEN BY: E. L. COFFEY
          C              DATE:  26 JULY 1976
          C
          C
0002            COMPLEX PAT,CEXP,J
0003            COMPLEX AF2
0004            REAL ZAVG(24,12),ALPHAX(24,12),ALPHAY(24,12),K
0005            REAL KX,KY
0006            REAL PHSX(24,12),AMAG(24,12),APHS(24,12),PHSY(24,12)
0007            REAL A(3,3)
          C
0008            COMMON /SYS/ RE,RE3,ALT,ALT3,A
0009            COMMON /ANT/ MSECT,NSECT,MEL,NEL,SX,SY,PX,PY,IHV,K,OMU4PI,
               $ZAVG,ALPHAX,ALPHAY,KX,KY,PXSECT,PYSECT
0010            COMMON /ELCTRC/ PHSX,PHSY,AMAG,APHS
          C
          C
0011            DATA J/(0.,1.)/
          C
          C........TRANSLATION FROM EARTH SURFACE TO UNROTATED ANTENNA.
0012            CYR=COS(YR)
0013            XP=-RE3*SIN(XR)*CYR
0014            YP=RE3*SIN(YR)
0015            ZP=RE3*(1.-COS(XR)*CYR)+ALT3
          C
          C........ANTENNA YAW,TILT,TWIST
0016            XPP=A(1,1)*XP+A(1,2)*YP+A(1,3)*ZP
0017            YPP=A(2,1)*XP+A(2,2)*YP+A(2,3)*ZP
0018            ZPP=A(3,1)*XP+A(3,2)*YP+A(3,3)*ZP
```

```
0019            RPP=SQRT(XPP*XPP+YPP*YPP+ZPP*ZPP)
0020            U=XPP/RPP
0021            V=YPP/RPP
0022            ALPHA1=ARCOS(U)
0023            ALPHA2=ARCOS(V)
0024            AF1=OMU4PI/RPP
          C
          C......TRANSLATE TO CENTER OF SUBARRAY
          C
0025            DX=SX*MEL
0026            DY=SY*NEL
0027            AF2=(0.,0.)
0028            YCENT=-FLOAT(NSECT+1)/2.0*DY
0029            DO 10 N=1,NSECT
0030            YCENT=YCENT+DY
0031            XCENT=-FLOAT(MSECT+1)/2.0*DX
0032            DO 10 M=1,MSECT
0033            XCENT=XCENT+DX
0034            UP=COS(ALPHA1-ALPHAX(M,N))+PHSX(M,N)/KX
0035            VP=COS(ALPHA2-ALPHAY(M,N))+PHSY(M,N)/KY
0036            WP=SQRT(1.-(UP*UP+VP*VP))
0037            PHASE=K*(XCENT*UP+YCENT*VP+ZAVG(M,N)*WP)+M*PXSECT+N*PYSECT
               $+APHS(M,N)
0038            AF2=AF2+AF1*CMPLX(COS(PHASE),SIN(PHASE))*AF(UP,VP)
               $*AMAG(M,N)
0039         10 CONTINUE
          C
          C
0040            PAT=AF2
0041            RETURN
0042            END
```

```
0001          SUBROUTINE GENER
0002          REAL ZAVG(24,12),ALPHAX(24,12),ALPHAY(24,12),K
0003          REAL KX,KY
0004          REAL UARRAY(1001),VARRAY(1001)
0005          COMMON /PATTRN/ UARRAY,VARRAY,UMAX,VMAX,DU,DV
0006          COMMON /ANT/ MSECT,NSECT,MEL,NEL,SX,SY,PX,PY,IHV,K,DMU4PI,
             $ZAVG,ALPHAX,ALPHAY,KX,KY,PXSECT,PYSECT
        C
        C........THIS ROUTINE GENERATES PATTERN DATA FOR THE ARRAYS UARRAY AND VARRAY.
        C
0007          NULNUM=3
0008          UMAX=6.28318531E0/K/(MEL*SX)*NULNUM
0009          VMAX=6.28318531E0/K/(NEL*SY)*NULNUM
0010          IF(UMAX.GT.1.0) UMAX=1.0
0011          IF(VMAX.GT.1.0) VMAX=1.0
        C
0012          DU=UMAX*1E-3
0013          DV=VMAX*1E-3
        C
        C
0014          DO 10 I=1,1001
0015          U=(I-1)*DU
0016          PSIX=KX*U+PX
0017          PSIX2=0.5*PSIX
0018          U1=1.0
0019          IF(PSIX.NE.0.) U1=SIN(MEL*PSIX2)/(MEL*SIN(PSIX2))
0020          IF(IHV.EQ.1.AND.ABS(U).NE.1.0)U1=U1*COS(1.570796E0*U)/SQRT(1.-U*U)
0021          UARRAY(I)=U1
        C
0022          V=(I-1)*DV
0023          PSIY=KY*V+PY
0024          PSIY2=0.5*PSIY
0025          V1=1.0
0026          IF(PSIY.NE.0.) V1=SIN(NEL*PSIY2)/(NEL*SIN(PSIY2))
0027          IF(IHV.EQ.2.AND.ABS(V).NE.1.)V1=V1*COS(1.570796E0*V)/SQRT(1.-V*V)
0028          VARRAY(I)=V1
0029       10 CONTINUE
        C
```

```
          C
0030            RETURN
0031            END
```

```
DOS FORTRAN IV 360N-FO-479 3-9          AF                    DATE   12/17/76     TIME    09.17.55

      FUNCTION AF(U1,V1)
C
C........THIS FUNCTION CALCULATES THE ARRAY FACTOR OF A SUBPANEL BY
C           "TABLE LOOK-UP" IF U < UMAX AND V < VMAX.   OTHERWISE, THE F NCTION
C           IS COMPUTED IN THE USUAL WAY.
C
C           LINEAR INTERPOLATION IS USED IN THE TABLE LOOK-UP.
C
      REAL ZAVG(24,12),ALPHAX(24,12),ALPHAY(24,12),K
      REAL KX,KY
      REAL UARRAY(1001),VARRAY(1001)
C
      COMMON /PATTRN/ UARRAY,VARRAY,UMAX,VMAX,DU,DV
      COMMON /ANT/ MSECT,NSECT,MEL,NEL,SX,SY,PX,PY,IHV,K,OMU4PI,
     $ZAVG,ALPHAX,ALPHAY,KX,KY,PXSECT,PYSECT
C
C
      U=ABS(U1)
      V=ABS(V1)
C
      IF(U.GT.UMAX) GO TO 10
C........U IS IN RANGE
      FU=U/DU+1.0
      IFU=IFIX(FU)
      DIFF=FU-IFU
      UPAT=(1.0-DIFF)*UARRAY(IFU)+DIFF*UARRAY(IFU+1)
      GO TO 15
   10 CONTINUE
      PSIX2=(KX*U+PX)*0.5
      UPAT=SIN(MEL*PSIX2)/(MEL*SIN(PSIX2))
      IF(IHV.EQ.1) UPAT=UPAT*COS(1.570796E0*U)/SQRT(1.-U*U)
   15 CONTINUE
      IF(V.GT.VMAX) GO TO 20
C........V IS IN RANGE
      FV=V/DV+1.0
      IFV=IFIX(FV)
      DIFF=FV-IFV
      VPAT=(1.0-DIFF)*VARRAY(IFV)+DIFF*VARRAY(IFV+1)
```

DOS FORTRAN IV 360N-FO-479 3-9 AF DATE 12/17/76 TIME 09.17.55

```
      GO TO 25
   20 CONTINUE
      PSIY2=(KY*V+PY)*0.5
      VPAT=SIN(NEL*PSIY2)/(NEL*SIN(PSIY2))
      IF(IHV.FQ.2) VPAT=VPAT*COS(1.570796E0*V)/SQRT(1.-V*V)
   25 CONTINUE
      AF=UPAT*VPAT/(MSECT*NSECT)
      RETURN
      END
```

```
            SUBROUTINE OUTPUT(NUMPAT)
C
C
            INTEGER BUFFER(1000),SYS13
            REAL CON(10)
            INTEGER PR1,PR2,PL1,PL2,PL3,TP1,TP2
            DATA RADDEG/0.01745329E0/
C
C
            COMMON /IO/ PR1,PR2,PL1,PL2,PL3,TP1,TP2,NCON,CON,STARTX,STOPX,
           $DELTAX,STARTY,STOPY,DELTAY,CONLOW,CONMAX,NPTSX,NPTSY,FLOOR,DASH
C
C
            READ(1,8) PR1,PR2
            READ(1,8) PL1,PL2,PL3
            READ(1,8) TP1,TP2
            IF(PL1+PL2+PL3.EQ.0) GO TO 10
C.........INITIALIZE PLOT BUFFER
C
            NBUF=1000
            SYS13=13
            CALL PLOTS(BUFFER,NBUF,SYS13)
C
         10 CONTINUE
            READ(1,6) STRXD,STPXD
            READ(1,6) STRYD,STPYD
            STARTX=STRXD*RADDEG
            STOPX=STPXD*RADDEG
            STARTY=STRYD*RADDEG
            STOPY=STPYD*RADDEG
            IF(PL2.EQ.1) READ(1,7) NCON
            IF(PL2.EQ.1) READ(1,6) (CON(JJ),JJ=1,NCON)
            IF(PR2.EQ.1) [illegible]D(1,6) CONLOW,CONMAX
            IF(PR2+PL2+[illegible].GE.1) READ(1,7) NPTSX,NPTSY
            DELTAX=(STOPX-STARTX)/(NPTSX-1)
            DELTAY=(STOPY-STARTY)/(NPTSY-1)
            DXD=DELTAX*57.295
            DYD=DELTAY*57.295
```

```
C
C........OUTPUT PRINT/PLOT INFORMATION
C
          WRITE(3,103)
      103 FORMAT(////20X,'PRINT/PLOT INFORMATION:'/25X,'REQUESTED OUTPUT:')
          IF(PR1.EQ.1) WRITE(3,104)
          IF(PR2.EQ.1) WRITE(3,105)
          IF(PL1.EQ.1) WRITE(3,106)
          IF(PL2.EQ.1) WRITE(3,107)
          IF(PL3.EQ.1) WRITE(3,108)
      104 FORMAT(30X,'PRINTER PROFILE')
      105 FORMAT(30X,'PRINTER CONTOUR')
      106 FORMAT(30X,'PLOTTER PROFILE')
      107 FORMAT(30X,'PLOTTER CONTOUR')
      108 FORMAT(30X,'PLOTTER THREE-D')
C
          IF(PL2.NE.1 ) GO TO 24
          WRITE(3,109) (CON(I),I=1,NCON)
      109 FORMAT(//25X,'CONTOURS TO BE PLOTTED: ',5(F6.2,3X)/49X,5(F6.2,3X))
       24 CONTINUE
          IF(PR2+PL2+PL3.GE.1) WRITE(3,110) NPTSX,NPTSY
      110 FORMAT(25X,'PLOT RESOLUTION: ',I3,' X ',I3,' POINTS'//)
          WRITE(3,111) STRXD,STPXD,DXD
      111 FORMAT(25X,'STARTX = ',F8.3/25X,'STOPX = ',F8.3/25X,'DELTAX = ',
         $F8.3/)
          WRITE(3,112) STRYD,STPYD,DYD
      112 FORMAT(25X,'STARTY = ',F8.3/25X,'STOPY = ',F8.3/25X,'DELTAY = ',
         $F8.3//)
        6 FORMAT(8F10.0)
        7 FORMAT(2I5)
        8 FORMAT(5I1)
          RETURN
          END
```

```
0001            SUBROUTINE PROFIL(DATA,NPT,NUMPAT)
          C
          C      DATA = DATA INPUT (DESTROYED)
          C      NPT = NUMBER OF POINTS
          C      NUMPAT = PATTERN NUMBER
          C
0002            INTEGER SF
0003            INTEGER OUTPUT(81)
0004            INTEGER BLANK,PLUS,SLASH,STAR
0005            REAL DATA(501,2),BOUND(81)
0006            DATA BLANK,PLUS,SLASH,STAR /' ','+','|','*' /
          C
          C       FIND THE RANGE OF DEPENDENT DATA AND SCALE IF NECESSARY
          C
0007            IF(NPT.GT.501) GO TO 999
0008            BIG=-1.E10
0009            SMALL = 1.E10
0010            DO 1 J=1,NPT
0011            IF(DATA(J,2).LT.-60.0) DATA(J,2)=-60.0
0012            IF(DATA(J,2).LT.SMALL) SMALL=DATA(J,2)
0013            IF(DATA(J,2).GT.BIG) BIG=DATA(J,2)
0014          1 CONTINUE
0015            DIFF=ABS(BIG-SMALL)
0016            SF = 0
0017            IF(DIFF.LT.1.) GO TO 10
0018            IF(DIFF.LT.100.)GO TO 21
0019            DO 2 J=1,10
0020            IF(DIFF*10.**(-J).GT.100.) GO TO 2
0021            SF=J
0022            GO TO 20
0023          2 CONTINUE
0024        400 WRITE(3,100)
0025        100 FORMAT('0 YOUR DATA IS TOO LARGE FOR THIS PROGRAM.')
0026            RETURN
0027         10 DO 3 J=1,10
0028            K=11-J
0029            IF(DIFF*10**K.GT.100.) GO TO 3
0030            SF=-K
```

```
      GO TO 20
    3 CONTINUE
      GO TO 400
   20 DO 4 J=1,NPT
    4 DATA(J,2) = DATA(J,2)*10.**(-SF)
C
C         CALCULATE BOUNDS
C
   21 SCALE=DIFF/80.
      DO 5 J=1,81
      K=J-1
    5 BOUND(J)=(BIG-K*SCALE)*10.**(-SF)
      SFDB=20.*SF
C
C         PRINT TITLE
C
      WRITE(3,640) NUMPAT
  640 FORMAT(26X,'PATTERN NUMBER ',I5//)
      IF (SF.EQ.0) GO TO 200
      WRITE(3,4004) SF
 4004 FORMAT(53X,'SCALE FACTOR IS 10**',I2/)
  200 WRITE(3,650) (BOUND(J),J=1,81,16)
  650 FORMAT(3X,'DB.',5X,'REAL',2X,6(F7.4,9X))
      DO 6 J1=1,NPT
      J=NPT+1-J1
      DO 50 K=1,81
   50 OUTPUT(K)=BLANK
      IF((J-1)/8*8-(J-1)) 62,61,62
   61 DO 40 K=1,81,8
   40 OUTPUT(K)=PLUS
      GO TO 87
   62 OUTPUT(1)=SLASH
      OUTPUT(81)=SLASH
   87 DO 7 K=1,80
      IF(DATA(J,2).GT.BOUND(K)) GO TO 7
      IF(DATA(J,2).LE.BOUND(K+1)) GO TO 7
      OUTPUT(K)=STAR
      GO TO 69
```

```
      7 CONTINUE
        OUTPUT(81)=STAR
     69 IF(DATA(J,2).EQ.0.0) DATA(J,2) = 1.0E-6
        DATADB=20.*ALOG10(ABS(DATA(J,2)))+SFDB
    141 WRITE(3,4000) DATADB,DATA(J,2),OUTPUT,DATA(J,1)
   4000 FORMAT(1X,F6.2,2X,F8.3,2X,81A1,1X,F9.4)
        GO TO 6
      6 CONTINUE
        WRITE(3,650) (BOUND(J),J=1,81,16)
        WRITE(3,651)
    651 FORMAT(1H1)
    999 RETURN
        END
```

```
F 3S FORTRAN IV 360N-FO-479 3-9          PATCON               DATE   12/17/76     TIME    09.18.35

0001                SUBROUTINE PATCON(A    ,CONLOW,CONMAX,STARTX,STOPX,STARTY,STOPY,
                   $NUMPAT)
            C
            C         THIS ROUTINE CALLS SUBROUTINE CONTUR THREE TIMES TO GENERATE A
            C         COMPLETE 151 X 151 TWO-DIM. PLOT.
            C
0002                DIMENSION A(151,151)
0003                DY=(STOPY-STARTY)/3.0
0004                CALL CONTUR(A ,1,CONLOW,CONMAX,STARTX,STOPX,STARTY,STARTY+DY,
                   $NUMPAT)
0005                CALL CONTUR(A ,2,CONLOW,CONMAX,STARTX,STOPX,STARTY+DY,STOPY-DY,
                   $NUMPAT)
0006                CALL CONTUR(A ,3,CONLOW,CONMAX,STARTX,STOPX,STOPY-DY,STOPY,NUMPAT)
0007                RETURN
0008                END
```

```
DOS FORTRAN IV 360N-FO-479 3-9          CONTUR               DATE    12/17/76     TIME    09.18.44

                SUBROUTINE CONTUR(A,ICODE,CONLOW,CONMAX,STARTX,STOPX,STARTY,STOPY,
               $NUMPAT)
          C
          C      THIS ROUTINE PRINTS A  51 X 151 CONTOUR PLOT OF THE FOOTPRINT.
          C      TO OBTAIN A COMPLETE 151 X 151 PLOT, THIS ROUTINE IS CALLED THREE
          C      TIMES BY SUBROUTINE PATCON.  THEN THE THREE SEPARATE PLOTS ARE
          C      JOINED TOGETHER TO MAKE THE COMPOSITE.
          C
          C
                REAL A(151,151),LOW(12),HIGH(12),AXIS(11)
                INTEGER OUTPUT(101),LEVEL(12),BLANK,DOT
          C
          C
                DATA LEVEL/'0','1','2','3','4','5','6','7','8','9',' ','+'/
                DATA BLANK /' '/
          C
                WRITE(3,10) NUMPAT
             10 FORMAT(1H1,37X,'PRINTER CONTOUR PLOT FOR SIMULATION NUMBER ',I3//
               $///)
          C
                DELTAX=(STOPX-STARTX)/150.0
                DELTAY=(STOPY-STARTY)/10.0
                NUMCON=10
                CONINT=(CONMAX-CONLOW)/FLOAT(NUMCON-1)
                DELCON=CONINT*0.5
                DO 71 J=1,NUMCON
                LOW(J)=CONLOW+(J-1)*CONINT-DELCON
                HIGH(J)=LOW(J)+CONINT+1E-5
             71 CONTINUE
                LOW(11)=-1E50
                HIGH(12)=1E50
                HIGH(11)=LOW(1)
                LOW(12)=HIGH(NUMCON)
          C
                DO 40 I=1,11
             40 AXIS(I)=STARTY+(I-1)*DELTAY
                WRITE(3,42) (AXIS(I),I=1,11)
             42 FORMAT(6X,11(F8.3,2X)/10X,10('|.........'),'|')
```

```
      DO 50 N=1,151
      X=STARTX+(N-1)*DELTAX
      DO 51 K=1,101
   51 OUTPUT(K)=BLANK
C
      DO 60 M=1,51
      MM=2*M-1
      M1=M+50*(ICODE-1)
      F=A(N,M1)
      IF(F.LE.LOW(1)) GO TO 1001
      IF(F.GT.HIGH(NUMCON)) GO TO 1002
      DO 61 K=1,NUMCON
      IF(F.GT.LOW(K) .AND. F.LE.HIGH(K)) GO TO 62
   61 CONTINUE
 1002 OUTPUT(MM)=LEVEL(12)
      GO TO 60
 1001 OUTPUT(MM)=LEVEL(11)
      GO TO 60
   62 OUTPUT(MM)=LEVEL(K)
   60 CONTINUE
C
C........OUTPUT
C
      IF(ICODE.EQ.1) WRITE(3,1) X,OUTPUT
      IF(ICODE.EQ.2) WRITE(3,2) OUTPUT
      IF(ICODE.EQ.3) WRITE(3,3) OUTPUT,X
    1 FORMAT(1X,F8.4,'.',101A1)
    2 FORMAT(10X,101A1)
    3 FORMAT(10X,101A1,'.',1X,F8.4)
   50 CONTINUE
      WRITE(3,43) (AXIS(I),I=1,11)
   43 FORMAT(10X,10('|.........'),'|'/6X,11(F8.3,2X))
C
C
      IF(ICODE.NE.2) GO TO 80
      WRITE(3,44)
   44 FORMAT(///51X,'CONTOUR LEVEL KEY'//)
      DO 45 I=1,4
```

```
   45 WRITE(3,46) (LEVEL(J),LOW(J),HIGH(J),J=I,12,4)
   46 FORMAT(2X,3(A1,': ',E14.7,' TO ',E14.7,3X))
   80 CONTINUE
      RETURN
      END
```

```
DOS FORTRAN IV 360N-FO-479 3-9          PLOT1               DATE   03/02/77     TIME    10.00.47

0001                SUBROUTINE PLOT1(PSTRT,PEND,IP,CODE,CONST,NUMPAT,PTS)
              C
              C
              C        PROFILE PLOT ROUTINE
              C
              C        WRITTEN BY: E. L. COFFEY
              C              DATE: 22 JUNE 1976
              C
              C        INPUT:
              C     PSTRT= BEGINNING OF PLOT
              C     PEND= END OF PLOT
              C     IP= NUMBER OF POINTS TO BE PLOTTED
              C     CODE= LABELLING CODE -- 1 FOR X-AXIS, 2 FOR Y-AXIS
              C     CONST= "OTHER" AXIS CONSTANT
              C     NUMPAT= PATTERN NUMBER...USER DEFINED
              C
              C
0002                INTEGER CODE
0003                DIMENSION PTS(501)
0004                CALL PLOT(8.,2.,23)
0005                CALL FACTOR(0.7)
0006                FNUM=NUMPAT
              C
              C        DRAW AXES AND LABEL THEM
              C
0007                Y=0.05
0008                DO 11 J=1,11
0009                X=-5.0+(J-1)*1.0
0010                CALL PLOT(X,-Y,3)
0011             11 CALL PLOT(X,Y,2)
0012                CALL PLOT(5.,0.,3)
0013                CALL PLOT(-5.,0.,2)
              C
0014                CALL PLOT(0.,5.5,3)
0015                CALL PLOT(0.,0.,2)
0016                X=0.05
0017                DO 10 J=1,6
0018                Y=0.5+(J-1)*1.0
```

```
0019             CALL PLOT(-X,Y,3)
0020          10 CALL PLOT(X,Y,2)
          C
          C
0021             CALL NUMBER(-5.25,-.75,0.125,PSTRT,0.,6)
0022             PMID=(PSTRT+PEND)*0.5
0023             CALL NUMBER(-.25,-.75,0.125,PMID,0.,6)
0024             CALL NUMBER(4.75,-.75,0.125,PEND,0.,6)
0025             CALL SYMBOL(-5.0,-1.5,0.125,7HPATTERN,0.,7)
0026             CALL NUMBER(-3.5,-1.5,0.125,FNUM,0.,-1)
          C
0027             IF(CODE.EQ.1) CALL SYMBOL(-2.0,-1.5,0.125,32HX-AXIS PROFILE ALONG
                $LATITUDE = ,0.,32)
0028             IF(CODE.EQ.2) CALL SYMBOL(-2.0,-1.5,0.125,33HY-AXIS PROFILE ALONG
                $LONGITUDE = ,0.,33)
0029             CALL NUMBER(2.0,-1.5,0.125,CONST,3)
0030             CALL ZIP(1,3,18)
          C
          C         PLOT IT
          C
0031             IF(PTS(1).LT.-50.) PTS(1)=-50.0
0032             FS=PTS(1)/10.+5.5
0033             CALL PLOT(-5.0,FS,3)
0034             DELTA=10./FLOAT(IP-1)
0035             DO 1 IWI=1,IP
0036             X=-5.0+(IWI-1)*DELTA
0037             Y=PTS(IWI)/10.+5.5
0038             IF(Y .LT. 0.5) GO TO 1
0039             CALL PLOT(X,Y,2)
0040           1 CONTINUE
0041             CALL FACTOR(1.0)
0042             CALL PLOT(8.0,-2.0,23)
0043             CALL ZIP(3,3,18)
0044             RETURN
0045             END
```

```
      SUBROUTINE PLOT2(N,M,CONTUR,NCON,NUMPAT,DASH)
C                                                                00000240
C     A= N BY M MATRIX OF DATA POINTS
C     CONTUR= ARRAY OF CONTOURS TO BE PLOTTED
C     NCON= NUMBER OF CONTOURS TO BE PLOTTED
C     NUMPAT= PATTERN NUMBER SPECIFIED BY USER
C     DASH= CONTOURS BELOW DASH ARE PLOTTED AS DASHED LINES
C
C                                                                00000310
      DIMENSION A(151,151),RA(151),RB(151),X(151),Y(151)
      REAL CONTUR(10)
      COMMON /ARRAY/ A                                           00000335
      CALL PLOT(8.,0.,23)
      CALL FACTOR (0.7)
      JJ=1
      MS=M                                                       00000340
      NS=N                                                       00000350
      RATIO=MS/NS                                                00000360
      SCALE=10.
      ANM=AMAXO(N-1,M-1)                                         00000380
      IF(RATIO-1.0)1,1,2                                         00000390
    1 SX=ANM                                                     00000400
      SY=RATIO*ANM                                               00000410
      GO TO 3                                                    00000420
    2 SX=1./RATIO*ANM                                            00000430
      SY=ANM                                                     00000440
    3 SMAX=AMAX1(SX,SY)                                          00000450
      SS=SX/SMAX                                                 00000460
      SYS=SY/SMAX                                                00000470
      CALL PLOT(2.0,.25,3)
      DO 300 I=1,10
      CALL PLOT(FLOAT(I)+2.0,.25,2)
      CALL PLOT(FLOAT(I)+2.0,.5,2)
      CALL PLOT(FLOAT(I)+2.0,.25,2)
  300 CONTINUE
      DO 301 I=1,10
      YY=FLOAT(I)+.25
      CALL PLOT(12.,YY,2)
```

```
      CALL PLOT(11.75,YY,2)
      CALL PLOT(12.,YY,2)
  301 CONTINUE
      DO 302 I=1,10
      XX=12.-FLOAT(I)
      CALL PLOT(XX,10.25,2)
      CALL PLOT(XX,10.,2)
      CALL PLOT(XX,10.25,2)
  302 CONTINUE
      DO 303 I=1,10
      YY=10.25-FLOAT(I)
      CALL PLOT(2.,YY,2)
      CALL PLOT(2.25,YY,2)
      CALL PLOT(2.,YY,2)
  303 CONTINUE
      CALL PLOT(1.00,0.25,3)
      CALL PLOT(0.60,0.25,2)
      CALL PLOT(0.60,8.25,2)
      CALL PLOT(1.00,8.25,2)
      CALL PLOT(1.00,0.25,2)
      CALL SYMBOL (0.88,0.45,0.12,10HPATTERN = ,90.,10)
      FNUM=NUMPAT
      CALL NUMBER(0.88,2.075,0.12,FNUM,90.,-1)
      CALL ZIP(1,3,18)
C
C        SORT CONTOURS FROM SMALLEST TO LARGEST
C
      NCON1=NCON-1
      DO 200 I=1,NCON1
      I1=I+1
      DO 201 J=I1,NCON
      IF(CONTUR(I).LE.CONTUR(J)) GO TO 201
      TEMP=CONTUR(I)
      CONTUR(I)=CONTUR(J)
      CONTUR(J)=TEMP
  201 CONTINUE
  200 CONTINUE
C
```

```
C
 1125 YCONA=1.0/SMAX
      DELTAX=SX/FLOAT(N-1)
      X(1)=0.0
      Y(1)=0.0
      RB(1) = A(1,1)
      DO 27 J=2,N
       RB(J)=A(J,1)
   27  X(J)=X(J-1)+DELTAX
      DELTAY=SY/FLOAT(M-1)
      DO 28 J=2,M
   28  Y(J)=Y(J-1)+DELTAY
      DO 118 K=2,M
       DO 30 J=1,N
       RA(J)=RB(J)
   30  RB(J)=A(J,K)
      DO 118 J=2,N
   35  ASSIGN 112 TO L
      RR=RA(J)
      XX=X(J)
      YY=Y(K-1)
   37 RL=RR
      XL=XX
      YL=YY
   39 IF(RL-RA(J-1))   41,40 ,40
   40 IF(RL-RB(J))42,50 ,50
   41 RL=RA(J-1)
      XL=X (J-1)
      YL= Y(K-1)
      GO TO 40
   42 RL=RB(J)
      XL=X (J)
      YL=Y(K)
      GO TO 50
   50 RS=RR
      XS=XX
      YS=YY
      IF(RS-RA(J-1)) 52, 52,53
```

```
      52 IF(RS-RB(J)) 60,60,54
      53 RS=RA(J-1)
         XS=X (J-1)
         YS =Y(K-1)
         GO TO 52
      54 RS=RB(J)
         XS=X (J)
         YS=Y (K)
         GO TO 60
      60 RM=RR
         XM=XX
         YM=YY
         IF(RM-RS) 62, 62,61
      61 IF(RM-RL)70 ,62 ,62
      62 RM=RA(J-1)
         XM=X (J-1)
         YM=Y (K-1)
         IF(RM-RS) 64,64,63
      63 IF(RM-RL) 70,64,64
      64 RM = RB(J)
         XM=X (J)
         YM=Y (K)
      70 YCS=YS*YCONA
         YCM=YM*YCONA
         YCL=YL*YCONA
      71 YS=YS-SY
         YM=YM-SY
         YL=YL-SY
      72  XCS=XS/SMAX
          XCM=XM/SMAX
          XCL=XL/SMAX
         JJ=1
      80 IF(JJ .GT. NCON) GO TO 110
         RC=CONTUR(JJ)
         IF ( RC .NE. RM ) GO TO 91
      81 IF ( RM .NE. RS ) GO TO 91
      82 IF ( RL .EQ. RM ) GO TO 100
      91 IF(RC-RS)100,95,92
```

```
      92 IF(RC-RM)96,93,94                                      00001460
      93 XPA=XCM                                                00001470
         YPA=YCM                                                00001480
         GO TO 99                                               00001490
      94 IF(RC-RL)106,103,110                                   00001500
      95 Q=0.0                                                  00001510
         GO TO 97                                               00001520
      96 Q = (RC-RS)/(RM-RS)                                    00001530
      97 XPA = XCS-Q*(XCS-XCM)                                  00001540
         YPA = YCS-Q*(YCS-YCM)                                  00001550
      99 Q = (RC-RS)/(RL-RS)                                    00001560
         XPB = XCS-Q*(XCS-XCL)                                  00001570
         YPB = YCS-Q*(YCS-YCL)                                  00001580
         IF(RC-DASH) 10115,10115,10116
   10115 XPB1=0.5*(XPA+XPB)                                     00001600
         YPB1=0.5*(YPA+YPB)                                     00001610
         IF(ABS (XPA-XPB1)-.001)5001,5002,5002                  00001620
    5001 IF(ABS (YPA-YPB1)-.001)100,5002,5002                   00001630
    5002 CALL PLOT(SCALE*XPA+2.,SCALE*YPA+0.25,3)
         CALL PLOT(SCALE*XPB1+2.,SCALE*YPB1+0.25,2)
         GO TO 100                                              00001650
   10116 IF(ABS (XPA-XPB)-.001)5003,5004,5004                   00001660
    5003 IF(ABS (YPA-YPB)-.001)100,5004,5004                    00001670
    5004 CALL PLOT(SCALE*XPA+2.,SCALE*YPA+0.25,3)
         CALL PLOT(SCALE*XPB+2.,SCALE*YPB+0.25,2)
     100 JJ=JJ+1
         GO TO 80                                               00001700
     103 XPA = XCL                                              00001710
         YPA = YCL                                              00001720
         GO TO 99                                               00001730
     106 Q=(RC-RM)/(RL-RM)                                      00001740
         XPA=XCM-Q*(XCM-XCL)                                    00001750
         YPA=YCM-Q*(YCM-YCL)                                    00001760
         GO TO 99                                               00001770
     110  GO TO L,(112,118)                                     00001780
     112  ASSIGN 118 TO L                                       00001790
         RR    =RR(J-1)                                         00001800
         XX    =X (J-1)                                         00001810
```

```
DOS FORTRAN IV 360N-FO-479 3-9          PLOT2               DATE   03/02/77     TIME     10.01.01

0178           YY    =Y (K)                                                              00001820
0179           GO TO 37                                                                  00001830
0180       118 CONTINUE                                                                  00001840
0181           CALL FACTOR(1.0)
0182           CALL PLOT(SCALE+6.,0.,23)
0183           CALL ZIP(3,3,18)
0184            RETURN                                                                   00001860
0185            END                                                                      00001870
```

```
C           SUBROUTINE PLOT3
C
C           PURPOSE:  TO DRAW A PERSPECTIVE VIEW OF A CONTOURED SURFACE.
C
C
C           DESCRIPTION OF PARAMETERS AND IMPORTANT VARIABLES:
C
C           N        - NUMBER OF DATA POINTS ALONG FIRST AXIS.
C
C           M        - NUMBER OF DATA POINTS ALONG THE SECOND AXIS.
C
C           NUMPAT   - PATTERN NUMBER (FOR LABELLING).
C
C           K        - CODE THAT TELLS WHETHER TO DRAW THE GRID LINES:
C                            K=1: ALONG THE N-DIMENSION ONLY.
C                            K=2: ALONG THE M-DIMENSION ONLY.
C                            K=3: ALONG BOTH DIMENSIONS.
C
C           DISTS    - DISTANCE FROM SURFACE TO EYE WHEN PERSPECTIVE IS
C                      CALCULATED -- SDISTS > 6 USUALLY WONT'T SHOW ANY
C                      DISTORTION DUE TO PARALLAX.
C
C           YAW      - (IN DEGREES) HOW FAR THE OBJECT IS TURNED AWAY FROM
C                      THE VIEWER.
C
C           PITCH    - (IN DEGREES) HOW THE SURFACE IS LOWERED OR RAISED AT
C                      THE FRONT EDGE.  (POSITIVE PITCH TENDS TO EXPOSE THE
C                      TOP OF THE FIGURE).
C
C           SIZE     - (IN INCHES) THE SIZE OF THE CUBE THAT ENCLOSES THE
C                      FIGURE.
C
C           KODE     - "HIDDEN LINE" SWITCH.  IF KODE=0 DO NOT DRAW HIDDEN
C                      LINES...IF KODE=1, ALL HIDDEN LINES ARE PLOTTED.
C
C           MGN      - WHETHER TO DRAW THE OUTLINE OF THE CUBE TO HELP ORIENT
C                      THE VIEWER.  MGN=0: DO NOT DRAW ANY OUTLINE OF THE
C                      CUBE.  MGN=1:  DRAW THE OUTLINE OF THE CUBE SEPARATE
```

```
C                    FROM THE FIGURE.  MGN=2:  DRAW THE OUTLINE OF THE
C                    CUBE SUPERIMPOSED ON THE SURFACE PLOT.  MGN=3:  DRAW
C                    ONLY THE THREE EDGES OF THE CUBE THAT MEET AT THE
C                    ORIGIN, SUPERIMPOSED ON THE SURFACE PLOT.
C
C        SCALF     - HOW TALL TO MAKE THE SURFACE RELATIVE TO THE HEIGHT
C                    OF THE CUBE.  SCALF=0: DO NOT SCALE THE DATA AT ALL
C                    BUT TRUST THE USER THAT THE DATA IS NOT SO HIGH THAT
C                    IT RUNS OFF THE PAPER.  SCALF=1: SCALE THE DATA SO
C                    THE TOP OF THE DATA JUST TOUCHES THE TOP OF THE CUBE.
C                    SCALF=0.3: SCALE THE DATA SO THE TOP OF THE SURFACE IS
C                    THREE TENTHS AS HIGH AS THE CUBE.
C
C
C
C        REMARKS.
C
C      I. IT IS VERY EXPENSIVE TO DRAW OPAQUE SURFACES, BECAUSE THE
C         PROGRAM HAS TO DETERMINE THE VISIBILITY OF EVERY POINT, THE
C         COMPUTER TIME DOUBLES OR TRIPLES...DEPENDING ON HOW MANY LINE
C         SEGMENTS ARE PARTIALLY VISIBLE.
C
C     II. THE CONTENTS OF ARRAY A ARE DESTROYED IN COMPUTATION.
C
C
C        COMMON BLOCKS REQUIRED:
C
C              COMMON /ARRAY/ A
C              COMMON /THREE6/ ANGA,ANGB,HV,D,SH,SV
C              COMMON /THREE7/ SL,SM,SN,CX,CY,CZ,QX,QY,QZ,SD
C
C
C        SUBROUTINE AND FUNCTION SUBPROGRAMS REQUIRED:
C              THREE2
C              THREE3
C              THREE4
C              THREE5
C              PLOT
```

```
DOS FORTRAN IV 360N-FO-479 3-9          MAINPGM              DATE   03/02/77     TIME    10.01.24

                C            FACTOR
                C            SYMBOL
                C            NUMBER
                C
                C
                C
                C        REFERENCE:HOWARD JESPERSON, IOWA STATE UNIVERSITY.
                C
                C        MODIFIED FOR USE AT VPI BY:  ROBERT D. KEPHART.
                C                                     S. R. KAUFFMAN
                C                                     W. L. STUTZMAN
                C                                     F. L. COFFEY
                C
                C
                C
 0001                 SUBROUTINE PLOT3(N,M,NUMPAT)                                    00000320
                C                                                                     00000330
                C                                                                     00000370
 0002                 COMMON /ARRAY/ A                                                00000389
 0003                 COMMON /THREE6/ ANGA,ANGB,HV,D,SH,SV                            00000390
 0004                 COMMON /THREE7/ SL,SM,SN,CX,CY,CZ,QX,QY,QZ,SD                   00000400
 0005                 DIMENSION H(10),V(10),X(2),Y(2),Z(2),XP(8),A(151,151)           00000410
 0006                 K=3                                                             00000420
 0007                 SPISTS=6.0                                                      00000430
 0008                 PITCH=30.                                                       00000440
 0009                 YAW=45.                                                         00000450
 0010                 SIZE=10.
 0011                 KODE=0                                                          00000470
 0012                 MCN=0                                                           00000480
 0013                 SCALE=1.0
 0014                 CALL FACTOR(1.0)
 0015                 CALL PLOT(8.,.2,23)
 0016                 CALL PLOT(.4,0.,2)                                              00000510
 0017                 CALL PLOT(.4,8.,2)                                              00000520
 0018                 CALL PLOT(0.,8.,2)                                              00000530
 0019                 CALL PLOT(0.,0.,2)                                              00000540
 0020                 CALL ZIP(3,3,18)
 0021                 CALL SYMBOL(0.3,1.0  ,0.12,10HPATTERN = ,90.,10)
```

```
0022          FNUM=FLOAT(NUMPAT)
0023          CALL NUMBER(0.3,2.130 ,0.12,FNUM,90.,-1)
0024          CALL ZIP(1,3,18)
0025          CALL PLOT(1.5,-.2,23)
       C***** ********
0026          ANGA = (YAW+270.) * .0174532
0027          ANGB = PITCH * .0174532
0028          HV = SIZE
       C  DIRECTION COMPONENTS TO THE EYE.
0029           SL = -COS( ANGA ) * COS( ANGB )
0030           SM = -SIN( ANGA ) * COS( ANGB )
0031           SN = -SIN ( ANGB )
0032                IF ( ABS( SN ) .NE. 1.0 ) GO TO 10
0033              WRITE(  6       ,    20  )
0034       20   FORMAT (  '1' , 20X,  20('*') , / '0', 'YOU ARE ATTEMPTING TO LO
          :K  STRAIGHT DOWN ( OR UP ) AT THE SURFACE ' )
0035                 GO TO 2150
0036       10  CONTINUE
0037          SD = 1.0 / SQRT( 1.0 - SN ** 2  )
0038           X(1) = 1
0039           X(2) = N
0040           Y(1) = 1
0041           Y(2) = M
0042          T=MAX0(M,N)
       C  FIND THE DIAGONAL OF THE "CUBE".
0043           D = M ** 2  +  N ** 2  +  T ** 2
0044           D  =   SQRT ( D )
0045           SCL = SDISTS * D
       C  COORDINATES OF YOUR EYE.
0046           CX = -SL * SCL
0047           CY = -SM * SCL
0048           CZ = -SN * SCL
       C  COORDINATES OF THE PROJECTION PLANE.
0049           OX = CX + D * SL
0050           OY = CY + D * SM
0051           OZ = CZ + D * SN
       C       PPPPPPP2PPPPPPPPPPPPPPPPPP
0052           GO TO 2060
```

```
            C      WRITE(6,100) CX,CY,CZ                                           00000910
            C      WRITE(6,100) QX,QY,QZ                                           00000920
0053        100   FORMAT(1X,3F15.3)                                                00000930
0054         2060 Z(2)=A(1,1)
0055              Z(1)=A(1,1)
0056              DO 1000 J=1,N
0057              DO 1000 K=1,M
0058              Z(1)=AMIN1(Z(1),A(J,K))
0059              Z(2)=AMAX1(Z(2),A(J,K))
0060         1000 CONTINUE
0061              RANGE= (Z(2)-Z(1))                                               00000950
0062               DOL=1.0                                                         00000960
0063               IF(SCALE.NE.0)  DOL=T/RANGE*SCALE                               00000970
            C  SCALE THE SURFACE TO MAKE A "CUBE".                                 00000980
0064               DO 30 I = 1 , N                                                 00000990
0065               DO 30 J = 1 , M                                                 00001000
0066               A ( I , J ) = ( A ( I , J ) - Z ( 1 ) ) * DOL                   00001010
0067           30 CONTINUE                                                         00001020
0068               Z(1) = 0.0                                                      00001030
0069               Z(2) = T                                                        00001040
0070         2080 CALL THREE2  ( X, Y, Z, XP , H , V ,KODE)                        00001050
0071               DO 2130 I = 1 , 8                                               00001060
0072               H( I ) = ( (XP(I) - QX ) * SM - (  H(I) - QY ) * SL ) * SD      00001070
0073               V ( I ) = (  V( I ) - QZ ) * SD                                 00001080
0074         2130 CONTINUE                                                         00001090
0075         2100 H(10)=H(1)
0076              H(9)=H(1)
0077              DO 1001 J=1,8
0078              H(9)=AMIN1(H(9),H(J))
0079              H(10)=AMAX1(H(10),H(J))
0080         1001 CONTINUE
0081         2120 V(9)=V(1)
0082              V(10)=V(1)
0083              DO 1002 J=1,8
0084              V(9)=AMIN1(V(9),V(J))
0085              V(10)=AMAX1(V(10),V(J))
0086         1002 CONTINUE
0087              IF( MGN .EQ. 0) GO TO 2140                                       00001120
```

```
      S=HV
      IF(MGN .EQ. 1) S=1.5
      SH = S/ (H(10)-H(9) )
      SV = S/ (V(10)-V(9) )
      SH = SIGN( AMIN1(SH,SV),SH )
      SV = SIGN(SH,SV)
      IF(MGN .EQ. 1)CALL PLOT (0.,2.,-3)
      CALL SYMBOL((H(1)-H(9))*SH,(V(1)-V(9))*SV,.14,'O',0.,1)
      CALL SYMBOL((H(3)-H(9))*SH,(V(3)-V(9))*SV,.14,'M',0.,1)
      CALL SYMBOL((H(2)-H(9))*SH,(V(2)-V(9))*SV,.14,'Z',0.,1)
      CALL SYMBOL((H(5)-H(9))*SH,(V(5)-V(9))*SV,.14,'N',0.,1)
       CALL PLOT(.03,.05,-3)
      CALL PLOT ( (H(1)-H(9))*SH, (V(1)-V(9))*SV,3)
      CALL PLOT ( (H(2)-H(9))*SH, (V(2)-V(9))*SV,2)
      CALL PLOT ( (H(1)-H(9))*SH, (V(1)-V(9))*SV,2)
      CALL PLOT ( (H(3)-H(9))*SH, (V(3)-V(9))*SV,2)
      CALL PLOT ( (H(1)-H(9))*SH, (V(1)-V(9))*SV,2)
      CALL PLOT ( (H(5)-H(9))*SH, (V(5)-V(9))*SV,2)
      IF( MGN .EQ. 3) GO TO 2139
      CALL PLOT ( (H(6)-H(9))*SH, (V(6)-V(9))*SV,2)
      CALL PLOT ( (H(2)-H(9))*SH, (V(2)-V(9))*SV,2)
      CALL PLOT ( (H(4)-H(9))*SH, (V(4)-V(9))*SV,2)
      CALL PLOT ( (H(3)-H(9))*SH, (V(3)-V(9))*SV,2)
      CALL PLOT ( (H(7)-H(9))*SH, (V(7)-V(9))*SV,2)
      CALL PLOT ( (H(5)-H(9))*SH, (V(5)-V(9))*SV,2)
      CALL PLOT ( (H(6)-H(9))*SH, (V(6)-V(9))*SV,2)
      CALL PLOT ( (H(8)-H(9))*SH, (V(8)-V(9))*SV,2)
      CALL PLOT ( (H(4)-H(9))*SH, (V(4)-V(9))*SV,2)
      CALL PLOT ( (H(8)-H(9))*SH, (V(8)-V(9))*SV,2)
      CALL PLOT ( (H(7)-H(9))*SH, (V(7)-V(9))*SV,2)
 2139  IF(MG  .NE. 1) GO TO 2140
      CALL PLOT (AINT((H(10)-H(9))*SH+2.),-2.05,23)
 2140 CALL THREE3(X,Y,N,M,H,V,K,KODE)
 2150 CONTINUE
        LL PLOT(16.,0.,23)
      CALL ZIP(3,3,18)
         RETURN
      END
```

```
0001             SUBROUTINE THREE2 ( X, Y, Z, XP , H , V ,KODE)              00001670
           C FIND THE CORNERS OF THE ROTATED CUBE.                           00001680
           C                                                                  00001690
0002              DIMENSION X(2),Y(2),Z(2),H(10),V(10),XP(8)                 00001700
           C                                                                  00001710
0003         050  L = 0                                                       00001720
0004         070  DO 180 I = 1, 2                                             00001730
           C                                                                  00001740
0005         090   DO 170 J = 1, 2                                            00001750
           C                                                                  00001760
0006         110    DO 160 K = 1, 2                                           00001770
           C                                                                  00001780
0007         130    L = L + 1                                                 00001790
0008         140    CALL THREE4 ( X(I), Y(J), Z(K), XP( L ),                  00001800
                1     H(L) , V( L ),KODE )                                    00001810
0009         160 CONTINUE                                                     00001820
0010         170 CONTINUE                                                     00001830
0011         180 CONTINUE                                                     00001840
0012         190 RETURN                                                       00001850
0013              END                                                         00001860
```

```
0001          SUBROUTINE THREE4 ( X, Y, Z, XP , YP , ZP ,KODE)                00001870
        C  FIND THE LOCATION OF A POINT IN THE ROTATED CURF.                 00001880
0002          COMMON /THREE6/ ANGA , ANGB , HV , D, SH,SV                     00001890
0003          COMMON /THREE7/SL , SM , SN , CX , CY , CZ , QX , QY , QZ , SD  00001900
0004          SK = D / (  (X - CX ) * SL + ( Y - CY ) * SM + ( Z - CZ ) *SN)  00001910
0005          XP = CX + SK * ( X - CX )                                       00001920
0006          YP = CY + SK * ( Y - CY )                                       00001930
0007          ZP = CZ + SK * ( Z - CZ )                                       00001940
0008                RETURN                                                    00001950
0009                         END                                              00001960
```

```
0001            SUBROUTINE THREE3 (X,Y,N,M,H,V,K,KODE)                          00001970
           C  DRAW THE FIGURE.                                                  00001980
0002             COMMON /THREE6/ ANGA , ANGB , HV , D, SH,SV                    00001990
0003            COMMON /THREE7/SI,SM,SN,CX,CY,CZ,OX,OY,OZ,SD                    00002000
           C                                                                    00002010
0004            DIMENSION X(2),Y(2),H(10),V(10),A(151,151)                      00002020
0005       .    COMMON /ARRAY/ A                                                00002025
0006            INTEGER UP , DOWN , PEN , P , Q                                 00002030
0007              INTEGER P1 , P0                                               00002040
           C                                                                    00002050
           C                                                                    00002070
0008                 END = 1.0 / 16.0                                           00002080
           C  CAN USE 1 / 32 OR  1 / 64 FOR FINER INTERPOLATION                 00002090
           C                                                                    00002100
           C                                                                    00002110
0009            UP   = 3                                                        00002120
0010            DOWN = 2                                                        00002130
0011            SH =  HV / ( H ( 10 ) - H ( 9 ) )                               00002140
0012            SV = HV / ( V ( 10 ) - V ( 9 ) )                                00002150
0013            SH = SIGN(AMIN1(SH,SV),SH)                                      00002160
0014            SV = SIGN(SH,SV)                                                00002170
0015             MM = M                                                         00002180
0016             NN = N                                                         00002190
           C 080 IF(K-1) 100,120,100
           C                                                                    00002210
           C 100 IF(K-3) 1110,120,1110
           C                                                                    00002230
           C  DRAW LINES ALONG THE Y-AXIS                                       00002240
0017         120 CONTINUE                                                       00002250
0018            L = 0                                                           00002260
0019            LD = 1                                                          00002270
0020              DD = 0.5 * LD                                                 00002280
           C                                                                    00002290
0021         140  DO 1060 J = 1, M                                              00002300
0022            Q    = 0                                                        00002310
0023            YJ = J                                                          00002320
0024         160  DO 1030 I = 1, NN                                             00002330
           C                                                                    00002340
```

```
              L = L + LD
            XI = L
          CALL THREE5 (    XI ,YJ , N , M , P ,KODE)
            PEN = UP
               IF ( P ) 510 , 520 , 530
      510 CONTINUE
             IF ( Q ) 540 , 550 , 540
      520 CONTINUE
             IF ( Q ) 610 , 1020 , 610
      530  CONTINUE
             IF ( Q ) 540 , 550 , 540
      540  CONTINUE
            PEN = DOWN
           GO TO 170
      550  CONTINUE
              IF ( I .EQ. 1 ) GO TO 170
             DI = DD
          TO = L - LD
            T = TO + DI
            P1 = 1
      560  IF ( ABS( DI )  .LT.  END  )  GO TO 570
          CALL THREE5 (T,YJ,N,M,PO,KODE)
            DI = DI * 0.5
           IF ( PO  .EQ.  0  )  GO TO 565
             TO = T
            P1 = PO
            T =  T - DI
            GO TO 560
      565  T = T + DI
            GO TO 560
      570  CONTINUE
           T = TO
          IF ( P1 * P  )  170 , 170 , 580
      580 CONTINUE
      590 CONTINUE
          ZP = A(L-LD,J)+(T-L+LD)*(A(L,J)-A(L-LD,J))/LD
          CALL THREE4(T,YJ,ZP,XP,HH,VV,KODE)
           HH = ( ( XP-OX)*SM- (HH - OY )*SL ) * SO
```

```
            VV =  ( VV - OZ ) * SD
             HH = ( HH - H(9) ) * SH
             VV = ( VV - V(9) ) * SV
             CALL PLOT ( HH , VV , PEN )
  600       PEN = 5 - PEN
            GO TO 170
  610 CONTINUE
              PEN = DOWN
               DI = DD
             TO = L - LD
            T = TO + DI
               P1 = Q
  620       IF ( ABS( DI )  .LT.  END  )  GO TO 630
           CALL THREE5 (T,YJ,N,M,PO,KODE)
            DI = DI * 0.5
             IF ( PO  .EQ.  0  )  GO TO 625
             TO = T
            P1 = PO
            T = T + DI
             GO TO 620
  625        T = T - DI
               GO TO 620
  630        CONTINUE
             T = TO
               IF (  P1 * Q )  600 , 600 , 590
  170         CALL THREE4 ( XT , YJ , A( L, J ), XP , HH ,VV ,KODE)
            VV =  ( VV - OZ ) * SD
            HH = ( ( XP-QX)*SM- (HH - QY )*SL ) * SD
  190         HH = ( HH - H(9) ) * SH
  200         VV = ( VV - V(9) ) * SV
            CALL PLOT (  HH , VV , PEN )
 1020       Q = P
C
C
            L = L + LD
 1030       CONTINUE
            LD = -LD
               DD =-DD
```

```
             C                                                          00003110
 0099         1060 CONTINUE                                             00003120
             C                                                          00003130
             C                                                          00003140
             C1090 IF(K-3) 2060,1110,2060
             C                                                          00003160
             C   DRAW LINES ALONG THE X-AXIS.                           00003170
 0100         1110 CONTINUE                                             00003180
             C                                                          00003190
 0101                L = 0                                              00003200
 0102                LD = 1                                             00003210
 0103                  DD = 0.5 * LD                                    00003220
 0104         1140 DO 2040 I = 1 , N                                    00003230
 0105                    XI = I                                         00003240
 0106                 Q = 0                                             00003250
 0107         1160     DO 2020 J = 1 , MM                               00003260
 0108                        L = L + LD                                 00003270
 0109                      YJ = L                                       00003280
 0110                CALL THREES (XI,YJ,N,M,P,KODE)
 0111                 PEN = UP                                          00003300
 0112                      IF ( P ) 1510 , 1520 , 1530                  00003310
 0113         1510 CONTINUE                                             00003320
 0114                   IF ( Q ) 1540 , 1550 , 1540                     00003330
 0115         1520    CONTINUE                                          00003340
 0116                  IF ( Q )  1610 , 2010 , 1610                     00003350
 0117        1530    CONTINUE                                           00003360
 0118                    IF ( Q ) 1540 , 1550 , 1540                    00003370
 0119         1540    CONTINUE                                          00003380
 0120                  PEN = DOWN                                       00003390
 0121                 GO TO 1170                                        00003400
 0122         1550        CONTINUE                                      00003410
 0123                 IF ( J .EQ.  1  )  GO TO 1170                     00003420
 0124                  DI = DD                                          00003430
 0125                TO=L-LD
 0126                 T = TO + DI                                       00003450
 0127                 PI = 0                                            00003460
 0128         1560  IF (  ABS( DI )  .LT.  END  )  GO TO 1570           00003470
 0129                CALL THREES (XI,T,N,M,PD,KODE)
```

```
             DI = DI * 0.5                                          00003490
          IF ( PO  .EQ.  0  )  GO TO 1565                           00003500
               TO = T                                               00003510
            PI = PO                                                 00003520
            T =  T - DI                                             00003530
               GO TO 1560                                           00003540
     1565 T = T + DI                                                00003550
                GO TO 1560                                          00003560
     1570   CONTINUE                                                00003570
            T = TO                                                  00003580
          IF ( PI * P  )  1170 , 1170 , 1580                        00003590
     1580 CONTINUE                                                  00003600
     1590 CONTINUE                                                  00003610
          ZP=A(I,L-LD) + (T-L+LD) * (A(I,L) - A(I,L-LD))/LD         00003620
               CALL THREE4 ( XI , T , ZP , XP,HH,VV ,KODE)          00003630
          HH = ( ( XP-OX)*SM- (HH - OY )*SL ) * SD                  00003640
          VV =  ( VV - OZ ) * SD                                    00003650
             HH = ( HH - H(9) ) * SH                                00003660
             VV = ( VV - V(9) ) * SV                                00003670
           CALL PLOT ( HH , VV , PEN )                              00003680
     1600 PEN = 5 - PEN                                             00003690
             GO TO 1170                                             00003700
     1610  CONTINUE                                                 00003710
              PEN = DOWN                                            00003720
               DI = DD                                              00003730
             TO = L - LD                                            00003740
           T = TO + DI                                              00003750
                PI = 0                                              00003760
     1620  IF ( ABS( DI )  .LT.  END  )  GO TO 1630                 00003770
          CALL THREE5 (XI,T,N,M,PO,KODE)
              DI = DI * 0.5                                         00003790
             IF ( PO .EQ. 0 )  GO TO 1625                           00003800
              TO = T                                                00003810
           PI = PO                                                  00003820
             T = T + DI                                             00003830
             GO TO 1620                                             00003840
     1625    T = T - DI                                             00003850
              GO TO 1620                                            00003860
```

```
0168        1630    CONTINUE                                                  00003870
0169                 T = TO                                                   00003880
0170                 IF ( PI * Q ) 1600 , 1600 , 1590                         00003890
0171        1170    CALL THREE4 ( XI, YJ, A( I, L ), XP , HH ,VV ,KODE)       00003900
0172                HH = ( ( XP-OX)*SM- (HH - OY )*SL ) * SD                  00003910
0173                VV =  ( VV - OZ ) * SD                                    00003920
0174        1180       HH = ( HH - H(9) ) * SH                                00003930
0175        1190       VV = ( VV - V(9) ) * SV                                00003940
0176                  CALL PLOT (  HH , VV ,  PEN  )                          00003950
0177        2010    Q = P                                                     00003960
0178        2020     CONTINUE                                                 00003970
           C                                                                  00003980
0179                L = L + LD                                                00003990
0180                LD = - LD                                                 00004000
0181                   DD =-DD                                                00004010
0182        2040    CONTINUE                                                  00004020
           C                                                                  00004030
0183        2060 CONTINUE                                                     00004040
           C                                                                  00004050
0184        2130    RETURN                                                    00004060
0185                 END                                                      00004070
```

```
C
C
C         SUBROUTINE THREE5
C
C
C         PURPOSE: TO SEE IF A POINT ON THE PROJECTED THREE DIMENSIONAL
C         FIGURE IS VISIBLE.
C
C
C         USAGE:
C
C         CALL THREE5(XI,YJ,M,N,P,KODE)
C
C
C         DESCRIPTION OF PARAMETERS:
C
C
C         XI        - ABSCISSA OF THE PROJECTED POINT
C
C         YJ        - ORDINATE OF THE PROJECTED POINT
C
C         M         - NUMBER OF HORIZONTAL POINTS
C
C         N         - NUMBER OF VERTICAL POINTS
C
C         P         - PLOT CODE;  IF P = -1  INVISIBLE TO VISIBLE
C                                     1  VISIBLE TO INVISIBLE
C                                     0  VISIBLE TO VISIBLE OR
C                                        INVISIBLE TO INVISIBLE.
C
C         KODE      - HIDDEN LINE CODE  (SEE SUBROUTINE PLOT3)
C
C
C
C         COMMON BLOCKS REQUIRED:
C
C         COMMON /ARRAY/ A
C         COMMON /THREE6/ ANGA,ANGB,HV,D,SH,SV
```

```
C        COMMON /THREE7/ SL,SM,SN,CX,CY,CZ,QX,QY,QZ,SD
C
C
C        SUBROUTINE AND FUNCTION SUBPROGRAMS REQUIRED:NONE.
C
C
C
      SUBROUTINE THREE5 (XI,YJ,M,N,P,KODE)
      DIMENSION Z(151,151)
       COMMON /THREE6/ ANGA , ANGB , HV , D, SH,SV                     00004100
      COMMON /THREE7/SL,SM,SN,CX,CY,CZ,QX,QY,QZ,SD                     00004110
      COMMON /ARRAY/ Z
       INTEGER  CUM , CNT , P                                          00004120
         REAL I , J , II , JJ                                          00004130
      IF( KODE .EQ. 1) GO TO 78                                        00004150
      IR = XI                                                          00004160
      JC = YJ                                                          00004170
        ZB = Z ( IR , JC )                                             00004180
      IF (  XI  .EQ.  IR  )  GO TO 2                                   00004190
       ZB = Z(IR ,JC ) + ( XI - IR) * (Z(IR + 1 , JC ) - Z( IR ,JC))   00004200
           GO TO 4                                                     00004210
    2  IF ( YJ .EQ.  JC )        GO TO 4                               00004220
       ZB = Z(IR , JC) + (YJ-JC)*(Z(IR,JC+1) - Z(IR,JC ))              00004230
    4  CONTINUE                                                        00004240
       XEND = 0.0                                                      00004250
       DX = 0.0                                                        00004260
       YMULT = 0.0                                                     00004270
       ZMULT = 0.0                                                     00004280
         IF (XI   .EQ.  CX   ) GO TO 10                                00004290
      YMULT = (YJ - CY ) /  (XI - CX )                                 00004300
         ZMULT = ( ZB - CZ ) / ( XI - CX )                             00004310
      DX = 1.0                                                         00004320
        XEND = M + 1                                                   00004330
        IF ( XI  .LT.  CX)  GO TO 10                                   00004340
        DX = -1.0                                                      00004350
       XEND = 0.0                                                      00004360
   10 CONTINUE                                                         00004370
      YEND = 0.0                                                       00004380
```

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```
      DY = 0.0
       XMULT = 0.0
       IF ( YJ  .EQ.  CY  )  GO TO 20
      XMULT = ( XI - CX ) / (YJ - CY )
       IF (  ZMULT  .EQ.  0.0  )  ZMULT=(ZB - CZ ) / ( YJ - CY )
      DY = 1.0
      YEND = N + 1
      IF ( YJ  .LT.  CY )  GO TO 20
      DY = -1.0
       YEND = 0.0
   20 CONTINUE
      CUM = 0
      CNT = 0
      P = 0
       XB = XI
      YB = YJ
   30 CONTINUE
      II = AINT( XB )
      JJ = AINT( YB )
      XSTEP = DX
      YSTEP = DY
        IF ( XB  .EQ.  II )  GO TO 40
        IF ( DX  .LT.  0.0 )  XSTEP = 0.0
      GO TO 45
   40  IF ( YB  .EQ.  JJ )  GO TO 45
        IF ( DY  .LT.  0.0 )  YSTEP = 0.0
   45 CONTINUE
        I = II + XSTEP
        J = JJ + YSTEP
        IF ( I  .EQ.  XEND )  GO TO 80
        IF ( J  .EQ.  YEND )  GO TO 80
      XB = CX + XMULT * ( J - CY )
      YB = CY + YMULT * ( I - CX )
        IF ( DX  .LT.  0.0 )  GO TO 55
        IF ( XB  .LT.  I  )  GO TO 60
   50 XB = I
       GO TO 65
   55 IF ( XB  .LT.  I )  GO TO 50
```

```
   60 YB = J
   65  CONTINUE
      ZB = CZ + ZMULT * ( XB - CX )
      IR = I
      JC = J
        IF ( YB  .NE.  J )  GO TO 70
       IDX = I - DX
      ZS = Z( IR, JC ) - DX * ( XB - I ) * (Z(IDX,JC) - Z(IR,JC))
      GO TO 75
 70   JDY=J-DY
      ZS = Z( IR,JC ) - DY * ( YB-J ) * (Z( IR,JDY ) - Z( IR,JC ) )
   75 CONTINUE
      SGN = 1
      IF (  ZB  .LT.  ZS  )  SGN = -1
      CUM = CUM + SGN
      CNT = CNT + 1
      IF (  IABS ( CUM)  .EQ.  CNT  )  GO TO 30
       GO TO 90
  78  P=1
      GO TO 95
   80 CONTINUE
      P = 1
          IF ( CUM ) 84 , 86 , 90
   84 P = -1
             GO TO 90
   86  CONTINUE
              IF ( ZB  .LE.  CZ  )  GO TO 90
       P = -1
   90  CONTINUE
  95    RETURN
      END
```