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Estimating the Performance of Telecommunication Systems Using the Ionospheric Transmission Channel

Ionospheric Communications Analysis and Prediction Program User's Manual

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PREFACE

The Institute for Telecommunication Sciences and its predecessors in the U.S. Department of Commerce have been collecting ionospheric data and developing methods to use these data in the prediction of the expected performance of high-frequency (HF) skywave systems since the start of World War II.

Much of these data and the techniques for using the data are stored for use by computers. Also several "standard" output formats have emerged to assist in the planning and operation of high-frequency systems using skywaves. This report describes the use of the latest developed method the "Ionospheric Communications Analysis and Prediction Program" (IONCAP). The input and output characteristics in this report relate to IONCAP Version 78.03. The version number was generated to historically document the IONCAP program as it currently exists and to facilitate a means of identifying subsequent versions of the program. The version number 78.03 indicates that this version of IONCAP was developed in 1978 and is the third version of the IONCAP program. The earlier versions of the program, 77.01 and 77.02, were developmental versions and were not distributed.

For many years, numerous organizations have been employing the HF spectrum to communicate over long distances. It was recognized in the late thirties that these communication systems were subject to marked variations in performance. The effective operation of long-distance HF systems increased in proportion to the ability to predict variations in the ionosphere, since such an ability permitted the selection of optimum frequencies, antennas, and other circuit parameters. A worldwide network of ionosondes was established to measure ionospheric parameters. Worldwide noise measurement records were taken and observed variations in signal and amplitudes were recorded over various HF paths. The results of this research established that most variations in HF system performance were directly related to changes in the ionosphere, which in turn are affected in a complex manner by solar activity, seasonal and diurnal variations, as well as latitude and longitude. By 1948 a treatise of ionospheric radio propagation was published by the Central Radio Propagation Laboratory (CRPL) of the National Bureau of Standards. This document (CRPL, 1948) outlined the state of the art in HF propagation. Manual techniques were given for analyzing HF circuits of short, intermediate, and long distances. Because the manual methods were laborious and time consuming, various organizations developed computer programs to analyze HF circuit performance. All these programs were based on manual methods for short or intermediate distances and used various numeric representations of the ionospheric data. The program described here is a direct descendant of these programs. Use of the Ionospheric Communications Analysis and Prediction Program (IONCAP) is described in this report.

The Ionospheric Communications Analysis and Prediction Program (IONCAP) is in modular form and coded in simple FORTRAN, following as much as possible the ANSI 66 standard. The modular form allows any subsection to be replaced without affecting the rest of the program. As much as possible, table look-up techniques are used to reduce computer run time, to facilitate the modular structure, and to assist in the detection of errors in any subsection. In particular, iterative search procedures are eliminated as these tend to become unstable under some ionospheric conditions. The program is divided into seven largely independent sections:

1. input subroutines,
2. path geometry subroutines,
3. antenna subroutines,
4. ionospheric parameter subroutines,
5. maximum usable frequency subroutines,
6. system performance subroutines, and
7. output subroutines.

The input subroutines handle the various input options. There are three inputs: card images, a long-term data tape image, and an antenna tape image. The card images contain the circuit parameters and control run options. The long-term data tape contains numeric coefficients for ionospheric parameters and for atmospheric noise as well as tables of parameters needed for circuit performance. The antenna tape contains optional antenna patterns which can either be generated by the IONCAP program or obtained from some other source. Simplification of the input card images, greater input flexibility, plus extended and newly developed input features improve this section over previous models.

The path geometry subroutines determine the circuit geometry, select areas to sample the ionosphere, and evaluate the magnetic field at these sample areas. There are no significant improvements in this section over previous models.

The antenna subroutines process antenna data input cards, calculate antenna gains, and output antenna patterns. The program has the simple subroutine from ITSA-1 (Lucas and Haydon, 1966) for the basic antenna models. These assume the antennas are associated with existing systems that have been properly designed.

The ionospheric parameter subroutines evaluate the ionospheric parameters needed by the program. Previous programs assumed an implicit two parabola ionosphere. An explicit electron density profile is used in this program. The profile consists of a D-E region starting at 70 km, an F2 region, an F1 ledge, and an E-F valley. [A method of including the top side is given in a Radio Science article (Haydon and Lucas, 1968).] Other electron density profile subroutines may be substituted and will not affect the operation of the program. Observation indicates that absorption equations using the secant law require modification when frequencies do not traverse the entire absorbing region, i.e., with reflection heights lower than 90 km. An empirical modification to the secant law is included in this program.

The maximum usable frequency (MUF) subroutine is a direct determination of the junction frequency based on an electron density profile derived from monthly median parameters of the ionosphere rather than an iterative search. A corrected form of Martyn's theorem (Martyn, 1959) is used. The E, F1, and F2 layer MUFs are considered. There is also a separate sporadic-E MUF. The program also includes the classical nomogram method as an option (Lucas and Haydon, 1961).

The system performance subroutines evaluate all the usual circuit performance parameters. There are two basic subroutines: one for shorter distances and one for long distances (greater than 10,000 km). The models for the shorter distances are replacements for previous computer programs. The long-distance models have not previously been incorporated into a computer program. The short-distance models correspond to the manual method given by Haydon et al. (1969). A manual method somewhat like the long-distance models is given in NBS Report 462, (CRPL, 1948). The short-distance model evaluates all possible ray paths for the circuit, including high and low angle modes; E, F1, and F2 modes; above the MUF modes; and sporadic-E modes. Losses include regular D-E absorption (CCIR-252 loss), deviative losses, and sporadic-E losses. The CCIR-252 loss is basically for F2 modes. For E-layer modes, an adjustment of the absorption is required, and for frequencies which have low reflection heights (less than 90 km) a further correction to the frequency dependence is added. The noise at the receiver site is evaluated and combined with signal statistics to estimate the signal-to-noise statistics.

An extension of the single-hop model to long paths would lead to the expectation that failure of propagation at any of the reflection areas would cause propagation to fail altogether. Empirically, however, it has been found that propagation does not fail until the ionosphere either fails to launch a skywave or does not permit skywave reception; i.e., these are control areas about 2,000 km from each end of the path. The long-distance model evaluates a skywave launch capability at the transmitter and a skywave intercept capability at the receiver, using an antenna-gain-minus-ionosphere-loss function at each end of the path. Losses are the same as for the short paths at each end of the path, with a loss per kilometer function used to fill in the path. Noise and signal statistics are the same for the short-distance or the long-distance paths.

The output subroutines generate all the output options as line printer images which can be printed, written to magnetic tape, or saved on disk. The available output options and the corresponding input required to generate the output is described in this report.

The HF communications systems performance program has been extensively revised. The chief limitations to further improvements appear to be the lack of better statistical knowledge of the ionospheric and noise parameters and their interrelations. There are six areas of expected improvement incorporated into this revision of the program:

1. A more complete description of the ionosphere.
2. Loss equations modified to include E-mode adjustments, sporadic-E effects, over-the-MUF losses, and losses for low reflection heights.
3. Revision of the ray path geometry calculations by an empirical adjustment of Martyn's theorem.
4. Revision of the loss statistics to include the effects of the sporadic-E layer and over-the-MUF modes.
5. The development of a long-distance model by using the single-hop models to select an efficient launch path at the transmitter, to select an efficient intercept path at the receiver, and to evaluate the ionosphere losses between the launch and intercept areas of the ionosphere.
6. Revisions of the antenna gain models.

Much of the work completed is an incorporation of the combined efforts of various laboratories, both government and private, and both domestic and foreign. Although this program is coded so that revision of any subpart is relatively easy, it is difficult to join so many diverse submodels while maintaining consistency and continuity of the entire program. The whole in this case is much more than a sum of the parts.

The use of the program with a description of input and output options is described in this report. The underlying assumptions and the mathematical-physical models are described in a companion report.

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LIST OF SYMBOLS

The meanings of the most commonly used symbols are as follows (except as otherwise defined within the text for local usage) (where feasible the symbol definition is the same as in the list in Davies, 1969):

GREEK LETTERS

α	Coefficient used in exponential tail of electron density profile, Section 3.2.
γ	Euler constant 0.57721.
Δ	Angle of elevation or take-off measured from earth's surface to ray.
ε	Permittivity.
$\varepsilon_o, \varepsilon_r$,	Permittivity of free space.
ε_h', ε_o, ε	Errors used in correction of Martyn's theorem; Section 4.4.
Θ	Angle measured from true ray path to earth's normal. (Positive for up going ray, negative for down going ray.)
θ_j	A sampled θ in true ray path model, Section 5.0.
λ	Wavelength in a medium.
μ	Refractive index (real part of n).
μ_o	Permeability of free space.
μ'	Group refractive index.
$\mu'(h, f)$	Corresponds to a particular true height h and operating frequency f, Section 4.2.
ν	Electron collision frequency.
$\bar{\nu}$	Average ν in a region, used in loss equations, Section 6.1.
ξ	$\sqrt{f^2 - ff_H}$
π	Pi, 3.14...
ρ	Reflection coefficient.
σ	Standard deviation of various distributions.

τ	Time constant.
ϕ_t	Angle between virtual ray and earth's normal at true reflection height.
ϕ	Angle between virtual ray and earth's normal at virtual reflection height. (Usually at one-half path distance.)
ϕ_j	Angle between virtual ray and earth's normal at a virtual height corresponding to a sampled ground distance, Section 5.0.
χ	Absorption index.
χ	Sun's zenith angle.
χ_m	Maximum sun's zenith angle at which median predicted F1 layer exists, Section 2.4.2.
ψ	One-half of the angle subtended by a radio path at the center of the earth, i.e., one-half path ground distance divided by the radius of the earth.
ω	Angular frequency.
ω_H	Angular gyrofrequency.

ROMAN LETTERS

$A(f_v)$	Absorption factor corresponding to f_v, Section 6.1.
$\bar{A}$	Averaged absorption factor, Section 6.1.
A_D	Deviative loss absorption factor, Section 6.2.
A_E	E mode absorption factor for corrected loss, Section 6.2.
$A_T(f_v)$	Sum of absorption factors, Section 6.2.
a	Radius of the earth.
$B(f_v)$	Absorption factor for A_D, includes averaged collision frequency ($\bar{\nu}$) profile, Section 6.2.
C_E	Coefficient for $B(f_v)$ in E region, Section 6.3.
C_F	Coefficient for $B(f_v)$ in F2 region.
C_1	Coefficient for $B(f_v)$ in F1 region, Section 6.3.
C_2	Coefficient for $B(f_v)$ in F2 region when F1 layer is present, Section 6.3.

c	Velocity of waves in free space.
D	Ground distance of a radio path.
D_j	Ground distance to a sampled point of a radio path, Section 5.0.
E	RMS field strength referred to one microvolt per meter.
e	Charge on the electron.
F	Coefficient used in exponential tail of electron density profile, Section 3.2.
fbEs	Sporadic E blanketing frequency.
f_c	Critical or penetration frequency.
f_H	Gyrofrequency.
f_N	Plasma frequency.
f_{ob}	Frequency of oblique radio path.
f_v	Vertical sounding frequency.
f_pE	Penetration frequency of E layer.
fmEs	Equivalent oblique frequency corresponding to foEs.
foE	Critical frequency of the ordinary component of the E layer.
foEs	Highest frequency of the ordinary component of the sporadic E layer.
foF1	Critical frequency of the ordinary component of the F1 layer.
foF2	Critical frequency of the ordinary component of the F2 layer.
f_u, f_v	Plasma frequencies used for filling in the valley in an electron density profile, Section 3.4.
G_t	Transmitting antenna power gain relative to an isotropic antenna in free space.
G_r	Receiving antenna power gain relative to an isotropic antenna in free space.
h	True or real height.
h'	Virtual height, equivalent height, group height.

h_p	Phase height.
h'Es	The minimum virtual height of the sporadic E layer.
hmE, hmF1, hmF2	Height of maximum electron density of E layer, or F1 or F2 layers.
h'E	The minimum virtual height of the E layer.
h'F	The minimum virtual height of the F layer (F1 or F2).
h'F2	The minimum virtual height of the F2 layer.
hpF2	The virtual height of the F2 layer at a vertical sounding frequency f_v = 0.834 foF2.
h'_v	Virtual height from vertical sounding as used in corrected Martyn's theorem, Section 4.3.
h'_{ob}	Corrected virtual height for an oblique radio path, Section 4.3.
h_o	Minimum height of electron density profile, Section 4.2.
h_r	True height upper limit of integration for a virtual height, Section 4.2.
h_j	A sampled true height integration for a virtual height, Section 4.2.
h_2	True height of F2 layer at foF1, Section 3.5.
h_u	True height of F2 layer at a frequency of $f_u = X_u$foE, used in valley of electron density profile, Section 3.4.
h_v	True height of top of E layer at $f_v = X_u$ foE, Section 3.4.
$(h'-h)_N$	Normalized height difference factor used in non-deviative loss, Section 6.2.
I	Absorption index.
k	Correction factor in oblique transmission curve.
L_{bf}	Free space basic transmission loss.
L_b	Basic transmission loss, i.e., system loss, L_s, where actual antennas are replaced by isotropic, loss-free antennas.
$L(f_v)$	Ionospheric loss for an oblique radio path at frequency, f_v, Section 6.1.

$L(f_{ob})$	Ionospheric loss for an oblique radio path at frequency, f_{ob}, Section 6.1.
L_c	Loss correction factor for E modes, Section 6.2.
L_i	Losses caused by ionospheric absorption.
L_o	Sporadic-E obscuration loss for a mode passing through the layer, Section 6.3.
L_R	Sporadic-E reflection loss for a mode reflection for the layer.
L_s	Signal power available at the receiving antenna terminals relative to the available power at the transmitting antenna terminals, in decibels. This excludes any transmitting or receiving antenna transmission line losses.
M(D)	M factor of a ground distance D, the ratio of f_{ob} to f_c.
M(3000)F2	M factor for F2 layer at a distance of 3000 km.
m	Exponent of nonlinear transformation used in integration, Section 42.
N	Electron density.
n	Complex refractive index, $(\mu - i\chi)$.
o	Ordinary wave.
P	Phase path; power; probability.
P'	Virtual path; equivalent path; group path.
R	Sunspot number; retardation.
SSN	Sunspot number.
S	Quantity relating hpF2 and M(3000)F2 (usually taken as 1490.) Section 2.4.2.
S_1	Slope of a linear F1 layer, at a frequency of foF1, Section 3.5.
S_2	Slope of a parabolic F2 layer, at a frequency of foF1, Section 3.5.
t	Time.
X_u	Frequency ratio at F2 layer for valley fill, Section 3.4.

X_v	Frequency ratio at E layer for valley fill, Section 3.4.
X_j	An abscisssca for Gaussian integration, Section 4.2.
w_j	Weight for Gaussian integration, Section 4.2.
ym	Half thickness of a parabola.
ymE, ymF1, ymF2	For E, F1, or F2 layer.

ESTIMATING THE PERFORMANCE OF TELECOMMUNICATION SYSTEMS USING THE IONOSPHERIC TRANSMISSION CHANNEL

Ionospheric Communications Analysis and Prediction Program User's Manual

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This report describes the operation and use of the Ionospheric Communications Analysis and Prediction Program (IONCAP). The computer program is an integrated system of subroutines designed to predict high-frequency (HF) skywave system performance and analyze ionospheric parameters. These computer-aided predictions may be used in the planning and operation of high-frequency communication systems using skywaves.

This report contains instructions for the use of IONCAP. A description of the input data requirements, including data definition, organization, and instructions for setup of the various analysis tasks, is presented. Procedures and formats are given for preparing the input data and executing the program. The various outputs are presented and described with an interpretation of the analysis results.

Key Words: communications; computer model; high frequency; ionosphere; LUF; MUF; skywave; user's manual

1. INTRODUCTION

For many years, numerous organizations have been employing the HF spectrum to communicate over long distances. It was recognized in the late 1930's that these communication systems were subject to marked variations in performance, and it was hypothesized that most of these variations were directly related to changes in the ionosphere. Considerable effort was made in the United States, as well as in other countries, to investigate ionospheric parameters and determine their effect on radio waves and the associated reliability of HF circuits. The effective operation of long-distance HF systems increased in proportion to the ability to predict variations in the ionosphere, since such an ability permitted the selection of optimum frequencies, antenna systems, and other circuit parameters. With

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the encouragement provided by these findings, it was decided that more basic ionospheric data were necessary in order to develop adequate models to anticipate ionospheric conditions affecting HF propagation. A worldwide network of vertical incidence ionosondes was established to measure values of parameters such as foE, foF1, foEs, foF2, and h'F. Worldwide noise measurement records were started and steps were taken to record observed variations in signal amplitudes over various HF paths. The results of this research established that ionized regions ranging from approximately 80 to 600 km above the earth's surface provide the medium of transmission for electromagnetic energy in the HF spectrum (3 to 30 megahertz (MHz)). Most variations in HF system performance are directly related to changes in these ionized regions, which in turn are affected in a complex manner by solar activity, seasonal and diurnal variations, and latitude and longitude.

The Radio Propagation Unit of the U.S. Army Signal Corps provided a great deal of information and guidance on the phenomena of HF propagation in 1945 (RPU, 1945). By 1948, a treatise of ionospheric radio propagation was published by the Central Radio Propagation Laboratory (CRPL) of the National Bureau of Standards. This document (CRPL, 1948) outlined the state of the art in HF propagation. Techniques were included for: (1) predicting the maximum usable frequencies (MUF); (2) determining the MUF for any path at any time, taking into account the various possible modes of propagation by combining theory and operational experiences; and (3) estimating skywave field strengths. The model used to make the MUF predictions employed the "two control point" method and assumed the ionosphere to be concentric with reflection occurring only from the regular E and F2 layers.

Laitinen and Haydon (1950) of the U.S. Army Signal Radio Propagation Agency furthered the science of predicting HF system performance by developing empirical ionospheric absorption equations and combining them with the theoretical ground loss, free-space loss, and antenna gain factors so that expected field strengths could be estimated for radio signals reflected from the E and F2 regions, considering the effect of solar activity, and seasonal and diurnal variations.

The accumulated techniques and methods presented in the above cited literature and a number of other studies were then combined to establish effective manual methods for predicting the expected performance of HF communication systems; however, these methods were laborious and time consuming even when only estimates of the MUF and optimum traffic frequency (FOT) were needed.

To alleviate this problem, electronic computer routines were developed by such organizations as Stanford Research Institute (1957), and the Central Radio

Propagation Laboratory (Lucas and Haydon, 1961). All of these routines were based upon the established manual prediction methods. The latter program gave the first computerized technique that incorporated the numerical coefficient representation of the ionospheric characteristics (Jones and Gallet, 1962). However, only the expected MUF and FOT were predicted.

In 1962, CRPL issued a report on a computer routine that used the then most recent improvements in the theory of performance predictions, combining the more predictable ionospheric characteristics with circuit parameters to calculate expected HF system performance; e.g., MUF-FOT, system loss, reliability, etc. (Lucas and Haydon, 1962).

By 1960, it was recognized that high-frequency radar systems could detect aircraft at considerable distance, and consideration was given to the idea of applying the already developed computer programs used to predict the ionospheric effect on HF communication to HF radar systems (Headrick and Skolnik, 1974). At the outset, simple revisions were made to the HF prediction program, including doubling the ionospheric losses associated with a given point-to-point path.

The predicted signal-to-noise ratios obtained by these modifications were compared with actual backscatter amplitudes, and the results were encouraging. However, there were obvious deficiencies in the skywave model communication that appeared immediately, when only simple modification of the model was used to predict the backscatter amplitudes; e.g.:

1. Mirror reflection for the E-F2 layers was not satisfactory.
2. The F1 layer was not included as a separate layer.
3. The sporadic-E layer was not included.
4. Ionospheric tilts and their effects on antenna requirements and absorption were not included.
5. Fading characteristics of adjacent frequencies were not adequately included.
6. Takeoff angles were not dependent on frequency.
7. Predicted losses were in error when transmission via the lower layers was nearly specular.

It was not possible to revise the prediction model to resolve all of the above deficiencies in one effort; however, the development of the parabolic distribution of electron density model established in ITSA-1 (Lucas and Haydon, 1966) was a first step. In this model, the electron density profile at each sample area was assumed to be adequately represented by two parabolic layers; i.e., the E and F2 layers. The height of maximum ionization, layer thickness, and electron density were derived from locations as defined by the classical "two control point" method previously used in the calculation of the upper limit of frequencies and transmission loss and at the path midpoint.

This work was continued in two separate paths, one for communication analysis and predictions, reported in ITS-78 (Barghausen et al., 1969) and another for analysis and prediction of over-the-horizon (OTH) radar systems reported in NRL Tech. Reports 2226 and 2500 (Headrick et al., 1971; Lucas et al., 1972). The IONCAP program is intended to bring together the two branches and especially to make the techniques developed for HF skywave radar coverage available to HF communication users. Radar techniques based on well-defined ray paths are applied to the single-hop model; however, multihop paths exhibit different behavior patterns (Whale, 1969). Available ionospheric parameters, the use of these parameters to predict electron density profiles, and the use of the profiles to predict the geometry and losses associated with skywave propagation are discussed in an unpublished document entitled "Estimating the performance of telecommunication systems using the ionospheric transmission channel--Techniques for analyzing ionospheric effects upon HF systems," by J. L. Lloyd, D. L. Lucas, G. W. Haydon, and L. R. Teters.

The stimulus for the development of IONCAP comes mainly from two sources: (1) the radar backscatter data, which results in the revision of the single-path model, and (2) the computation of efficient launch at intercept path. For the single hops, this revision was based on the radar analysis model developed jointly by ITS and the Naval Research Laboratory (Headrick et al., 1971). It includes a complete electron density profile (D, E, F1, and F2 regions) as well as the sporadic-E layer. Both the low-angle and high-angle rays are included. It is recognized that ray treatment is not complete, indeed it is inappropriate at times, so "over-the-MUF" propagation is included as well as Es propagation. For short-distance propagation, the stochastic factors affecting the behavior of the ionosphere frustrate the prediction of discrete multihop modes and make the extension of the short-distance techniques both inapropriate and inaccurate. The method developed for long-distance propagation is similar to those developed at CRPL (1948) and those developed by Harnischmacher and Rawer at Zentralsetelle fur Funkberatung, and at SPIM (Harnischmacher, 1960). They also include methods developed at the Radio Research Centre (Whale, 1969), Auckland, New Zealand; e.g., such concepts as "azimuth diversity" rather than great circle propagation alone, and coverage by stochastic "scattering" rather than following an individual ray through an absorbing region. Both the short-distance and the long-distance models are used out to the limit of short-distance hop propagation; beyond this range only the long-distance models are used. The basic theoretical guides used were the monograph by Davies (1969) and those by Bremmer (1949) and by Budden (1966).

The output representations of ionospheric communication predictions presented in this report include the historically accepted and proven outputs of ITS-78 (Barghausen et al., 1969).

In the initial planning or in the modification of many communication system, there may be an appreciable delay between the circuit planning and the actual circuit construction or modification. This is of particular importance for high frequency circuits which have marked time and geographic variations in optimum frequency, required power, and system performance. Predictions of ionospheric characteristics and techniques for using these characteristics are, however, available and may be used to anticipate the performance of HF communication circuits and thereby provide the lead time for necessary equipment selection, frequency selection, and frequency and time-sharing arrangements.

High-frequency radio communication depends upon the ability of the ionosphere to return the radio signals back to earth. Prediction of ionization levels in the various regions of the ionosphere is, therefore, essential to any prediction of HF skywave circuit performance. The maximum frequency returned from the ionosphere usually establishes the upper limit of the useful HF range. The degree of ionization in the various regions is useful in estimating probable modes, and the transmission loss for these modes is combined with the antenna performance and transmitter power available to estimate the expected HF skywave signal available anywhere at any time.

The expected skywave signal may be compared with the expected radio noise environment to predict the likelihood that the circuit will operate satisfactorily. This likelihood may be used to select optimum frequencies, proper antennas, required transmitter power, optimum time of operation, and broadcast coverage as a function of time and/or frequency.

This user's manual is subdivided into several sections. Section 2 describes the primary program-related requirements, including a program operation review, computer implementation requirements, and data files used by IONCAP. The input language definition, input data description, input card image formats, and input requirements (including data organization, maximum system size, restrictions, and default values) are presented in Section 3. The various IONCAP task options and control parameters are also discussed in Section 3. Section 4 describes the output options and possible program termination error messages. Several applications for system performance predictions are presented in Section 5 along with a sample test case. The geometry of the internal antenna package, ITSA-1, and typical antenna patterns generated are presented in Figures 43 through 65. Section 5 also contains a summary of the tabular and graphical outputs available with the IONCAP version 78.03 computer program. The version number was generated to historically document the IONCAP program as it currently exists and to facilitate a means of identifying subsequent versions of the program. The version number 78.03 identifies that this version of IONCAP was developed in 1978 and is the third version of the program. The earlier versions of the program, 77.01 and 77.02, were developmental versions and were not distributed. Section 6 briefly describes the data base file used with the program. Section 7 contains input examples to assist the user in constructing IONCAP input.

2. PRIMARY PROGRAM RELATED REQUIREMENTS

This section briefly describes the primary program related requirements of the IONCAP program. Included are computer implementation requirements, data files used by IONCAP, and a program operation review.

2.1 Computer Implementation Requirements

The IONCAP program was developed on the U.S. Department of Commerce CDC-6600 computer using FORTRAN Extended Version 4 and the KRONOS 2.1 Operating System.[1] The computer code is as close to being ANSI 66 Standard FORTRAN as was possible to ease adaptation to other computers.

The central processing unit (CPU) core memory necessary to load and execute IONCAP on the CDC-6600 using the FORTRAN Extended Version 4 compiler is:

IONCAP with internal ITSA-1 antennas 170000_8 60 bit words.

The computer installation must have sufficient file capabilities for eight files in addition to the normal printed output file. A listing of these files is given in Table 1, and a brief description of the files is described in Section 2.2. Not all of the program need be resident in core at the same time, nor are all the files necessary for most applications should the user choose to generate load modules for specific methods.

[1]Certain commercial equipment and materials are identified in this paper to specify adequately the software requirements. In no case does such identification imply recommendation or endorsement by the authors, the National Telecommunications and Information Administration, or the U.S. Department of Commerce.

2.2 Files Used by IONCAP

The primary input to the program is in the form of card images which are read from LU5 (logical unit number 5). The LU5 could be a copy of the system input file (card reader), a permanent file previously stored on disk or tape, or a working file previously generated by another program prior to executing IONCAP. The user may specify, as an input option, the use of the auxiliary input file LU15. This essentially allows the user to have card images from two different files used as input in the same run.

The primary output from the program is in the form of line printer images which are written on LU6. The LU6 could then be copied to the system output file (line printer), or a permanent file can be created and saved on tape or disk, or it can be used as input to some other program. The user may specify, as an input option, to use the auxiliary output file LU16. This essentially allows the user to have line printer images on two different files in the same run (see the AUXOUT control card discussed in subsection 3.3.5).

The ionospheric long-term data base file (LU2) contains yearly, seasonal, and monthly information essential to the ionospheric predictions generated by IONCAP. A complete description of this data base file can be found in Section 6. These data are not user-defined input.

The COMMON-MUFS file (LU20) is created, if specified, as a task option by the user. This file contains all of the variables contained in COMMON /MUFS/ which contains MUF, LUF, FOT, and other variables. It allows the user the flexibility of creating his own output format specification by writing a computer program which uses this file as its input. Therefore, LU20 can be stored as a permanent file for later use or can be used as a working file should a user output program be executed after IONCAP terminates execution (see Section 5). Use of this option generally requires programming interface.

The antenna output file (LU25) is created if specified by the user. This file contains antenna patterns created by the IONCAP antenna package (ITSA-1). These antenna patterns can be saved as a permanent file and used as input to the IONCAP program at a later date or possibly used as input to some other analysis program. This is discussed in Section 3.4.

The antenna input file (LU26) is a permanent file used to read antenna patterns that have previously been created by IONCAP or by some other antenna package or routine. If specified by the user, the antenna patterns are read from this file instead of being computed by the IONCAP program (see ANTENNA control card subsection). Use of this option to input antenna patterns not generated by IONCAP generally requires the user to create a software interface to IONCAP.

The procedure file (LU35) is a scratch file created by the IONCAP program to read and write input procedures, if any are created by the user. (Refer to Section 3.3.6 for procedural definition and use.) Note that this is a local scratch file which is manipulated by the IONCAP program itself and should not be tampered with by the user or programmer.

The debug output file (LU61) was used during the development of the IONCAP program. It contains printed output which was used to verify and debug the IONCAP program. This file is not available to the user.

2.3 Program Operation Review

The first step in using the IONCAP program is to assemble the appropriate data for the system configuration to be analyzed. These data are then prepared on punched card images which are read as input directly to the computer program or perhaps stored on a disk or magnetic tape file for reading as input to the program at a later date.

Each input card image contains a name identifier that is used as a label to identify the specific type of data on that particular card image. A listing of all valid name identifiers is given in Table 2, and a complete description of each name identifier and the associated input data is given in Section 3.3.

The user may also create his own name identifier by defining an input procedure. The input procedure definition, discussed in Section 3.3.6, allows the user to represent several card images by a single name identifier. When reference is made to the procedure name during program execution, the program essentially replaces the procedure name with the card images constituting the procedure definition.

Program execution begins by examining the entire input file for any user-defined procedures. If any are located, the procedure names are stored in a table of valid name identifiers and the actual procedure definitions are written on a scratch file for later reference. This allows the procedure definition to occur anywhere in the input file, and thus, a procedure need not be defined before a reference is made to it. (Computer programmer types may see parallels to this technique in other applications.)

The computer program then checks the name identifier of each card image on the input file with the internal table of valid name identifiers. If an invalid name identifier is located, the program flags the card image in error and continues to examine the name identifier on each of the remaining card images. Errors in the name identifier are most often caused by (1) a spelling error in the identifier name or (2) a reference to an undefined procedure. If any name identifier errors are located, a message is printed and program execution is terminated. This is henceforth referred to as Phase 1 of the IONCAP execution.

At this time, there is little or no diagnostic check of the data contained on any card image. Only the name identifier is examined. Thus, program execution will continue if there are no name identifier errors even though there may possibly be errors in the actual input data. It is, therefore, essential for the user to examine each card image to insure that it is punched correctly and that it contains the necessary data before attempting to execute the IONCAP program.

If no name identifier errors are located on the input file, the program rewinds the user-defined input file and begins to read and process the data on each card image to define a system configuration. Once the configuration is complete, the analysis is performed. The analysis portion of IONCAP is henceforth referenced to as Phase 2. A flow diagram of the basic IONCAP control is given in Figure 2.

The IONCAP program performs four basic analysis tasks in Phase 2. These tasks are discussed in detail in the IONCAP theoretical report and summarized below:

(1) Ionospheric Parameters. The ionosphere is predicted using parameters which describe four ionospheric regions: E, F1, F2, and Es. For each sample area, the location, time of day, and all ionospheric parameters are derived. These may be used to find an electron density profile, which may be integrated to construct a predicted ionogram. These options are specified by methods 1 and 2, which are briefly described in Table 3.

(2) Antenna Patterns. The user may precalculate the antenna gain pattern needed for the system performance predictions. These options are specified by methods 13, 14, and 15, which are briefly described in Table 3. If the pattern is precalculated, then the antenna gain is computed for all frequencies (1-30 MHz) and elevation angles. If the pattern is not precalculated, then the gain value is determined for a particular frequency and elevation angle as needed.

(3) Maximum usable frequency (MUF). The maximum frequency at which a skywave mode exists can be predicted. The 10% (FOT), 50% (MUF), and 90% (HPF) levels are calculated for each of the four ionospheric regions predicted. These numbers are a description of the state of the ionosphere between two

locations on the earth and not a statement on the actual performance of any operational communications circuit. These options are specified by methods 3 to 12, which are briefly described in Table 3.

(4) Systems Performance. A comprehensive prediction of radio system performance parameters (up to 22) is provided. Emphasis is upon the statistical performance over a period of a month. A search to find the lowest usable high frequency (LUF) is provided. These options are specified by methods 16 to 29, which are briefly described in Table 3.

3. INPUT DATA REQUIREMENTS

This section describes the general data requirements and the input language definition. It also includes a complete description of all user-defined input data and the corresponding input card image formats. The minimum input requirements and default values for each analysis and prediction method are presented, as are the data organization and input restrictions.

3.1 General Data Requirements

The data requirements of the IONCAP program consist of a fixed data base and user-defined input data. Much of the basic data required to use the IONCAP program is stored on the ionospheric long-term data base file. This data base includes geographic and time variations of the ionosphere and of atmospheric noise levels, the relationship between the ionospheric characteristics and the propagation path geometry and signal attenuation, and the theoretical performance of common antenna systems. The data base is fixed to the user and is not part of the user-defined input data. A complete description of the ionospheric long-term data base is contained in Section 6. However, the user may execute the IONCAP program without the data base file by specifying certain user-defined data (see Section 3.3.4). This, however, generally requires specific information concerning the ionosphere.

The user-defined input data consist of card images and perhaps an optional antenna file and the input depends primarily on the complexity of the analysis or system performance prediction requested (see Section 3.4). As an example, to determine the upper useful frequency limits, only the geographic location of the circuit terminals and the time are required. For more complex predictions such as the expected reliability of communications, additional user-defined input data are required. This data would include frequency of operation, the type of antenna used, the transmitter power, the type of service required, and the man-made noise environment, among others. A complete description of all user-defined data is presented in Section 3.3, and the required user-defined input data for each analysis or prediction method are summarized in Section 3.4. The input required for each run option is given in Table 13. The details of each card format are given in Section 3.5.

3.2 Input Language Definition

The name identifiers mentioned in Section 2.3 constitute an input language which is the primary communication link between the user and the actual program analysis. The language provides the user with the means of describing complex physical configurations in somewhat familiar terms. It also provides a means of controlling the type and the extent of the analysis to be performed as well as the type and amount of output desired. Desirable characteristics of the input language include (1) format simplicity of the input statement and (2) quasi-order independence of the input data for a particular system configuration. Thus, the input card images can often be presented to the program in any order (with some restrictions) to describe the topology of a system configuration, the type of analysis to be performed, and the output desired. Once these characteristics for a particular configuration have been defined, the program can be executed. Another desirable characteristic is the ability to alter certain characteristics of the configuration without having to redefine all other characteristics. This allows the user to alter certain parameters in the system configuration while keeping other parameters fixed. The benefit of this is that it allows the user to execute the program for several configurations that have common characteristics in the same run without redefining all characteristics of the system configuration.

3.3 Description of the User-defined Input Data

The user-defined input data are in the form of card images and perhaps an optional antenna data file. As mentioned in Section 2.3, each input card image contains a name identifier that is used as a label to identify the specific type of data on that particular card image. A listing of all valid name identifiers is presented in Table 2, and a complete description of each name identifier and the associated data is given in the following subsections along with card formats and examples. Each input card image will henceforth be called a control card with the name identifier used as the name of the control card. Formats for each control card are given in Section 3.5. All cards start with a 10 column identifier. All data fields are five columns long. Tables 14 and 15 contain all card formats and comments concerning these cards.

3.3.1 Program Control, Execution, and Termination Control Cards

The following control cards define the analysis task to be performed, indicate when the task will be performed for the current system configuration, and indicate how the program will reach a normal termination.

METHOD control card

The METHOD card defines the analysis task to be performed for a particular system configuration and also specifies the initial page number for the output file. The two parameters on the METHOD card are (see Control Card 1. References to the control cards contain an example of each card along with a table of the contents of the card):

(a) METHOD is the parameter which controls the type of program analysis and predictions performed. At the present time there are 30 task options available. Many of these tasks differ only in the representation of the output and require the same (or nearly the same) computations. The basic tasks consist of (1) tabulation of ionospheric parameters and ionograms from the ionospheric data base file, (2) MUF-FOT calculation and graphs, (3) computation and tabulation of antenna patterns, (4) system performance predictions, and (5) LUF calculation and graphs. A brief description of each method available is given in Table 3, and a presentation of the output generated by each method is given in Section 4.

(b) NPAGO is the parameter that controls the initial page number on the output file. The initial output page is set to this value if NPAGO is positive. If the variable is left blank, negative or zero, then the initial page on the output file is set to one.

EXECUTE control card

The EXECUTE card causes the program to perform the indicated analysis task for the currently defined system configuration. This requires the user to specify the program control card and the system configuration cards prior to the EXECUTE card (see Control Card 2). There is only one parameter on the EXECUTE card described as follows:

KRUN is the parameter that indicates the layers at the ionospheric parameters that are calculated. If KRUN is less than or equal to zero, then the parameters of all layers (E, F1, F2, and Es) are calculated; if KRUN = 1, then the parameters of the E layer, F1 layer, and F2 layers are calculated; if KRUN = 2, the parameters for the Es layer only are calculated; if KRUN is greater than or equal to three, then no ionospheric parameters are calculated. This allows the user to skip the calculation of ionospheric parameters and use the last set previously calculated or a set of ionospheric parameters entered with the input cards. The use of the KRUN option may require additional consideration beyond that presented here.

It is also often possible to cause program analysis to be performed by having two consecutive control cards with the same name identifier. The control cards that allow this are:

METHOD
CIRCUIT
EXECUTE

Thus, if the user desires to have both a tabulation of two circuits, he may accomplish this by having two consecutive CIRCUIT cards on the input file. The remainder of this system configuration is unchanged if this technique is used.

QUIT control card

The QUIT card causes termination of the IONCAP program. It must, therefore, be the last physical control card on the user-defined input file. This card is essential to the program since it is used when examining the name identifiers on the control cards in Phase 1, and as a default termination of a month-sunspot loop (to be discussed in NEXT control card subsection) as well as the program termination indicator in Phase 2. There are no data parameters on the QUIT control card (see Control Card 3).

3.3.2 Diurnal, Month, and Solar Activity Control Cards

The following control cards define the time of day, the month, year, and sunspot number of the solar activity period of interest for which the analysis and predictions are performed.

It should be noted that the months and sunspots specified on the following control cards constitute a loop. That is to say, the analysis and predictions are performed for every linear combination of months and sunspots indicated. Separate control cards are, therefore, not required for each month and/or solar activity period of interest. The month-sunspot (or sunspot-month) loop is discussed in the NEXT control card subsection, with examples given in Figures 3 through 8. Thus, several months can be executed with one sunspot number and/or several sunspots can be executed for a single month. This also demonstrates a procedure example. In order to do selected month, or combination of months, with individual sunspot numbers, use the PROCEDURE card. For example, the set below will do the calculations for all seasons of 1976 for each of the circuits defined in the procedure called NORTH. See Section 3.3.6 for a further discussion of the PROCEDURE card. The fixed field formats of each card are presented on the corresponding control card.

```
PROCEDURE NORTH
CIRCUIT  cards representing necessary communication paths
EXECUTE
END
Control cards defining system configuration:
MONTH      1976    4
SUNSPOT    12.6
NORTH
MONTH      1976    6
SUNSPOT    12.2
NORTH
MONTH      1976    9
SUNSPOT    14.3
NORTH
MONTH      1976   12
SUNSPOT    14.8
NORTH
QUIT
```

TIME control card

The TIME card indicates the time of day for which the analysis and predictions are to be performed. The hours can be either universal time or local mean time at the transmitter, depending on an input parameter. There are four parameters on the TIME control card, described as follows (see Control Card 4):

(a) IHRO indicates the starting hour in universal time or in local mean time at the transmitter.

(b) IHRE indicates the ending hour in universal time or in local mean time at the transmitter.

(c) IHRS indicates the hourly increment. The hourly increment is added to the starting hour to determine the next hour. This incremental process continues until the ending hour is reached.

(d) ITIM indicates that the specified time is universal time or local mean time. If ITIM is negative, then the specified times are local mean times

(LMT) at the transmitter, otherwise the specified times are universal time (UT).

MONTH control card

The MONTH card indicates the year and months for which the analysis and prediction are to be performed. The year is used for identification purposes only and has no effect on the program calculations. June and December are typical of seasonal extremes for long-range planning. The parameters on the MONTH control card are as follows (see Control Card 5):

(a) NYEAR indicates the year, but has no effect on the program calculations.

(b) MONTHS is an array of up to 12 months where 1 represents January, 2 represents February, etc. The program analysis and predictions are performed for each of the months the user specifies. The program assumes there are no additional months to process when a blank or a zero month is encountered. The desired months can be specified in any order. This, for example, allows the user to perform the analysis and predictions for December before January if he so desires. Predictions for each month specified on the MONTH card are performed for each sunspot number specified on the SUNSPOT card.

MONTHLOOP control card

The MONTHLOOP card is similar to the MONTH card in that it indicates the year and the months for which the analysis and predictions are to be performed. The difference between the two cards is that the user specifies the individual months desired on the MONTH card, and he specifies a range of months desired on the MONTHLOOP card. As previously mentioned, the year is used for identification purposes only and has no effect on the program calculations. The four parameters on the MONTHLOOP card are as follows (see Control Card 6):

(a) NYEAR indicates the year, but has no effect on the program calculations.

(b) MINIT indicates the starting month where 1 represents January, 2 represents February, etc.

(c) MFINAL indicates the ending month where 1 represents January, 2 represents February, etc.

(d) MINC indicates the monthly increment. The monthly increment is added to the starting month to determine the next month. This incrementing process continues until the ending month is reached.

The MONTHLOOP card, along with a corresponding sunspot number, requires the program to read the ionospheric long-term data base file to obtain months and seasonal information. Predictions for each month specified on the MONTHLOOP card are performed for each sunspot number specified on the SUNSPOT card.

SUNSPOT control card

The SUNSPOT card indicates the sunspot numbers of the solar activity period of interest and is the 12-month running average for each of the months specified. A sunspot number of 10 is typical for low solar activity and sunspot numbers between 110 and 130 are typical of high solar activity. NOTE: monthly or daily solar activity indices are not used, only the expected 12-month running average is used. The parameter on the SUNSPOT card is as follows (see Control Card 7):

SUNSP is an array of up to 12 sunspot numbers. The program analysis and predictions are performed for each of the solar activity periods the user specifies and for each month specified. The desired sunspot numbers can be specified in any order with the one restriction, that, if a zero sunspot number is desired, it must be the first one indicated on the control card. This restriction is necessary since the program assumes that there are no additional sunspot numbers to process when a blank or zero sunspot number is encountered. The program uses a "look-ahead" procedure which allows the first specified sunspot number to be blank or zero.

NEXT control card

The NEXT control card is the termination of a month-sunspot (or sunspot-month) loop. Each of the control cards that occur after the MONTH (or MONTHLOOP) card and the SUNSPOT card, but before the NEXT card, is processed for every combination of months and sunspot numbers specified. Thus, the body of the loop consists of all the control cards after the MONTH-SUNSPOT cards up to the NEXT card. A month-sunspot loop is generated if the MONTH (or MONTHLOOP) card precedes the SUNSPOT card. A typical deck structure for a month-sunspot loop is given in Figure 3, and the effect of a typical month-sunspot loop is demonstrated in Figure 4. A sunspot-month loop is generated if the SUNSPOT card precedes the MONTH (or MONTHLOOP) card. A typical deck structure for a sunspot-month loop is given in Figure 5, and the effect of a typical sunspot-month loop is demonstrated in Figure 6. Several month-sunspot (or sunspot-month) loops may occur in the same run, as demonstrated in Figure 7. However, nesting of month-sunspot loops is not permissible. The QUIT card acts as the terminator to a month-sunspot (or sunspot-month) loop if no NEXT control card is present, as demonstrated in Figure 8. There are no parameters on the NEXT control card (see Control Card 8). This card is not necessary if only one MONTH-SUNSPOT loop combination is defined.

3.3.3 System Configuration Control Cards

The following control cards identify and define the system configuration to be analyzed. This includes a label to identify the system coordinates, the location of the transmitter and the receiver, and the actual system parameters necessary to define the system configuration.

LABEL control card

The LABEL card contains alphanumeric information used to describe the system location on both the input and output. A recommended usage of the LABEL card is to specify a label for each transmitter-receiver configuration used, where the alphanumeric information describes the location of the coordinates given on the CIRCUIT control card. The parameters on the LABEL card are as follows (see Control Card 9):

(a) ITRAN is an array of 20 alphanumeric characters used to describe the transmitter location.

(b) IRCVR is an array of 20 alphanumeric characters used to describe the receiver location.

It should be noted that the information on the LABEL card is used for identification purposes only. Thus, the user is allowed a maximum of 40 alphanumeric characters to describe the transmitter-receiver location and need not be concerned with which characters are stored in ITRAN and which are stored in IRCVR.

CIRCUIT control card

The CIRCUIT card contains the geographic coordinates of the transmitter and receiver and a variable to indicate the user's choice between shorter or longer great circle paths from the transmitter to the receiver. Normally the short circle path is desired by the user. On the CIRCUIT control card, the symbol N denotes northern hemisphere, S denotes southern hemisphere, W denotes western hemisphere, and E denotes eastern hemisphere (the directions may be spelled out if desired; such as NORTH). The parameters on the CIRCUIT card are as follows (see Control Card 10):

(a) TLATD indicates the latitude at the transmitter in degrees.

(b) ITLAT indicates the northern (N) or southern (S) hemisphere at the transmitter.

(c) TLONGD indicates the longitude at the transmitter in degrees.

(d) ITLONG indicates the eastern (E) or western (W) hemisphere at the transmitter.

(e) RLATD indicates the latitude at the receiver in degrees.

(f) IRLAT indicates the northern (N) or southern (S) hemisphere at the receiver.

(g) RLONGD indicates the longitude at the receiver in degrees.

(h) IRLONG indicates the eastern (E) or western (W) hemisphere at the receiver.

(i) NPSL indicates the user's choice between shorter or longer great circle paths from the transmitter to the receiver. The longer great circle path is used if the user specifies NPSL = 1, otherwise the shorter great circle path is used. Often desired is the shortest distance between transmitter and receiver. This is accomplished by leaving the variable NPSL blank, therefore, selecting the shorter great circle path by default.

SYSTEM control card

The SYSTEM card includes parameters necessary to define the system configuration. This includes the transmitter power, man-made noise level, minimum takeoff angle, required circuit reliabilities, required signal-to-noise ratio, the maximum difference in delayed signal power for multipath, and the maximum difference in delay time for multipath. The parameters defined on the SYSTEM card are described below (see Control Card 11):

(a) PWR indicates the transmitter power in kilowatts. Note that this is the power delivered to the transmitting antenna. (The program internally converts this to decibels (dB) above a kilowatt as needed for computations.)

(b) XNOISE indicates the expected man-made noise level at the receiver in dBW (decibels below 1W) in a 1 Hz bandwidth at 3 MHz. XNOISE should be input as a positive value unless the user desires to designate the receiving location area as industrial, residential, rural, or remote unpopulous by specifying:
XNOISE = -1. for industrial (the program then uses -125. dBW)
XNOISE = -2. for residential (the program then uses -136. dBW)
XNOISE = -3. for rural (the program then uses -148. dBW)
XNOISE = -4. for remote unpopulous (the program then uses -164. dBW)
Typical values of man-made noise relative to population of the receiving area are given in Figure 9. In remote unpopulous areas, cosmic noise will normally dominate over man-made noise.

(c) AMIND indicates the minimum takeoff angle in degrees. The value is normally very small unless antenna performance is expected to be so poor at low angles that these angles should not be used in the estimation of upper useful frequencies, or if the horizon is so obstructed that low takeoff and reception angles appear unlikely. The program uses a default value of 3° if this parameter is not set by the user. A value of 0.001 will effectively give the full range of possible radiation angles and should be specified by the user if the 3° default is not required.

(d) XLUFP indicates the required circuit reliability, which is an estimate of the percentage of days within the month that the signal quality will be acceptable, and should be specified for calculation of the LUF or time availability for service probability. (NOTE: XLUFP is expressed as a percentage.) The program uses a default value of 90 if this parameter is not set by the user.

(e) RSN indicates the required signal-to-noise and is the ratio of the hourly median signal power in the occupied bandwidth relative to the hourly median noise in a 1 Hz bandwidth, which is necessary to provide the type and quality of service required (expressed in decibels). Table 4 and Table 5 show typical required S/N ratios for radiotelephone service and radioteletype service. NOTE: The S/N values in this report and in the computer model are the ratio of signal in occupied bandwidth to noise in a 1 Hz bandwidth.

(f) The user may choose the multipath computations. The multipath probability is an estimate of the likelihood that two or more skywave modes will exist within the specified power tolerance and outside the time delay tolerance.

PMP indicates the maximum difference in delayed signal power in decibels between skywave modes to permit satisfactory system performance in the presence of multiple signals. If PMP is blank or zero, multipath is not considered.

(g) DMPX indicates the maximum difference in delay time in milliseconds between skywave propagation modes to permit satisfactory system performance in the presence of multiple signals. The program uses a default value of .85 if this parameter is not set by the user.

FREQUENCY control card

The FREQUENCY complement control card contains up to 11 user-defined frequencies that are used in the calculation. The FREQUENCY card is not necessary with the analysis and prediction options dealing only with ionospheric parameters, ionograms, MUFs, antennas, or LUFs. System performance requires the FREQUENCY card. The parameter on the FREQUENCY card is as described below (see Control Card 12):

FREL is the array of up to 11 user-defined frequencies in megahertz. If the first frequency on the control card is left blank, then the FOT is inserted as the first frequency. If the entire FREQUENCY card is left blank, then the 11 frequencies used in the calculation are computed for each hour by the program. The computed frequency range then begins at 2 MHz and ends at the HPF on a non-linear scale based on the E-MUF and F-MUF values. It should be noted that, in this manner, a different frequency complement is generated for each hour.

<u>ANTENNA control card</u>

The ANTENNA control card defines whether the antenna is transmitting or receiving, specifies the type of the antenna, the ground conductivity, and dielectric constants in addition to the other parameters necessary to compute the necessary antenna patterns. Typical values for selected ground types are given in Table 6 where typical good ground is low hills with unforested rich soil or flat wet coastal regions; fair ground is medium hills or forested heavy soil; and typical poor ground includes rocky steep hills, sandy dry coastal regions, and city industrial areas. The ground constants are optional on each antenna card. If not specified by the user, they will be calculated with the land mass map from the ionospheric long-term data base file. The ground constants will be set to poor ground as a default if they are not specified by the user and the land mass map is not available. It is permissible for the user to specify up to three transmitter antennas and three receiver antennas to cover the frequency range considered for each system configuration. It is also possible to indicate that the antenna is to be input from an external antenna file (LU25) instead of being calculated by the program. The input parameters required vary with antenna type. The basic ANTENNA card parameters are described below, and the geometric description of each available antenna type is given in Figures 43 through 65, Table 16, and Control Cards 32 through 43.

(a) IAT indicates whether the antenna is transmitting or receiving, IAT = 1 for transmitting, IAT = 2 for receiving.

(b) IANTR indicates the number which corresponds to the antenna type desired. The user has the option to input the antenna pattern from the optional external antenna file as discussed in Section 3.4.

(c) AETA indicates the antenna bearing in degrees from east of north. Negative denotes the off azimuth angle from the circuit path. Positive denotes the main beam direction.

(d) ASIG indicates the ground conductivity (σ) in mhos per meter.

(e) AEPS indicates the relative dielectric constant (ε_r).

The following parameters describe various characteristics dependent on the antenna type specified. The user should refer to Section 3.4 for the description of the following antenna parameters and the antenna characteristics required for each antenna type.

(f) AND
(g) ANL
(h) ANH
(i) AEX

The definition and description of these parameters depend on the antenna type specified.

(j) AFQB indicates the ending frequency when the user specifies more than one transmitting type or receiving antenna type for the frequency range considered. The next antenna type used for the transmitter or receiver would then begin at 1 MHz greater than the ending frequency specified here.

(k) IAIN indicates the antenna number (up to three) when the user specifies more than one transmitter or receiver antenna for the frequency range considered. This parameter is also used as a control parameter to specify the location on the optional external antenna file if one is used. This usage is discussed in Section 3.4.

3.3.4 User-defined Data Base and System Override Cards

The following control cards allow the user to specify an external data base consisting of (1) the geographical and geomagnetic parameters relating to a specified sample area, (2) the critical frequency, semi-thickness, and height of maximum ionization for the E, F1, and F2 layers, (3) lower, median, and upper decile values of the critical frequency and the virtual height of reflection, and (4) the true height and electron density. The ionospheric long-term data base file is not necessary when these ionospheric parameters are defined by the user. The user may also override internal program characteristics such as (1) the integration scheme used for the E and F2 layers and (2) the critical frequency multipliers to adjust the heights of the ionospheric layers. These values can be obtained using METHOD equal to 1 in a previous run. Use of the control cards in this section require in-depth information of ionospheric parameters and would be avoided by most users. These control cards are used to alter the use of predefined ionospheric data.

SAMPLE control card

The SAMPLE control card contains the following geographic and geomagnetic parameters relating to a specified sample area. A maximum of five sample areas may be defined by the user (see Control Card 13).

(a) I indicates the specific sample area number, 1 to 5.

(b) SLAT indicates the geographic latitude of the sample area in degrees.

(c) ISLAT indicates the geographic latitude of the sample area is in the northern or southern hemisphere (N or S).

(d) SLONG indicates the geographic longitude of the sample area in degrees.

(e) ISLONG indicates the geographic longitude of the sample area is in the eastern or western hemisphere (E or W).

(f) SGLAT indicates the geomagnetic latitude in degrees.

(g) ISGLAT indicates the geomagnetic latitude is in the northern or southern hemisphere (N or S).

(h) RD(I) indicates the distance from the sample area to the transmitter in kilometers.

(i) GYZ(I) indicates the gyrofrequency in megahertz.

(j) CLCK(I) indicates the local mean time at the sample area.

(k) GMDIP(I) indicates the geomagnetic dip angle at the sample area.

(l) ARTIC(I) indicates the auroral loss at the sample area.

(m) SIGPAT(I) indicates the ground conductivity at the sample area.

(n) EPSPAT(I) indicates the relative dielectric constant at the sample area.

EFVAR control card

The EFVAR control card allows the user to indicate the critical frequency, semi-thickness, and the height of maximum ionization for the E, F1, and F2 layers for a specified sample area. The user may specify the following parameters for each of the sample areas defined on the SAMPLE control cards (see Control Card 14).

(a) I indicates the specific sample area number, 1 to 5.

(b) FI(1,I) indicates the critical frequency for the E layer, foE, in megahertz for the specified sample area.

(c) YI(1,I) indicates the semi-thickness for E layer, ymE, in kilometers for the specified sample area.

(d) HI(1,I) indicates the height of maximum ionization for the E layer, hmE, in kilometers for the specified sample area.

(e) FI(2,I) indicates the critical frequency for the F1 layer, foF1, in megahertz for the specified sample area.

(f) YI(2,I) indicates the semi-thickness for the F1 layer, ymF1, in kilometers for the specified sample area.

(g) HI(2,I) indicates the height of maximum ionization for the F1 layer, hmF1, in kilometers for the specified sample area.

(h) FI(3,I) indicates the critical frequency for the F2 layer, foF2, in megahertz for the specified sample area.

(i) YI(3,I) indicates the semi-thickness for the F2 layer, ymF2, in kilometers for the specified sample area.

(j) HI(3,I) indicates the height of maximum ionization for the F2 layer, hmF2, in kilometers for the specified sample area.

ESVAR control card

The ESVAR control card allows the user to indicate lower, median, and upper decile values for the Es layer and the virtual height of reflection for a specified sample area. The user may specify the following parameters for each of the sample areas defined on the SAMPLE control cards (see Control Card 15).

(a) I indicates the specific sample area number, 1 to 5.

(b) FS(1,I) indicates the lower decile critical frequency for the Es layer, foEs, in megahertz for the specified sample area (example lowest value = 2 MHz).

(c) FS(2,I) indicates the median decile critical frequency for the Es layer, foEs, in megahertz for the specified sample area (example median value = 4 MHz).

(d) FS(3,I) indicates the upper decile critical frequency for the Es layer, foEs, in megahertz for the specified sample area (example highest value = 6 MHz).

(e) HS(I) indicates the virtual height of reflection for the Es layer in kilometers for the specified sample area (example vertical height = 110 kilometers).

EDP control card

The EDP control card allows the user to read and use an external electron density profile for a specified sample area. Current implementation restrictions prohibit defining more than one sample area if an external electron density profile is used. The user may specify the following parameters for one sample area (see Control Card 16). A temporary parameter is used to switch to the internal electron density profile if desired.

(a) JSAMP indicates the specific sample area number (=1).

(b) ITEMP is a temporary parameter which causes the internal electron density profile to be used if the user specifies the word "OFF." Thus, this parameter acts as a switch to "turn off" the external electron density profile and "turn on" the internal electron density profile. If not "OFF," then the EDP control card is followed by eight cards which contain:

HTR is the array of 50 that indicates the true heights in kilometers (four cards, see Control Card 17).

FNSQ is the array of 50 that indicates plasma frequency squared in $(MHz)^2$ (four cards, see Control Card 18).

INTEGRATE control card

The INTEGRATE control card allows the user to specify model segment integration for the F2 layer instead of the slower Gaussian integration. Thus, the user can request fast integration for the E layer and for the F2 layer when the F1 is not present. The D-E layer is preset using calculations from the Gaussian integration. A temporary parameter is used to allow the user to alternate between the model-segment and Gaussian integration. The program performs the slow Gaussian integration as a default if no INTEGRATE card is present.

(a) INTEG is the temporary parameter used to specify the integration method. If the user specifies "-1" on the INTEGRATE control card, then Gaussian integration is performed. If the user specifies a value greater than or equal to zero, then model-segment integration is performed. If "OFF" is specified (variable ITEMP), the program returns to the fast integration (see Control Card 19).

FPROB control card

The FPROB control card allows the user to adjust the heights of the E, F1, F2, and Es ionospheric layers. The predicted critical frequencies are multiplied by the parameters on the FPROB card to raise or lower each corresponding ionospheric layer. If the user-defined parameter is greater than one, the critical frequencies used by the program will be larger than the predicted critical frequencies. If the user-defined parameter is less than one, the critical frequencies used by the program will be smaller than the predicted critical frequencies. The user may remove the F1 and Es layers entirely by specifying the value "0.0" for the critical frequency multiplier for either layer. The user should not, however, specify the value "0.0" for the critical frequency multiplier for the E or F2 layers. The following default values are used if (1) the critical frequency multipliers are not specified by the user or (2) the value specified for the E or F2 layer is negative or zero. The program uses the default value of 1.0 for the critical frequency multipliers for the E, F1, and F2 layers. Thus, the actual predicted critical frequency values are used by the program and the corresponding ionospheric layer ionization is neither raised nor lowered. The default value of the critical frequency multiplier for the Es layer is 0.7 to allow for median losses. A temporary parameter is specified if the user desires to use the default values for the actual frequency multipliers rather than the values previously specified on the FPROB card. If the user indicates "OFF" on a subsequent FPROB control card, the default critical frequency multiplier values are used. The user may also redefine the critical frequency multipliers previously defined by providing a subsequent FPROB control card. The following parameters are on the FPROB control card (see Control Card 20):

(a) PSC(1) indicates the critical frequency multiplier for the E layer.
(b) PSC(2) indicates the critical frequency multiplier for the F1 layer.
(c) PSC(3) indicates the critical frequency multiplier for the F2 layer.
(d) PSC(4) indicates the critical frequency multiplier for the Es layer.

3.3.5 Input, Output, and Comment Control Cards

The following control cards allow the user to place comments in the input file, use auxiliary input and output files, and identify additional input/output options available to the user. These control cards are used to (1) create an external antenna pattern file and (2) allow the user to request the outputs of various program options without recomputing parameters.

COMMENT control card

The COMMENT control card permits the user to place comments anywhere in the user-defined input file. This may benefit the user in specifying the system configuration in terms of descriptive text, and any number of comment cards may be used. During program execution, the comment cards are listed along with the other control cards, but otherwise they have no effect on execution of the program (see Control Card 21).

AUXIN control card

The AUXIN control card allows the user to read all, or a portion, of the user-defined data from an auxiliary input file. This may be useful if the user has a portion of the system configuration stored on a permanent file or working file generated by some program before running IONCAP. The user may then use the primary input file to read part of the input data and the auxiliary input file to read the remainder. Thus, in essence, it is possible to specify the user-defined data from two files within the same run. A temporary alphanumeric parameter on the AUXIN control card is used to specify when the auxiliary input file is used (see Control Card 22). If the temporary parameter is left blank, the control cards that follow the AUXIN card are read from the auxiliary input file. This process continues until the user specifies a second AUXIN control card with the temporary parameter set to "OFF." The value "OFF" indicates that the control cards that follow the AUXIN card are once again read from the primary input file. It is, therefore, possible for the user to alternate between the primary and auxiliary input files several times in one run as demonstrated in Figure 10. If there is no AUXIN control card specified, then all control cards and input form the primary input file.

AUXOUT control card

The AUXOUT control card allows the user to write all or a portion of the program generated output to the auxiliary output file. Therefore, it is possible to write on two files within the same run. This may be desirable if a portion of the generated output is to be saved as a permanent file or if two separate reports are generated.

A temporary alphanumeric parameter on the AUXOUT control card is used to specify when the auxiliary output file is used (see Control Card 23). If the temporary parameter is left blank, the output generated by the program that follows the AUXOUT card is written to the auxiliary output file. This continues until the user specifies a second AUXOUT control card with the temporary parameter set to "OFF." The value "OFF" indicates that the program generated output that follows the AUXOUT card is once again written to the primary output file. It is, therefore, possible for the user to alternate between the primary and auxiliary output files several times in one run as demonstrated in Figure 11. If there is no AUXOUT control card specified, then all program generated printed output is written to the primary output file.

ANTOUT control card

The ANTOUT control card allows the user to write antenna patterns generated by the IONCAP program to a separate binary file if the program option to generate antenna patterns is used (methods 13, 14, 15). This file could then be saved as a permanent file for use at a later date with the IONCAP program, or possibly with some other analysis program. This may be a desirable capability for the user who plans to use the same antennas for several sets of read data or to use the same antenna configuration for several periodic runs. The user could generate and save the antenna patterns on a permanent file, then read the antennas from the permanent file when running each of his data sets. It is also possible for the file to be used as a working file for direct input to some other analysis program. The process of reading the antenna file is discussed in Section 6.

A temporary alphanumeric parameter on the ANTOUT control card is used to specify when antenna patterns are output to the antenna file (see Control Card 24). If the temporary parameter is left blank, then all antenna patterns generated following the ANTOUT card are written to the file. If the temporary parameter is set to "OFF," then none of the antenna patterns generated following the ANTOUT card are written to the file. It is often more efficient to generate the desired antenna patterns before performing other program analysis or predictions. This process is demonstrated in Figure 12, where transmitter/receiver antenna pattern pairs are generated.

The user should be aware that the antenna patterns are generated and written on the antenna file <u>only</u> if methods 13, 14, or 15 are specified. Thus, if the user has an ANTOUT control card but does not specify methods 13, 14, or 15, <u>no</u> antenna patterns are generated for output and consequently none are written to the antenna file. Also, should the user specify methods 13, 14, or 15 but not include an ANTOUT control card, then the antenna patterns <u>are</u> generated and written to the primary (or auxiliary) output file along with any other program generated output, but the patterns are not written to the binary antenna file. A method of using antenna patterns generated by the IONCAP program or by other means available to the user, is described in Section 6.3.

<u>OUTGRAPH control card</u>

The OUTGRAPH control card allows the user to specify the output of several methods without recomputing the variables. This is of particular use if several line printer graphs or other output forms are needed for various combinations of variables. A temporary alphanumeric parameter on the OUTGRAPH control card is used to indicate if additional output is requested for the current system configuration (see Control Card 25). If the word "OFF" is specified, then no additional output is desired. If the user desires additional output, he simply indicates the method numbers (up to 12) of the output desired on the OUTGRAPH card. As an example, if method 7 is run, the output from methods 8, 9, and 10 can be obtained without any additional computing as is demonstrated in Figure 13.

KTOUT is an array of up to 12 method numbers of the desired output.

The user should be aware that the particular program option specified on the METHOD card dictates the output that can be requested on the OUTGRAPH card. There are two limitations as to the output available with certain program analysis options. (1) The user may not request output on the OUTGRAPH card that requires computations which were not performed during the program analysis. As an example, the user may not request output for methods which require system performance if only the MUF was computed. (2) Several of the analysis options are performed within loops where the variables are not saved throughout the duration of the loop. Such analysis options cannot be requested on the OUTGRAPH card since the loops are terminated before the output requested on the OUTGRAPH card is generated. This implies that the user cannot always obtain the additional output by using the OUTGRAPH card. It is, therefore, optimal to run the program analysis options (specified on the METHOD card) that are performed within the loops and specify any additional desired output on the OUTGRAPH card.

Should the user specify output for a method on the OUTGRAPH card which violates one of the above restrictions, the program ignores the particular request and attempts to process any additional user requests for output. Thus, as an example, if the user should specify output for methods which require system performance and only the MUF was computed, the program would ignore the requests. Table 7 indicates the output available for methods specified on the OUTGRAPH card for each of the program analysis task options and also indicates the optimal combinations. The user may request LUF output (methods 26-29) if system performance has been calculated by methods 16-25. The LUF obtained would not be the computed LUF but would be the first frequency in the frequency complement that has a computed reliability greater than or equal to the required circuit reliability. If none if the reliabilities are as large as the required reliability, the frequency with the largest reliability is chosen as the LUF. A designator is printed to indicate the reliability. The user would compute the actual LUF by specifing methods 26-29 rather than specifying this on the OUTGRAPH control card.

The OUTGRAPH card acts as a software implemented "sense switch." Once the user specifies a desired output on an OUTGRAPH card, the user "enables" the software implemented "sense switch" and will continue to obtain the specified output options (when permissible) for every program analysis task he performs. This process continues until the user specifies either (1) an additional OUTGRAPH card or (2) an OUTGRAPH card with the word "OFF" specified, which disables the software implementation "sense switch." Should the user obtain much more output than he believes he has requested when using an OUTGRAPH card and when processing several system configurations, it is probable that he needs an OUTGRAPH "OFF" card somewhere (usually following an EXECUTE card). Should the user obtain less output than he has requested on an OUTGRAPH card, it is caused by an invalid user request that the program has ignored. The OUTGRAPH card may be specified anywhere before the EXECUTE card to request additional output options; however, the additional output will be generated after the current task option has been completed. If no OUTGRAPH card appears, the user receives only the output of the task option indicated on the METHOD card.

The output requested on the OUTGRAPH control card may be written to the auxiliary output file by specifying a negative method on the OUTGRAPH card.

TOPLINES control card

The TOPLINES control card allows the user to select the output header lines he desires to print when running method 23. The information output, for the most part, consists of the user-defined system configuration. This control card, along with the BOTLINES control card, allows the user to indicate the specific output lines he desires and thus together they constitute a user-defined output option. The user can select the output desired rather than those defined by other method numbers. There is one parameter array on the TOPLINES card. This option may be useful if the user does not desire the exact output generated by the task options implemented (see Control Card 26).

LINTP is an array of up to 8 user-selected header lines.

Table 8 describes the header lines available to the user, along with the corresponding values of the parameter LINTP. The user may redefine the header lines desired at any point in the input deck by specifying an additional TOPLINES card which overrides the previous specified lines. The user may also cancel the header lines previously selected by indicating the word "OFF" as the value of a temporary parameter on the TOPLINES card. The program has one default header line which consists of the program task option (METHOD), the program name and version number, as well as the page number. If the user does not include a TOPLINES card or specifies TOPLINES "OFF," the default header line is the only one printed when method 23 is indicated. The TOPLINES card has no effect on any program task option other than method 23.

BOTLINES control card

The BOTLINES control card allows the user to select the desired parameters to print when running method 23. The information output consists of the current values of the variables the user indicates. This control card, along with the TOPLINES control card, allows the user to indicate the specific output lines desired, and thus constitutes a user-defined output option. The user may, therefore, request the desired output rather than those specified by other method numbers. This may be useful if the user does not desire the exact output generated by the other task options. There is one parameter array on the BOTLINES card (see Control Card 27).

LINBD is an array of up to 14 user-selected variables.

Table 9 describes the variables available to the user along with the corresponding values of the parameter LINBD. The user may redefine the variables desired at any point by specifying an additional BOTLINES card which overrides the previous specified variables. The user also may cancel the variables previously selected by indicating the word "OFF" as the value of a temporary parameter on the BOTLINES card. The program outputs only the frequency complement as the default if the user does not include a BOTLINES card or specifies BOTLINES "OFF" when method 23 is indicated. The BOTLINES card has no effect on any program task option other than method 23. Table 10 describes the line numbers preset by using methods other than 23.

FREEFORM control card

NOTE: The freeform processor has not been developed for the IONCAP 78.03 version. Should the user specify a FREEFORM control card, the program will output a message to that effect and terminate program execution. Therefore, the user-defined control cards must be formatted card images, which are described in Section 3.4.

DEBUG control card

The DEBUG control card was implemented during the development of the IONCAP program as an aid in the validation of the program code. The use of the DEBUG card generated line printer output of temporary variables, iterative values of variables, and other information used to confirm the program analysis and predictions. Therefore, the DEBUG control card acts as a "do nothing" statement when specified by the user. The DEBUG control card is ignored, and the program processes the next control card (see Control Card 29).

3.3.6. Procedure Related Control Cards

The general purpose of an input procedure is to allow the user the capability of referencing a set of control cards by a single name identifier. In other words, it allows the user to reference several control cards by using a single control card. This could be useful if the set of control cards is to be referenced multiple times. The methodology and general program flow of creating an input procedure was discussed in Section 2.3. The following control cards describe the definition and usage of an input procedure. An input procedure may be defined anywhere in the user-defined input file since the procedure file is created during Phase 1, which occurs before execution of the analysis phase of the program. This allows the user to define a procedure after a reference is made to it if he so desires. It is, however, optimal to define the input procedures at the beginning of the user-defined input.

PROCEDURE control card

The PROCEDURE control card identifies the name of an input procedure and thus constitutes the beginning of the procedure definition. The user-defined procedure name is the only parameter on the PROCEDURE card (see Control Card 30). This temporary parameter is, as previously discussed, compared with and added to the table of reserved name identifiers that constitute the set of valid input control cards. The user may specify any name identifier for his procedure except those reserved control card identifiers which were given in Table 2. The program ignores the procedure definition and continues to process the remaining control cards should the user attempt to define a procedure with a reserved name identifier. All control cards following the PROCEDURE control card and preceding the END control card constitute the body of the procedure. Should the user specify two input procedures with the same name, the first definition takes preference and the other definition is ignored.

END control card

The END control card terminates an input procedure definition. Each user-defined input procedure must be terminated with an END control card since it is used (1) as a delimiter when creating the procedure file during the first phase of program execution and (2) indicates that the control cards following it are to be read from either the primary or auxiliary input file instead of the procedure file when encountered during the analysis phase of program execution. Thus, the END card indicates that the control cards following are not on the procedure file (see Control Card 31).

"USER DEFINED PROCEDURE NAME" control card

The "USER DEFINED PROCEDURE NAME" control card replaces the reference to the procedure name with the actual control cards which constitute the procedure definition. The characters on this card are to correspond to those used as a parameter on the procedure card. When the "USER DEFINED PROCEDURE NAME" is used as a control card, the procedure file is searched to locate the specified procedure. The control cards on the procedure file that occur before the END card are then processed as if they had occurred on the primary or auxiliary input files. A procedure file structure example is given in Figure 14.

3.4 Input Data Sheet

The required input data can be tabulated before data cards need to be punched by completing data sheets as given in Tables 11 and 12. The data required depend on the complexity of the computations requested by the user. The relationship between the input data and the output options is shown in Table 13. The principal options are ionospheric parameters, methods 1 and 2; antenna patterns, only methods 13, 14, and 15; MUFs, methods 3 to 12; or system performance and LUF, methods 16 to 29. See Section 4 for a description of the output options. These data sheets are formatted for the convenience of the card punch operator in the preparation of the input data cards, as described in Section 3.3, and may also be used when requesting predictions from ITS. Often the user who has gained some experience running the IONCAP program will not need to prepare the data sheets, but would generate the IONCAP card images directly. The following discussion is presented to assist in the preparation of these data sheets.

TABLE 11:

1. General Information. Lines 1 and 2 are self-explanatory and provide the identification of the person or organization requesting the prediction.

1(A) Year - If predictions are required for a specific time, the year should be specified. If predictions are for long-term planning, the general level of solar activity for the time period may be specified instead of the year; e.g., high, medium, low. In either case, the 12-month running average sunspot number (SSN) may be given. If the sunspot number is not given and predictions are requested from ITS, an appropriate number will be chosen. SSN 10 is typical for low solar activity and SSN 110-130 is typical for high solar activity. Monthly or daily solar activity indices are never used, only the expected 12-month running average.

1(B) Months - Circle the month or months for which predictions are required. June and December are typical of seasonal extremes for long-range planning.

1(C) Transmitter Site Electrical Characteristics - Specify the ground conductivity (σ) in mhos per meter and the relative dielectric constant (ε_r) at the transmitting site. Typical values for selected ground types are given in Table 6. If the electrical characteristics are unknown, the site may be described as sea water, or as good, fair, or poor ground. Typical good ground is low hills with unforested, rich soil or flat, wet coastal regions; fair ground is medium hills or forested heavy soil; and typical poor ground includes rocky, steep hills, sandy, dry coastal regions, and city industrial areas.

1(D) Receiver Site Electrical Characteristics - The same as (C), above, but for the receiver site.

2. Program Control Information.

2(A) Type Tabulation (Method) Desired - Table 3 summarizes the major outputs available for each tabulation, and Section 4 describes these outputs. Select the outputs required, and then choose the tabulation which provides this output. The tabulation number identification is also the identification of the "METHOD." Sample tabulations and detailed descriptions are shown in Section 4.

2(B) Beginning Hour of Calculation - The first hour for which predictions are required expressed in two digits; i.e., fractional hours may not be specified.

2(C) Ending Hour of Calculation - The last hour for which predictions are required.

2(D) Increment Hour of Calculation - The hourly increment of the computations. For graphs requiring the calculation of LUFs, it is recommended that the beginning hour be 02, the ending hour 24, and the increment 2. The hours are UT or LMT at the transmitter site dependent on specification by the user.

2(E) Antenna Pattern Tabulation - In all methods that require antenna characteristics, a tabulation of antenna gains is available. Indicate the tabulations desired.

2(F) Great Circle Path - Except for very long paths, only the short great circle is usually considered. If both long and short paths are required, separate computations are necessary.

3. Frequency Complement. The frequencies that should be considered. A choice of up to 11 frequencies is possible. See the FREQUENCY control card for additional information.

4. Circuit and System Performance Parameters.

4(A) Transmitter Location - The name and geographic coordinates expressed in degrees.

4(B) Receiver Location - As in 4(A) above.

4(C) Minimum Takeoff Angle - Normally 3.0 unless antenna performance is expected to be so poor at low angles that these angles should not be used in the estimation of upper useful frequency limits or if the horizon is so obstructed that low takeoff and reception angles appear unlikely.

4(D) Transmitter Power - The power delivered to the transmitting antenna expressed in kilowatts.

4(E) Required S/N Ratio - The ratio in decibels of the hourly median signal power in the occupied bandwidth relative to the hourly median noise in a 1 Hz bandwidth which is necessary to provide the type and quality of service required. Tables 4 and 5 show typical required S/N ratios. If the required S/N ratio is unknown, the required service may be given. Both the type and quality must be specified.

4(F) Man-Made Noise at the Receiver Site - Either the type of area (industrial, residential, rural, or remote) or the expected noise in a 1 Hz bandwidth at 3 MHz may be specified. Industrial area man-made noise is -125. dBW, residential is -136. dBW, rural is -148. dBW, and remote is -164. dBW. In remote unpopulous areas, cosmic noise will normally dominate over man-made noise. Specify this as a positive number unless one of the above defaults is desired.

4(G) Circuit Reliability Required - When a lowest usable frequency (LUF) or service probability computation is required, a minimum acceptable circuit reliability must be specified. A typical value is 90 percent.

4(H) Multipath Computation Required - Multipath probability is an estimate of the likelihood that two (or more) skywave propagation modes will exist within specified power and time delay tolerances.

4(I) Minimum Tolerable Power Ratio - The minimum tolerable power ratio between skywave modes at the receiver input terminal to permit satisfactory system performance in the presence of multiple signals.

4(J) Maximum Tolerable Time Delay - The maximum tolerable difference in delay times between skywave propagation modes (with power levels within the 4(I) criteria above) to permit satisfactory system performance in the presence of multiple signals.

TABLE 12:

Table 12, an extension of Table 11, is designed to record the required antenna information.

5. Antenna Parameters. Indicate the data required for the 11 antenna types. Figures 43 through 65 show the geometry involved to assist in the completion of Section 5 of Table 12 and also reflect the antenna gain patterns corresponding to the sample input data cards in Section 3.5. If an antenna other than the types

shown is being used, its performance may sometimes be approximated by selecting an antenna with a similar pattern. Some simple antennas (e.g., dipoles and verticals), permit the inclusion of additional gain to assist in this approximation. If this is not adequate, the program will allow reading of externally computed (or measured) patterns. This option may, however, require in-depth knowledge of the program and usually a software interface to IONCAP.

6. Transmitting Antennas. Tabulate the type of transmitting antenna or antennas to be used. The beginning and ending frequency for each antenna must be included in all cases, and these frequencies must not overlap. Up to three antennas may be used for the transmitter and/or for the receiver.

7. Receiving antennas. Tabulate similar information for the receiving antennas. All comments in (6) above apply.

3.5 Input Data Card Formats

This section lists the details of all the data cards valid for the IONCAP input file. All card formats and comments are given in Tables 14 and 15. This is followed by detailed control card diagrams for each card type, except the antenna cards. Table 16 gives examples of all the antenna cards where the control card diagrams (control cards 32-43) give the details of each antenna card. Section 3.3 describes the use of the cards, and Section 4 describes the output. Section 7 contains specific input examples.

Each card format consists of an alphanumeric name, up to 10 characters, followed by up to 14 data fields of five columns each. Each floating point variable may have a decimal inserted, while the integer variables must be right justified. Floating variables are read in an F5.1 format, except for the geographic latitudes and longitudes and the frequency card (CIRCUIT and SAMPLE cards) which are F5.2 format. Thus "12345" in the field is the number 1234.5 for all variables except the latitude or longitude variables which become 123.45. The hemisphere is specified by immediately following the number by "NORTH." "SOUTH," "EAST," or "WEST" or "N," "S," "E," "W" as appropriate.

4. OUTPUT OPTIONS

There are 30 output options that may be specified by the user (Table 3). These are divided into four subsets:

(1) ionospheric descriptions, METHOD = 1 or 2;

(2) antenna patterns, METHOD = 13, 14, or 15;

(3) MUF predictions, METHOD = 3 through 12; and

(4) LUF and system performance predictions, METHOD = 16 through 29.

The input required for each of the four run option subsets is summarized in Table 13. All the output figures described in the next three subsections were generated using the data cards listed in Figure 15. Each individual antenna type is described and an example given in the last subsection 4.4. The first line of all the output options gives the method number, program version, and a page number, the start of which is specified by the user.

4.1 Ionospheric Parameters Output Options, METHOD = 1 or 2

There are two outputs, a list of ionospheric parameters (Figure 16) and an ionogram (Figure 17). The data on Figure 16 are divided into a set of header lines and a body of output lines.

Line 2. The month, year, and sunspot number are given on the second line.

Line 3. The first 40 characters on the third line are those specified by the user on the LABEL card.

Line 4. The fourth line is the location of the transmitter and of the receiver. The azimuths, transmitter to receiver, and receiver to transmitter, are given in degrees east of north. The circuit distance is given in both nautical miles and kilometers.

Line 5. The semi-thickness of the E layer, YE, the height of maximum ionization, HE, and the reflection height of the Es layer, HS, are given in kilometers.

The body of the figure consists of the result of sampling the ionosphere at one, three, or five areas along the path. (There is only one sample area for this specific example.) Columns 1 and 2 give the sample area location. Columns 3 and 4 give the local time at the sample area and universal time (same for all sample areas). Column 5 is the median E critical frequency, foE, in megahertz. Columns 6, 7, and 8 are the F1-layer median critical frequency, foF1, in megahertz; semi-thickness, ymF1, in kilometers; and height of maximum ionization, hmF1, in kilometers. Column 9 is one-half the gyrofrequency, fH. Columns 10, 11, and 12 are F2 zero MUF, (foF2 + 1/2 fH), in megahertz; ymF2 in kilometers; and hmF2 in kilometers. Columns 13, 14, and 15 are lower, median, and upper decile from the maps of the minimum of foE or foEs, in megahertz. Note that a FPROB card was used to adjust the numbers to the predicted median (1.0 on all data fields). The normal (default) value is 0.7 of that predicted. Column 16 is the F2 M(3000) factor. Column 17 is the virtual height, hpF2, in kilometers. Column 18 is the ratio of hmF2 and ymF2. Columns 19 and 20 are the zenith angle and the maximum zenith angle at which the F1 layer exists, both in degrees. Column 21 is the geomagnetic latitude.

The ionogram output option, method 2, is in Figure 17. Up to three ionograms are constructed from the up to five sample areas along the circuit path. Lines 2, 3, and 4 are the same as for Figure 16. Line 5 gives the universal time, GMT, the local time at the sample area, the sample area location, the distances in kilometers from the transmitter at which the E and F parameters were taken, the type of integration used, and the manner in which the F1 layer was added to the electron density profile. The graph is vertical sounding frequency (in megahertz) versus true and virtual heights (in kilometers) where true and virtual height are represented by "." and "x" respectively in the graph. The Es layer is given by a line at the Es reflection height. The character "U" is used until the 90 percent value of foEs is exceeded; "M" is used until the 50 percent value is exceeded; and "L" is used until the 10 percent value is exceeded. The parameters for each layer are given in the upper left corner. The table on the right gives the sounding frequencies and the true and virtual heights.

4.2 MUF Output Options, METHOD = 3 through 12

The maximum usable frequency (MUF) output options include all mode information as well as the distributions of the MUF for each layer. First note that methods 3, 4, 5, and 6 refer to the MUFs for the E(F1) and F2 layers using the old nomogram method. This assumes a virtual height of about 300 km. The results of this model are not always valid in the 4000-10000 km range. The other MUF output comes from a complete electron density profile. All information possible from the MUF calculation are given in Figure 18. Lines 2, 3, and 4 are as described for Figure 16. Line 5 is the minimum radiation angle used to determine the MUF.

The body of the figure is composed of two lines for each hour, consisting of MUF information for each layer. Column 1 is universal time. Column 2 is local time at the transmitter. The next seven columns are for the E layer on one line and the F2 layer on the following. Column 3 is the 10 percent value of the MUF; i.e., the FOT, MHz. The MUF during a month is expected to exceed the FOT 90 percent of the days, and to be less than the FOT 10 percent of the days. Column 4 is the 50 percent value of the MUF in megahertz. Column 5 is the 90 percent value of the MUF; i.e., the HPF in megahertz. Column 6 is the radiation angle in degrees. Column 7 is the virtual height of reflection in kilometers. Column 8 is the true height of reflection in kilometers. Column 9 is the equivalent vertical frequency in megahertz. Columns 10 to 16 repeat the same information for the F1 layer on the first line and the Es layer on the second line. Note that, if the F1 layer is missing, the E values are used. Figures 19, 20, 21, and 22 are diurnal plots and tables of some of these parameters that have proved useful to analysis in the past.

4.3 System Performance Output Options, METHOD = 16 through 24

The prediction of the performance of a communication system operating between two points on the earth's surface is the main output of the IONCAP program. There are two principle forms of output: first, a table of up to 22 performance variables, and, second, a table or graph of the lowest usable high frequency (LUF). The program has been written in such a way that the user may specify the system performance lines desired. The header identification lines can also be selected. Table 8 shows the eight toplines available; Table 9 shows the 22 system performance lines available; Table 10 shows the line types specified by using the METHOD card. Table 7 shows the diurnal graphs that may be combined with the line selections.

Figures 23, 24, and 25 show a typical run with system performance output (method 16 with precalculation of antenna patterns). Figures 23 and 24 are tables of antenna gain in decibels at frequencies from 2 to 30 MHz and radiation angles from 0 to 90 degrees. These patterns and the input for each antenna type are described in detail in Section 4.4.

In METHOD 16, the header line information is largely input data supplied by the user.

Line 0: This appears on each output page and includes the method, program version, and page number.

User selected header lines are:

Line 1: Month, year, and sunspot number.

Line 2: Label as supplied by user, and headings for next line.

Line 3: Transmitter location, receiver location, the azimuth of the transmitter to the receiver in degrees east of north; the azimuth of the receiver to the transmitter in degrees east of north; path distance in nautical miles and kilometers.

Line 4: Minimum radiation angle in degrees.

Line 5: Antenna subroutine used (defining the antenna module used in IONCAP).

Line 6: Transmitter antenna line; up to three may be printed.
Information varies with antenna type (see Section 3.4). Typically, this is frequency range, antenna type, height of antenna above ground in meters (- is wavelengths), length of active part, an angle associated with the antenna structure in degrees, and the off main beam azimuth in degrees. Note, lengths specified should be "electrical" lengths.

Line 6A: Receiver antenna line. Up to three may be printed. The data are specified similar to the transmitter antenna line.

Line 7: System line which has: transmitter power in kilowatts, man-made noise level at 3 MHz in dBW, required reliability and required signal-to-noise ratio in decibels.

Line 8: Multipath line which has required power tolerance in decibels and required delay time tolerance in milliseconds.

The system performance lines are repeated each desired hour until the page is filled. The process is repeated if additional pages are necessary. The columns are time (universal) and up to 12 frequencies in megahertz; the first is the MUF and the remainder the frequency complement. Figures 25 to 32 give the various system performance output defined by methods 16 to 23 as indicated in Table 3. All possible output lines for system performance are as follows and shown in Figure 29.

Line 0, FREQ: Time and frequency line as associated with each column (default line always printed).

The first four lines always refer to the most reliable mode (MRM). The system performance parameter usually comes from the sum of all six modes. If no decision can be made, the selection of MRM is based on number of hops and then on SNR. All distribution refers to a diurnal period of an hour and a yearly period of a month.

Line 1, MODE: For the short path model, number of hop and mode type. E is E layer; F1 is F1 layer; F2 is F2 layer; ES is Es layer; N is a one hop Es with n F1 or F2 hops. (MRM)

For the long path model (Figure 30), the mode at the transmitter end and the mode at the receiver end are given. The user can force the long path model by specifying method 21 regardless of the actual path length.

Line 2, ANGLE: The radiation angle in degrees; for long paths (Figure 30), two lines are given: the first for the transmitter end, and the second for the receiver end. (MRM)

Line 3, DELAY: Time delay in milliseconds. (MRM)

Line 4, V HITE: Virtual height in kilometers. (MRM)

Line 5, F DAYS: The probability that the operating frequency will exceed the predicted MUF.

Line 6, LOSS: Median system loss in decibels for the most reliable mode.

Line 7, DBU: Median field strength expected at the receiver location in decibels above 1 microvolt per meter.

Line 8, S DBW: Median signal power expected at the receiver input terminals in decibels above a watt.

Line 9, N DBW: Median noise power expected at the receiver in decibels above a watt.

Line 10, SNR: Median signal-to-noise-ratio in decibels.

Line 11, RPWRG: Required combination of transmitter power and antenna gains needed to achieve the required reliability in decibels.

Line 12, REL: Reliability. The probability that the SNR exceeds the required SNR. Note this applies to all days of the month and includes the effect of all mode types: E, (F1), F2, Es, and over-the-MUF modes.

Line 13, MPROB: The probability of an additional mode within the multipath tolerances (short paths only).

Line 14, S PRB: Service probability. The probability that the required reliability will be met.

Line 15, SIG LW: Lower decile signal power (field strength and loss) increment in decibels.

Line 16, SIG UP: Upper decile signal power (field strength and loss) increment in decibels.

Lines 17, 18, 19, and 20 are experimental over-the-MUF to VHF scatter parameters and should be ignored by most users.

Line 17, VHFDBU: VHF median field strength in decibels above 1 microvolt per meter.

Line 18, VHF LW: VHF lower decile increment in decibels.

Line 19, VHF UP: VHF upper decile increment in decibels.

Line 20, VHFMOD: VHF mode type.

Line 21, SNR LW: Lower decile SNR increment in decibels.

Line 22, SNR UP: Upper decile SNR increment in decibels.

A composite table of reliabilities only is given in Figure 33 which comes from the user-selecting method 24. A similar table for any one variable can be selected by running method 23 and selecting the desired line. However, a frequency line will be printed each hour.

If information for each mode is required, method 25 will produce the data in Figures 34 and 35. For each hour, the ionospheric data, as in method 1, is printed. For each frequency, the mode and signal parameters are printed for each mode up to six. The last column is the selected most reliable mode. The same information is provided for the MUF.

Methods 26, 27, 28, and 29 will calculate the LUF, the lowest frequency having a specified circuit reliability, usually 0.90. Figure 36 is a table of LUF values with the MUF distribution and the median Es layer MUF. Figures 37, 38, and 39 are available diurnal plots of MUF prediction along with the LUF. Figures 40 and 41 provide MUF and system performance predictions for a long path (greater than 10000 km).

4.4 Antenna Output Options, METHOD = 13, 14, or 15

The detailed description of each antenna pattern and the required input definitions are given in this section. The gain subroutines used in the IONCAP are approximate models using the "one-term" theory and assume that the antenna parameters are within the design limits of each antenna and that the operating frequency is such that the antenna is close to resonance. These antenna models are appropriate when used in a propagation model where other uncertainties overshadow the uncertainties in the gain due to the antenna mode limitations. However, it is <u>not appropriate</u> to use these models to design antennas or to evaluate their performance outside of their design limits or far from resonance. Also, they will not typically produce accurate results for full-wavelength or multiple-full-wavelength antennas--again due to the limitations of one-term theory. The submodule described here also assumes the main beams are pointed along the circuit path. The input data card images in Figure 42 were used to generate the patterns of this section. Figures 43 to 65 are pairs for each pattern, the first giving the structure of the antenna and the second giving a sample pattern.

5. APPLICATIONS

The primary application of the IONCAP program is to use the system performance options to select a frequency complement. While intended mainly for program test and evaluation procedures, the other output options, if used with some interpretation, may provide the analyst with enough information to solve a particular problem. Some possible applications will be discussed in the same order as the program complexity; i.e., as

(1) ionospheric descriptions,
(2) MUF predictions,
(3) system performance predictions, and
(4) antenna applications.

5.1 Ionospheric Parameters Applications

The ionospheric description output consists of a table of parameters (Figure 16) and a graph and table of ionograms (Figure 17). The parameters are the output of the long-term world maps of the ionospheric parameters. The accuracy of the maps were determined when they were generated. The IONCAP theoretical report has details and references to these maps. The ionogram output includes the vertical sounding frequency and the virtual height, so that this ionogram may be compared to measured ionograms. Note, however, a monthly median may not be characteristic of that for a given day. An example of a predicted ionogram superimposed on a record of a month's measurements is given in Figure 66. The arrow points to the selected median ionogram, while the circles are from the IONCAP program. The effect of the changes of critical frequencies from the maps may be studied using the FPROB card (Control Card 20) or by use of the EFVAR and ESVAR cards (Control Cards 14 and 15).

5.2 MUF Applications

In the absence of any other criteria for the planning of a system using HF skywave, the first, and simplest, criteria is an estimate of the frequency having efficient ionospheric reflections. Normally, an estimate of the frequencies expected to have efficient ionospheric support 90 percent of the time, FOT, and those having efficient ionospheric support 50 percent of the time, MUF, are adequate estimates of upper frequency limits for system planning. Figures 18 through 22 show the possible MUF outputs. Note that Figure 18 (METHOD=7) gives all mode information and MUF distribution for each layer. These MUF calculations are only a description of the state of the ionosphere and do not include any system parameters. They should not be confused with the maximum operation frequency (MOF) for transmission between two points on an existing circuit. A full system performance calculation should be made to estimate the MOF or to compare with observed MOFs. If a full system performance computation is generated, the user should examine the frequency complement predictions rather than the MUF.

5.3 System Performance Applications

5.3.1 Selecting an Optimum Frequency

The complexities of propagation, the diversity of service requirements, and the fluctuation of spectrum congestion preclude any clear simple criteria for the selection of optimum frequencies. An adequate signal-to-noise ratio at the receiver for the specified type and quality of service is often a useful criterion. In general, within the HF spectrum, radio noise tends to decrease as frequency is increased. During the daylight hours when HF power requirements are highest, the propagation loss tends to decrease as frequency is increased. Since the noise normally decreases and signal normally increases with frequency, it is a general rule for HF skywave circuits that the higher the frequency the better the signal-to-noise ratio until frequency is increased to a point where reflection from the ionosphere becomes improbable. A first approximation to the optimum frequency in the absence of interference may, therefore, be made by estimating the highest frequency having an efficient ionospheric reflection consistent with the circuit reliability required; i.e., the MUF calculations described in Section 5.2 above.

Since there is normally limited flexibility in the selection of frequencies and since the optimum frequency based on the probable upper useful frequency limit has marked diurnal, seasonal, and other variations, it is desirable to establish the probable useful range of frequencies. The FOT as shown is based on a 90 percent probability of efficient ionospheric support and may be used as an estimate of the probable upper frequency limit; a corresponding lower useful frequency limit may be estimated by considering the probability that the available signal-to-noise ratio will be adequate. Since noise normally increases as frequency decreases and signal normally decreases as frequency decreases, there is usually a frequency below which the probability of an adequate signal-to-noise ratio is unacceptable. This probability is often set at 90 percent and the corresponding frequency is known as the lowest useful frequency (LUF). These limits; i.e., FOT and LUF, are shown in Figure 36 and graphically displayed in Figure 37.

5.3.2 Selecting a Frequency Complement for a Single Circuit in the Absence of Other Circuit Interference

The range of useful frequencies, such as shown in Figures 36 and 37, is basic to the selection of frequency complements and should be obtained for representative months over the time period the circuit under consideration will be required to operate. For a semi-permanent operation, diurnal variation of the useful frequency range for seasonal extremes (e.g., June and December) and solar activity extremes (e.g., sunspot number 10 and 110) are normally adequate.

5.3.3 Standard Frequency Complement

Absolute continuity of any radio service, however desirable, is improbable even with an unlimited choice of operation frequencies, when high frequency sky-wave propagation must be relied upon. Moreover, the return in improved continuity for an enlarged frequency complement beyond a certain size, depending upon the service, diminishes so rapidly that it can rarely be justified in the congested spectrum. Frequency complements can, however, be based on a concept of maximum feasible continuity; i.e., the theoretical increase in circuit continuity may be negligible if additional frequencies are added, but a significant decrease is possible if fewer frequencies are available. Since the required frequency complement depends upon the circuit parameters or usage, the following classification of circuits is introduced:

a. Circuits requiring maximum feasible continuity. These are the usually heavily loaded telegraph and telephone circuits, which must be available with good traffic capacity at all times. Because of their loading, they employ relatively elaborate terminal equipment. Telegraph circuits of this category are operated at machine speeds, while the telephone circuits generally employ several channels of a single-sideband system and are extended to line networks. Such circuits are characterized by the use of large directional antenna systems, diversity reception in telegraphy, and high-powered transmitters. Some other circuits, notably those immediately concerned with safety of life, may have an urgent need for continuous availability, although not necessarily carrying continuous traffic. The standard frequency complement for these circuits provides at least one frequency between the LUF and FOT at all times, plus one or two additional frequencies to permit flexible operations in the event of interference and during ionospheric disturbances. The maximum complement for these circuits should rarely exceed four. If more than four frequencies are considered necessary, re-engineering of the circuit should be investigated.

b. Circuits requiring moderate continuity. Distinct from circuits requiring maximum continuity, there exists a larger group of circuits which, by nature of their operation, require only moderate continuity. These circuits generally provide communication under circumstances where the needs are insufficiently critical to warrant the extension of wire, cable, or VHF facilities. Many such circuits are operated to provide occasional service to remote installations. There are also many circuits which may be designated nominally as continuous in operation, but on which the nature of the traffic is such as to allow occasional delays, reduction in transmitting speed, or rerouting. Judicious scheduling of traffic contributes significantly to the satisfactory operation of these circuits. Most circuits of an administrative nature belong in this category. For frequency-complement considerations, circuits (except safety services mentioned earlier) should generally be constrained to this category if they employ manual telegraphy or telephony not extended to line networks, or are equipped with simpler transmitting and receiving installations than are capable of providing maximum feasible continuity. Radio circuits of this kind have been operating on one or two frequencies in many parts of the world for many years, providing a quality of service consistent with particular needs. The standard frequency complement for these circuits is two, one day frequency and one night frequency.

5.3.4 Two-Frequency Complements

Two-frequency complements are recommended with the clear understanding that the services receiving such complements are of the kind which do not have sufficient traffic to justify attempts to operate them on a twenty-four hour basis. These circuits must nevertheless be assured of as many hours of communication per day as possible within the two-frequency limitation. Actually, in a very large number of cases during intermediate conditions of solar activity, two-frequency complements will give very nearly twenty-four hour service, except in the auroral regions where experience has shown that no complement of high frequencies can ever give a highly reliable service.

a. General considerations. There is available, at the present state of our knowledge, enough information on propagation, if the other factors such as terminal equipment, type of service, and actual operating conditions are known, to permit useful estimates of the total number of hours of satisfactory service, assuming no interference, to be expected from a given frequency over an average solar cycle. It is, however, impossible to estimate for any particular circuit the frequency that would give the maximum number of hours of useful service over the solar cycle. However, this frequency might not necessarily be one of the two frequencies assigned, since the cumulative number of hours of usefulness is a less urgent consideration than that of assuring operation during the normal peak traffic periods.

b. The day frequency. A simple method for selecting the day frequency consists of choosing a frequency just below the lowest daytime FOT curve. In the north temperate zone, this would be the FOT curve for June for the period of minimum solar activity. Simply choosing one frequency, or some small range of frequencies on this basis, ignores the situation with regard to LUF, and could lead, for an actual circuit, to failure to provide communication during the middle of the day in months of maximum absorption at the period of maximum solar activity. An improved method is derived from the opinion that, if possible, the day frequency should not fail to give service during the midday hours even at the condition of maximum normal absorption which occurs at the maximum levels of solar activity.

This approach suggests immediately that a band of particularly useful frequencies exists between the frequency which is just above the maximum midday LUF and the highest frequency that will provide essentially skip-free service during the middle period of the daylight hours in the months of minimum daytime FOT. The <u>lowest</u> frequency in such a band will provide the maximum hours of service, and such service may well exceed that obtained from a frequency selected only on the basis of minimum daytime FOTs. Fortunately, a useful band of frequencies does exist in nearly all cases, and the day frequency should be chosen in the lower part of this band.

The possibility of skip on frequencies chosen in this way is unlikely when consideration is given not only to normal FOTs, but also to the well-established role of sporadic-E reflections.

c. The night frequency. The choice of the night frequency is complicated, depending not only on the type of service, terminal equipment, and a number of propagational considerations, but also on the day frequency selected. As in the case of the selection of the best day frequency, it is not sufficient to select a frequency that will give the maximum number of hours of service throughout a complete solar cycle. The solution is to make the best choice for those hours that the day frequency is not suitable.

At night ionospheric absorption is minimal, except in the high latitudes, and the LUFs are rather critically dependent on the type of service and equipment used, including the antennas and the required signal levels. Too high a night frequency will be subject to skip too much of the time. However, a very low and, therefore, virtually skip-free night frequency may make it impossible to deliver adequate signal-to-noise ratios to the receiving location for substantial periods of time. The selection problem for this single night frequency is one of deciding what constitutes a suitable balance of these conflicting considerations. For circuits of 4000 km or less in length, the difference in local time between the terminals can never be large in the regions of the world where the bulk of the HF circuits operate. It is reasonable that traffic handling during the predawn hours be avoided, since, apart from the usual erratic behavior of the ionosphere during these hours, normal activities at both terminals are at their diurnal minimum during this period. In view of this sort of consideration, it would seem incorrect to choose a night frequency so low that skip-free operation was safely assured during the predawn period of the months and solar activity conditions having the lowest FOTs at the expense of rendering communications impossible during other time periods because of high noise levels normally experienced at the lower frequencies.

It is recommended, therefore, that the night frequency be chosen as the highest frequency of which less than four hours of skip is indicated on the lowest of the FOT curves for the required months of operation. This is usually during the winter months; e.g., December in the northern hemisphere and June in the southern hemisphere.

5.3.5 Three-Frequency Complement

Many radio circuits require a greater continuity of service than can generally be assured with two frequencies. This is especially true of telephone circuits intended for extension to line networks. The following suggestions are applicable to determining frequency complements for circuits less than 4000 km in length requiring maximum feasible continuity and employing telephony for extension to line networks, and also for speed of telegraphy for services not seriously troubled by multipath effects. Multipath protection required for certain types of high-speed machine telegraphy and facsimile services is not necessarily provided by these three-frequency complement standards.

There is some justification for enlarging the complement to four frequencies in the case of telephony and manual telegraph services subject to the severe magnetic disturbances characteristic of the high latitude regions. In other regions, however, it is possible by a suitable choice of three frequencies to maintain the signal-to-noise ratio high enough to provide an entirely adequate service. This is possible because higher frequencies are generally usable in the lower latitudes as a consequence of the observed higher complement-limiting FOTs, daytime levels of which survive in many cases far into the night. This situation is in marked contrast with the high latitudes where circuits are in all cases significantly more difficult to operate.

a. The high frequency. The highest frequency of a three-frequency complement is purely a day frequency. Since a middle frequency is available, it is no longer necessary for the highest frequency of the complement to be constrained to give useful service at the minimum phases of the solar cycle. This frequency should give many hours per day of useful service at all seasons during the maximum phases of the solar cycle. The high frequency is the highest frequency which will be below the FOT at least four hours during all months during the period the circuit is to be operated.

b. The low frequency. The lowest frequency of a three-frequency complement is entirely a night frequency. It must be selected on a basis related to the minimum FOT during any month the circuit is required to operate. Select the frequency which indicates less than two hours of skip on the lowest of the FOT curves for the required months of circuit operation.

c. The middle frequency. The middle frequency is selected so as to maximize the number of hours during which at least one frequency is between the LUF and FOT during the required period of circuit operation.

d. A special case for modifying the low frequency. Certain special considerations may affect the choice of a low frequency for circuits between about 3500 and 4000 km in length. For such circuits, the vertical angles of departure and arrival for single-reflection F2-layer transmission at night become very low. With many antennas, very little energy can be transmitted or received at these low angles. For these antennas, transmission, when possible, by two reflections from the F2 layer provides a superior service. If highly-directional broadside arrays, which are relatively efficient at low angles, are used at sites permitting use of low angles of departure and arrival, the single-reflection transmission remains useful. The possibility of site conditions which make impossible the use of low angles of arrival or departure should not be overlooked. During the conditions of lowest MUFs, unobstructed sites, and efficient low-angle antenna systems, the low frequencies for paths 3000-5000 km will remain useful, but there will usually be a skip on the higher vertical-angle two-reflection mode. With low-angle radiation or reception limited by inadequate antenna systems, terrain, etc., in the ways suggested, this skipping in the two-reflection mode may well interrupt the service. In these instances, where it appears that reliance must be placed on two-reflection transmission during the period of minimum MUFs, it is preferable to assign a frequency appropriate to two-reflection transmission. This frequency will be automatically displayed in Figure 18 or on graphs displayed in Figures 19 to 22 if the minimum vertical angle is set at the lower limit of adequate antenna performance; e.g., 3 to 5 degrees.

5.3.6 Four-Frequency Complements

Standard three-frequency complements are confined to a number of services, operated over paths less than 4000 km in length, where maximum feasible continuity of operation is required, but when the effects of multipath propagation are not serious. Services which use high-speed digital transmission techniques are seriously affected by multipath distortion, and a three-frequency complement may be insufficient. Many such services can, however, be adequately satisfied by a three-frequency complement with respect to both continuity and multipath protection. This is particularly true for circuits in the 2000 to 4000 km range of lengths, where the probability of multipath is low, and to a lesser extent for shorter circuits. Whether or not the three-frequency complement for a particular circuit provides the requisite multipath protection for high-speed service may be determined by a system performance prediction for the frequencies selected (e.g., METHOD=23, Figure 29 using a multipath tolerance of two milliseconds and a power tolerance of 10 dB) and noting the multipath probability for frequencies having an acceptable reliability.

It was suggested in the discussion on the applicability of three-frequency complements that there is some justification, apart from multipath considerations, for the assignment of a four-frequency complement to a circuit operating in high latitudes which has a critical need for maximum feasible continuity. If one or both terminals of a circuit lie above 60 degrees north geomagnetic latitude, the circuit may be regarded as sufficiently high latitude to merit consideration for a four-frequency complement.

a. The highest frequency. The highest frequency of a four-frequency complement is purely a day and evening frequency. Since three frequencies are available below it in a given complement, there is no longer any need that it give any important service at the minimum phases of the solar cycle, nor need it be the only frequency of the complement for service during maximum LUF periods. The main purpose of this frequency is to permit the reception of high-speed digital information free of destructive multipath distortion. It is usually required in afternoon and evening periods when the second highest frequency--while giving a perfectly adequate signal-to-noise ratio--would be subject to multipath distortion. This frequency must, therefore, be chosen with the maximum FOT in mind; it should nevertheless be as low as possible to give as much service as possible. In some of the complements, the highest frequency will give few cumulative hours of service over a solar cycle, though remaining indispensable to avoid multipath. In other complements, it will give considerable cumulative service and prove to be particularly useful in obtaining a good signal-to-noise ratio.

In general, the highest frequency is chosen to exceed 65 percent of the maximum FOT during the required period of circuit operation. This procedure is intended to provide substantial protection against multipath distortion on the highest frequency of the complement during hours and seasons of occurrence of maximum MUFs. At shorter distances, because of the impracticability of providing complete multipath protection, the factor provides as much protection as can reasonably be afforded by a four-frequency complement, while at the same time providing a highest frequency that will have significant usefulness at the maximum phases of the solar cycle.

It is necessary to invoke a LUF-determined lower limit or floor value below which the highest frequency of the complement is not selected regardless of the results of the above procedure. This limit is intended to provide a minimum additional margin of signal-to-noise ratio over that provided by the second highest frequency for high-grade service during periods of maximum LUF. The lower limit is set at 1.4 times the maximum LUF during the required period of circuit operation.

b. The second-highest frequency. The second-highest frequency of a four-frequency complement is the most important frequency of the complement in many ways. It is certainly the frequency likely to receive the greatest cumulative use over a solar cycle. It is low enough to provide reliable daytime operation at sunspot minimum during periods of minimum daytime MUF. While the frequency may receive considerable daytime use at sunspot maximum, it will also be needed during the evening and night transition periods at sunspot maximum to permit continuation of high-speed digital operation. Since there exists a frequency still higher in the complement and two lower, this frequency is chosen to remain just above the maximum LUF, as was the daytime frequency of the two-frequency complements. On some circuits, it can be expected that this frequency will provide service far into the night at sunspot maximum during much of the spring, summer, and autumn seasons. The principal use of this frequency is, nevertheless, as a day or evening frequency.

c. The third-highest frequency. The third-highest frequency of a four-frequency complement is probably the second most important frequency of the complement in terms of cumulative hours of use over a sclar cycle. While this frequency may receive some use in the early morning under certain conditions, its main use is as an evening or night frequency. During sunspot maximum conditions, it will, in a large number of cases, cover the late night period even in winter; it will certainly be sufficiently low for summer night use, even down to sunspot minimum in many temperate regions. In the high-noise regions, this frequency will nearly always be sufficiently low to cover the predawn period at the noisiest seasons, and for this reason it has not been necessary to give special consideration to high-noise-region floors for night frequencies in this report.

This frequency is the geometric mean of the second-highest and the lowest frequency of the complement. This procedure results in frequency intervals which provide the maximum possible multipath protection between these complement members. It provides, at the same time, a good order of frequencies for intended major usage during evening and night periods.

d. The lowest frequency. The lowest frequency of a four-frequency complement is entirely a night frequency. It must be relied upon at all times when the third-highest frequency is too high to carry the service. It is selected just below the minimum FOT during the period the circuit is required to operate.

5.3.7 Time Sharing on Circuits Separated Geographically

Since there are marked diurnal and geographical variations in the useful frequency range, it is often possible to use this variation to develop time sharing plans when circuits are separated geographically.

Tabulations or graphs of useful frequency range (Figures 36 and 37) should be obtained for the time period or time periods of interest. Whenever a frequency complement is such that it contains a frequency within the useful frequency range for one circuit, while outside the useful frequency range for the other circuit, this information may be used to develop time-sharing schedules. The time period may be extended whenever other frequencies in the complement are useful on the second circuit.

5.3.8 Time Sharing in the Same Geographic Area

When long and short paths are involved in the same geographic area, the useful frequency ranges for each may differ sufficiently that sharing plans may be developed in a manner similar to that described above (see Section 5.3.7).

5.3.9 Frequency Sharing

The development of frequency-sharing plans requires the prediction of the available signal along the unwanted as well as the wanted radio path, taking particular account of the expected antenna performance for the unwanted radio path. The circuit reliability estimates (e.g., METHOD=23) can be used to develop frequency-sharing plans (i.e., share whenever the reliability is high for the wanted paths but low for the unwanted paths).

A quick determination of a frequency sharing opportunity may sometimes be made by MUF-FOT computations for the wanted paths (e.g., Figure 19) and the HPF (frequency having efficient ionospheric support only 10 percent of the days) computation for the unwanted paths (e.g., Figure 20). Sharing should be possible if a frequency is below the FOT on the wanted path but above the HPF on the unwanted path.

5.3.10 Broadcast Coverage

Circuit reliability is probably the most valuable single output from the prediction program. As various parameters are fixed, a computation of circuit reliability as a function of a remaining variable will often assist in decision making. The question of broadcast coverage is a good example. With time, frequency, antenna, transmitter location, transmitter power, etc. fixed, circuit reliability to sample points within a geographic area of interest will describe the coverage of the area in terms of the percentage of days within the month that satisfactory reception may be expected. This process may be performed automatically by the computer to provide reliability tabulations over selected areas (e.g., one hemisphere). Although this output is not available as a "standard output", tabulations of this type can be made using a special input card processor and output variable formater.

5.3.11 Optimum Times for Communication

For given transmitter location, receiver location, antenna types, etc., the diurnal variation in circuit reliability may be used to choose optimum communication time (e.g., METHOD=23).

5.3.12 Selection of Relay Locations

Careful consideration should be given to increasing the frequency complement, increasing power, antenna redesign, etc. before relay stations are used. If there is no other solution, consider the use of relay stations. Normally, if possible, these relay stations should be separated by at least 3000 km and preferably not more than 7000 km. The relays should also assure the propagation path does not go to high latitudes; i.e., temperate or equivalent routes avoiding high noise regions are preferred. In the final selection, it is a question of computing circuit reliability for the direct path and making a comparison with potential relay sites.

5.3.13 Determination of Lowest Effective Transmitter Power

Compute circuit reliability as a function of transmitter power with other variables fixed and plot reliability vs. transmitter power. The lowest effective power is the lowest power providing the required reliability. An alternative is to use the required power plus antenna gain output, RPWRG, line 11, using METHOD=23.

5.4 Antenna Selection or Design

For the frequency or frequencies under consideration, make predictions covering the required time period of operation using a constant gain antenna with a typical gain; e.g., 12 dB. Determine the time or times the circuit reliability is the lowest. Using these times, repeat the computation for the antennas under consideration to select an antenna. Caution: the calculated vertical angle for the most reliable mode provides some guidance in determining the antennas to be considered, but this angle alone should never be used as the sole criterion for antenna selection. To select an antenna, repeat the computations for available antennas. To design an antenna, repeat computations for variables in the antenna design; e.g., antenna height, rhombic leg length, etc. Note, however, that these parameters must be part of a "well designed" antenna. See the comments in Section 4.4 above.

6. PROGRAM DATA FILES

6.1 BCD Program and Data Base Tape

The IONCAP program, along with the ionospheric long-term data base file denoted by LU2 and discussed in detail in the next section, are in general made available to the user on an externally coded (ASCII or EBCDIC) unlabled magnetic tape. This procedure allows for the installation of the IONCAP program on computers that have internal formats that differ from the CDC-6600. The problems, or potential problems, that arise from the differences in record block size that exist from computer to computer (and from operating system to operating system on the same computer) are avoided by using an external blocking procedure. The procedure consists of writing the IONCAP program to magnetic tape using card image format where each physical record on the magnetic tape consists of exactly one logical record; i.e., exactly one 80 character card image. This is initially accomplished by a direct write of the card image to the magnetic tape using a Fortran program rather than system copy routines on the CDC computer.

The ionospheric long-term data base is externally blocked into 120 characters per record format by a Fortran program called BCDBIN. The choice of the 120 character record size was partially decided upon by the desired sequential nature of the data, the massive volume of data, and a comparative study of internal block sizes on various computers. We found that some operating systems block records even when not desired, when the size of the record exceeds 128 characters. Program BCDBIN is also used to construct an internal binary data base from the externally blocked coded data base. This conversion is necessary prior to the execution of the IONCAP program since the program requires the data base to be in binary format for overall program efficiency. Thus, the character conversion to internal binary format is performed only once to eliminate the computer overhead for character conversion of the data base on each usage of the IONCAP program. The BCDBIN program is also available on the magnetic tape in card image format.

6.2 Long-Term Prediction File

This section describes the long-term data file used with the IONCAP program. Details of how each of the various parameters is used is given in the IONCAP theoretical report. The data file used here has evolved over many years. The basic criteria used in retention or inclusion of any of the data sets are: availability on a worldwide basis over all the time cycles (diurnal, yearly, and solar cycle) availability of distributions of the data, and consistency between the data sets. There are data sets available using somewhat different, perhaps better, mathematical representations which were not included here either because the new sets were not complete or did not represent an extended data base. There are also some data sets available which are not called for by the models implemented in the IONCAP program. Also some data sets are self-contained within some of the IONCAP subroutines, such as the mapping of the magnetic field in MAGFIN.

The long-term binary data file is divided into 18 blocks comprising 59 logical records (see Table 17). There is a year block (Table 18), followed in succession by season blocks (Table 19), followed by appropriate month blocks (Table 20). The data were arranged in this way to minimize storage requirements and to allow the months to be used in sequential order. For each month and sunspot number, the program will generate a single reduced data set.

The year block data (Table 18) consists of a single logical record containing coefficients for the F1 layer critical frequency, foF1, and the maximum zenith angle at which the F1 layer exists; a set of coefficients describing the land-sea areas of the globe; the coefficients describing the ratio of the height of maximum of the F2 layer to the semi-thickness of the layer; and the linear adjustment to the land mass map and ratio map. A source of the coefficients and a listing of them are given where possible.

The XF1COF array is reduced to monthly coefficients in subroutine REDMAP and evaluated in subroutine EF1VAR. The array FAKMAP is set into the seventh block of the P array and the XPMAP is reduced for sunspot number and set into the eighth block of the P array. They are evaluated in the subroutine NOISY.

Each season block (Table 19) consists of two logical records. There are four different data sets with the first, winter, repeated before the December month block. The seasons as named here refer to the months for the northern hemisphere; the appropriate data for the southern hemisphere is contained in the same season block; e.g., winter season block is the summer season block for the southern hemisphere. The first logical record contains the following tables (see the IONCAP theoretical report for the table values):

The F2D array contains the table of ratio of the daily F(3000)MUF to the monthly median F(3000)MUF expressed as a percentage value for the upper and lower deciles.

The F2D tables are stored in the array as follows: F2D(M,N,J).

(a) The sixteen values of F2D associated with the index M are the values for the zones in decreasing order of geomagnetic latitude for the percentage upper and lower decile values of the distribution of the F2(3000)MUF.

(b) The six values associated with the index N are the values for low, medium, and hign solar activity levels for the northern and southern hemisphere respectively.

(c) The six values associated with the index J are those values for the hour block of the day.

The F2D array is evaluated in subroutine F2DIS.

The DUD array contains the polynomial coefficients used for the evaluation of the decile values of the atmospheric radio noise (DU and DL).

The DUD array is arranged as follows:

NORTHERN HEMISPHERE	TIME BLOCK	SOUTHERN HEMISPHERE
DUD(M,1,N)	0000 - 0400 LMT	DUD(M,7,N)
DUD(M,2,N)	0400 - 0800 LMT	DUD(M,8,N)
DUD(M,3,N)	0800 - 1200 LMT	DUD(M,9,N)
DUD(M,4,N)	1200 - 1600 LMT	DUD(M,10,N)
DUD(M,5,N)	1600 - 2000 LMT	DUD(M,11,N)
DUD(M,6,N)	2000 - 2400 LMT	DUD(M,12,N)

The value N of 1 and 2 denotes the upper and lower deciles respectively. The value N of 3, 4, and 5 denotes the prediction errors sigma FAM, sigma DL, and sigma DU, respectively.

The DUD array is evaluated in subroutine GENFAM.

The FAM array contains the numerical coefficients used in the evaluation of the frequency dependence of the median 1 MHz atmospheric radio noise.

The FAM array is arranged as follows:

NORTHERN HEMISPHERE	TIME BLOCK	SOUTHERN HEMISPHERE
FAM(M,1)	0000 - 0400 LMT	FAM(M,7)
FAM(M,2)	0400 - 0800 LMT	FAM(M,8)
FAM(M,3)	0800 - 1200 LMT	FAM(M,9)
FAM(M,4)	1200 - 1600 LMT	FAM(M,10)
FAM(M,5)	1600 - 2000 LMT	FAM(M,11)
FAM(M,6)	2000 - 2400 LMT	FAM(M,12)

The FAM array is evaluated in subroutine GENFAM.

The SYS array contains the table of median and decile differences for the distribution of transmission loss. The SYS tables are stored in the array as follows:

SYS(M,N,J)

(a) The nine values of SYS associated with the index M are the values for the zones in increasing order of geomagnetic latitude.

(b) The 16 values of SYS associated with the index N are the values for the time blocks from 0100 LMT through 2400 LMT for the season of the northern and southern hemispheres, respectively; i.e., N greater than or equal to one and less than or equal to eight is the northern hemisphere, N greater than or equal to nine and less than or equal to 16 is the southern hemisphere.

(c) The six values of SYS associated with the index J are the values for the median value of system loss, for the difference between the median and lower decile value, and for the difference between the median and upper decile value divided into two parts for paths less than and greater than 2500 km respectively.

The table look-up process is accomplished by the subroutine SYSSY.

The PERR array contains the tables of the likely errors in predicting the available signal levels at the receiver.

The array PERR (9, 4, 6) is arranged in the following order:

NORTHERN HEMISPHERE	TIME BLOCK	SOUTHERN HEMISPHERE
PERR(M,1,I)	0100 - 0700 LMT	PERR(M,1,I)
PERR(M,2,I)	0700 - 1300 LMT	PERR(M,2,I)
PERR(M,3,I)	1300 - 1900 LMT	PERR(M,3,I)
PERR(M,4,I)	1900 - 0100 LMT	PERR(M,4,I)

The I values are 1 through 3 for the northern hemisphere and 4 through 6 for the southern hemisphere. The M values 1 through 9 are for the corresponding geomagnetic latitudes.

The second logical record contains noise data. The FAKP array uses the same computer memory as the first part of the P array to reduce storage requirements.

The P array contains the Fourier coefficients for the seasonal median 1 MHz dB kTB for 1 Hz bandwidth atmospheric radio noise maps. The P array also contains the coefficients for the representation of the major land bodies of the world and the hmF2/ymF2 ratio.

Median 1 MHz atmospheric radio noise

P(M,N,1)	0000 - 0400 LMT
P(M,N,2)	0400 - 0800 LMT
P(M,N,3)	0800 - 1200 LMT
P(M,N,4)	1200 - 1600 LMT
P(M,N,5)	1600 - 2000 LMT
P(M,N,6)	2000 - 2400 LMT

Major land bodies of the world P(M,N,7)

Semi-thickness ratio at a given sunspot number P(M,N,8)

These coefficients are evaluated in subroutine NOISY.

The 12-month data blocks contain four logical records. The first record contains:

IKIM(M,6) the summation limits, 10 each for the six sets of coefficients following in this data block.

XESMCF(M,N,2) the median value of foEs (or foE) for the low and high solar activity.

The second record contains:

XESLCF(M,N,2) } the decile values of foEs (or foE) for the
XESUCF(M,N,2) } low and high solar activity.

The third record contains:

XFM3CF(M,N,2) the median values of the F2 layer M(3000) factor for low and high solar activities.

XERCOF(M,N,2) the median values of foE for low and high solar activity.

The fourth record contains:

XF2COF(M,N,2) the median values of foF2 for low and high solar activity.

The six sets of coefficients are evaluated in the subroutines VIRTIM (universal time dependence), and VERSY (geographic dependence).

6.3 Antenna Patterns Stored on File

It is possible, but not mandatory, to execute the IONCAP program using antenna patterns that have been previously computed by (a) IONCAP using the ANTOUT control card discussed in Section 3.3.5, (b) some other analysis program that has been modified to create and write antenna patterns in the format expected by IONCAP or (c) to use field measurements and interpolation to create and write antenna patterns in the format expected by IONCAP. This use may require some in-depth knowledge of the working of IONCAP.

The antenna pattern input file (denoted by LU26) is stored on magnetic tape or disk as an internal binary file. The user should assign the local file name TAPE26 to the permanent tape or disk file prior to the execution of the IONCAP program. It is, of course, assumed that the user has previously created and stored the permanent file by one of the methods described above. The user would then specify antenna type 18 on the ANTENNA control card to indicate that the antenna pattern is to be input from the antenna file. The location of the desired antenna pattern on the antenna file is specified using variable IAIN for antenna type 18. (Note: This variable indicates from one to three antennas to cover the frequency range specified for the transmitter and receiver antennas for all antenna types except antenna type 18.)

It is necessary to specify the location of the desired antenna pattern on the antenna file since several antenna patterns could be written on the same antenna file. Locating the desired antenna pattern depends on whether the antenna pattern is beyond or before the current location on the antenna file. If the desired antenna pattern is beyond the current position on the antenna file, the variable IAIN indicates the number of antenna patterns to skip forward from the present position on the antenna file before reading the desired pattern. Thus, in this case, IAIN must be set to a positive number or zero by the user. For example, IAIN = 0 indicates that no antenna patterns are to be skipped from the current position, which means the next antenna pattern on the file is read. If IAIN = 3, then three antenna patterns are to be skipped from the current position before the desired antenna pattern is read. If the desired antenna pattern is before the current location on the antenna file, the variable IAIN indicates that the antenna pattern should be rewound before searching for the desired pattern. This is accomplished by setting IAIN negative. The negative number causes the file to be rewound, and the pattern read is specified by the absolute value of IAIN. For example, IAIN = -1 indicates that the antenna file is rewound before reading the desired antenna pattern and that the first pattern on the file is the antenna pattern read. If IAIN = -3, then the antenna file is rewound before reading the desired antenna pattern and the third pattern on the file is the antenna pattern read.

7. SPECIFIC INPUT EXAMPLES

This section is intended to demonstrate specific input options of the IONCAP program to reinforce information provided in earlier sections. Specific input requirements necessary to demonstrate particular IONCAP capabilities are discussed. References to corresponding output for each example is also presented.

7.1 Ionospheric Parameter Example

The input required to generate the ionospheric parameters for the control points of a particular circuit consists of the following control: METHOD, MONTH, SUNSPOT, TIME, LABEL, CIRCUIT, EXECUTE and QUIT. The input necessary to generate the similar output represented in Figure 16 consists of the following:

```
METHOD       1
MONTH      1970    1
SUNSPOT    100.
TIME         1    24     1    -1
LABEL     BOULDER, COLORADO TO ST. LOUIS, MO.
CIRCUIT   40.03N    105.3W    38.67N    90.25W
EXECUTE
QUIT
```

It should be noted that the sporadic-E critical frequency has been multiplied by .7 to allow for median losses in this example by program default. Figure 16, discussed earlier, is a presentation of the ionospheric parameters for this circuit without the sporadic-E critical frequency reduced.

7.2 Antenna Pattern Example

The input required to generate an antenna pattern for both a transmitter and receiver antenna consists of the following control cards: METHOD, ANTENNA, EXECUTE, and QUIT. The specific input necessary to generate the output represented in Figures 23 and 24 consists of the following:

```
METHOD      15
ANTENNA      1    2      .001    4.       -.5
ANTENNA      2    2      .001    4.       -.25
EXECUTE
QUIT
```

To generate the pattern of a transmitter antenna, only use method 13 and for a receiver antenna, only use method 14.

7.3 MUF Example

The input required to generate MUF predictions consists of the following control cards: METHOD, MONTH, SUNSPOT, TIME, LABEL, CIRCUIT, EXECUTE, and QUIT. The specific input necessary to generate the output represented in Figure 18 consists of the following:

```
METHOD       7
MONTH      1970    1
SUNSPOT    100.
TIME          1   24     1   -1
LABEL     BOULDER, COLORADO TO St. LOUIS, MO.
CIRCUIT   40.03N    105.3W    38.67N    90.25W
EXECUTE
QUIT
```

7.4 System Performance Example

The input required to generate system performance predictions consists of the following control cards: METHOD, MONTH, SUNSPOT, TIME, LABEL, CIRCUIT, ANTENNA, FREQUENCY, EXECUTE, and QUIT. The input necessary to generate output similar to the output represented in Figure 25 consists of the following:

```
METHOD       16
MONTH      1970    1
SUNSPOT    100.
TIME         12   24   12   -1
LABEL     BOULDER, COLORADO TO ST. LOUIS, MO.
CIRCUIT   40.03N    105.3W    38.67N    90.25W
ANTENNA       1    2      .001   4.       -.5
ANTENNA       2    2      .001   4.       -.25
FREQUENCY   2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0
EXECUTE
QUIT
```

It should be noted that the above input does not cause the transmitter and receiver antenna patterns to be precomputed as was the situation in Figure 25. (This is indicated by the absence of method 15 card to compute the gain pattern in this example.) The above input causes the antenna gain values to be computed as needed for specific frequencies and elevation angles. This indicates that the gain value for 7.5 MHz needed in Figure 25 was interpolated between 7 MHz and 8 MHz. The gain value for 7.5 MHz in the above example is computed as the frequency 7.5 MHz is processed. It should further be noted that this value would be recomputed for each hour specified in the above example. Thus, the gain is computed at each frequency and for each hour as needed.

7.5 User-Selected Output Example

The input required to generate user-selected system performance predictions consists of the following control cards: METHOD, TOPLINES, BOTLINES, MONTH, SUNSPOT, TIME, LABEL, CIRCUIT, ANTENNA, FREQUENCY, EXECUTE, and QUIT. The input necessary to generate output similar to the output represented in Figure 32 consists of the following:

```
METHOD       23
TOPLINES      1    2    3    4    5    6    7
BOTLINES      1    2    4   10   11   12
MONTH      1970    1
SUNSPOT    100.
TIME         12   24   12   -1
LABEL     BOULDER, COLORADO TO ST. LOUIS, MO.
CIRCUIT   40.03N    105.3W    38.67N    90.25W
ANTENNA       1    2      .001   4.       -.5
```

```
ANTENNA        2    2        .001   4.       -.25
FREQUENCY    2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0
EXECUTE
QUIT
```

The header lines specified on the TOPLINES are given in Table 8 and are listed below:

(1) month, year, and sunspot number

(2) alphanumeric information on the LABEL card

(3) transmitter and receiver information (coordinates)

(4) minimum takeoff angle

(5) transmitter antenna information

(6) receiver antenna information

(7) transmitter power, man-made noise, required reliability, and required SNR.

The output predictions specified on the BOTLINES card are given in Table 9 and listed below:

(1) number of hops and mode type

(2) radiation angle and transmitter

(4) virtual height of most reliable mode

(10) median SNR

(11) required power gain for most reliable mode

(12) reliability.

It should be noted that the above input does not cause the antenna pattern to be precomputed as was the case in Figure 32. (This is indicated by the absence of the method 15 card to compute the gain tables in this example.) The above input would compute the gain value of each frequency for each hour as needed. This has been discussed in Section 7.4.

7.6 LUF Example

The input required to generate LUF predictions consists of the following control cards: METHOD, MONTH, SUNSPOT, TIME, LABEL, CIRCUIT, ANTENNA, EXECUTE, and QUIT. The input necessary to generate output similar to the output represented in Figure 36 consists of the following:

```
METHOD      26
MONTH     1970    1
SUNSPOT    100.
TIME         2    24    2   -1
LABEL     BOULDER, COLORADO TO ST. LOUIS, MO.
CIRCUIT   40.03N    105.3W    38.67N    90.25W
ANTENNA      1    2       .001    4.        -.5
ANTENNA      2    2       .001    4.        -.25
EXECUTE
QUIT
```

It should be noted that the above input does not cause the antenna pattern to be precomputed as was the situation in Figure 36. (This is indicated above by the absence of the method 15 card to compute the gain tables in this example.) The above input would cause the antenna gain to be computed for the LUF rather than interpolate in the gain table as was the case in Figure 36.

7.7 Outgraph Example

The input required to generate the MUF predictions given in Figures 18 through 22 consists of the following control cards: METHOD, OUTGRAPH, MONTH, SUNSPOT, TIME, LABEL, CIRCUIT, EXECUTE, and QUIT. The specific input necessary to generate the output represented in Figures 18 through 22 consists of the following:

```
METHOD       7
OUTGRAPH     8    9   10   11
MONTH     1970    1
SUNSPOT    100.
TIME         1   24    1   -1
LABEL     BOULDER, COLORADO TO ST. LOUIS, MO.
CIRCUIT   40.03N    105.3W    38.67N    90.25W
EXECUTE
QUIT
```

The method card defines the predictions to be generated and the output form generated by that method. Therefore, the predictions generated consist of the MUF-FOT table for each ionospheric layer since method 7 was specified in this example. The user may select additional output providing that the computations for the output have already been generated. Therefore, in this case, the user can select the outputs of methods 8 through 11 consisting of the MUF-FOT graph, HPF-MUF-FOT graph, MUF-FOT-ANG graph, and MUF-FOT-Es graph, as is indicated in Table 7.

7.8 Procedure Example

The user may desire to have predictions for several circuits at several months and sunspot numbers, as was discussed in Section 3.3.2. The following input procedure will generate MUF predictions for several circuits at several month and sunspot numbers. The output generated would be similar to the output represented in Figure 19.

```
PROCEDURE CCIR
LABEL      TOKYO TO AKITO
CIRCUIT    35.7N     139.5E     39.73N     140.1E
EXECUTE
LABEL      BRACKNELL TO LUECHOW
CIRCUIT    52.00N    1.20W      53.00N     11.20E
EXECUTE
LABEL      SHANNON TO LUECHOW
CIRCUIT    52.7N     8.9W       53.00N     11.20E
EXECUTE
END
METHOD        8
TIME          1   24    1   -1
MONTH       1971   1
SUNSPOT     80.4
CCIR
MONTH       1971   4
SUNSPOT     70.9
CCIR
QUIT
```

The result of the above input is MUF-FOT graphs for each of the three specified circuits at each of the two months indicated. Thus, six output pages would be generated. It should be noted, as was presented in Section 3.3.2 and 3.3.6, that the procedure name, in this case CCIR, is placed in the input deck to allow the circuits predefined by the name CCIR to be placed in the position whenever the name CCIR is used.

7.9 External Antenna File Example

The user may wish to save the antenna gain table of his antennas for use on a separate run. This may be particuarly significant if the same antennas are used for several communication paths, or the predictions are generated with the same antennas each month, or the user has a specific antenna pattern created by another program, or possibly the actual measured antenna gain values. To create the antenna file corresponding to the patterns given in Figures 23 and 24, the following input should be used:

```
METHOD      15
ANTOUT
ANTENNA      1    2      .001   4.       -.5
ANTENNA      2    2      .001   4.       -.25
EXECUTE
QUIT
```

The user could then store the patterns generated on magnetic tape or disk for reference at a later time. See the discussion of the ANTOUT card in Sections 3.3.5 and 6.3. Use of the antenna patterns previously generated and stored externally, can be done using the following input, which will also generate the system performance output represented in Figure 25.

```
METHOD       16
MONTH      1970    1
SUNSPOT    100.
TIME         12   24   12   -1
LABEL     BOULDER, COLORADO TO ST. LOUIS, MO.
CIRCUIT   40.03N    105.3W    38.67N    90.25W
ANTENNA       1   18
ANTENNA       2   18
FREQUENCY   2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0
EXECUTE
QUIT
```

The difference in this example and the example presented in Section 7.4 is that the antenna patterns are read from a file instead of being computed. Section 6.3 explains this procedure in depth.

8. ACKNOWLEDGMENTS

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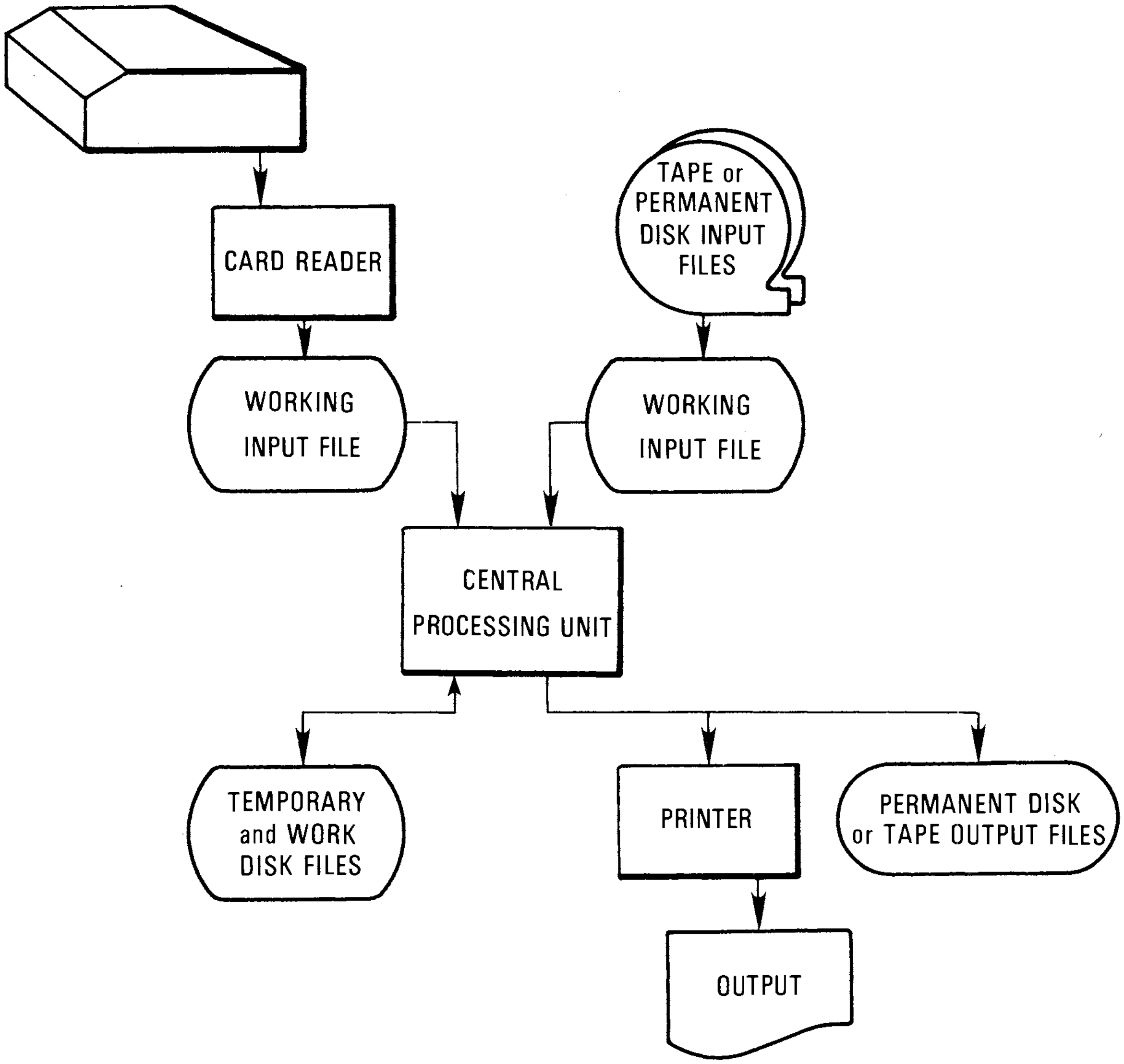


Figure 1. IONCAP computer resources used.

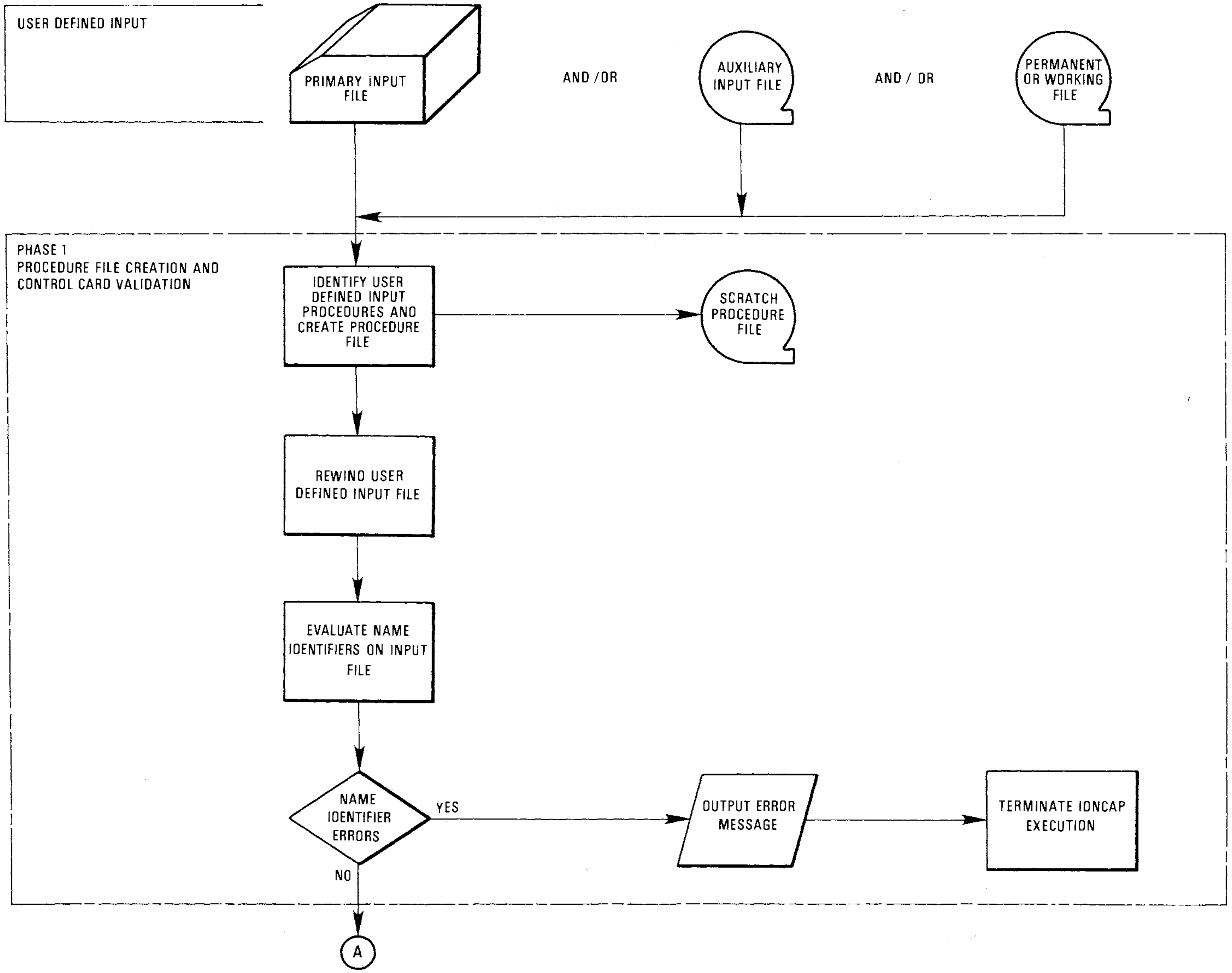


Figure 2. IONCAP control.

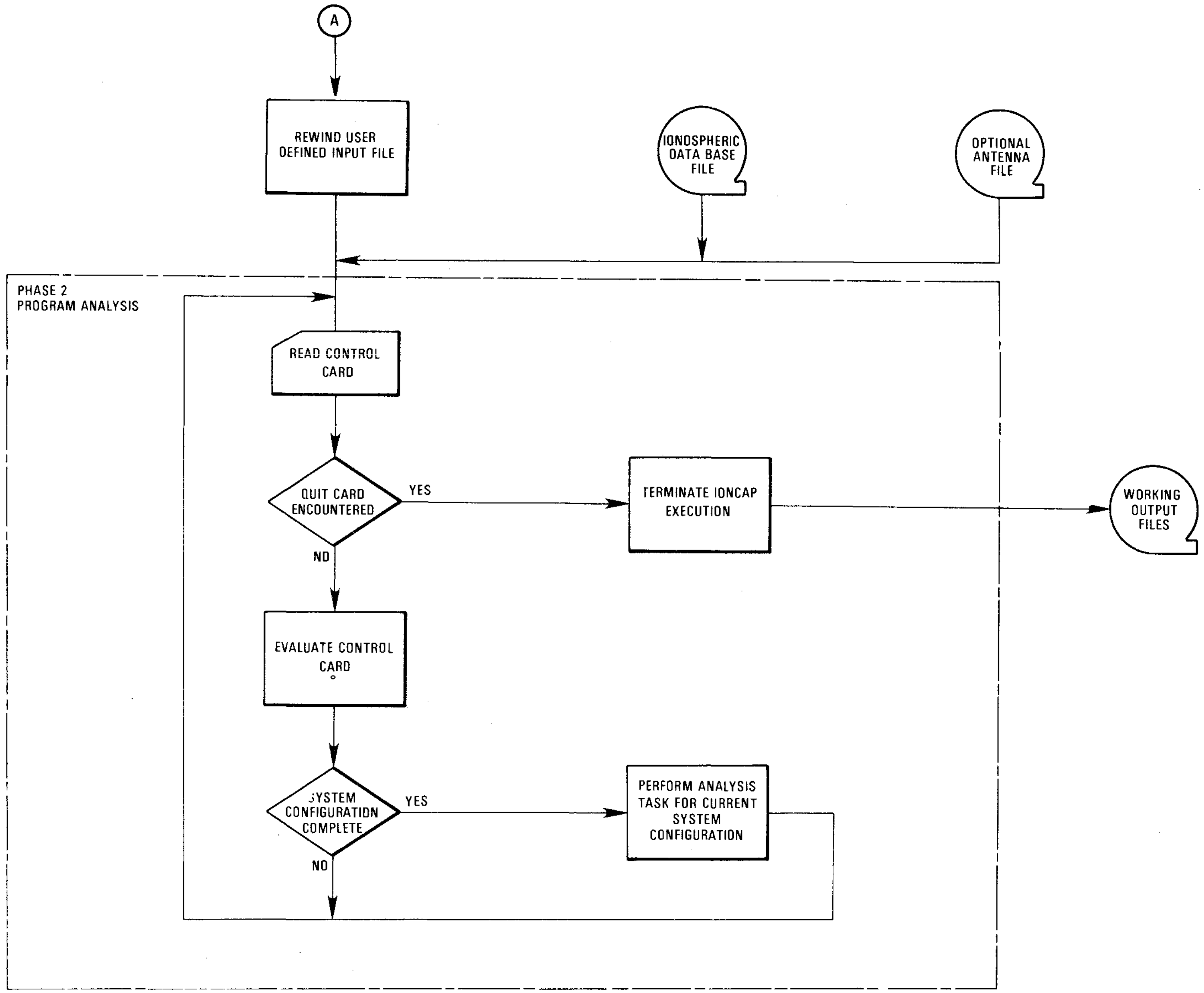


Figure 2. IONCAP control (continued).

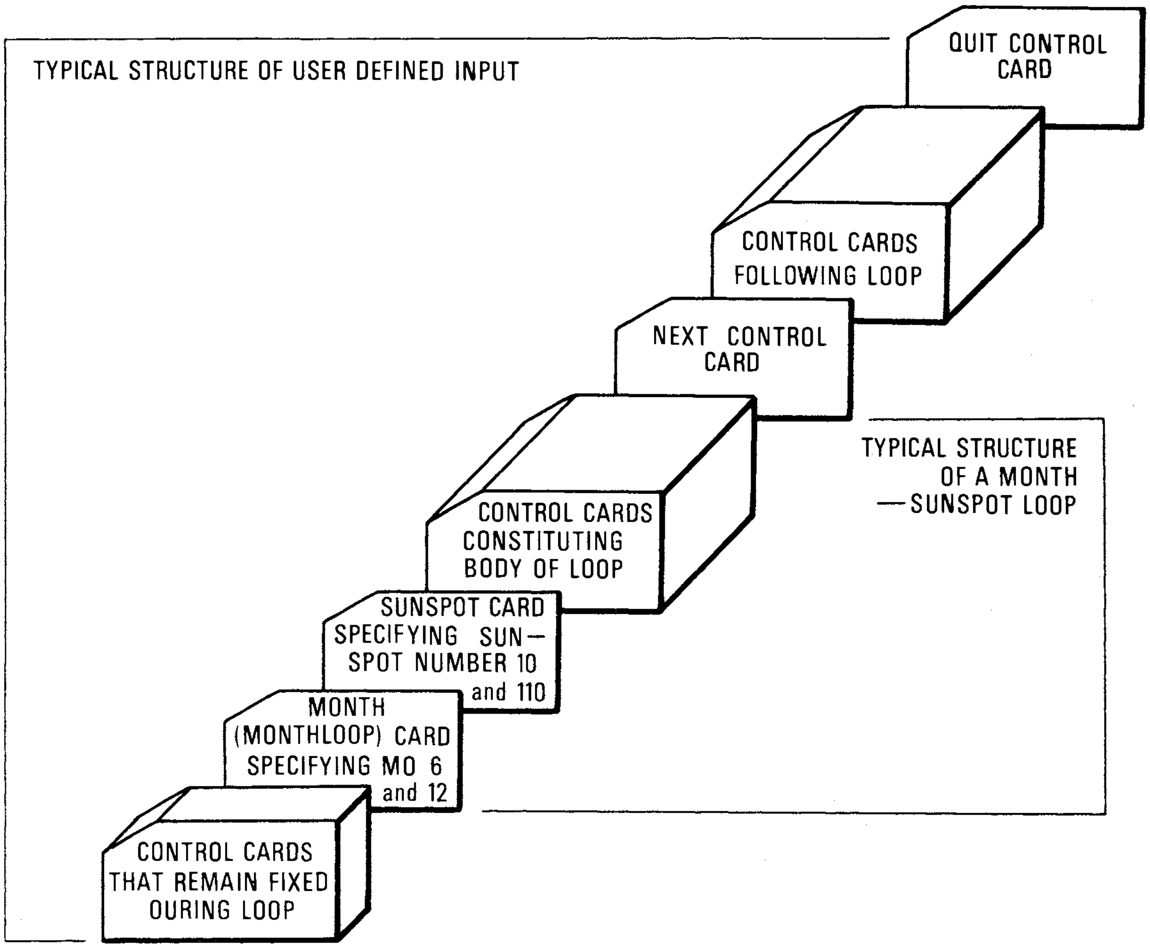


Figure 3. Typical deck structure for a MONTH-SUNSPOT number loop.

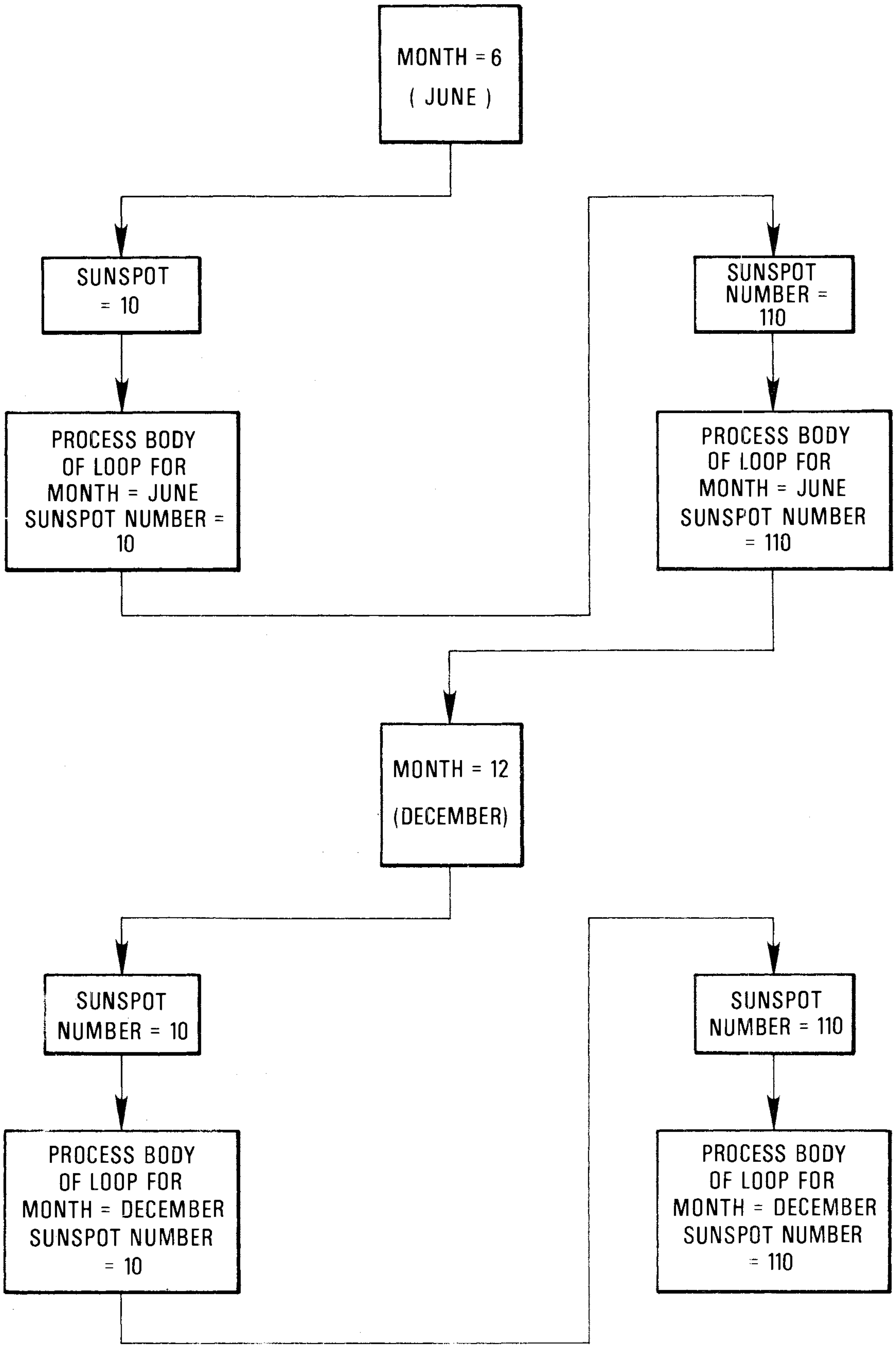


Figure 4. Effect of a typical MONTH-SUNSPOT number loop.

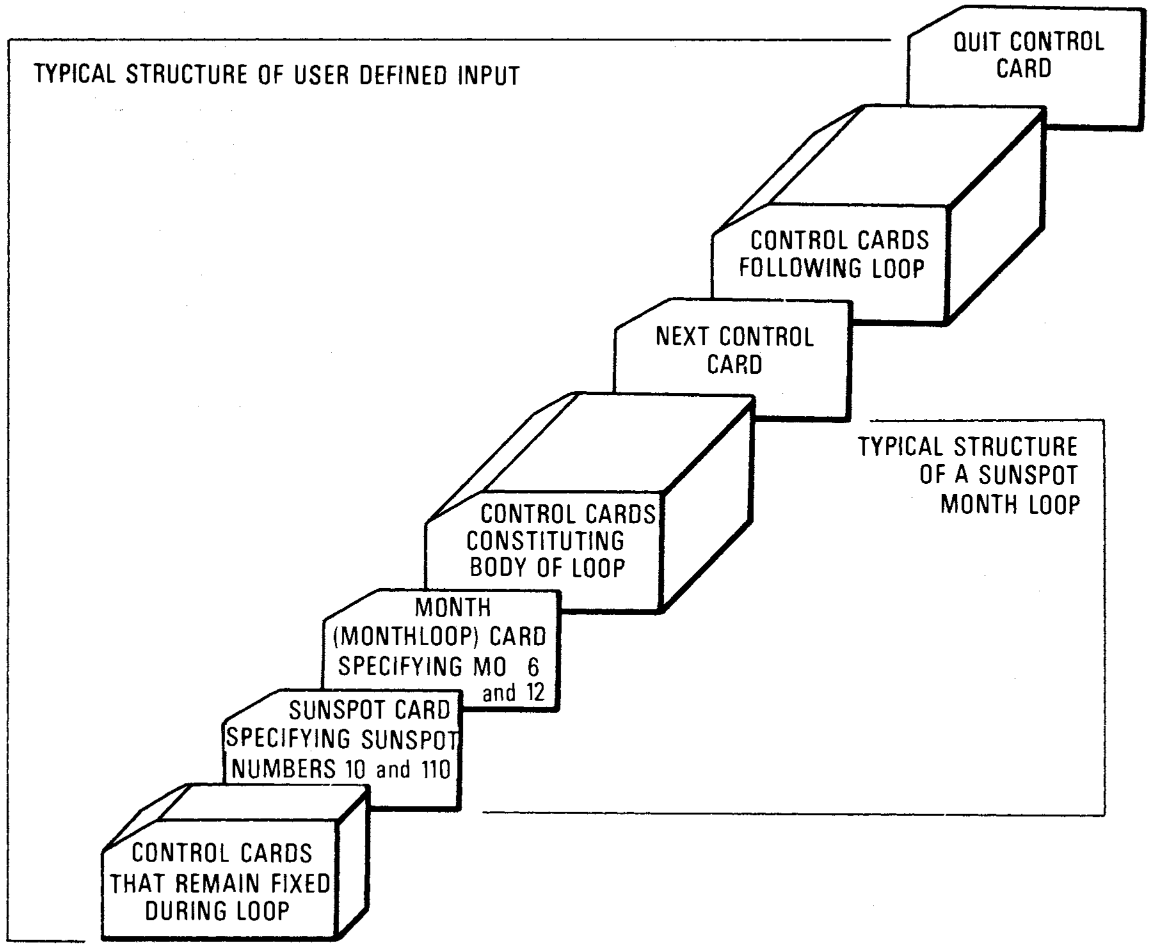


Figure 5. Typical deck structure for a SUNSPOT-MONTH number loop.

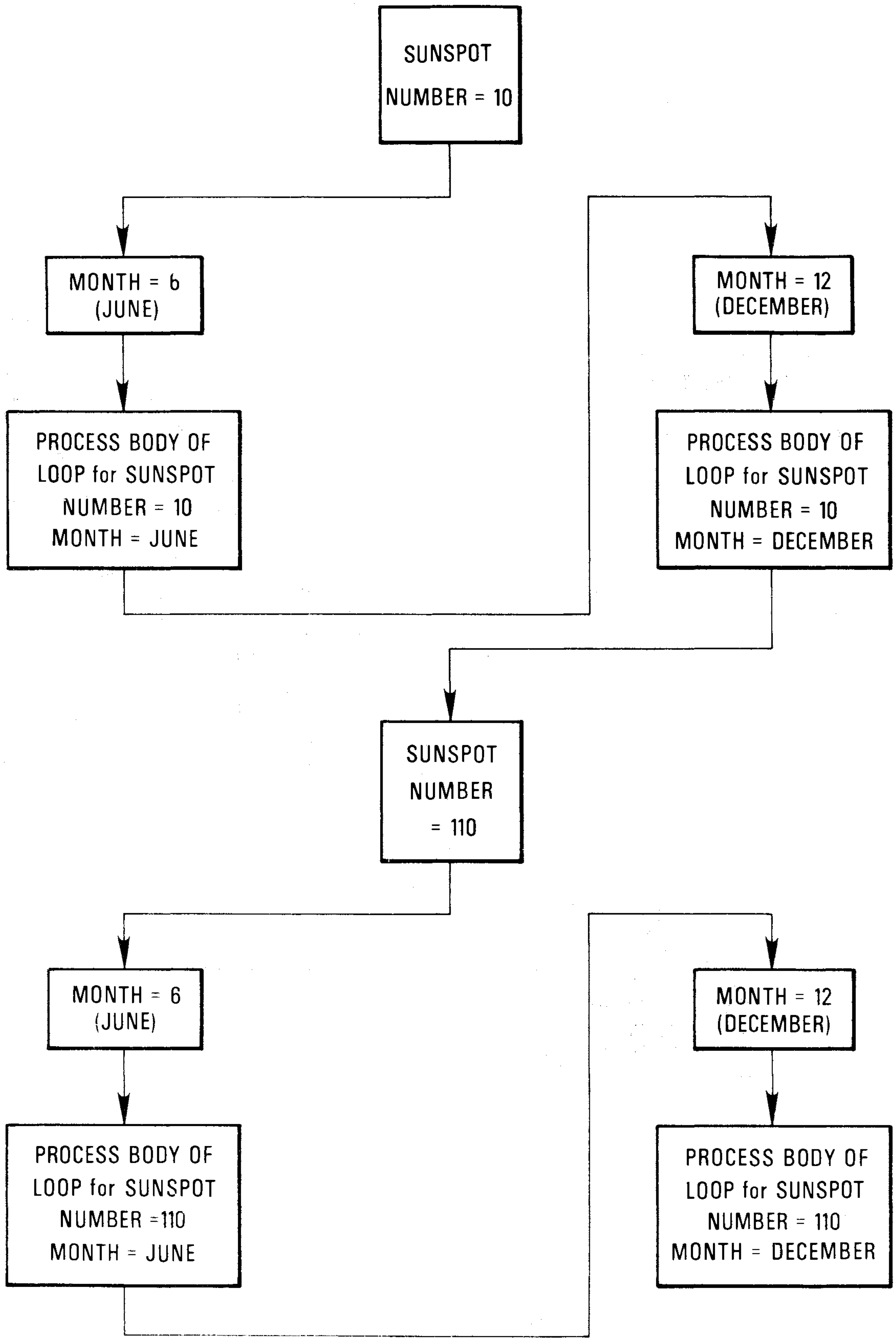


Figure 6. Effect of a typical SUNSPOT-MONTH number loop.

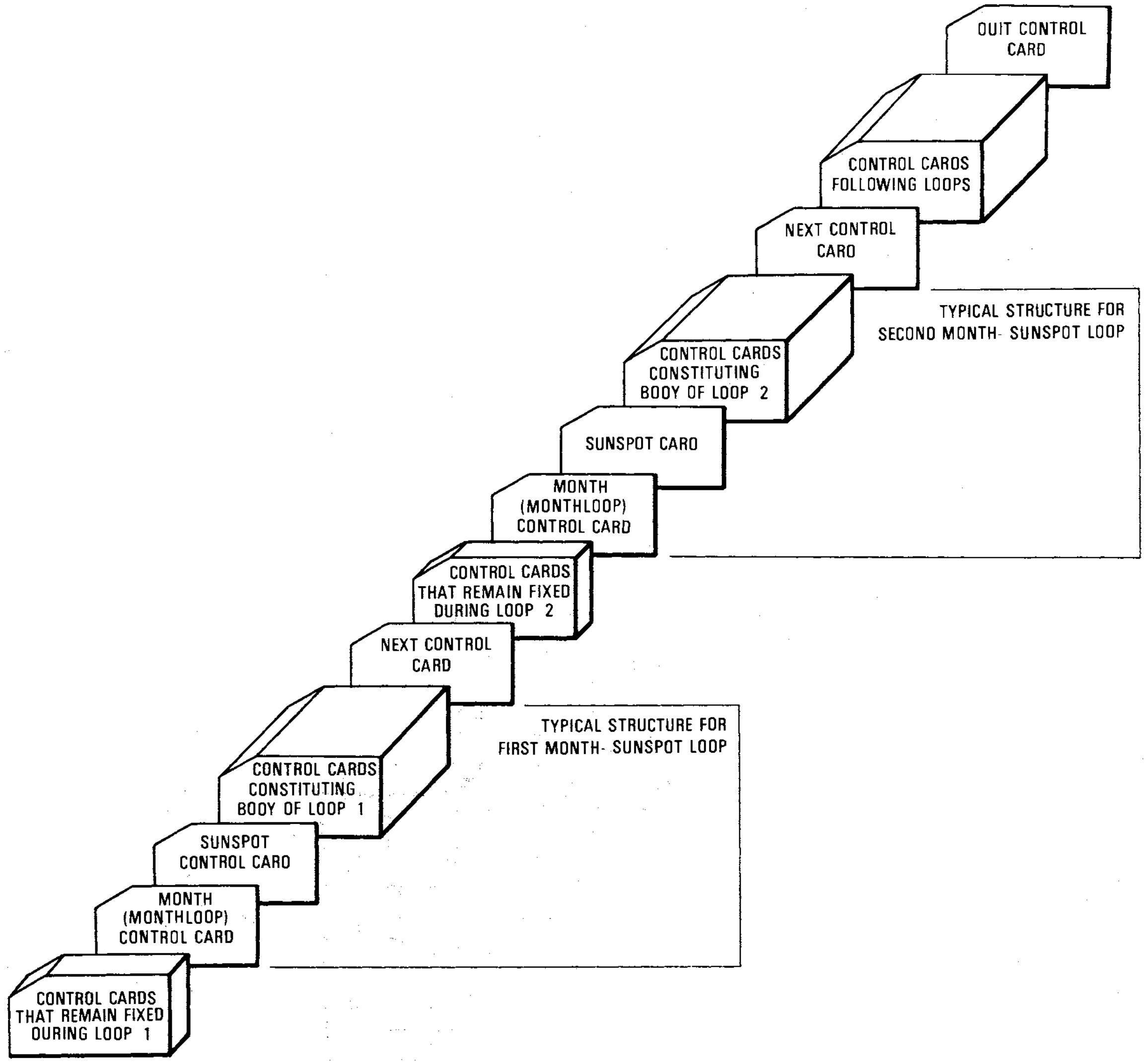


Figure 7. Typical deck structure for a sequence of MONTH-SUNSPOT number loops.

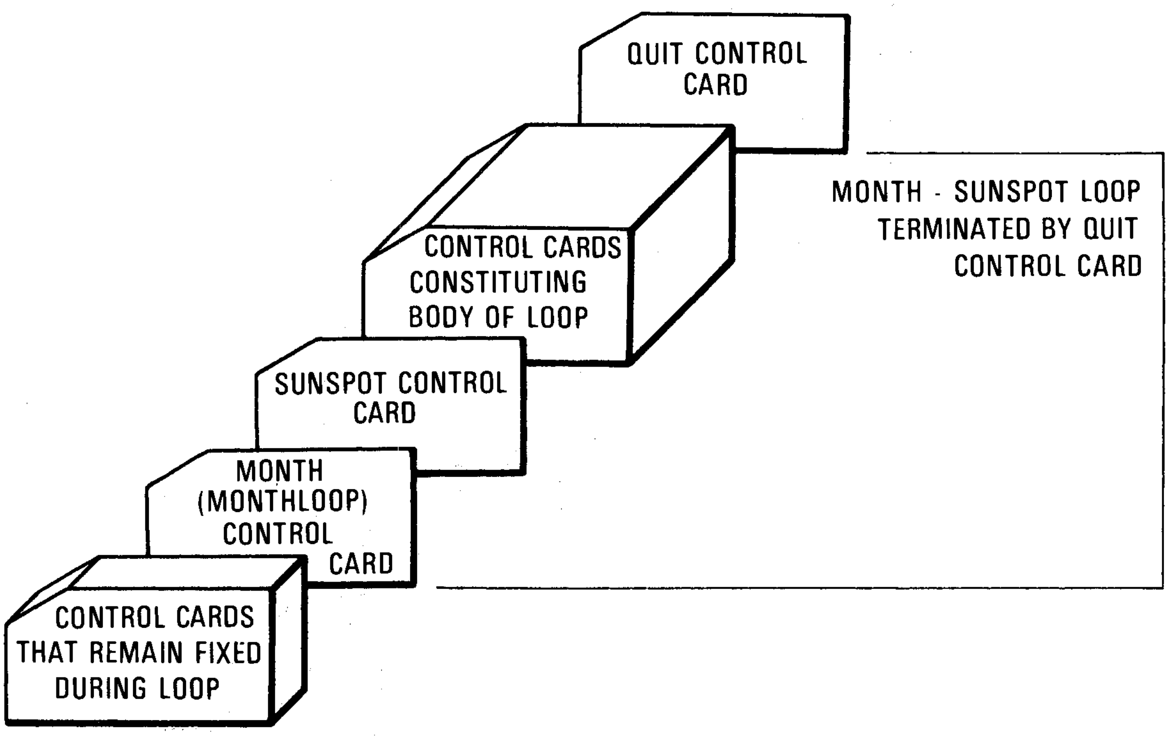


Figure 8. Deck structure using a QUIT card as a MONTH-SUNSPOT number loop terminator.

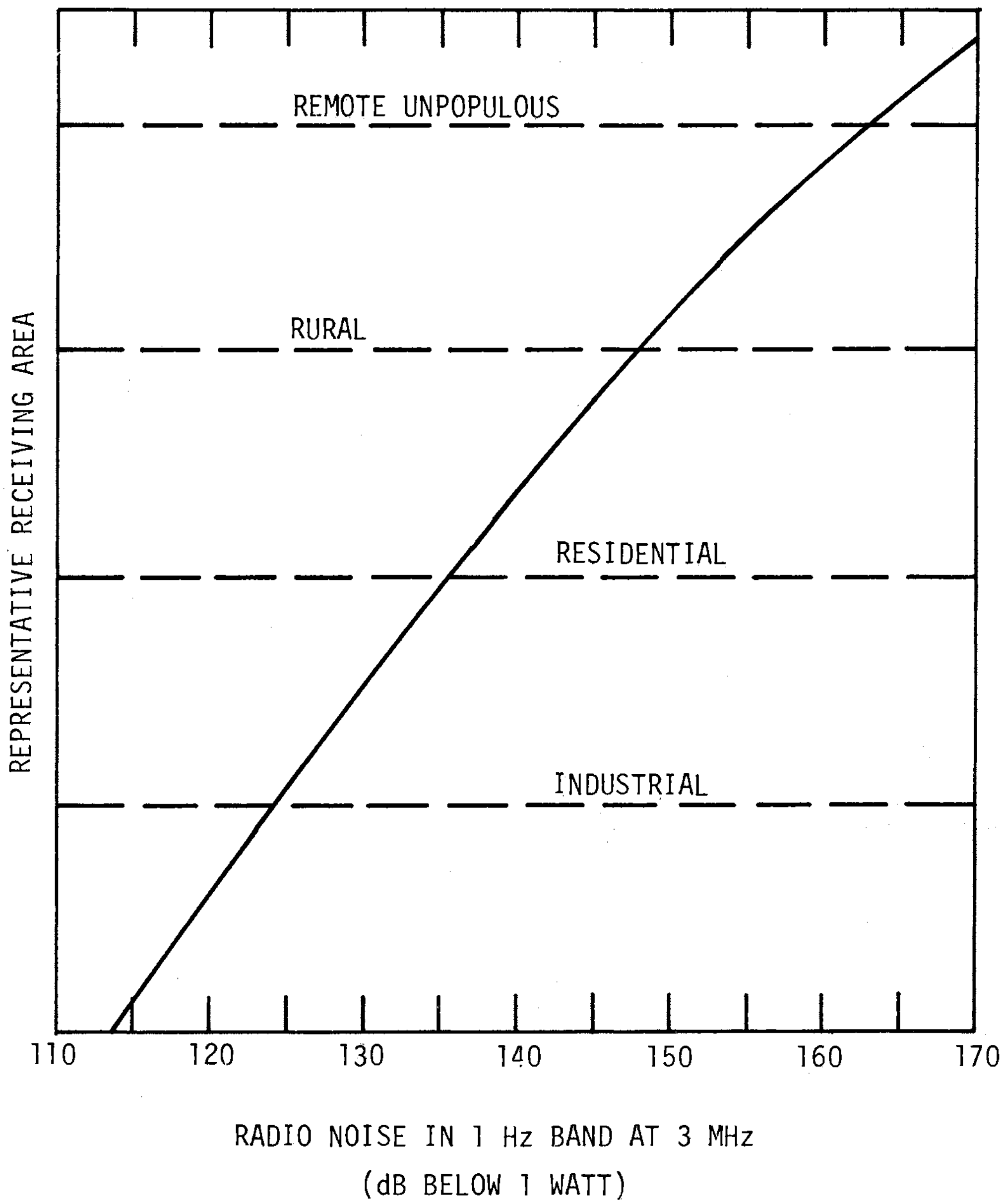


Figure 9. Man-made noise relative to population of receiving area.

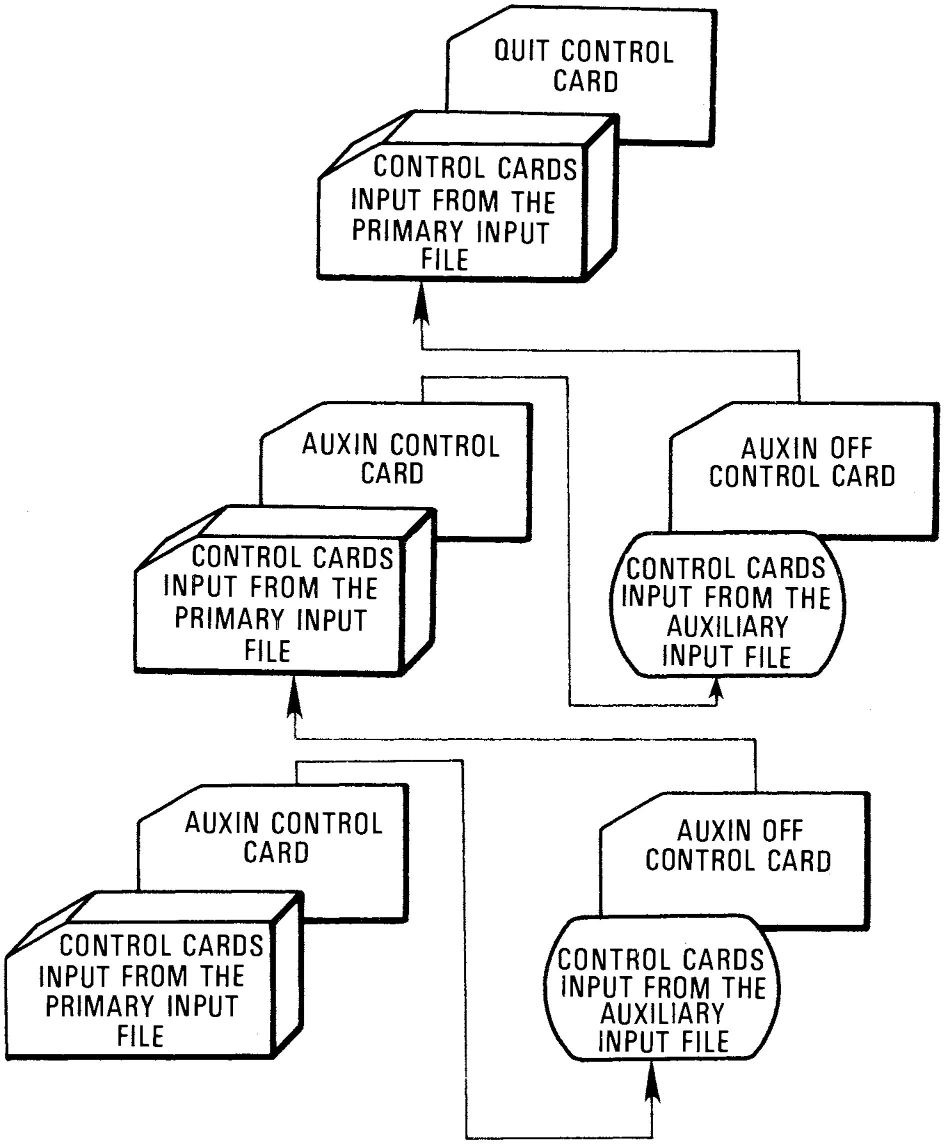


Figure 10. Example of the use of the AUXIN data card.

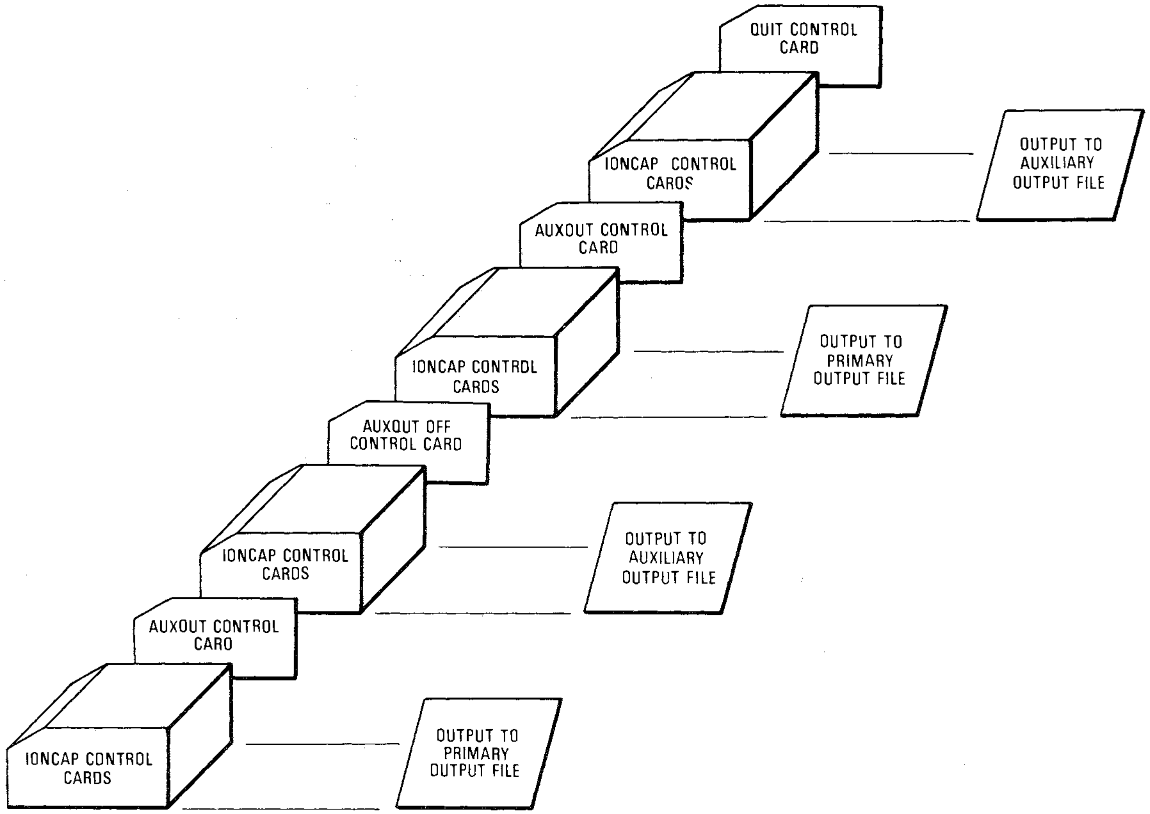


Figure 11. Example of the use of the AUXOUT data card.

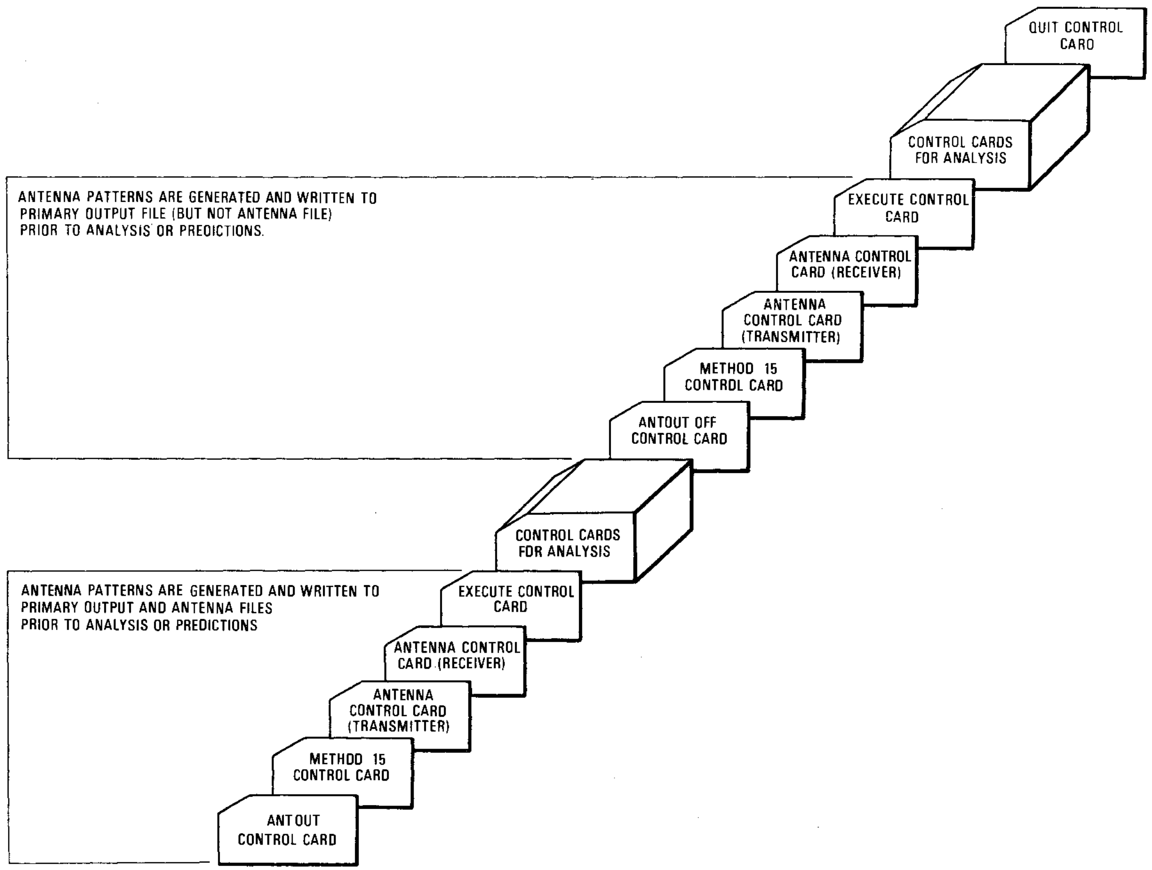


Figure 12. Example of the use of the ANTOUT data card.

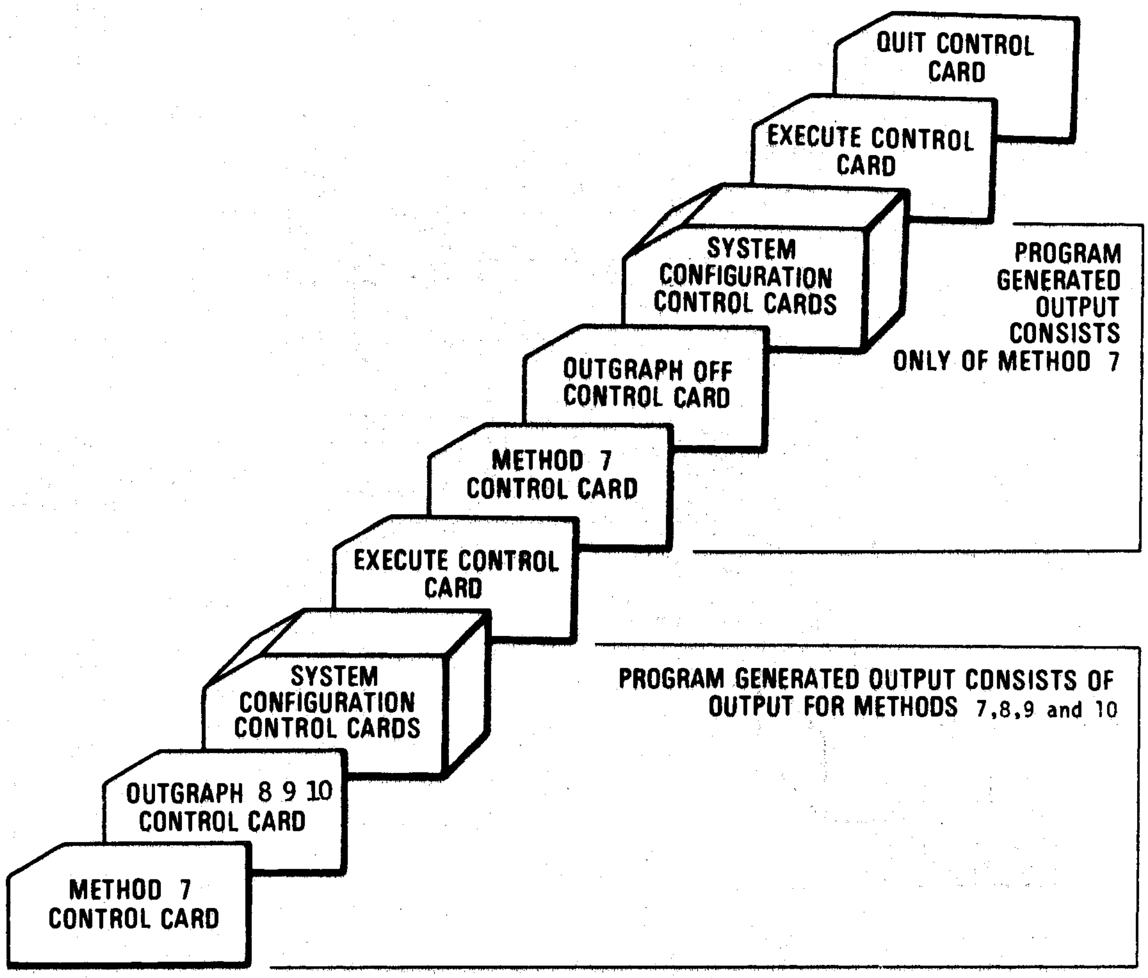


Figure 13. Example of the use of the OUTGRAPH data card.

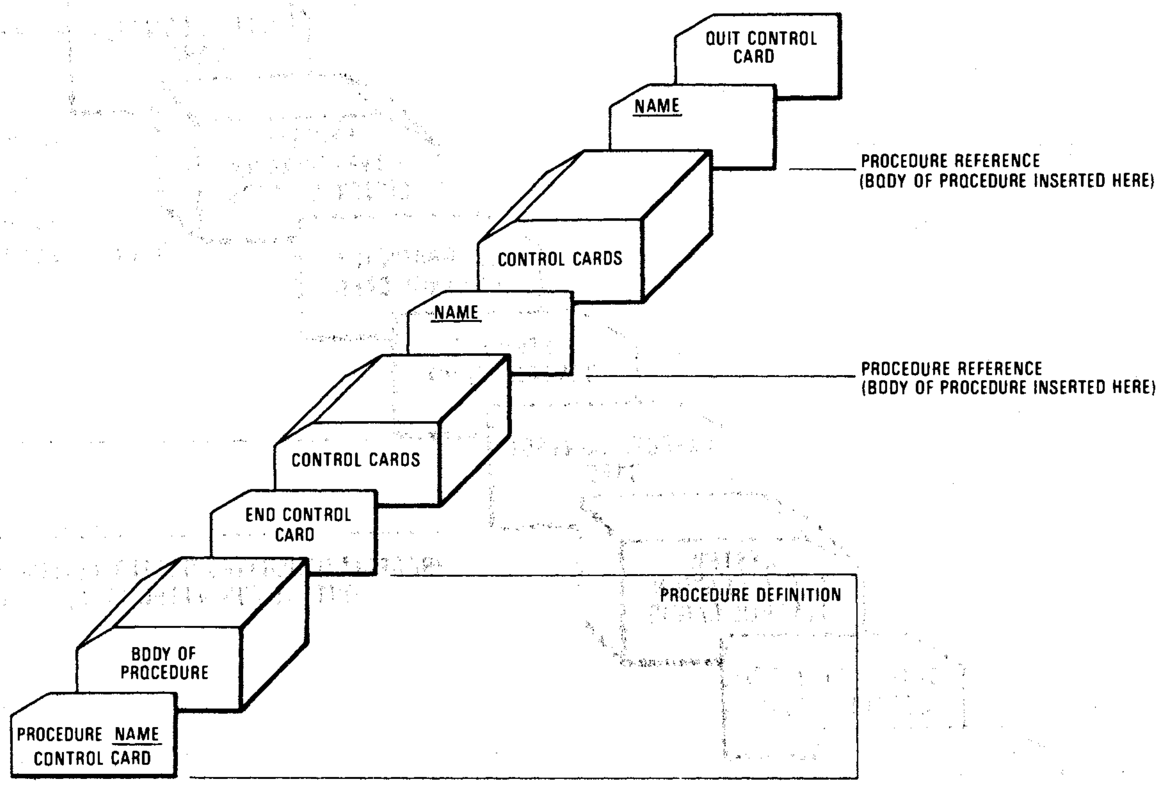


Figure 14. Procedure file structure example.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

COMMENT   **********************************************************************
COMMENT   SAMPLE INPUT TO RUN IONCAP 78.03 - ALL METHODS
COMMENT   **********************************************************************
COMMENT   DEFINE SYSTEM CONFIGURATION, MONTH, SUNSPOT, AND HOURS
LABEL     BOULDER,COLORADO TO ST. LOUIS,MO.
CIRCUIT   40.03N    105.3W    38.67N    90.25W        0
SYSTEM    30.     150.001    90 55.  10.  .85
MONTH      1970     1
SUNSPOT    100.
TIME          1    24     1    -1
COMMENT   **********************************************************************
COMMENT   METHOD 1 AND 2 ARE IONOSPHERIC PARAMETERS AND IONOGRAM
COMMENT   IONOSPHERIC PARAMETERS AS FROM MAPS
COMMENT   ES CRITICAL FREQUENCY NOT REDUCED TO ALLOW FOR MEDIAN LOSSES
FPROB     1.0  1.0  1.0  1.0
METHOD        1
EXECUTE
COMMENT   CHANGE CRITICAL FREQUENCY MULTIPLIER FOR ES BACK TO PROGRAM DEFAULT
FPROB     OFF
COMMENT   ES CRITICAL FREQUENCY NOW IS MULTIPLIED BY .7 TO ALLOW FOR MEDIAN LOSS
METHOD        2
TIME         12    12     1    -1
EXECUTE
COMMENT   **********************************************************************
COMMENT   METHODS 3 THROUGH 11 ARE MUF CALCULATIONS (METHOD 12 NOT IMPLEMENTED)
COMMENT   METHODS 3,4,5 AND 6 ARE MUF USING NOMOGRAM AND AREN#T PRESENTED HERE
TIME          1    24     1    -1
METHOD        7
COMMENT   OUTPUT METHODS 8 THROUGH 11 WITHOUT RECOMPUTATION USING #OUTGRAPH#
OUTGRAPH      8     9    10    11
EXECUTE
OUTGRAPH  OFF
COMMENT   **********************************************************************
COMMENT   METHODS 13 THROUGH 15 ARE ANTENNA PATTERN CALCULATIONS
COMMENT   METHODS 13 AND 14 ARE ANTENNAS ONE AT A TIME AND AREN#T PRESENTED HERE
METHOD       15
ANTENNA       1     2        .001 4.        -0.5
ANTENNA       2     2        .001 4.        -0.25
EXECUTE
COMMENT   **********************************************************************
COMMENT   METHODS 16 THROUGH 23 ARE SYSTEM PERFORMANCE PREDICTIONS
FREQUENCY   2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0
TIME         12    24    12    -1
METHOD       16
METHOD       17
METHOD       18
METHOD       19
METHOD       20
COMMENT   METHOD 21 FORCES THE PROGRAM TO EXERCISE THE #LONG# PATH MODEL
METHOD       21
COMMENT   METHOD 22 FORCES THE PROGRAM TO EXERCISE THE #SHORT# PATH MODEL
METHOD       22
EXECUTE
```

Figure 15. Input data cards for all output options.

```
COMMENT    METHOD 23 ALLOWS THE USER TO SELECT THE DESIRED OUTPUT BY SPECIFYING+
COMMENT    PREDEFINED LINE NUMBERS ON THE ≠TOPLINES≠ AND ≠BOTLINES≠ CARDS
COMMENT    LINES ARE NUMBERED IN ORDER AS IN METHOD 20 (SEE TABLES 8 AND 9)
METHOD       23
TOPLINES      1    2    3    4    5    6    7
BOTLINES      1    2    4   10   11   12
EXECUTE
COMMENT    **********************************************************************
COMMENT    METHOD 24 IS THE MUF-RELIABILITY TABLE
COMMENT    **********************************************************************
METHOD       24
TIME          1   24    1   -1
EXECUTE
COMMENT    **********************************************************************
COMMENT    METHOD 25 IS THE ALL MODES TABLE
METHOD       25
COMMENT    NOTE THAT THE MUF ALL MODES TABLE IS ALSO PRINTED
FREQUENCY   3.0
TIME         12   12    1   -1
EXECUTE
COMMENT    **********************************************************************
COMMENT    METHODS 26 THROUGH 29 ARE LUF PREDICTIONS
METHOD       26
COMMENT    OUTPUT METHODS 27, 28 AND 29 WITHOUT RECOMPUTATION USING ≠OUTGRAPH≠
OUTGRAPH     27   28   29
TIME          2   24    2  -1
EXECUTE
OUTGRAPH   OFF
COMMENT    **********************************************************************
COMMENT    INCLUDE A LONG PATH CIRCUIT EXAMPLE
LABEL      BOULDER,COLORADO TO AUCKLAND,N. Z.
CIRCUIT    40.03N     105.3W     36.92S    17475E
METHOD        7
TIME          6   18    6   -1
EXECUTE
FREQUENCY   2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0
METHOD       23
COMMENT    NOTE THAT THE PREVIOUSLY DEFINED ≠TOPLINES≠ AND ≠BOTLINES≠ STILL USED
EXECUTE
QUIT
```

Figure 15. Input data cards for all output options. (Continued)

METHOD 1 IONCAP 78.03 PAGE 1

JAN 1970 SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO. AZIMUTHS N. MI. KM
40.03 N 105.30 W - 38.67 N 90.25 W 91.84 281.42 702.6 1301.1

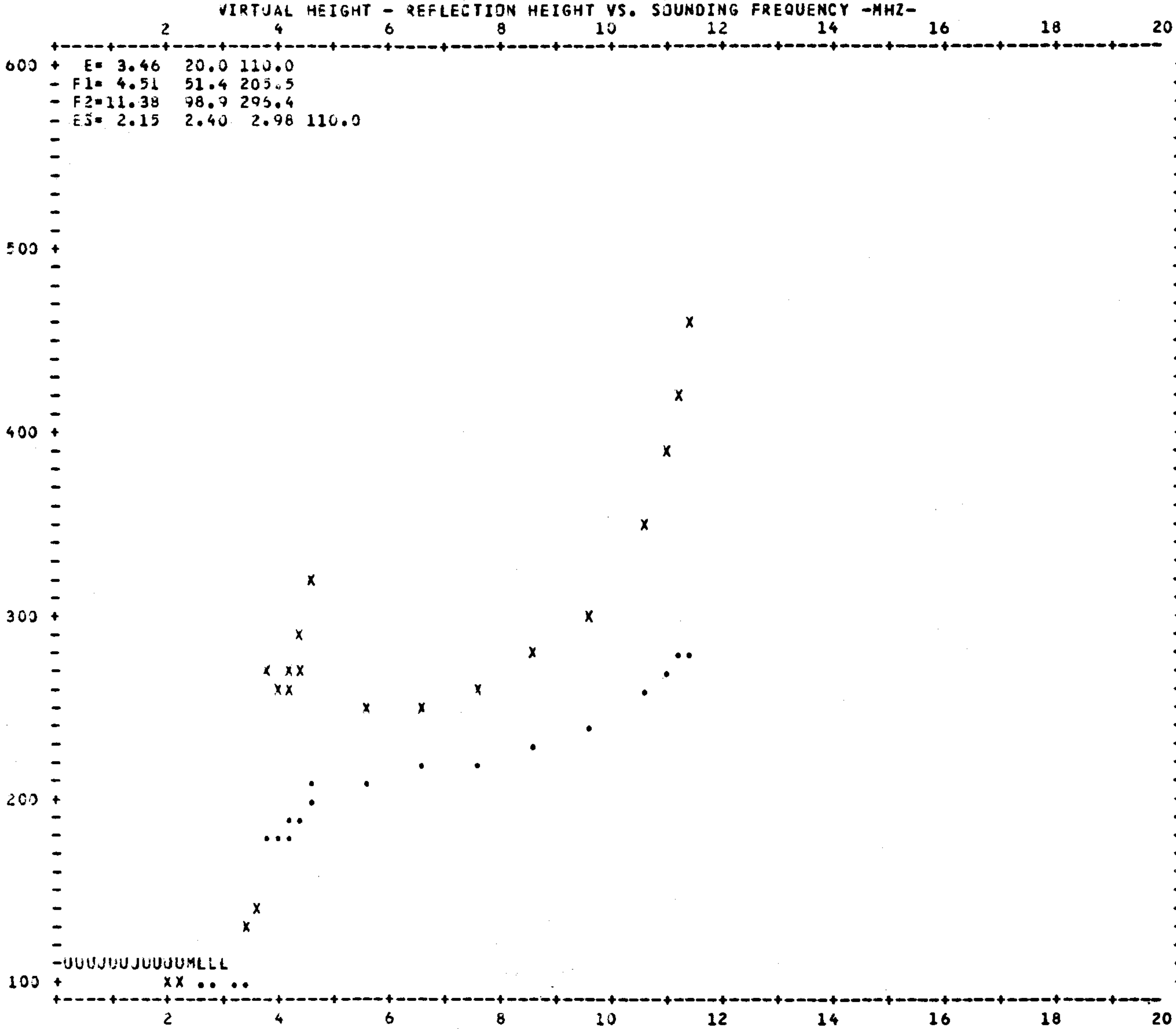
YE = 20.0 HE = 110.0 HS = 110.0

LAT	LONG	LMT	UT	E	F1	Y1	H1	FH/2	F2Z	Y2	H2	ES	MED	HI	M3000	HPF2	RAT	ZEN	ZMAX	MAGL
39.6N	97.7W	1.5	8.0	.58	0.0	0.0	0.0	.7	4.4	70.3	325.4	1.3	1.8	4.0	2.97	325.7	4.6	154.7	66.1	49.4N
39.6N	97.7W	2.5	9.0	.58	0.0	0.0	0.0	.7	4.5	72.3	330.7	1.2	1.8	3.7	2.94	331.0	4.6	144.2	66.1	49.4N
39.6N	97.7W	3.5	10.0	.61	0.0	0.0	0.0	.7	4.1	75.6	338.9	1.1	1.7	3.5	2.89	339.3	4.5	132.9	66.1	49.4N
39.6N	97.7W	4.5	11.0	.74	0.0	0.0	0.0	.7	3.5	79.4	343.0	1.1	1.7	3.4	2.87	343.9	4.3	121.3	66.1	49.4N
39.6N	97.7W	5.5	12.0	1.02	0.0	0.0	0.0	.7	3.4	82.2	335.8	1.2	1.7	3.5	2.90	337.8	4.1	109.9	66.1	49.4N
39.6N	97.7W	6.5	13.0	1.44	0.0	0.0	0.0	.7	4.2	83.9	318.3	1.5	1.9	3.7	3.00	320.8	3.8	99.0	66.1	49.4N
39.6N	97.7W	7.5	14.0	1.95	0.0	0.0	0.0	.7	6.0	85.4	298.3	1.8	2.1	3.9	3.13	300.5	3.5	88.7	66.1	49.4N
39.6N	97.7W	8.5	15.0	2.48	0.0	0.0	0.0	.7	8.0	88.4	283.8	2.2	2.5	4.2	3.23	285.8	3.2	79.5	66.1	49.4N
39.6N	97.7W	9.5	16.0	2.93	0.0	0.0	0.0	.7	9.3	93.7	279.2	2.6	2.9	4.4	3.26	281.3	3.0	71.7	66.1	49.4N
39.6N	97.7W	10.5	17.0	3.26	4.4	51.9	234.3	.7	10.2	100.9	283.7	2.9	3.3	4.5	3.23	285.9	2.8	66.0	66.1	49.4N
39.6N	97.7W	11.5	18.0	3.44	4.5	51.4	205.5	.7	10.9	105.7	287.9	3.1	3.4	4.4	3.16	295.0	2.7	63.0	66.1	49.4N
39.6N	97.7W	12.5	19.0	3.46	4.5	51.4	205.5	.7	11.4	98.9	296.4	3.1	3.4	4.3	3.11	302.8	3.0	63.0	66.1	49.4N
39.6N	97.7W	13.5	20.0	3.28	0.0	0.0	0.0	.7	11.5	99.5	304.2	2.9	3.2	4.0	3.09	305.9	3.1	66.1	66.1	49.4N
39.6N	97.7W	14.5	21.0	2.93	0.0	0.0	0.0	.7	11.2	95.8	303.5	2.6	2.9	3.7	3.10	304.9	3.2	71.8	66.1	49.4N
39.6N	97.7W	15.5	22.0	2.43	0.0	0.0	0.0	.7	10.8	91.0	301.4	2.2	2.5	3.5	3.11	302.4	3.3	79.6	66.1	49.4N
39.6N	97.7W	16.5	23.0	1.88	0.0	0.0	0.0	.7	9.9	86.1	299.7	1.8	2.2	3.4	3.13	300.4	3.5	88.8	66.1	49.4N
39.6N	97.7W	17.5	.0	1.33	0.0	0.0	0.0	.7	8.7	81.6	299.2	1.5	1.9	3.5	3.13	299.7	3.7	99.1	66.1	49.4N
39.6N	97.7W	18.5	1.0	.99	0.0	0.0	0.0	.7	7.2	77.7	300.6	1.3	1.7	3.7	3.12	301.0	3.9	110.1	66.1	49.4N
39.6N	97.7W	19.5	2.0	.74	0.0	0.0	0.0	.7	6.0	74.7	304.5	1.2	1.7	3.9	3.10	304.8	4.1	121.5	66.1	49.4N
39.6N	97.7W	20.5	3.0	.61	0.0	0.0	0.0	.7	5.1	72.7	311.1	1.2	1.7	4.2	3.06	311.4	4.3	133.0	66.1	49.4N
39.6N	97.7W	21.5	4.0	.55	0.0	0.0	0.0	.7	4.3	71.6	318.7	1.3	1.7	4.4	3.01	319.0	4.5	144.4	66.1	49.4N
39.6N	97.7W	22.5	5.0	.54	0.0	0.0	0.0	.7	3.8	70.9	324.1	1.4	1.8	4.5	2.98	324.5	4.6	154.8	66.1	49.4N
39.6N	97.7W	23.5	6.0	.56	0.0	0.0	0.0	.7	3.8	70.2	325.6	1.4	1.8	4.4	2.97	326.0	4.6	162.3	66.1	49.4N
39.6N	97.7W	.5	7.0	.58	0.0	0.0	0.0	.7	4.1	69.7	324.7	1.4	1.8	4.2	2.97	325.1	4.7	162.2	66.1	49.4N

Figure 16. Ionospheric parameters output. (METHOD=1)

METHOD 2 IONCAP 78.03 PAGE 2

JAN 1970 SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO. AZIMUTHS N. MI. KM
40.03 N 105.30 W - 38.67 N 90.25 W 91.84 281.42 702.6 1301.1
GMT = 19.0 LMT = 12.5 LAT = 39.59 N 97.70 W DIST = 651. 651. KM GAUSSIAN HP F1 IS PARABOLIC



	FVERT	HTRUE	HPRIM
1	.01	70.00	70.00
2	.61	84.51	87.40
3	1.22	88.52	94.00
4	1.82	93.00	98.68
5	2.12	94.26	100.20
6	2.42	95.71	102.65
7	2.71	97.68	107.15
8	3.01	100.27	113.74
9	3.31	104.22	125.25
10	3.42	107.19	140.45
11	3.63	175.03	272.40
12	3.72	176.60	265.11
13	3.81	178.21	260.71
14	3.91	179.87	258.30
15	4.00	181.93	260.03
16	4.09	184.04	261.31
17	4.19	186.55	267.24
18	4.28	189.39	272.40
19	4.37	193.16	286.66
20	4.47	198.69	315.63
21	4.56	205.70	317.23
22	5.54	209.98	254.92
23	6.53	215.37	253.41
24	7.51	222.07	261.50
25	8.50	230.59	277.36
26	9.48	241.72	302.05
27	10.47	257.65	345.63
28	10.92	268.73	385.09
29	11.15	276.76	422.56
30	11.26	282.55	457.29

Figure 17. Ionogram output. (METHOD=2)

METHOD 7 IONCAP 78.03 PAGE 3

JAN 1970 SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO. AZIMUTHS N. MI. KM
40.03 N 105.30 W - 38.67 N 90.25 W 91.84 281.42 702.6 1301.1
MINIMUM ANGLE .0 DEGREES

		ELAYER/F2LAYER							F1LAYER(E)/ESLAYER						
GMT	LMT	FOT	MUF	HPF	ANGLE	VIRTL	TRUE	FVERT	FOT	MUF	HPF	ANGLE	VIRTL	TRUE	FVERT
8.0	1.0	2.2	2.5	2.8	7.9	125.	104.	.6	2.2	2.5	2.8	7.9	125.	104.	.6
		6.6	8.0	10.1	27.1	387.	303.	4.2	4.3	5.9	12.9	6.6	110.	110.	1.3
9.0	2.0	2.2	2.5	2.8	7.9	125.	104.	.6	2.2	2.5	2.8	7.9	125.	104.	.6
		6.5	8.0	9.4	27.5	393.	308.	4.3	4.0	5.7	12.0	6.6	110.	110.	1.2
10.0	3.0	2.3	2.6	3.0	7.9	125.	104.	.6	2.3	2.6	3.0	7.9	125.	104.	.6
		5.9	7.2	8.5	28.1	404.	315.	3.9	3.7	5.5	11.4	6.6	110.	110.	1.2
11.0	4.0	2.8	3.2	3.6	7.9	125.	104.	.7	2.8	3.2	3.6	7.9	125.	104.	.7
		5.0	6.1	7.2	28.6	412.	317.	3.4	3.4	5.4	11.1	6.6	110.	110.	1.2
12.0	5.0	3.8	4.3	4.9	7.9	125.	104.	1.0	3.8	4.3	4.9	7.9	125.	104.	1.0
		4.7	5.8	6.8	28.4	410.	309.	3.2	3.4	5.5	11.3	6.6	110.	110.	1.2
13.0	6.0	5.4	6.1	6.9	7.9	125.	104.	1.4	5.4	6.1	6.9	7.9	125.	104.	1.4
		6.4	7.5	8.4	27.4	392.	290.	4.0	3.7	6.0	11.9	6.6	110.	110.	1.3
14.0	7.0	7.3	8.4	9.4	7.9	125.	104.	1.9	7.3	8.4	9.4	7.9	125.	104.	1.9
		9.5	11.2	12.6	25.8	367.	268.	5.7	4.3	7.0	12.8	6.6	110.	110.	1.5
15.0	8.0	9.2	10.6	12.0	7.9	125.	104.	2.4	9.2	10.6	12.0	7.9	125.	104.	2.4
		13.0	15.3	17.1	24.7	350.	251.	7.4	5.0	8.2	13.6	6.6	110.	110.	1.8
16.0	9.0	10.9	12.5	14.1	7.9	125.	104.	2.8	10.9	12.5	14.1	7.9	125.	104.	2.8
		15.3	18.0	20.1	24.3	344.	244.	8.6	5.8	9.5	14.3	6.6	110.	110.	2.0
17.0	10.0	12.2	13.9	15.7	7.9	125.	104.	3.1	9.9	11.4	12.8	17.7	249.	192.	4.3
		16.6	19.3	22.0	24.7	351.	245.	9.4	6.6	10.6	14.6	6.6	110.	110.	2.3
18.0	11.0	12.8	14.7	16.6	7.9	125.	104.	3.3	9.4	10.8	12.2	19.2	271.	188.	4.3
		17.5	20.4	23.2	25.1	356.	246.	10.0	8.0	11.2	14.4	6.6	110.	110.	2.4
19.0	12.0	12.9	14.8	16.7	7.9	125.	104.	3.3	8.9	10.2	11.5	20.6	290.	189.	4.3
		18.1	21.1	24.0	25.7	365.	259.	10.5	8.5	11.1	13.8	6.6	110.	110.	2.4
20.0	13.0	12.3	14.1	15.9	7.9	125.	104.	3.1	12.3	14.1	15.9	7.9	125.	104.	3.1
		18.0	21.0	23.9	26.2	373.	267.	10.6	8.0	10.5	13.0	6.6	110.	110.	2.3
21.0	14.0	10.9	12.5	14.1	7.9	125.	104.	2.8	10.9	12.5	14.1	7.9	125.	104.	2.8
		17.7	20.6	23.5	26.1	372.	268.	10.4	6.7	9.4	12.1	6.6	110.	110.	2.0
22.0	15.0	9.1	10.4	11.7	7.9	125.	104.	2.3	9.1	10.4	11.7	7.9	125.	104.	2.3
		17.1	19.9	22.7	25.8	368.	269.	10.0	5.0	8.2	11.4	6.6	110.	110.	1.8
23.0	16.0	7.0	8.1	9.1	7.9	125.	104.	1.8	7.0	8.1	9.1	7.9	125.	104.	1.8
		15.9	18.5	21.1	25.6	364.	269.	9.3	4.3	7.1	11.1	6.6	110.	110.	1.5
.0	17.0	5.1	5.9	6.6	7.9	125.	104.	1.3	5.1	5.9	6.6	7.9	125.	104.	1.3
		14.0	16.3	18.6	25.4	361.	271.	8.1	3.8	6.2	11.3	6.6	110.	110.	1.3
1.0	18.0	3.7	4.2	4.8	7.9	125.	104.	.9	3.7	4.2	4.8	7.9	125.	104.	.9
		10.7	13.6	17.4	25.5	362.	274.	6.8	3.5	5.7	11.9	6.6	110.	110.	1.2
2.0	19.0	2.8	3.2	3.6	7.9	125.	104.	.7	2.8	3.2	3.6	7.9	125.	104.	.7
		8.9	11.3	14.4	25.7	366.	280.	5.7	4.0	5.5	12.7	6.6	110.	110.	1.2
3.0	20.0	2.3	2.6	2.9	7.9	125.	104.	.6	2.3	2.6	2.9	7.9	125.	104.	.6
		7.4	9.4	12.0	26.1	372.	288.	4.8	4.1	5.5	13.6	6.6	110.	110.	1.2
4.0	21.0	2.1	2.4	2.7	7.9	125.	104.	.5	2.1	2.4	2.7	7.9	125.	104.	.5
		6.2	7.9	10.1	26.6	380.	296.	4.1	4.3	5.6	14.3	6.6	110.	110.	1.2
5.0	22.0	2.0	2.3	2.6	7.9	125.	104.	.5	2.0	2.3	2.6	7.9	125.	104.	.5
		5.7	6.9	8.7	27.0	386.	302.	3.6	4.6	5.7	14.5	6.6	110.	110.	1.2
6.0	23.0	2.1	2.4	2.7	7.9	125.	104.	.5	2.1	2.4	2.7	7.9	125.	104.	.5
		5.6	6.8	8.6	27.1	388.	304.	3.6	4.7	5.9	14.3	6.6	110.	110.	1.3
7.0	24.0	2.1	2.5	2.8	7.9	125.	104.	.6	2.1	2.5	2.8	7.9	125.	104.	.6
		6.1	7.4	9.4	27.0	387.	303.	3.9	4.6	5.9	13.8	6.6	110.	110.	1.3

Figure 18. MUF complete output table. (METHOD=7)

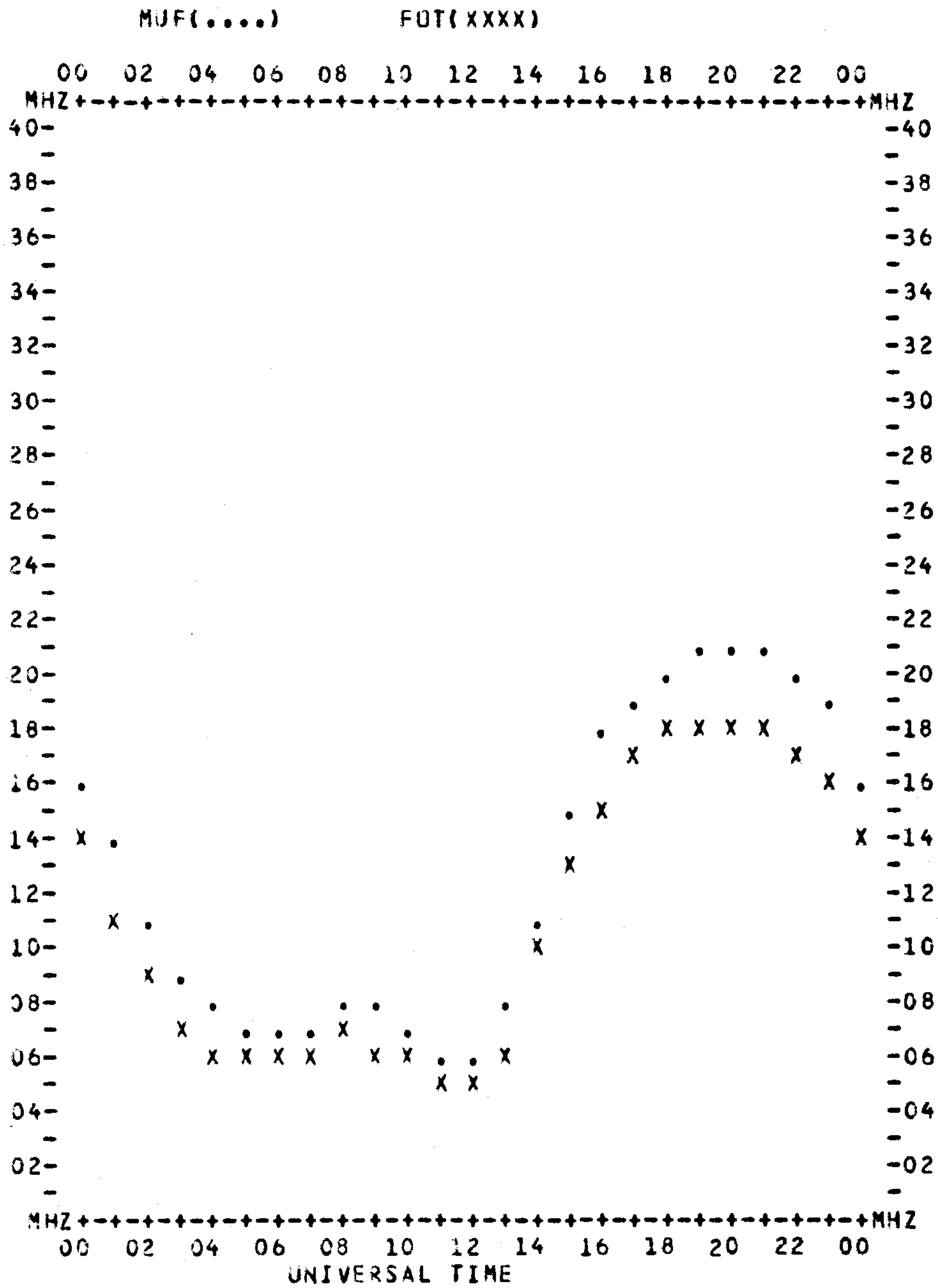
METHOD 8 IONCAP 78.03 PAGE 4

JAN 1970 SSN = 100.

BOULDER,COLORADO TO ST. LOUIS,MO. AZIMUTHS N. MI. KM

40.03 N 105.30 W - 38.67 N 90.25 W 91.84 281.42 702.6 1301.1

MINIMUM ANGLE .0 DEGREES



GMT	MUF	FOT
1.0	13.6	10.7
2.0	11.3	8.9
3.0	9.4	7.4
4.0	7.9	6.2
5.0	6.9	5.7
6.0	6.8	5.6
7.0	7.4	6.1
8.0	8.0	6.6
9.0	8.0	6.5
10.0	7.2	5.9
11.0	6.1	5.0
12.0	5.8	4.7
13.0	7.5	6.4
14.0	11.2	9.5
15.0	15.3	13.0
16.0	18.0	15.3
17.0	19.3	16.6
18.0	20.4	17.5
19.0	21.1	18.1
20.0	21.0	18.0
21.0	20.6	17.7
22.0	19.9	17.1
23.0	18.5	15.9
.0	16.3	14.0

Figure 19. MUF-FOT graph. (METHOD=8)

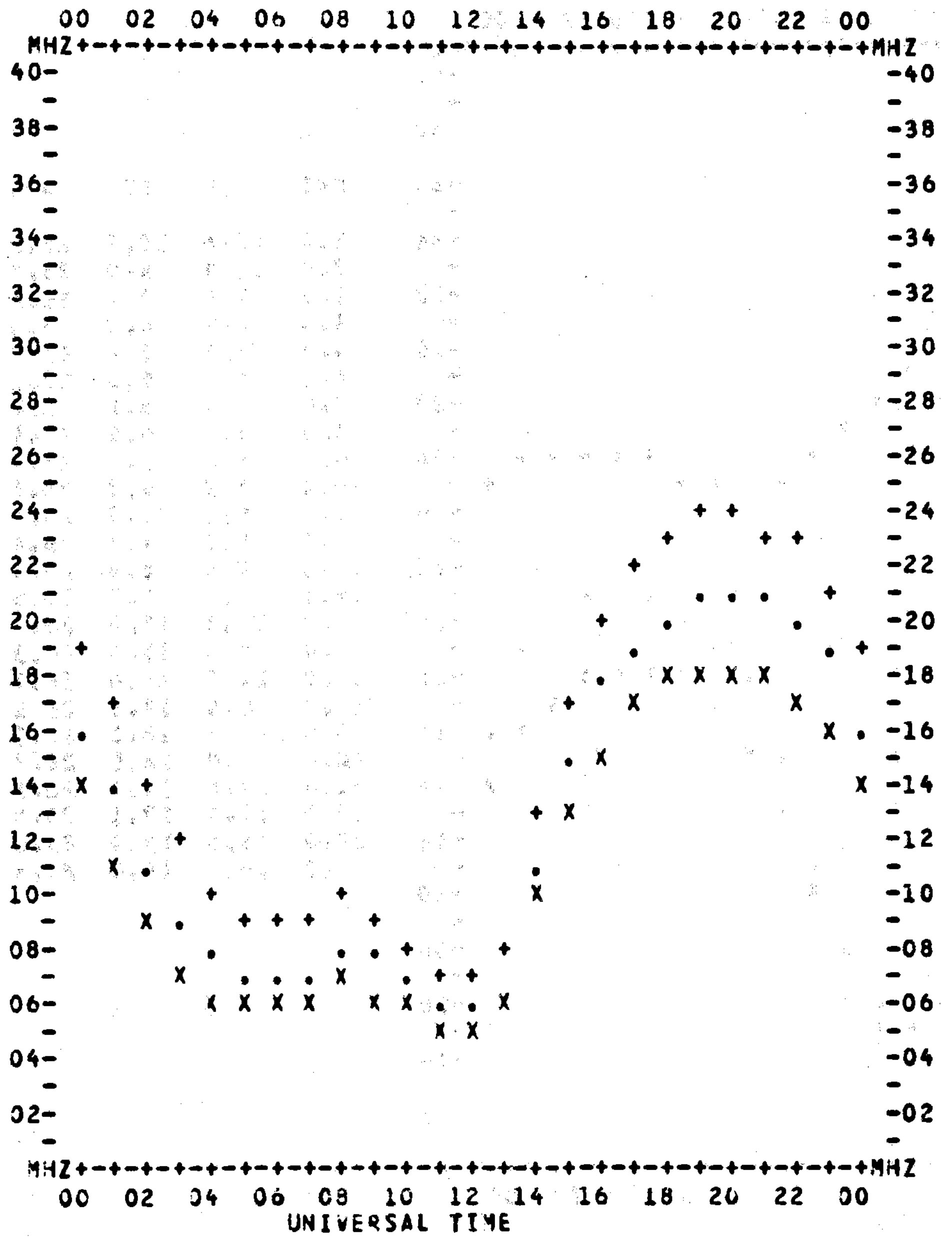
JAN 1970 SSN = 100.

BOULDER,COLORADO TO ST. LOUIS,MO. AZIMUTHS N. MI. KM

40.03 N 105.30 W - 38.67 N 90.25 W 91.84 281.42 702.6 1301.1

MINIMUM ANGLE .0 DEGREES

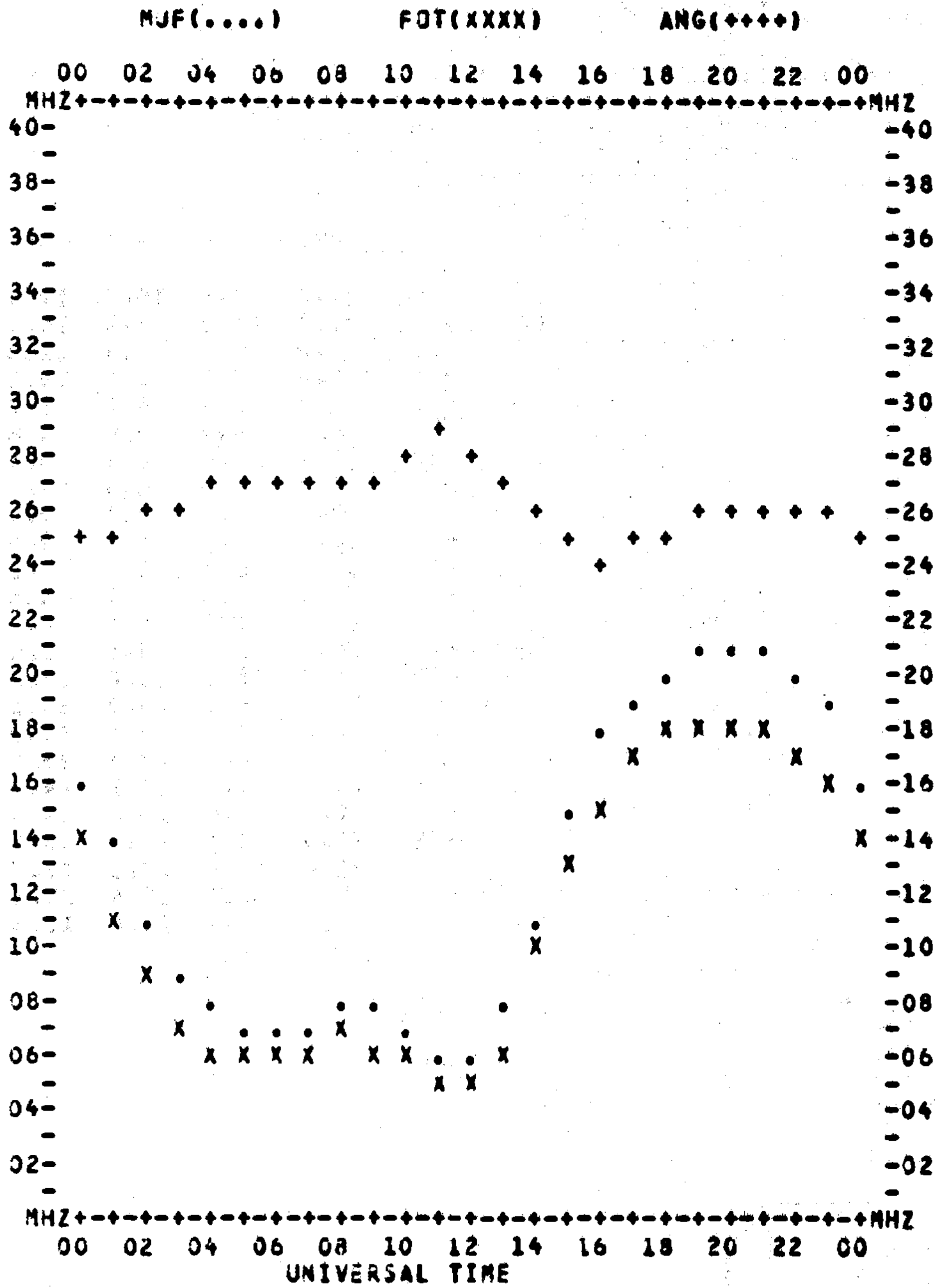
MUF(....) FOT(XXXX) HPF(++++)



GMT	MUF	FOT	HPF
1.0	13.6	10.7	17.4
2.0	11.3	8.9	14.4
3.0	9.4	7.4	12.0
4.0	7.9	6.2	10.1
5.0	6.9	5.7	8.7
6.0	6.8	5.6	8.6
7.0	7.4	6.1	9.4
8.0	8.0	6.6	10.1
9.0	8.0	6.5	9.4
10.0	7.2	5.9	8.5
11.0	6.1	5.0	7.2
12.0	5.8	4.7	6.8
13.0	7.5	6.4	8.4
14.0	11.2	9.5	12.6
15.0	15.3	13.0	17.1
16.0	18.0	15.3	20.1
17.0	19.3	16.6	22.0
18.0	20.4	17.5	23.2
19.0	21.1	18.1	24.0
20.0	21.0	18.0	23.9
21.0	20.6	17.7	23.5
22.0	19.9	17.1	22.7
23.0	18.5	15.9	21.1
.0	16.3	14.0	18.6

Figure 20. MUF-FOT-HPF graph. (METHOD=9)

JAN 1970 SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO. AZIMUTHS N. MI. KM
40.03 N 105.30 W - 38.67 N 90.25 W 91.84 281.42 702.6 1301.1
MINIMUM ANGLE .0 DEGREES



GMT	MUF	FOT	ANG
1.0	13.6	10.7	25.5
2.0	11.3	8.9	25.7
3.0	9.4	7.4	26.1
4.0	7.9	6.2	26.6
5.0	6.9	5.7	27.0
6.0	6.8	5.6	27.1
7.0	7.4	6.1	27.0
8.0	8.0	6.6	27.1
9.0	8.0	6.5	27.5
10.0	7.2	5.9	28.1
11.0	6.1	5.0	28.6
12.0	5.8	4.7	28.4
13.0	7.5	6.4	27.4
14.0	11.2	9.5	25.8
15.0	15.3	13.0	24.7
16.0	18.0	15.3	24.3
17.0	19.3	16.6	24.7
18.0	20.4	17.5	25.1
19.0	21.1	18.1	25.7
20.0	21.0	18.0	26.2
21.0	20.6	17.7	26.1
22.0	19.9	17.1	25.8
23.0	18.5	15.9	25.6
.0	16.3	14.0	25.4

Figure 21. MUF-FOT-ANG graph. (METHOD=10)

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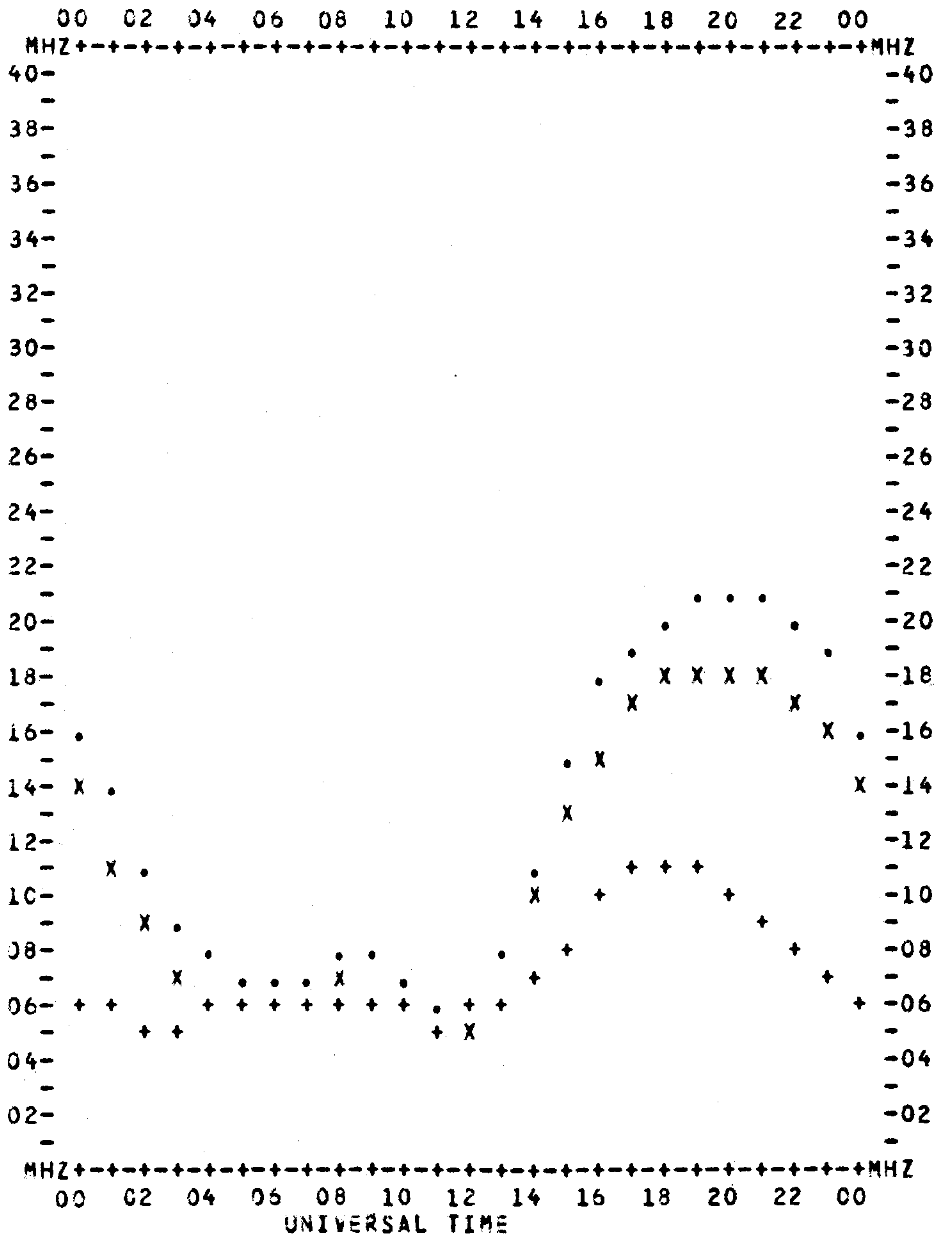
JAN 1970 SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO. AZIMUTHS N. MI. KM
40.03 N 105.30 W - 38.67 N 90.25 W 91.84 281.42 702.6 1301.1
MINIMUM ANGLE .0 DEGREES

MUF(....) FOT(XXXX) ESMUF(++++)



GMT	MUF	FOT	ESMUF
1.0	13.6	10.7	5.7
2.0	11.3	8.9	5.5
3.0	9.4	7.4	5.5
4.0	7.9	6.2	5.6
5.0	6.9	5.7	5.7
6.0	6.8	5.6	5.9
7.0	7.4	6.1	5.9
8.0	8.0	6.6	5.9
9.0	8.0	6.5	5.7
10.0	7.2	5.9	5.5
11.0	6.1	5.0	5.4
12.0	5.8	4.7	5.5
13.0	7.5	6.4	6.0
14.0	11.2	9.5	7.0
15.0	15.3	13.0	8.2
16.0	18.0	15.3	9.5
17.0	19.3	16.6	10.6
18.0	20.4	17.5	11.2
19.0	21.1	18.1	11.1
20.0	21.0	18.0	10.5
21.0	20.6	17.7	9.4
22.0	19.9	17.1	8.2
23.0	18.5	15.9	7.1
.0	16.3	14.0	6.2

Figure 22. MUF-FOT-Es MUF graph. (METHOD=11)

ITS- 1 ANTENNA PACKAGE

ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	VER MONOPOLE	0.000	-.500	0.000	0.000	0.000	0.000	0.000	0.000	.001	4.000

ELEVATION ANGLE IN DEGREES

	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30	
90	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	90
88	-36.5	-35.5	-35.0	-34.7	-34.5	-34.4	-34.3	-34.2	-34.2	-34.1	-34.1	-34.1	-34.1	-34.0	-34.0	-34.0	-34.0	-34.0	-34.0	-34.0	-34.0	88
86	-30.5	-29.5	-29.0	-28.7	-28.5	-28.4	-28.3	-28.2	-28.2	-28.1	-28.1	-28.1	-28.0	-28.0	-28.0	-28.0	-28.0	-28.0	-28.0	-28.0	-27.9	86
84	-27.0	-26.0	-25.5	-25.2	-25.0	-24.8	-24.8	-24.7	-24.6	-24.6	-24.6	-24.5	-24.5	-24.5	-24.5	-24.5	-24.4	-24.4	-24.4	-24.4	-24.4	84
82	-24.6	-23.6	-23.0	-22.7	-22.5	-22.4	-22.3	-22.2	-22.1	-22.1	-22.1	-22.0	-22.0	-22.0	-22.0	-21.9	-21.9	-21.9	-21.9	-21.9	-21.9	82
80	-22.7	-21.7	-21.1	-20.8	-20.6	-20.4	-20.3	-20.2	-20.2	-20.1	-20.1	-20.1	-20.1	-20.0	-20.0	-20.0	-20.0	-20.0	-19.9	-19.9	-19.9	80
78	-21.2	-20.2	-19.6	-19.2	-19.0	-18.8	-18.7	-18.7	-18.6	-18.5	-18.5	-18.5	-18.5	-18.4	-18.4	-18.4	-18.4	-18.3	-18.3	-18.3	-18.3	78
76	-20.0	-18.9	-18.3	-17.9	-17.7	-17.5	-17.4	-17.3	-17.2	-17.2	-17.1	-17.1	-17.1	-17.0	-17.0	-17.0	-17.0	-17.0	-17.0	-16.9	-16.9	76
74	-18.9	-17.8	-17.1	-16.8	-16.5	-16.3	-16.2	-16.1	-16.1	-16.0	-16.0	-15.9	-15.9	-15.8	-15.8	-15.8	-15.8	-15.8	-15.7	-15.7	-15.7	74
72	-18.0	-16.8	-16.1	-15.7	-15.5	-15.3	-15.2	-15.1	-15.0	-14.9	-14.9	-14.9	-14.8	-14.8	-14.7	-14.7	-14.7	-14.7	-14.7	-14.6	-14.6	72
E 70	-17.2	-15.9	-15.2	-14.8	-14.5	-14.4	-14.2	-14.1	-14.0	-14.0	-13.9	-13.9	-13.8	-13.8	-13.8	-13.7	-13.7	-13.7	-13.7	-13.6	-13.6	70
L 68	-16.4	-15.1	-14.4	-14.0	-13.7	-13.5	-13.3	-13.2	-13.1	-13.1	-13.0	-13.0	-12.9	-12.9	-12.8	-12.8	-12.8	-12.8	-12.7	-12.7	-12.7	68
E 66	-15.7	-14.4	-13.6	-13.2	-12.9	-12.7	-12.5	-12.4	-12.3	-12.2	-12.2	-12.1	-12.1	-12.0	-12.0	-11.9	-11.9	-11.9	-11.9	-11.9	-11.8	66
V 64	-15.0	-13.6	-12.9	-12.4	-12.1	-11.9	-11.7	-11.6	-11.5	-11.4	-11.4	-11.3	-11.3	-11.2	-11.2	-11.1	-11.1	-11.1	-11.1	-11.0	-11.0	64
A 62	-14.3	-12.9	-12.2	-11.7	-11.4	-11.2	-11.0	-10.9	-10.8	-10.7	-10.6	-10.6	-10.5	-10.5	-10.4	-10.4	-10.3	-10.3	-10.3	-10.3	-10.2	62
T 60	-13.6	-12.2	-11.5	-11.0	-10.7	-10.4	-10.3	-10.1	-10.0	-10.0	-9.9	-9.8	-9.8	-9.7	-9.7	-9.6	-9.6	-9.5	-9.5	-9.5	-9.5	60
I 58	-12.8	-11.6	-10.8	-10.3	-10.0	-9.7	-9.6	-9.4	-9.3	-9.2	-9.2	-9.1	-9.1	-9.0	-8.9	-8.9	-8.8	-8.8	-8.8	-8.8	-8.7	58
O 56	-12.1	-10.9	-10.1	-9.6	-9.3	-9.0	-8.9	-8.7	-8.6	-8.5	-8.5	-8.4	-8.4	-8.3	-8.2	-8.2	-8.1	-8.1	-8.1	-8.1	-8.0	56
N 54	-11.3	-10.2	-9.4	-8.9	-8.6	-8.4	-8.2	-8.1	-8.0	-7.9	-7.8	-7.7	-7.7	-7.6	-7.5	-7.5	-7.5	-7.4	-7.4	-7.4	-7.3	54
52	-10.6	-9.5	-8.8	-8.3	-8.0	-7.7	-7.5	-7.4	-7.3	-7.2	-7.1	-7.1	-7.0	-6.9	-6.9	-6.8	-6.8	-6.8	-6.7	-6.7	-6.7	52
A 50	-9.8	-8.8	-8.1	-7.6	-7.3	-7.1	-6.9	-6.8	-6.6	-6.6	-6.5	-6.4	-6.4	-6.3	-6.2	-6.2	-6.1	-6.1	-6.1	-6.0	-6.0	50
N 48	-9.0	-8.1	-7.4	-7.0	-6.7	-6.4	-6.3	-6.1	-6.0	-5.9	-5.9	-5.8	-5.7	-5.7	-5.6	-5.5	-5.5	-5.5	-5.4	-5.4	-5.4	48
G 46	-8.2	-7.4	-6.8	-6.3	-6.0	-5.8	-5.6	-5.5	-5.4	-5.3	-5.3	-5.2	-5.1	-5.1	-5.0	-4.9	-4.9	-4.9	-4.8	-4.8	-4.8	46
L 44	-7.4	-6.7	-6.1	-5.7	-5.4	-5.2	-5.1	-4.9	-4.8	-4.7	-4.7	-4.6	-4.6	-4.5	-4.4	-4.4	-4.3	-4.3	-4.3	-4.2	-4.2	44
E 42	-6.7	-6.0	-5.5	-5.1	-4.9	-4.7	-4.5	-4.4	-4.3	-4.2	-4.1	-4.1	-4.0	-3.9	-3.9	-3.8	-3.8	-3.7	-3.7	-3.7	-3.7	42
40	-6.0	-5.4	-4.9	-4.6	-4.3	-4.1	-4.0	-3.8	-3.7	-3.7	-3.6	-3.5	-3.5	-3.4	-3.4	-3.3	-3.3	-3.2	-3.2	-3.2	-3.2	40
I 38	-5.3	-4.8	-4.4	-4.1	-3.8	-3.6	-3.5	-3.3	-3.2	-3.2	-3.1	-3.1	-3.0	-2.9	-2.9	-2.8	-2.8	-2.8	-2.7	-2.7	-2.7	38
N 36	-4.7	-4.3	-3.9	-3.6	-3.3	-3.1	-3.0	-2.9	-2.8	-2.7	-2.7	-2.6	-2.6	-2.5	-2.4	-2.4	-2.3	-2.3	-2.3	-2.3	-2.2	36
34	-4.1	-3.8	-3.4	-3.1	-2.9	-2.7	-2.6	-2.5	-2.4	-2.3	-2.2	-2.2	-2.1	-2.1	-2.0	-2.0	-1.9	-1.9	-1.9	-1.9	-1.8	34
D 32	-3.6	-3.3	-3.0	-2.7	-2.5	-2.3	-2.2	-2.1	-2.0	-1.9	-1.9	-1.8	-1.8	-1.7	-1.7	-1.6	-1.6	-1.6	-1.5	-1.5	-1.5	32
E 30	-3.1	-2.9	-2.6	-2.4	-2.2	-2.0	-1.9	-1.8	-1.7	-1.6	-1.6	-1.5	-1.5	-1.4	-1.4	-1.3	-1.3	-1.3	-1.2	-1.2	-1.2	30
G 28	-2.7	-2.6	-2.3	-2.1	-1.9	-1.7	-1.6	-1.5	-1.4	-1.4	-1.3	-1.3	-1.2	-1.2	-1.1	-1.1	-1.0	-1.0	-1.0	-1.0	-.9	28
R 26	-2.4	-2.3	-2.1	-1.9	-1.7	-1.5	-1.4	-1.3	-1.2	-1.2	-1.1	-1.1	-1.0	-1.0	-.9	-.9	-.9	-.8	-.8	-.8	-.8	26
E 24	-2.1	-2.1	-1.9	-1.7	-1.5	-1.4	-1.3	-1.2	-1.1	-1.1	-1.0	-1.0	-.9	-.9	-.8	-.8	-.7	-.7	-.7	-.7	-.7	24
E 22	-2.0	-2.0	-1.8	-1.6	-1.5	-1.3	-1.2	-1.1	-1.1	-1.0	-1.0	-.9	-.9	-.8	-.8	-.7	-.7	-.7	-.7	-.6	-.6	22
S 20	-1.9	-2.0	-1.8	-1.6	-1.5	-1.4	-1.3	-1.2	-1.1	-1.1	-1.0	-1.0	-.9	-.9	-.8	-.8	-.8	-.7	-.7	-.7	-.7	20
18	-1.9	-2.0	-1.9	-1.8	-1.6	-1.5	-1.4	-1.3	-1.3	-1.2	-1.2	-1.1	-1.1	-1.0	-1.0	-.9	-.9	-.9	-.9	-.8	-.8	18
16	-2.1	-2.2	-2.1	-2.0	-1.9	-1.8	-1.7	-1.6	-1.5	-1.5	-1.4	-1.4	-1.4	-1.3	-1.3	-1.2	-1.2	-1.2	-1.1	-1.1	-1.1	16
14	-2.4	-2.6	-2.5	-2.4	-2.3	-2.2	-2.1	-2.0	-2.0	-1.9	-1.9	-1.8	-1.8	-1.7	-1.7	-1.7	-1.6	-1.6	-1.6	-1.6	-1.5	14
12	-2.9	-3.1	-3.1	-3.0	-2.9	-2.8	-2.7	-2.6	-2.6	-2.5	-2.5	-2.4	-2.4	-2.4	-2.3	-2.3	-2.2	-2.2	-2.2	-2.2	-2.2	12
10	-3.6	-4.0	-3.9	-3.9	-3.8	-3.7	-3.6	-3.5	-3.4	-3.4	-3.4	-3.3	-3.3	-3.2	-3.2	-3.2	-3.1	-3.1	-3.1	-3.1	-3.1	10
8	-4.7	-5.1	-5.2	-5.1	-5.0	-4.9	-4.8	-4.7	-4.7	-4.6	-4.6	-4.6	-4.5	-4.5	-4.4	-4.4	-4.4	-4.4	-4.3	-4.3	-4.3	8
6	-6.4	-6.9	-6.9	-6.9	-6.8	-6.7	-6.6	-6.5	-6.5	-6.4	-6.4	-6.4	-6.3	-6.3	-6.2	-6.2	-6.2	-6.2	-6.1	-6.1	-6.1	6
4	-9.1	-9.6	-9.7	-9.7	-9.6	-9.5	-9.4	-9.4	-9.3	-9.3	-9.2	-9.2	-9.2	-9.1	-9.1	-9.0	-9.0	-9.0	-9.0	-9.0	-8.9	4
2	-14.3	-14.9	-15.0	-15.0	-14.9	-14.8	-14.8	-14.7	-14.7	-14.6	-14.6	-14.5	-14.5	-14.5	-14.4	-14.4	-14.4	-14.3	-14.3	-14.3	-14.3	2
0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	0
	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30	

FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
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

FREQUENCY IN MEGAHERTZ

Figure 23. Transmitter antenna pattern. (METHOD=15)

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ITS- 1 ANTENNA PACKAGE — ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	VER MONOPOLE	0.000	-.250	0.000	0.000	0.000	0.000	0.000	0.000	.001	4.000

		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30	
	90	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	90
	88	-29.7	-30.0	-30.1	-30.2	-30.2	-30.2	-30.2	-30.2	-30.2	-30.1	-30.1	-30.1	-30.1	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-29.9	-29.9	88
	86	-23.6	-24.0	-24.1	-24.2	-24.2	-24.2	-24.2	-24.2	-24.1	-24.1	-24.1	-24.1	-24.1	-24.0	-24.0	-24.0	-24.0	-23.9	-23.9	-23.9	-23.9	86
	84	-20.1	-20.4	-20.6	-20.7	-20.7	-20.7	-20.7	-20.6	-20.6	-20.6	-20.6	-20.6	-20.5	-20.5	-20.5	-20.5	-20.4	-20.4	-20.4	-20.4	-20.4	84
	82	-17.6	-18.0	-18.1	-18.2	-18.2	-18.2	-18.2	-18.1	-18.1	-18.1	-18.1	-18.1	-18.0	-18.0	-18.0	-18.0	-17.9	-17.9	-17.9	-17.9	-17.9	82
	80	-15.7	-16.0	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.1	-16.1	-16.1	-16.1	-16.1	-16.0	-16.0	-16.0	-16.0	-16.0	-16.0	80
	78	-14.1	-14.4	-14.6	-14.7	-14.7	-14.7	-14.6	-14.6	-14.6	-14.6	-14.6	-14.6	-14.5	-14.5	-14.5	-14.5	-14.4	-14.4	-14.4	-14.4	-14.4	78
	76	-12.8	-13.1	-13.3	-13.3	-13.3	-13.3	-13.3	-13.3	-13.3	-13.3	-13.2	-13.2	-13.2	-13.2	-13.2	-13.1	-13.1	-13.1	-13.1	-13.1	-13.1	76
	74	-11.6	-11.9	-12.1	-12.2	-12.2	-12.2	-12.2	-12.1	-12.1	-12.1	-12.1	-12.1	-12.1	-12.0	-12.0	-12.0	-12.0	-11.9	-11.9	-11.9	-11.9	74
	72	-10.6	-10.9	-11.1	-11.2	-11.2	-11.2	-11.2	-11.1	-11.1	-11.1	-11.1	-11.1	-11.0	-11.0	-11.0	-11.0	-11.0	-10.9	-10.9	-10.9	-10.9	72
E	70	-9.7	-10.0	-10.2	-10.3	-10.3	-10.3	-10.3	-10.2	-10.2	-10.2	-10.2	-10.2	-10.1	-10.1	-10.1	-10.1	-10.1	-10.0	-10.0	-10.0	-10.0	70
L	68	-8.9	-9.2	-9.4	-9.4	-9.5	-9.5	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4	-9.3	-9.3	-9.3	-9.3	-9.2	-9.2	-9.2	-9.2	-9.2	68
E	66	-8.1	-8.5	-8.6	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.6	-8.6	-8.6	-8.6	-8.6	-8.5	-8.5	-8.5	-8.5	-8.5	-8.5	66
V	64	-7.4	-7.8	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0	-7.9	-7.9	-7.9	-7.9	-7.9	-7.8	-7.8	-7.8	-7.8	-7.8	64
A	62	-6.8	-7.2	-7.3	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.3	-7.3	-7.3	-7.3	-7.3	-7.2	-7.2	-7.2	-7.2	-7.2	62
T	60	-6.2	-6.6	-6.8	-6.8	-6.9	-6.9	-6.9	-6.8	-6.8	-6.8	-6.8	-6.8	-6.8	-6.7	-6.7	-6.7	-6.7	-6.7	-6.6	-6.6	-6.6	60
I	58	-5.7	-6.1	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.2	-6.2	-6.2	-6.2	-6.2	-6.1	-6.1	-6.1	-6.1	58
O	56	-5.2	-5.6	-5.8	-5.8	-5.9	-5.9	-5.9	-5.8	-5.8	-5.8	-5.8	-5.8	-5.8	-5.7	-5.7	-5.7	-5.7	-5.7	-5.7	-5.6	-5.6	56
N	54	-4.6	-5.2	-5.3	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.2	-5.2	-5.2	-5.2	-5.2	54
	52	-4.4	-4.7	-4.9	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-4.9	-4.9	-4.9	-4.9	-4.9	-4.8	-4.8	-4.8	-4.8	-4.8	52
A	50	-4.0	-4.4	-4.5	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.5	-4.5	-4.5	-4.5	-4.5	-4.5	-4.4	-4.4	50
N	48	-3.6	-4.0	-4.2	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.1	-4.1	-4.1	-4.1	-4.1	48
G	46	-3.3	-3.7	-3.9	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.8	-3.8	-3.8	-3.8	-3.8	46
L	44	-3.0	-3.4	-3.6	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.5	-3.5	44
E	42	-2.7	-3.2	-3.4	-3.4	-3.5	-3.5	-3.5	-3.5	-3.5	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	42
	40	-2.5	-2.9	-3.1	-3.2	-3.3	-3.3	-3.3	-3.3	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	40
I	38	-2.3	-2.8	-3.0	-3.0	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-2.9	-2.9	-2.9	-2.9	38
N	36	-2.1	-2.6	-2.8	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	36
	34	-2.0	-2.5	-2.7	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	34
D	32	-1.9	-2.4	-2.6	-2.7	-2.7	-2.8	-2.8	-2.8	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	32
E	30	-1.8	-2.3	-2.6	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	30
G	28	-1.8	-2.3	-2.6	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	28
R	26	-1.8	-2.4	-2.6	-2.7	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	26
E	24	-1.9	-2.5	-2.7	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	24
E	22	-2.0	-2.6	-2.9	-3.0	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	22
S	20	-2.2	-2.9	-3.1	-3.3	-3.3	-3.3	-3.4	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.2	-3.2	-3.2	-3.2	-3.2	20
	18	-2.5	-3.2	-3.5	-3.6	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	18
	16	-2.9	-3.6	-3.9	-4.0	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	16
	14	-3.4	-4.1	-4.5	-4.6	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	14
	12	-4.1	-4.8	-5.2	-5.3	-5.4	-5.5	-5.5	-5.5	-5.5	-5.5	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.3	12
	10	-5.0	-5.8	-6.1	-6.3	-6.4	-6.4	-6.4	-6.5	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.3	-6.3	-6.3	10
	8	-6.2	-7.1	-7.5	-7.6	-7.7	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	8
	6	-8.0	-8.9	-9.3	-9.5	-9.6	-9.6	-9.7	-9.7	-9.7	-9.7	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	6
	4	-10.7	-11.7	-12.2	-12.4	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.4	-12.4	4
	2	-16.0	-17.0	-17.5	-17.7	-17.8	-17.9	-17.9	-17.9	-17.9	-17.9	-17.9	-17.9	-17.9	-17.9	-17.9	-17.8	-17.8	-17.8	-17.8	-17.8	-17.8	2
	0	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	0
		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30	

FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
-.5	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6

FREQUENCY IN MEGAHERTZ

Figure 24. Receiver-antenna pattern. (METHOD=15)

METHOD 16 IONCAP 78.03 PAGE 10

JAN 1970 SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO. AZIMUTHS N. MI. KM
40.03 N 105.30 W - 38.67 N 90.25 W 91.84 281.42 702.6 1301.1
MINIMUM ANGLE .0 DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR 2.0 TO 30.0 VER MONOPOLE H 0.00 L -.50 A 0.0 OFF AZ 0.0
RCVR 2.0 TO 30.0 VER MONOPOLE H 0.00 L -.25 A 0.0 OFF AZ 0.0
POWER = 30.000 KW 3 MHZ NOISE = -150.0 DBW REQ. REL = .90 REQ. SNR = 55.0
MULTIPATH POWER TOLERANCE = 10.0 DB MULTIPATH DELAY TOLERANCE = .850 MS

UT	MUF												
19.0	21.1	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	1F2	1 E	1 E	1ES	2F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	MODE
	25.7	4.0	4.3	6.5	39.6	22.8	20.0	18.2	18.5	20.1	25.7	25.7	ANGLE
	5.1	4.4	4.4	4.4	5.9	4.9	4.8	4.7	4.8	4.8	5.1	5.1	DELAY
	365.	80.	85.	110.	290.	321.	281.	257.	261.	283.	365.	365.	V HITE
	.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.94	.68	.04	.00	F DAYS
	140.	234.	229.	183.	161.	139.	137.	136.	135.	135.	162.	214.	LOSS
	41.	-66.	-57.	-8.	16.	39.	41.	44.	45.	48.	21.	-29.	DBU
	-95	-189	-183	-137	-114	-90	-90	-89	-90	-88	-117	-168	S DBW
	-173	-145	-150	-156	-161	-164	-165	-167	-170	-172	-175	-178	N DBW
	78.	-44.	-34.	19.	47.	73.	74.	77.	80.	84.	59.	9.	SNR
	-6.	106.	96.	44.	16.	-9.	-12.	-14.	-18.	-19.	22.	72.	RPWRG
	.95	.00	.00	.00	.14	1.00	1.00	1.00	1.00	1.00	.57	.01	REL
	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	MPROB
7.0	7.4	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	1F2	1F2	1F2	1F2	1F2	1F2	1ES	1ES	1F2	1F2	1F2	1F2	MODE
	25.9	21.4	19.8	20.0	27.0	27.0	6.6	6.6	27.0	27.0	27.0	27.0	ANGLE
	5.1	4.9	4.8	4.8	5.2	5.2	4.4	4.4	5.2	5.2	5.2	5.2	DELAY
	368.	301.	278.	282.	387.	387.	110.	110.	387.	387.	387.	387.	V HITE
	.50	1.00	1.00	.99	.47	.05	.14	.07	.00	.00	.00	.00	F DAYS
	123.	120.	119.	118.	125.	146.	168.	192.	224.	225.	227.	229.	LOSS
	53.	46.	47.	52.	47.	31.	15.	-7.	-45.	-45.	-45.	-45.	DBU
	-73	-72	-72	-72	-79	-100	-122	-147	-178	-180	-182	-184	S DBW
	-157	-140	-145	-151	-157	-163	-167	-169	-171	-173	-175	-178	N DBW
	83.	68.	72.	78.	77.	62.	44.	23.	-8.	-8.	-7.	-6.	SNR
	-17.	-5.	-10.	-17.	-10.	9.	25.	57.	70.	70.	69.	68.	RPWRG
	1.00	.98	1.00	1.00	.99	.71	.30	.06	.00	.00	.00	.00	REL
	.00	.78	.94	.00	.00	.00	.00	.00	.00	.00	.00	.00	MPROB

Figure 25. System performance. (METHOD=16)

```
          JAN      1970          SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.           AZIMUTHS          N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W      91.84  281.42       702.6   1301.1
                               MINIMUM ANGLE    .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR    2.0  TO   30.0  VER MONOPOLE H     0.00 L     -.50 A     0.0  OFF AZ     0.0
RCVR    2.0  TO   30.0  VER MONOPOLE H     0.00 L     -.25 A     0.0  OFF AZ     0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0
MULTIPATH POWER TOLERANCE = 10.0 DB   MULTIPATH DELAY TOLERANCE =    .850 MS

 UT  MUF

19.0 21.1  2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   1 E   1 E   1ES   2F2   1F2   1F2   1F2   1F2   1F2   1F2   1F2 MODE
     25.7   4.0   4.5   6.6  39.6  22.8  20.0  18.2  18.5  20.1  25.7  25.7 ANGLE
      .50  1.00  1.00  1.00  1.00  1.00  1.00  1.00   .94   .68   .04   .00 F DAYS
      41.  -66.  -57.   -8.   16.   39.   41.   44.   45.   48.   21.  -29. DBU
      78.  -44.  -34.   19.   47.   73.   74.   77.   80.   84.   59.    9. SNR
      .95   .00   .00   .00   .14  1.00  1.00  1.00  1.00  1.00   .57   .01 REL

 7.0  7.4   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   1F2   1F2   1F2   1F2   1F2   1ES   1ES   1F2   1F2   1F2   1F2 MODE
     25.9  21.4  19.8  20.0  27.0  27.0   6.6   6.6  27.0  27.0  27.0  27.0 ANGLE
      .50  1.00  1.00   .99   .47   .05   .14   .07   .00   .00   .00   .00 F DAYS
      53.   46.   47.   52.   47.   31.   15.   -7.  -45.  -45.  -45.  -45. DBU
      83.   68.   72.   78.   77.   62.   44.   23.   -8.   -8.   -7.   -6. SNR
     1.00   .98  1.00  1.00   .99   .71   .30   .06   .00   .00   .00   .00 REL
```

Figure 26. Condensed system performance, reliabilities. (METHOD=17)

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                    METHOD 18   IONCAP 78.03   PAGE  12

       JAN    1970            SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.        AZIMUTHS           N. MI.     KM
40.03 N  105.30 W - 38.67 N   90.25 W      91.84  281.42      702.6   1301.1
                              MINIMUM ANGLE    .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR    2.0  TO   30.0  VER MONOPOLE H    0.00 L    -.50 A    0.0  OFF AZ    0.0
RCVR    2.0  TO   30.0  VER MONOPOLE H    0.00 L    -.25 A    0.0  OFF AZ    0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0
```

UT	MUF												
19.0	21.1	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	1F2	1 E	1 E	1ES	2F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	MODE
	25.7	4.0	4.5	6.6	39.6	22.8	20.0	18.2	18.5	20.1	25.7	25.7	ANGLE
	.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.94	.68	.04	.00	F DAYS
	41.	-66.	-57.	-8.	16.	39.	41.	44.	45.	46.	21.	-29.	DBU
	78.	-44.	-34.	19.	47.	73.	74.	77.	80.	84.	59.	9.	SNR
	.58	.00	.00	.00	.10	.70	.77	.83	.88	.87	.24	.01	S PRB
7.0	7.4	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	1F2	1F2	1F2	1F2	1F2	1F2	1ES	1ES	1F2	1F2	1F2	1F2	MODE
	25.9	21.4	19.8	20.0	27.0	27.0	6.6	6.6	27.0	27.0	27.0	27.0	ANGLE
	.50	1.00	1.00	.99	.47	.05	.14	.07	.00	.00	.00	.00	F DAYS
	53.	46.	47.	52.	47.	31.	15.	-7.	-45.	-45.	-45.	-45.	DBU
	83.	68.	72.	78.	77.	62.	44.	23.	-8.	-8.	-7.	-6.	SNR
	.77	.55	.69	.85	.69	.30	.12	.04	.00	.00	.00	.00	S PRB

Figure 27. Condensed system performance, service probability. (METHOD=18)

JAN 1970 SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO. AZIMUTHS N. MI. KM
40.03 N 105.30 W - 38.67 N 90.25 W 91.84 281.42 702.6 1301.1
MINIMUM ANGLE .0 DEGREES

UT	MUF											
19.0	21.1	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0 FREQ
	1F2	1 E	1 E	1ES	2F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2 MODE
	25.7	4.0	4.5	6.5	39.6	22.8	20.0	18.2	18.5	20.1	25.7	25.7 ANGLE
	5.1	4.4	4.4	4.4	5.9	4.9	4.8	4.7	4.8	4.8	5.1	5.1 DELAY
	365.	80.	85.	110.	290.	321.	281.	257.	261.	283.	365.	365. V HITE
	.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.94	.68	.04	.00 F DAYS
7.0	7.4	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0 FREQ
	1F2	1F2	1F2	1F2	1F2	1F2	1ES	1ES	1F2	1F2	1F2	1F2 MODE
	25.9	21.4	19.8	20.0	27.0	27.0	6.6	6.6	27.0	27.0	27.0	27.0 ANGLE
	5.1	4.9	4.8	4.8	5.2	5.2	4.4	4.4	5.2	5.2	5.2	5.2 DELAY
	368.	301.	278.	282.	387.	387.	110.	110.	387.	387.	387.	387. V HITE
	.50	1.00	1.00	.99	.47	.05	.14	.07	.00	.00	.00	.00 F DAYS

Figure 28. Propagation path geometry. (METHOD=19)

```
         JAN    1970               SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.          AZIMUTHS            N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W      91.84  281.42       702.6   1301.1
                                  MINIMUM ANGLE    .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR    2.0  TO  30.0  VER MONOPOLE H     0.00 L     -.50 A     0.0  OFF AZ     0.0
RCVR    2.0  TO  30.0  VER MONOPOLE H     0.00 L     -.25 A     0.0  OFF AZ     0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0
MULTIPATH POWER TOLERANCE = 10.0 DB   MULTIPATH DELAY TOLERANCE =   .850 MS
```

UT	MUF												
19.0	21.1	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	1F2	1 E	1 E	1ES	2F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	MODE
	25.7	4.0	4.5	6.6	39.6	22.8	20.0	18.2	18.5	20.1	25.7	25.7	ANGLE
	5.1	4.4	4.4	4.4	5.9	4.9	4.8	4.7	4.8	4.8	5.1	5.1	DELAY
	365.	80.	85.	110.	290.	321.	281.	257.	261.	283.	365.	365.	V HITE
	.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.94	.68	.04	.00	F DAYS
	140.	234.	229.	183.	161.	139.	137.	136.	135.	135.	162.	214.	LOSS
	41.	-66.	-57.	-8.	16.	39.	41.	44.	45.	48.	21.	-29.	DBU
	-95	-189	-183	-137	-114	-90	-90	-89	-90	-88	-117	-168	S DBW
	-173	-145	-150	-156	-161	-164	-165	-167	-170	-172	-175	-178	N DBW
	78.	-44.	-34.	19.	47.	73.	74.	77.	80.	84.	59.	9.	SNR
	-6.	106.	96.	44.	16.	-9.	-12.	-14.	-18.	-19.	22.	72.	RPWRG
	.95	.00	.00	.00	.14	1.00	1.00	1.00	1.00	1.00	.57	.01	REL
	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	MPROB
	.58	.00	.00	.00	.10	.70	.77	.83	.88	.87	.24	.01	S PRB
	16.	3.	3.	3.	3.	5.	3.	3.	3.	7.	25.	25.	SIG LW
	7.	2.	2.	2.	3.	5.	3.	2.	2.	5.	20.	25.	SIG UP
	41.	-66.	-57.	-8.	16.	39.	41.	44.	45.	48.	21.	-24.	VHFDBU
	16.	3.	3.	3.	3.	5.	3.	3.	3.	7.	25.	6.	VHF LW
	7.	2.	2.	2.	3.	5.	3.	2.	2.	5.	20.	8.	VHF UP
	F	E	E	ES	F2	F2	F2	F2	F2	F2	F	F	VHFMOD
	18.	7.	7.	8.	8.	8.	7.	7.	7.	10.	26.	26.	SNR LW
	11.	9.	9.	9.	9.	10.	9.	9.	9.	10.	22.	26.	SNR UP
7.0	7.4	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	1F2	1F2	1F2	1F2	1F2	1F2	1ES	1ES	1F2	1F2	1F2	1F2	MODE
	25.9	21.4	19.8	20.0	27.0	27.0	6.6	6.6	27.0	27.0	27.0	27.0	ANGLE
	5.1	4.9	4.8	4.8	5.2	5.2	4.4	4.4	5.2	5.2	5.2	5.2	DELAY
	368.	301.	278.	282.	387.	387.	110.	110.	387.	387.	387.	387.	V HITE
	.50	1.00	1.00	.99	.47	.05	.14	.07	.00	.00	.00	.00	F DAYS
	123.	120.	119.	118.	125.	146.	168.	192.	224.	225.	227.	229.	LOSS
	53.	46.	47.	52.	47.	31.	15.	-7.	-45.	-45.	-45.	-45.	DBU
	-73	-72	-72	-72	-79	-100	-122	-147	-178	-180	-182	-184	S DBW
	-157	-140	-145	-151	-157	-163	-167	-169	-171	-173	-175	-178	N DBW
	83.	68.	72.	78.	77.	62.	44.	23.	-8.	-8.	-7.	-6.	SNR
	-17.	-5.	-10.	-17.	-10.	9.	25.	57.	70.	70.	69.	68.	RPWRG
	1.00	.98	1.00	1.00	.99	.71	.30	.06	.00	.00	.00	.00	REL
	.00	.78	.94	.00	.00	.00	.00	.00	.00	.00	.00	.00	MPROB
	.77	.55	.69	.85	.69	.30	.12	.04	.00	.00	.00	.00	S PRB
	10.	3.	1.	2.	10.	15.	13.	24.	3.	3.	3.	3.	SIG LW
	5.	3.	3.	1.	7.	17.	25.	25.	8.	1.	1.	1.	SIG UP
	53.	46.	47.	52.	47.	31.	25.	25.	25.	25.	25.	26.	VHFDBU
	10.	3.	1.	2.	10.	15.	6.	6.	6.	6.	6.	6.	VHF LW
	5.	3.	3.	1.	7.	17.	8.	8.	8.	8.	8.	8.	VHF UP
	F	F2	F2	F2	F	F	F	F	F	F	F	F	VHFMOD
	12.	8.	7.	7.	12.	17.	15.	25.	7.	7.	7.	7.	SNR LW
	9.	10.	9.	8.	10.	19.	26.	26.	12.	9.	9.	9.	SNR UP

Figure 29. Complete system performance. (METHOD=20)

```
          JAN     1970            SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.           AZIMUTHS              N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W       91.84  281.42        702.6   1301.1
                                  MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR    2.0  TO  30.0  VER MONOPOLE H     0.00 L     -.50 A     0.0  OFF AZ    0.0
RCVR    2.0  TO  30.0  VER MONOPOLE H     0.00 L     -.25 A     0.0  OFF AZ    0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0
MULTIPATH POWER TOLERANCE = 10.0 DB   MULTIPATH DELAY TOLERANCE =   .850 MS
```

UT	MUF												
19.0	21.1	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	F2F2	E E	E E	F1F1	F1F1	F1F1	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	MODE
	18.0	3.0	.5	42.1	25.2	18.0	20.0	18.0	16.0	18.0	25.7	25.7	ANGLE
	18.0	3.0	.5	42.1	25.2	18.0	20.0	18.0	16.0	18.0	25.7	25.7	ANGLE
	5.2	4.9	6.6	5.2	4.9	4.9	4.8	4.8	5.2	5.1	5.1	5.1	DELAY
	282.	79.	84.	273.	274.	265.	281.	257.	257.	273.	365.	365.	V HITE
	.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.94	.68	.04	.00	F DAYS
	143.	242.	290.	171.	144.	139.	136.	136.	137.	140.	162.	213.	LOSS
	39.	-71.	-92.	-1.	29.	37.	41.	44.	44.	42.	21.	-29.	DBU
	-98	-197	-245	-125	-98	-94	-91	-90	-92	-94	-116	-168	S DBW
	-173	-145	-150	-156	-161	-164	-165	-167	-170	-172	-175	-178	N DBW
	75.	-51.	-95.	31.	63.	70.	74.	77.	78.	78.	59.	10.	SNR
	-3.	114.	157.	32.	0.	4.	-12.	-14.	-13.	-8.	22.	71.	RPWRG
	.93	.00	.00	.00	.89	.85	1.00	1.00	1.00	.98	.58	.01	REL
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	MPROB
	.53	.00	.00	.01	.45	.43	.77	.82	.79	.65	.24	.01	S PRB
	16.	3.	3.	3.	3.	17.	3.	3.	6.	13.	25.	25.	SIG LW
	7.	2.	2.	2.	2.	7.	2.	2.	3.	5.	20.	25.	SIG UP
7.0	7.4	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	MODE
	22.0	20.0	18.0	18.0	22.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	ANGLE
	22.0	20.0	18.0	18.0	22.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	ANGLE
	5.2	5.2	5.2	5.2	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	DELAY
	330.	305.	280.	280.	336.	387.	387.	387.	387.	387.	387.	387.	V HITE
	.50	1.00	1.00	.99	.47	.05	.00	.00	.00	.00	.00	.00	F DAYS
	125.	111.	114.	117.	126.	146.	183.	221.	224.	225.	227.	229.	LOSS
	47.	49.	51.	53.	47.	29.	-6.	-43.	-45.	-45.	-44.	-44.	DBU
	-80	-66	-68	-72	-81	-101	-137	-176	-179	-180	-182	-183	S DBW
	-157	-140	-145	-151	-157	-163	-167	-169	-171	-173	-175	-178	N DBW
	77.	75.	77.	79.	77.	62.	29.	-7.	-8.	-7.	-6.	-6.	SNR
	-10.	-12.	-14.	-17.	-10.	13.	49.	70.	70.	70.	69.	68.	RPWRG
	.99	1.00	1.00	1.00	.99	.67	.11	.00	.00	.00	.00	.00	REL
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	MPROB
	.69	.72	.78	.84	.67	.30	.05	.00	.00	.00	.00	.00	S PRB
	10.	3.	3.	4.	11.	19.	22.	5.	3.	3.	3.	3.	SIG LW
	6.	1.	1.	1.	7.	17.	25.	25.	1.	1.	1.	1.	SIG UP

Figure 30. Forced long-path model. (METHOD=21)

```
                                METHOD 22   IONCAP 78.03   PAGE  16

       JAN     1970            SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.          AZIMUTHS          N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W      91.84  281.42      702.6   1301.1
                                MINIMUM ANGLE    .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO  30.0  VER MONOPOLE H    0.00 L     -.50 A    0.0  OFF AZ    0.0
RCVR   2.0  TO  30.0  VER MONOPOLE H    0.00 L     -.25 A    0.0  OFF AZ    0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0
MULTIPATH POWER TOLERANCE = 10.0 DB   MULTIPATH DELAY TOLERANCE =   .850 MS
```

UT	MUF												
19.0	21.1	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	1F2	1 E	1 E	1ES	2F2	1F2	1F2	1F2	1F2	1F2	1F2	1F2	MODE
	25.7	4.0	4.5	6.6	39.6	22.8	20.0	18.2	18.5	20.1	25.7	25.7	ANGLE
	5.1	4.4	4.4	4.4	5.9	4.9	4.8	4.7	4.8	4.8	5.1	5.1	DELAY
	365.	80.	85.	110.	290.	321.	281.	257.	261.	283.	365.	365.	V HITE
	.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.94	.68	.04	.00	F DAYS
	140.	234.	229.	183.	161.	139.	137.	136.	135.	135.	162.	214.	LOSS
	41.	-66.	-57.	-8.	16.	39.	41.	44.	45.	48.	21.	-29.	DBU
	-95	-189	-183	-137	-114	-90	-90	-89	-90	-88	-117	-168	S DBW
	-173	-145	-150	-156	-161	-164	-165	-167	-170	-172	-175	-178	N DBW
	78.	-44.	-34.	19.	47.	73.	74.	77.	80.	84.	59.	9.	SNR
	-6.	106.	96.	44.	16.	-9.	-12.	-14.	-18.	-19.	22.	72.	RPWRG
	.95	.00	.00	.00	.14	1.00	1.00	1.00	1.00	1.00	.57	.01	REL
	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	MPROB
	.58	.00	.00	.00	.10	.70	.77	.83	.88	.87	.24	.01	S PRB
	16.	3.	3.	3.	3.	5.	3.	3.	3.	7.	25.	25.	SIG LW
	7.	2.	2.	2.	3.	5.	3.	2.	2.	5.	20.	25.	SIG UP
7.0	7.4	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	1F2	1F2	1F2	1F2	1F2	1F2	1ES	1ES	1F2	1F2	1F2	1F2	MODE
	25.9	21.4	19.8	20.0	27.0	27.0	6.6	6.6	27.0	27.0	27.0	27.0	ANGLE
	5.1	4.9	4.8	4.8	5.2	5.2	4.4	4.4	5.2	5.2	5.2	5.2	DELAY
	368.	301.	278.	282.	387.	387.	110.	110.	387.	387.	387.	387.	V HITE
	.50	1.00	1.00	.99	.47	.05	.14	.07	.00	.00	.00	.00	F DAYS
	123.	120.	119.	118.	125.	146.	168.	192.	224.	225.	227.	229.	LOSS
	53.	46.	47.	52.	47.	31.	15.	-7.	-45.	-45.	-45.	-45.	DBU
	-73	-72	-72	-72	-79	-100	-122	-147	-178	-180	-182	-184	S DBW
	-157	-140	-145	-151	-157	-163	-167	-169	-171	-173	-175	-178	N DBW
	83.	68.	72.	78.	77.	62.	44.	23.	-8.	-8.	-7.	-6.	SNR
	-17.	-5.	-10.	-17.	-10.	9.	25.	57.	70.	70.	69.	68.	RPWRG
	1.00	.98	1.00	1.00	.99	.71	.30	.06	.00	.00	.00	.00	REL
	.00	.78	.94	.00	.00	.00	.00	.00	.00	.00	.00	.00	MPROB
	.77	.55	.69	.85	.69	.30	.12	.04	.00	.00	.00	.00	S PRB
	10.	3.	1.	2.	10.	15.	13.	24.	3.	3.	3.	3.	SIG LW
	5.	3.	3.	1.	7.	17.	25.	25.	8.	1.	1.	1.	SIG UP

Figure 31. Forced short-path model. (METHOD=22)

```
          JAN    1970            SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.          AZIMUTHS          N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W      91.84  281.42     702.6   1301.1
                                 MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR    2.0  TO   30.0  VER MONOPOLE H     0.00 L     -.50 A     0.0  OFF AZ     0.0
RCVR    2.0  TO   30.0  VER MONOPOLE H     0.00 L     -.25 A     0.0  OFF AZ     0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0

 UT  MUF

19.0 21.1  2.0   3.0   5.0   7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
      1F2  1 E   1 E   1ES   2F2  1F2  1F2  1F2  1F2  1F2  1F2  1F2 MODE
     25.7  4.0   4.5   6.6  39.6 22.8 20.0 18.2 18.5 20.1 25.7 25.7 ANGLE
     365.  80.   85.  110.  290. 321. 281. 257. 261. 283. 365. 365. V HITE
      78. -44.  -34.   19.   47.  73.  74.  77.  80.  84.  59.   9. SNR
      -6. 106.   96.   44.   16.  -9. -12. -14. -18. -19.  22.  72. RPWRG
      .95  .00   .00   .00   .14 1.00 1.00 1.00 1.00 1.00  .57  .01 REL

 7.0  7.4  2.0   3.0   5.0   7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
      1F2  1F2   1F2   1F2   1F2  1F2  1ES  1ES  1F2  1F2  1F2  1F2 MODE
     25.9 21.4  19.8  20.0  27.0 27.0  6.6  6.6 27.0 27.0 27.0 27.0 ANGLE
     368. 301.  278.  282.  387. 387. 110. 110. 387. 387. 387. 387. V HITE
      83.  68.   72.   78.   77.  62.  44.  23.  -8.  -8.  -7.  -6. SNR
     -17.  -5.  -10.  -17.  -10.   9.  25.  57.  70.  70.  69.  68. RPWRG
     1.00  .98  1.00  1.00   .99  .71  .30  .06  .00  .00  .00  .00 REL
```

Figure 32. User-selected system performance. (METHOD=23)

```
         JAN     1970             SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.             AZIMUTHS          N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W         91.84  281.42     702.6    1301.1
                              MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO  30.0  VER MONOPOLE H     0.00 L     -.50 A     0.0  OFF AZ     0.0
RCVR   2.0  TO  30.0  VER MONOPOLE H     0.00 L     -.25 A     0.0  OFF AZ     0.0
POWER =   30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0
```

FREQUENCY / RELIABILITY

GMT	LMT	MUF	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	MUF
8.0	1.0	8.0	.99	1.00	1.00	1.00	.88	.31	.02	.00	.00	.00	.00	1.00
9.0	2.0	8.0	.99	1.00	1.00	1.00	.59	.11	.00	.00	.00	.00	.00	.99
10.0	3.0	7.2	.99	1.00	1.00	.90	.34	.04	.00	.00	.00	.00	.00	.94
11.0	4.0	6.1	1.00	1.00	1.00	.64	.29	.02	.00	.00	.00	.00	.00	.91
12.0	5.0	5.8	.99	1.00	1.00	.52	.31	.03	.00	.00	.00	.00	.00	.91
13.0	6.0	7.5	.79	1.00	1.00	.97	.35	.07	.00	.00	.00	.00	.00	.97
14.0	7.0	11.2	.01	.18	.99	1.00	1.00	.59	.01	.00	.00	.00	.00	.96
15.0	8.0	15.3	.00	.00	.35	.99	1.00	1.00	.99	.50	.03	.00	.00	.96
16.0	9.0	18.0	.00	.00	.07	.99	1.00	1.00	1.00	1.00	.67	.00	.00	.99
17.0	10.0	19.3	.00	.00	.01	.37	.95	1.00	1.00	1.00	.88	.17	.00	.99
18.0	11.0	20.4	.00	.00	.00	.20	.91	1.00	1.00	1.00	1.00	.42	.00	.99
19.0	12.0	21.1	.00	.00	.00	.14	1.00	1.00	1.00	1.00	1.00	.57	.01	.95
20.0	13.0	21.0	.00	.00	.00	.96	1.00	1.00	1.00	1.00	1.00	.55	.01	1.00
21.0	14.0	20.6	.00	.00	.06	.98	1.00	1.00	1.00	1.00	1.00	.45	.00	.99
22.0	15.0	19.9	.00	.00	.38	.97	.99	.99	1.00	1.00	.96	.28	.00	.97
23.0	16.0	18.5	.03	.22	.94	.99	.99	1.00	1.00	.99	.76	.06	.00	.96
.0	17.0	16.3	.35	.80	.98	.99	1.00	1.00	1.00	.75	.35	.00	.00	.96
1.0	18.0	13.6	.63	.94	.99	1.00	1.00	1.00	.90	.65	.34	.01	.00	.99
2.0	19.0	11.3	.77	.98	1.00	1.00	1.00	.89	.57	.21	.02	.00	.00	.99
3.0	20.0	9.4	.93	.99	1.00	1.00	.95	.61	.18	.01	.00	.00	.00	.98
4.0	21.0	7.9	.99	1.00	1.00	1.00	.80	.34	.10	.00	.00	.00	.00	.99
5.0	22.0	6.9	.99	1.00	1.00	.96	.55	.34	.13	.00	.00	.00	.00	1.00
6.0	23.0	6.8	.99	1.00	1.00	.96	.53	.34	.11	.00	.00	.00	.00	1.00
7.0	24.0	7.4	.98	1.00	1.00	.99	.71	.30	.06	.00	.00	.00	.00	1.00

Figure 33. Reliability table output. (METHOD=24)

```
                                   METHOD 25   IONCAP 78.03   PAGE  19

        JAN    1970               SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.            AZIMUTHS         N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W     91.84  281.42      702.6    1301.1
                                   MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR    2.0  TO   30.0  VER MONOPOLE H    0.00 L    -.50 A    0.0  OFF AZ    0.0
RCVR    2.0  TO   30.0  VER MONOPOLE H    0.00 L    -.25 A    0.0  OFF AZ    0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0

                                   YE =  20.0     HE = 110.0     HS = 110.0
```

LAT	LONG	LMT	UT	E	F1	Y1	H1	FH/2	F2Z	Y2	H2	ES	MED	HI	M3000	HPF2	RAT	ZEN	ZMAX	MAGL
39.6N	97.7W	12.5	19.0	3.46	4.5	51.4	205.5	.7	11.4	98.9	296.4	1.8	2.4	3.0	3.11	302.8	3.0	63.0	66.1	49.4N

FREQ =   3.0 MHZ UT = 19.0

	1. E	2. E	3. E	1. E
TIME DEL.	4.404	4.533	4.760	4.404
ANGLE	4.480	13.921	22.325	4.480
VIR. HITE	85.198	90.152	94.091	85.198
TRAN.LOSS	229.059	253.769	267.537	229.058
T. GAIN	-8.881	-2.613	-1.993	-8.881
R. GAIN	-10.948	-4.146	-2.600	-10.948
ABSORB	106.188	73.077	54.072	
FS. LOSS	104.406	104.657	105.082	
FIELD ST.	-56.596	-88.109	-103.423	-56.593
SIG. POW.	-184.000	-208.000	-222.000	-183.000
SNR	-33.713	-58.424	-72.192	-33.698
MODE PROB	1.000	1.000	1.000	1.000
R. PWRG	1000.000	1000.000	1000.000	96.150
RELIABIL	.000	.000	.000	.000
SERV PROB	0.000	0.000	0.000	0.000
SIG LOW	2.557	2.557	2.557	2.557
SIG UP	2.187	2.187	2.187	2.187

```
NOISE =    -150      S. POWER =   -183
SIGNAL =     2.6     5.0     2.2  /    2.3     3.3     .7
NOISE =      9.0  -150.6     7.0  /     1.5     3.0     1.5
RELIAB =     9.3   -33.7     7.5
SPROB =     27.5    -5.0    27.5
```

Figure 34. All modes output (user-defined freq.).   (METHOD=25)

```
                                      METHOD 25   IONCAP 78.03   PAGE  20

        JAN     1970            SSN = 100.
 BOULDER,COLORADO TO ST. LOUIS,MO.             AZIMUTHS             N. MI.      KM
 40.03 N  105.30 W - 38.67 N   90.25 W        91.64  281.42        702.6   1301.1
                                      MINIMUM ANGLE     .0  DEGREES
 ITS- 1 ANTENNA PACKAGE
 XMTR    2.0  TO   30.0  VER MONOPOLE H     0.00 L     -.50 A     0.0  OFF AZ      0.0
 RCVR    2.0  TO   30.0  VER MONOPOLE H     0.00 L     -.25 A     0.0  OFF AZ      0.0
 POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0


                         FREQ =  21.1 MHZ  UT =  19.0

                 1.F2        1.ES        2.ES        1.F2
 TIME DEL.      5.083       4.437       4.616       5.083
 ANGLE         25.688       6.583      17.069      25.688
 VIR. HITE    365.395     110.000     110.000     365.395
 TRAN.LOSS    139.976   25148.373   82371.112     139.976
 T. GAIN        -.845      -5.617      -1.040       -.845
R. GAIN        -2.711      -8.986      -3.790      -2.711
 ABSORB         2.860       6.333       3.905
 FS. LOSS     122.580     121.398     121.743
 FIELD ST.     41.176   *********   *********      41.176
 SIG. POW.    -95.000   *********   *********     -95.000
 SNR           78.409   *********   *********      78.407
 MODE PROB       .500        .000        .000        .500
R. PWRG      1000.000    1000.000    1000.000      -5.594
RELIABIL         .954        .003        .000        .954
 SERV PROB      0.000        .001        .001       0.000
 SIG LOW       16.498      25.000       2.557      16.498
  SIG  UP       7.287      25.000       2.187       7.287
 NOISE =     -173        S. POWER =     -95
 SIGNAL =     2.6      5.0     2.2  /     2.3      3.3       .7
 NOISE =      8.6 -173.6     6.7  /      1.2      2.6      1.2
 RELIAB =    11.3     78.4    17.8
 SPROB =     27.5     -5.0    27.5
```

Figure 35. All modes output (MUF). (METHOD=25)

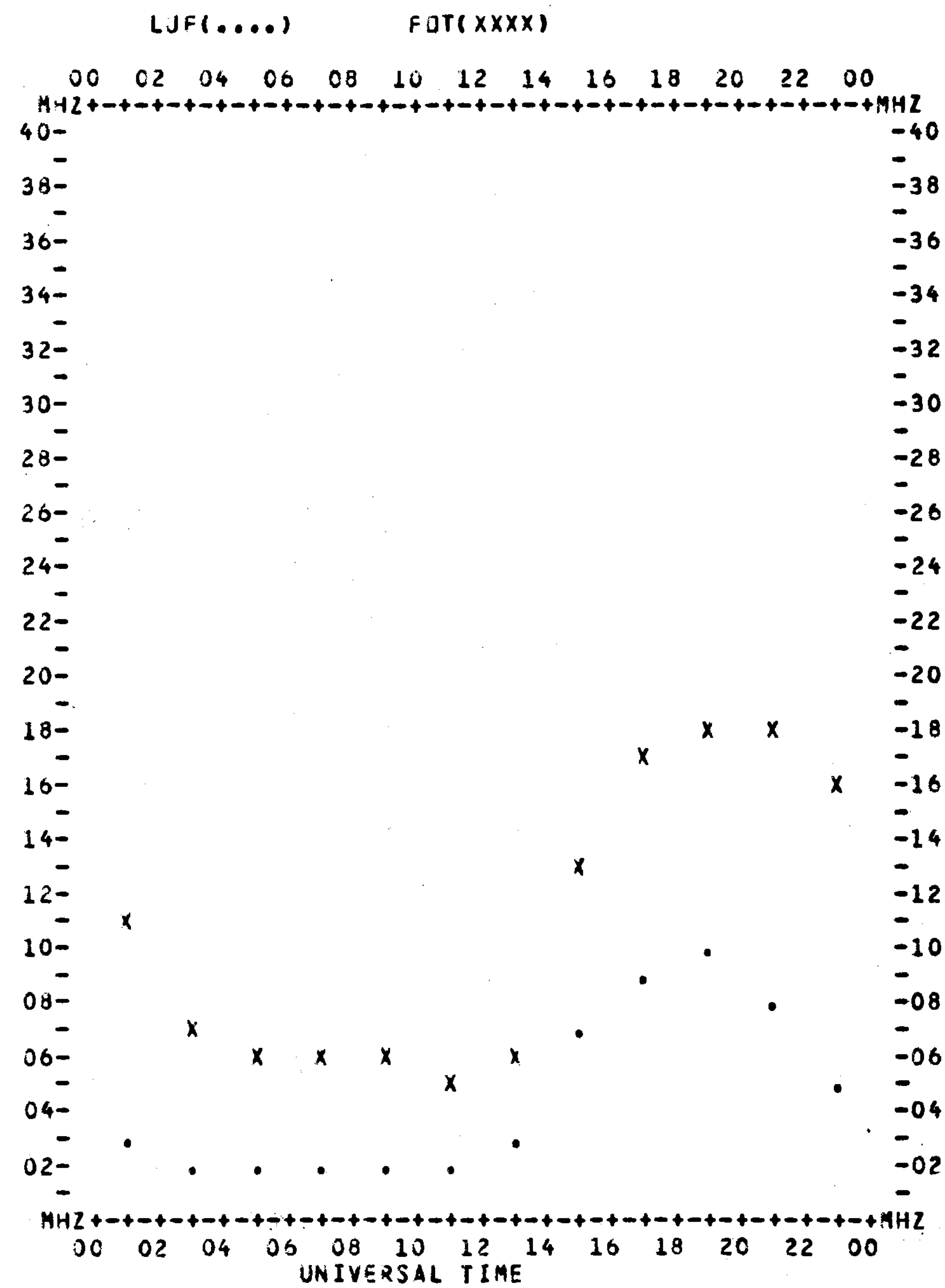
```
        JAN     1970          SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.            AZIMUTHS          N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W       91.84  281.42      702.6    1301.1
                              MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO   30.0  VER MONOPOLE H    0.00 L     -.50 A     0.0  OFF AZ    0.0
RCVR   2.0  TO   30.0  VER MONOPOLE H    0.00 L     -.25 A     0.0  OFF AZ    0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0
```

GMT	LMT	FOT	HPF	ESMUF	MUF	LUF
1.0	18.0	10.75	17.42	5.68	13.61	3.31
3.0	20.0	7.42	12.02	5.45	9.39	2.00
5.0	22.0	5.71	8.74	5.72	6.88	2.00
7.0	24.0	6.12	9.36	5.94	7.37	2.00
9.0	2.0	6.48	9.37	5.75	8.01	2.00
11.0	4.0	4.96	7.17	5.43	6.12	2.00
13.0	6.0	6.39	8.42	6.04	7.51	2.50
15.0	8.0	12.97	17.09	8.19	15.26	6.75
17.0	10.0	16.61	22.02	10.60	19.32	8.96
19.0	12.0	18.11	24.01	11.14	21.06	10.19
21.0	14.0	17.70	23.46	9.41	20.58	8.03
23.0	16.0	15.95	21.14	7.05	18.55	5.05

Figure 36. LUF-MUF table. (METHOD=26)

```
                              METHOD 27   IONCAP 78.03   PAGE  22

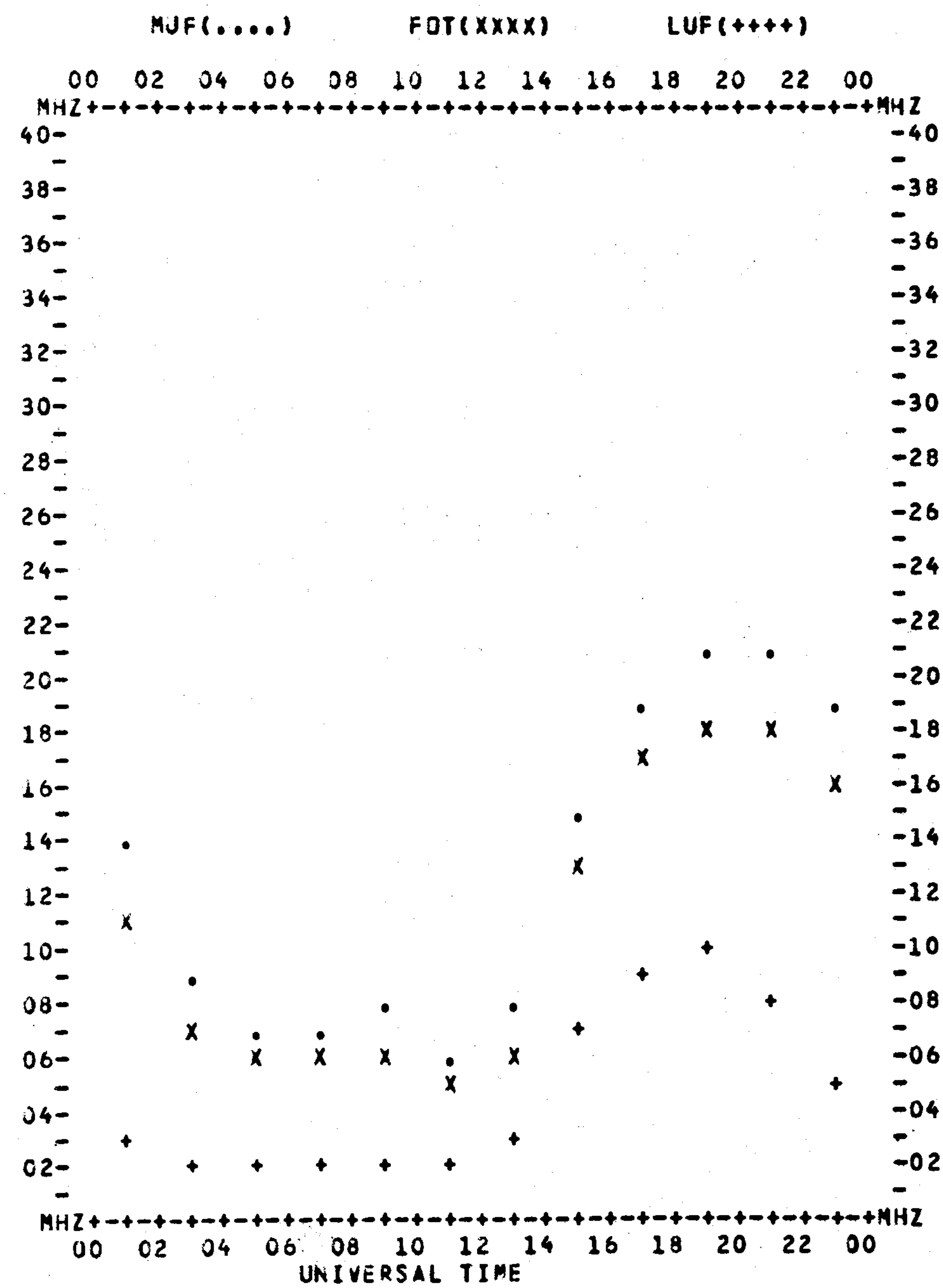
         JAN     1970              SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.          AZIMUTHS            N. MI.       KM
40.03 N  105.30 W - 38.67 N   90.25 W      91.84  281.42       702.6    1301.1
                              MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO   30.0  VER MONOPOLE H    0.00 L     -.50 A     0.0  OFF AZ     0.0
RCVR   2.0  TO   30.0  VER MONOPOLE H    0.00 L     -.25 A     0.0  OFF AZ     0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0
```



GMT	LUF	FOT
1.0	3.3	10.7
3.0	2.0	7.4
5.0	2.0	5.7
7.0	2.0	6.1
9.0	2.0	6.5
11.0	2.0	5.0
13.0	2.5	6.4
15.0	6.8	13.0
17.0	9.0	16.6
19.0	10.2	18.1
21.0	8.0	17.7
23.0	5.0	15.9

Figure 37. LUF-FOT graph. (METHOD=27)

```
          JAN     1970           SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.          AZIMUTHS          N. MI.       KM
40.03 N  105.30 W - 38.67 N   90.25 W      91.84  281.42     702.6    1301.1
                                 MINIMUM ANGLE    .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO  30.0  VER MONOPOLE H    0.00 L    -.50 A    0.0  OFF AZ     0.0
RCVR   2.0  TO  30.0  VER MONOPOLE H    0.00 L    -.25 A    0.0  OFF AZ     0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0
```



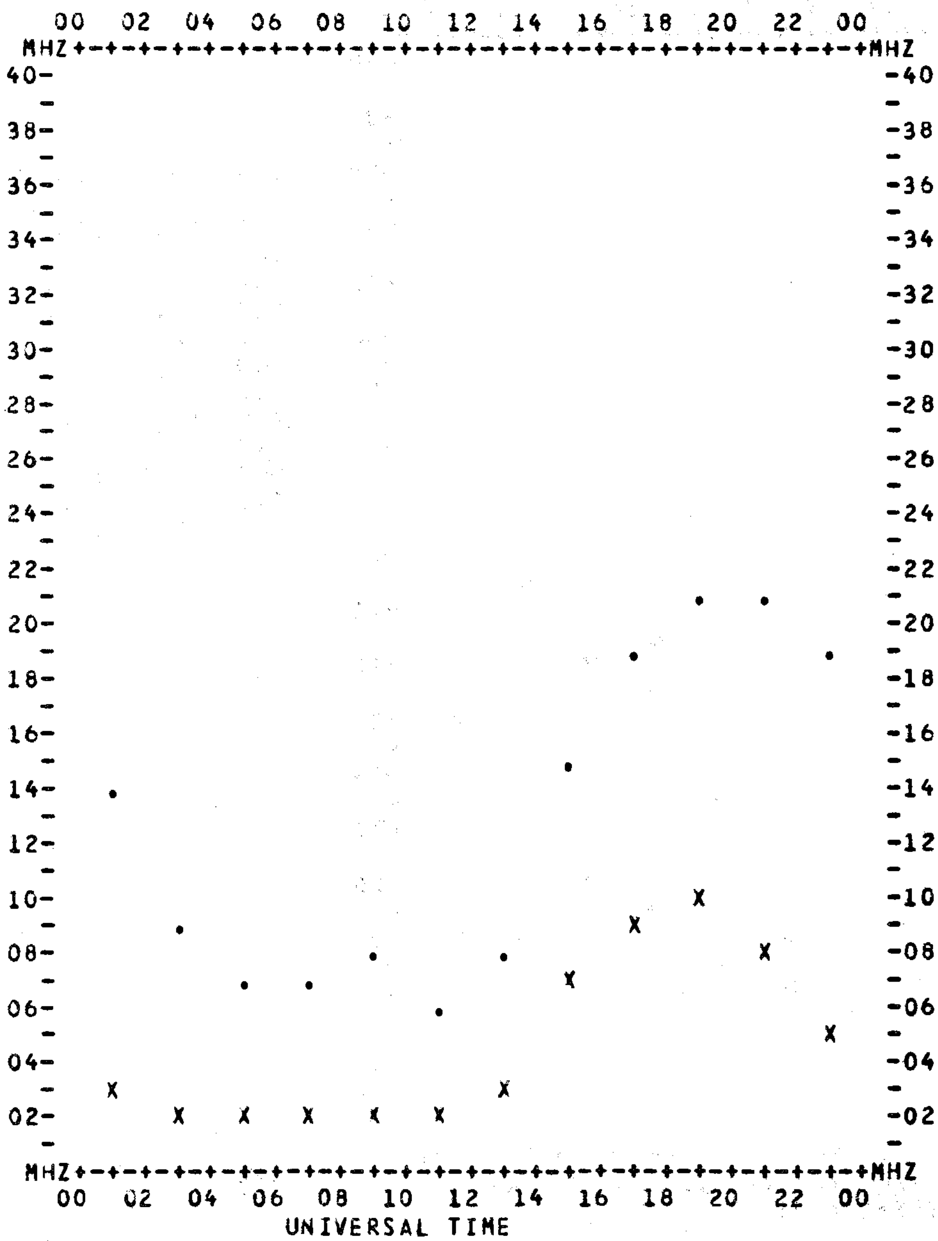
GMT	MUF	FOT	LUF
1.0	13.6	10.7	3.3
3.0	9.4	7.4	2.0
5.0	6.9	5.7	2.0
7.0	7.4	6.1	2.0
9.0	8.0	6.5	2.0
11.0	6.1	5.0	2.0
13.0	7.5	6.4	2.5
15.0	15.3	13.0	6.8
17.0	19.3	16.6	9.0
19.0	21.1	18.1	10.2
21.0	20.6	17.7	8.0
23.0	18.5	15.9	5.0

Figure 38. LUF-MUF-FOT graph. (METHOD=28)

```
                              METHOD 29   IONCAP 78.03   PAGE  24

        JAN     1970            SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.                AZIMUTHS            N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W        91.84  281.42        702.6    1301.1
                              MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO  30.0  VER MONOPOLE H    0.00 L    -.50 A    0.0  OFF AZ    0.0
RCVR   2.0  TO  30.0  VER MONOPOLE H    0.00 L    -.25 A    0.0  OFF AZ    0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0
```

MUF(....)   LUF(XXXX)



GMT	MUF	LUF
1.0	13.6	3.3
3.0	9.4	2.0
5.0	6.9	2.0
7.0	7.4	2.0
9.0	8.0	2.0
11.0	6.1	2.0
13.0	7.5	2.5
15.0	15.3	6.8
17.0	19.3	9.0
19.0	21.1	10.2
21.0	20.6	8.0
23.0	18.5	5.0

Figure 39. LUF-MUF graph. (METHOD=29)

METHOD 7 IONCAP 78.03 PAGE 25

JAN 1970 SSN = 100.
BOULDER, COLORADO TO AUCKLAND, N. Z. AZIMUTHS N. MI. KM
40.03 N 105.30 W - 36.92 S 174.75 E 235.07 51.75 6377.8 11810.7
MINIMUM ANGLE .0 DEGREES

		ELAYER/F2LAYER							F1LAYER(E)/ESLAYER						
GMT	LMT	FOT	MUF	HPF	ANGLE	VIRTL	TRUE	FVERT	FOT	MUF	HPF	ANGLE	VIRTL	TRUE	FVERT
13.0	6.0	4.7	5.4	6.1	.7	125.	104.	1.0	4.7	5.4	6.1	.7	125.	104.	1.0
		8.4	11.1	14.5	3.4	447.	300.	3.3	3.0	4.7	10.6	1.9	110.	110.	.9
19.0	12.0	13.0	14.9	16.8	.7	125.	104.	2.7	13.0	14.9	16.8	.7	125.	104.	2.7
		24.8	28.5	32.5	4.6	492.	298.	8.7	9.4	13.6	17.7	1.9	110.	110.	2.5
1.0	18.0	6.8	7.8	8.9	.7	125.	104.	1.4	6.8	7.8	8.9	.7	125.	104.	1.4
		24.8	29.2	34.5	2.6	416.	267.	8.3	5.0	8.2	15.1	1.9	110.	110.	1.5

Figure 40. MUF complete output table (long-path example). (METHOD=7)

```
          JAN     1970            SSN = 100.
BOULDER,COLORADO TO AUCKLAND,N. Z.             AZIMUTHS            N. MI.      KM
40.03 N  105.30 W - 36.92 S  174.75 E     235.07    51.75     6377.8  11810.7
                                  MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR    2.0   TO   30.0   VER MONOPOLE H     0.00 L     -.50 A     0.0  OFF AZ     0.0
RCVR    2.0   TO   30.0   VER MONOPOLE H     0.00 L     -.25 A     0.0  OFF AZ     0.0
POWER =  30.000 KW  3 MHZ NOISE = -150.0 DBW   REQ. REL = .90  REQ. SNR = 55.0
```

UT	MUF												
13.0	11.1	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	F2F2	EF2	EF2	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	F2F2	MODE
	3.0	5.0	14.0	12.0	12.0	9.9	3.4	3.4	3.4	3.4	3.4	3.4	ANGLE
	12.0	14.0	12.0	12.0	12.0	12.0	12.0	3.0	3.0	16.1	3.0	3.4	ANGLE
	378.	239.	210.	297.	309.	445.	383.	384.	392.	546.	479.	447.	V HITE
	35.	-13.	2.	30.	41.	45.	32.	4.	-25.	-40.	****	****	SNR
	45.	76.	60.	32.	31.	36.	49.	77.	106.	121.	182.	187.	RPWRG
	.14	.00	.00	.00	.02	.22	.13	.01	.00	.00	.00	.00	REL
19.0	28.5	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	F2F2	E E	E E	E E	E E	EF2	F1F2	F1F2	F2F2	F2F2	F2F2	F2F2	MODE
	14.7	.5	.5	1.0	1.0	1.0	13.0	9.1	8.0	18.0	16.0	12.9	ANGLE
	5.0	1.0	1.0	1.0	1.0	12.2	10.0	10.0	18.0	12.0	12.0	4.6	ANGLE
	558.	80.	85.	91.	95.	242.	284.	283.	290.	294.	432.	554.	V HITE
	41.	****	****	****	****	-79.	-17.	4.	18.	29.	46.	34.	SNR
	40.	****	866.	507.	296.	144.	94.	77.	46.	37.	35.	46.	RPWRG
	.20	.00	.00	.00	.00	.00	.00	.01	.00	.00	.18	.16	REL
1.0	29.2	2.0	3.0	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0	FREQ
	F2F2	E E	E E	F2 E	F2 E	F2 E	F2F1	F2F1	F2F2	F2F2	F2F2	F2F2	MODE
	3.0	4.0	5.0	13.4	8.0	8.0	16.0	18.0	18.0	10.0	8.0	2.6	ANGLE
	16.0	.5	.5	.5	1.0	1.0	16.0	11.9	11.6	7.7	18.0	17.0	ANGLE
	452.	84.	88.	211.	169.	163.	234.	247.	363.	356.	357.	614.	V HITE
	36.	****	****	****	****	****	-35.	-7.	24.	30.	42.	35.	SNR
	45.	****	****	435.	280.	194.	99.	71.	41.	37.	39.	46.	RPWRG
	.16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.09	.15	REL

Figure 41. User-selected system performance (long path example). (METHOD=23)

```
IONOSPHERIC COMMUNICATIONS ANALYSIS AND PREDICTION PROGRAM - IONCAP   VERSION 78.03

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

COMMENT   ****************************************************************
COMMENT   ITSA-1 ANTENNA PACKAGE (REVISED 1977)
COMMENT   ****************************************************************
METHOD       15
COMMENT
COMMENT   TERMINATED RHOMBIC TRANSMITTER ANTENNA
COMMENT   BEARING OF ANTENNA = 0 DEGREES EAST OF NORTH,
COMMENT   GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
COMMENT   TILT ANGLE (HALF OF LARGE INTERIOR ANGLE) = 67.5 DEGREES,
COMMENT   ANTENNA LEG LENGTH = 88.39 METERS, ANTENNA HEIGHT = 16.76 METERS,
COMMENT   ENDING FREQUENCY = 30 MHZ (DEFAULT) , NUMBER OF ANTENNAS = 1 (DEFAULT)
ANTENNA      1    1      .001 4.00 67.588.3916.76
COMMENT
COMMENT   VERTICAL MONOPOLE RECEIVER ANTENNA
COMMENT   GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
COMMENT   ANTENNA HEIGHT = 1/4 WAVELENGTH, GAIN ABOVE DIPOLE = 0 DB,
COMMENT   ENDING FREQUENCY = 30 MHZ , NUMBER OF ANTENNAS = 1
ANTENNA      2    2      .001  4.0      -0.25                          30.     1
EXECUTE
COMMENT
COMMENT   HORIZONTAL DIPOLE TRANSMITTER ANTENNA
COMMENT   BEARING OF ANTENNA = 0 DEGREES EAST OF NORTH,
COMMENT   GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
COMMENT   ANTENNA LENGTH = 1/2 WAVELENGTH, ANTENNA HEIGHT = 1/4 WAVELENGTH,
COMMENT   GAIN ABOVE HALF WAVELENGTH HORIZONTAL DIPOLE = 0 DB,
COMMENT   ENDING FREQUENCY = 30 MHZ , NUMBER OF ANTENNAS = 1
ANTENNA      1    3      .001  4.0        -.5 -.25 0.0                 30.     1
COMMENT
COMMENT   HORIZONTAL YAGI RECEIVER ANTENNA
COMMENT   BEARING OF ANTENNA = 0 DEGREES EAST OF NORTH,
COMMENT   GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
COMMENT   ANTENNA LENGTH = 1/2 WAVELENGTH, ANTENNA HEIGHT = 1/4 WAVELENGTH
COMMENT   GAIN ABOVE HALF WAVELENGTH HORIZONTAL DIPOLE = 3 DB,
COMMENT   ENDING FREQUENCY = 30 MHZ (DEFAULT) , NUMBER OF ANTENNAS = 1 (DEFAULT)
ANTENNA      2    4      .001  4.0        -.5 -.25  3.0
EXECUTE
COMMENT
COMMENT   VERTICAL LOG PERIODIC ARRAY OF MONOPOLES TRANSMITTER ANTENNA
COMMENT   GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
COMMENT   ANTENNA HEIGHT = 1/4 WAVELENGTH,
COMMENT   GAIN ABOVE QUARTER WAVELENGTH VERTICAL MONOPOLE = 2 DB,
COMMENT   ENDING FREQUENCY = 30 MHZ (DEFAULT) , NUMBER OF ANTENNAS = 1 (DEFAULT)
ANTENNA      1    5      .001 4.       -.25        2.
COMMENT
COMMENT   CURTAIN RECEIVER ANTENNA
COMMENT   BEARING OF ANTENNA = 0 DEGREES EAST OF NORTH,
COMMENT   GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
COMMENT   NUMBER OF BAYS = 2, ANTENNA ELEMENT LENGTH = 22 METERS,
COMMENT   HEIGHT TO 1ST ELEMENT = 16 METERS, NUMBER OF ELEMENTS PER BAY = 4,
COMMENT   DISTANCE BETWEEN ELEMENT CENTERS = 26 METERS,
COMMENT   VERTICAL SPACING OF ELEMENTS=13 METERS, DISTANCE FROM SCREEN=7 METERS,
COMMENT   ENDING FREQUENCY = 30 MHZ , NUMBER OF ANTENNAS = 1
ANTENNA      2    6      .001  4.0  2.0  22.  16.  4.0  26.  13.   7.  30.     1
EXECUTE
COMMENT
COMMENT   TERMINATED SLOPING VEE TRANSMITTER ANTENNA
COMMENT   BEARING OF ANTENNA = 0 DEGREES EAST OF NORTH,
COMMENT   GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
```

Figure 42. Antenna pattern input cards.

```
COMMENT    HALF APEX ANGLE = 22.5 DEGREES, ANTENNA LEG LENGTH = 121.9 METERS,
COMMENT    ANTENNA HEIGHT = 15.24 METERS, TERMINATED HEIGHT = 1.829 METERS,
COMMENT    ENDING FREQUENCY = 30 MHZ , NUMBER OF ANTENNAS = 1
ANTENNA        1     7  0.0 .001  4.0 22.5121.915.241.829                    30.     1
COMMENT
COMMENT    INVERTED L RECEIVER ANTENNA
COMMENT    BEARING OF ANTENNA = 0 DEGREES EAST OF NORTH,
COMMENT    GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
COMMENT    ANTENNA LENGTH = 21.34 METERS, ANTENNA HEIGHT = 10 METERS,
COMMENT    ENDING FREQUENCY = 30 MHZ , NUMBER OF ANTENNAS = 1
ANTENNA        2     8       .001  4.0      21.34 10.0                       30.     1
EXECUTE
COMMENT
COMMENT    TERMINATED SLOPING RHOMBIC TRANSMITTER ANTENNA
COMMENT    BEARING OF ANTENNA = 0 DEGREES EAST OF NORTH,
COMMENT    GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
COMMENT    HALF LARGE INTERIOR ANGLE = 22.5 DEGREES, LEG LENGTH = 88.39 METERS,
COMMENT    ANTENNA HEIGHT = 16.76 METERS, TERMINATED HEIGHT = 8.382 METERS,
COMMENT    ENDING FREQUENCY = 30 MHZ (DEFAULT) , NUMBER OF ANTENNAS = 1 (DEFAULT)
ANTENNA        1     9       .001 4.0   22.5 88.3916.768.382
COMMENT
COMMENT    INTERLACED RHOMBIC RECEIVER ANTENNA
COMMENT    BEARING OF ANTENNA = 0 DEGREES EAST OF NORTH,
COMMENT    GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
COMMENT    HALF LARGE INTERIOR ANGLE = 70 DEGREES, LEG LENGTH = 114 METERS,
COMMENT    LOWER ANTENNA HEIGHT = 20 METERS, VERTICAL DISPLACEMENT = 4 METERS,
COMMENT    HORIZONTAL FEED POINT DISPLACEMENT = 33 METERS,
COMMENT    ENDING FREQUENCY = 30 MHZ (DEFAULT) , NUMBER OF ANTENNAS = 1 (DEFAULT)
ANTENNA        2    10       .001 4.    70. 114.  20. 4.    33.
EXECUTE
COMMENT
COMMENT    CONSTANT GAIN TRANSMITTER ANTENNA
COMMENT    GAIN ABOVE AN ISOTROPIC = 10 DB,
COMMENT    GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
COMMENT    ANTENNA EFFICIENCY = 0 DB
COMMENT    ENDING FREQUENCY = 30 MHZ (DEFAULT) , NUMBER OF ANTENNAS = 1 (DEFAULT)
ANTENNA        1    12 10.  .001 4.               0.
COMMENT
COMMENT    CONSTANT GAIN RECEIVER ANTENNA
COMMENT    GAIN ABOVE AN ISOTROPIC = 10 DB,
COMMENT    GROUND CONDUCTIVITY = .001 MHOS/M, DIELECTRIC CONSTANT = 4,
COMMENT    ANTENNA EFFICIENCY = -1.87 DB
COMMENT    ENDING FREQUENCY = 30 MHZ (DEFAULT) , NUMBER OF ANTENNAS = 1 (DEFAULT)
ANTENNA        2    12 10.  .001 4.             -1.87
EXECUTE
QUIT
```

Figure 42. Antenna pattern input cards (continued).

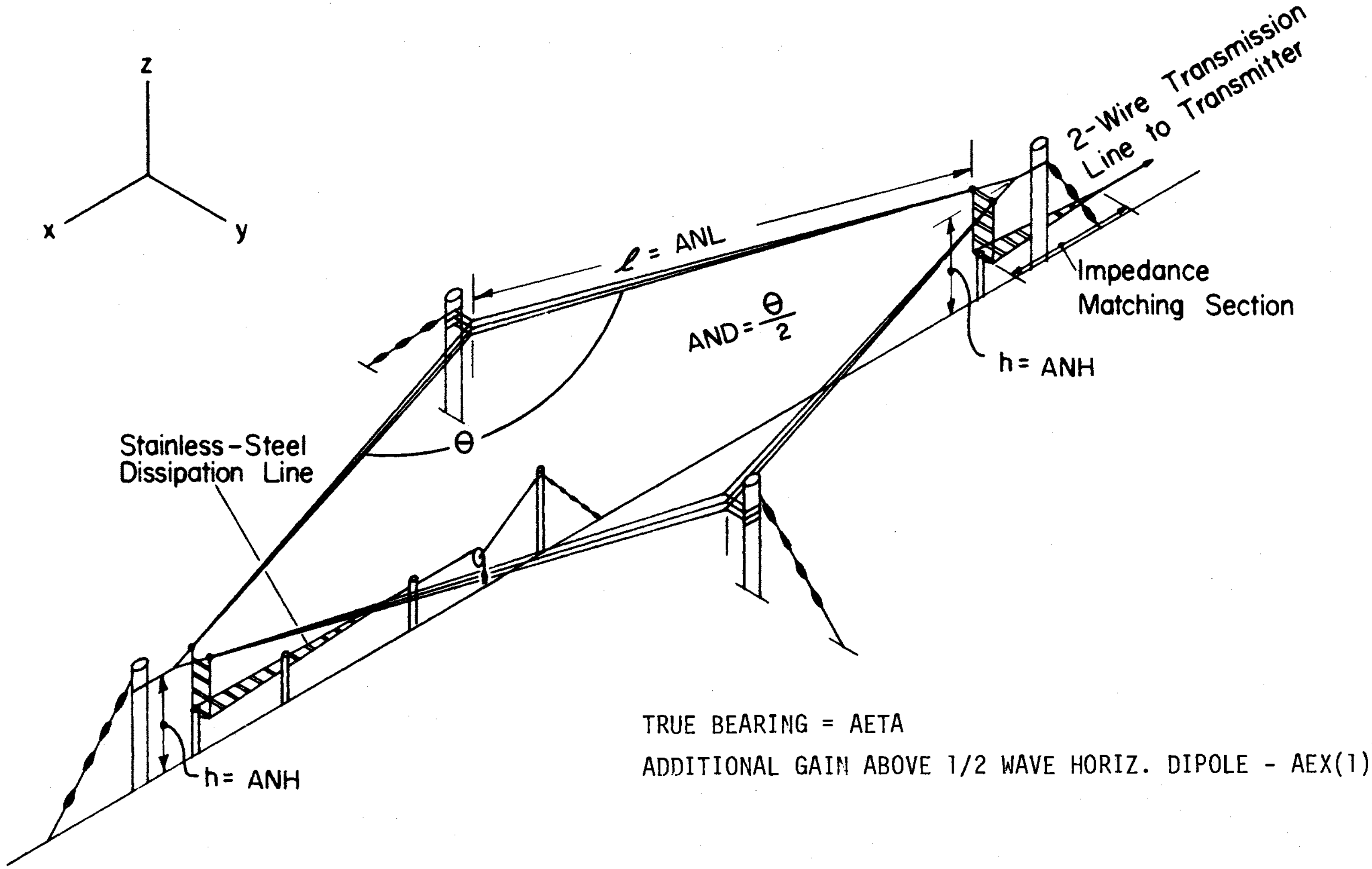


Figure 43. Horizontal rhombic structure (1).

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ITS- 1 ANTENNA PACKAGE ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	TER. RHOMBIC	16.760	88.390	67.500	0.000	0.000	0.000	0.000	0.000	.001	4.000

		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
	90	-3.7	-11.7	-11.7	-2.4	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-3.0	-11.7	-11.7	-11.7	-11.7	-11.7	-2.5	-11.7	-11.7	-11.7	-11.7
	88	-3.1	-11.7	-11.7	-2.5	-7.7	-11.7	-11.7	-8.8	-11.7	-11.7	-3.1	-6.1	-11.7	-5.8	-11.7	-8.0	-6.8	-11.7	-8.2	-11.7	-3.1
	86	-2.7	-11.7	-11.7	-3.0	-5.4	-11.7	-11.7	-8.2	-11.7	-11.7	-5.6	-2.4	-11.7	-5.7	-11.7	-3.9	-11.7	-4.4	-11.7	-11.7	-7.3
	84	-2.2	-11.7	-11.7	-4.0	-3.7	-11.7	-11.7	-8.8	-8.0	-11.7	-11.7	-1.6	-6.7	-11.7	-11.7	-6.4	-11.7	-3.7	-11.7	-6.1	-11.7
	82	-1.9	-7.8	-11.7	-5.4	-2.7	-11.7	-11.7	-11.7	-5.8	-11.7	-11.7	-3.4	-2.2	-11.7	-8.8	-11.7	-3.4	-11.7	-9.2	-11.7	-6.1
	80	-1.5	-5.9	-11.7	-7.4	-2.1	-9.5	-11.7	-11.7	-5.3	-7.6	-11.7	-8.8	-1.1	-11.7	-7.4	-11.7	-1.2	-11.7	-5.9	-11.7	-2.5
	78	-1.3	-4.2	-11.7	-11.7	-2.1	-6.4	-11.7	-11.7	-6.3	-4.0	-11.7	-11.7	-3.0	-11.7	-11.7	-11.7	-7.3	-5.6	-11.7	-8.7	-11.7
	76	-1.1	-2.8	-11.7	-11.7	-2.7	-4.3	-11.7	-11.7	-9.1	-2.6	-6.9	-11.7	-9.0	-4.9	-11.7	-3.9	-11.7	-.7	-11.7	-6.8	-11.7
	74	-.9	-1.6	-11.7	-11.7	-3.8	-3.0	-11.7	-11.7	-11.7	-3.1	-2.4	-11.7	-11.7	-1.9	-11.7	-4.4	-11.7	-4.9	-7.4	-11.7	-2.9
	72	-.8	-.5	-11.7	-11.7	-5.6	-2.3	-8.0	-11.7	-11.7	-5.4	-.6	-5.0	-11.7	-2.6	-11.7	-11.7	-1.7	-11.7	-2.2	-11.7	-5.3
E	70	-.8	.5	-8.0	-11.7	-8.3	-2.4	-5.4	-11.7	-11.7	-11.7	-.9	-.6	-11.7	-7.8	-6.2	-11.7	-.3	-11.7	-7.5	-7.2	-11.7
L	68	-.8	1.2	-5.1	-11.7	-11.7	-3.1	-3.7	-11.7	-11.7	-11.7	-3.4	1.0	-2.2	-11.7	-3.8	-11.7	-6.4	-.0	-11.7	-5.2	-11.7
E	66	-.8	1.9	-2.7	-11.7	-11.7	-4.6	-2.9	-7.3	-11.7	-11.7	-8.7	.2	1.4	-11.7	-5.9	-7.3	-11.7	1.2	-7.4	-11.7	-4.1
V	64	-.9	2.5	-.7	-11.7	-11.7	-7.0	-2.9	-5.1	-11.7	-11.7	-11.7	-3.1	2.1	-8.0	-11.7	-4.5	-11.7	-6.4	1.4	-11.7	-9.8
A	62	-1.1	2.9	.9	-8.9	-11.7	-11.7	-3.7	-3.8	-7.1	-11.7	-11.7	-11.7	.2	-.2	-11.7	-6.6	-3.4	-11.7	.3	-2.8	-11.7
T	60	-1.3	3.2	2.3	-4.9	-11.7	-11.7	-5.4	-3.4	-5.0	-8.4	-11.7	-11.7	-4.9	3.0	-11.7	-11.7	-1.2	-7.4	-11.7	1.1	-9.4
I	58	-1.6	3.5	3.4	-1.8	-11.7	-11.7	-8.4	-3.9	-3.9	-5.0	-10.0	-11.7	-11.7	3.0	-2.2	-11.7	-5.2	1.1	-11.7	-5.5	-1.0
O	56	-1.9	3.6	4.4	.7	-9.9	-11.7	-11.7	-5.4	-3.8	-3.4	-4.6	-11.7	-11.7	-.2	2.6	-11.7	-11.7	1.3	.2	-11.7	-3.7
N	54	-2.2	3.7	5.1	2.7	-4.9	-11.7	-11.7	-8.2	-4.5	-3.0	-2.1	-4.6	-11.7	-8.3	3.5	-2.7	-11.7	-5.8	4.2	-2.6	-11.7
	52	-2.6	3.7	5.7	4.3	-1.1	-11.7	-11.7	-11.7	-6.3	-3.7	-1.3	-.8	-4.6	-11.7	.8	2.2	-11.7	-11.7	.5	5.0	-5.9
A	50	-3.1	3.6	6.2	5.6	1.8	-7.0	-11.7	-11.7	-9.5	-5.3	-2.0	.6	.2	-11.7	-7.3	3.0	-1.9	-11.7	-11.7	3.7	4.9
N	48	-3.6	3.4	6.5	6.7	4.1	-2.0	-11.7	-11.7	-11.7	-8.0	-3.8	.2	2.2	-3.5	-11.7	-.6	1.8	-5.4	-11.7	-7.9	5.2
G	46	-4.2	3.1	6.7	7.5	6.0	1.7	-7.0	-11.7	-11.7	-11.7	-6.7	-1.8	2.1	2.5	-11.7	-11.7	1.1	-.7	-5.0	-11.7	-4.9
L	44	-4.8	2.8	6.7	8.2	7.5	4.5	-1.5	-11.7	-11.7	-11.7	-11.7	-5.1	.3	5.1	-.2	-11.7	-5.4	.4	-1.1	-3.3	-11.7
E	42	-5.5	2.3	6.6	8.6	8.6	6.8	2.6	-4.9	-11.7	-11.7	-11.7	-10.0	-3.4	5.2	5.4	-5.0	-11.7	-3.4	-.9	1.2	-1.2
	40	-6.2	1.8	6.5	8.9	9.5	8.5	5.7	.6	-8.2	-11.7	-11.7	-11.7	-8.9	3.2	7.6	4.4	-11.7	-11.7	-3.7	-.6	3.8
I	38	-7.0	1.3	6.2	9.0	10.1	9.9	8.1	4.6	-1.2	-11.7	-11.7	-11.7	-11.7	-1.0	7.2	8.5	3.0	-11.7	-11.7	-4.9	1.1
N	36	-7.8	.6	5.8	8.9	10.5	10.9	9.9	7.6	3.7	-2.6	-11.7	-11.7	-11.7	-7.9	4.4	9.4	8.9	2.0	-11.7	-11.7	-6.2
	34	-8.7	-.1	5.3	8.7	10.8	11.6	11.3	9.9	7.3	3.1	-3.3	-11.7	-11.7	-11.7	-1.0	7.8	10.8	9.2	1.8	-11.7	-11.7
D	32	-9.7	-.9	4.7	8.4	10.8	12.1	12.4	11.7	10.0	7.2	3.0	-3.2	-11.7	-11.7	-11.7	3.4	9.9	11.9	9.7	2.6	-11.7
E	30	-11.7	-1.8	4.0	7.9	10.6	12.3	13.1	13.0	12.1	10.3	7.5	3.4	-2.4	-11.7	-11.7	-4.6	6.2	11.4	12.8	10.7	4.4
G	28	-11.7	-2.8	3.2	7.3	10.3	12.3	13.5	13.9	13.6	12.6	10.9	8.2	4.4	-8.3	-11.7	-11.7	-1.1	7.9	12.4	13.7	12.0
R	26	-11.7	-3.8	2.3	6.6	9.8	12.1	13.6	14.5	14.7	14.3	13.3	11.6	9.2	1.3	-11.7	-11.7	-11.7	.7	8.9	13.1	14.5
E	24	-11.7	-5.0	1.3	5.8	9.2	11.7	13.5	14.7	15.4	15.5	15.1	14.2	12.7	7.6	-1.4	-11.7	-11.7	-11.7	1.3	9.1	13.4
E	22	-11.7	-6.2	.2	4.9	8.4	11.1	13.2	14.7	15.7	16.2	16.3	16.0	15.2	12.1	6.4	-3.1	-11.7	-11.7	-11.7	.8	8.7
S	20	-11.7	-7.5	-1.0	3.8	7.5	10.4	12.7	14.4	15.7	16.6	17.1	17.2	16.9	15.2	11.7	6.0	-3.4	-11.7	-11.7	-11.7	-1.1
	18	-11.7	-8.9	-2.3	2.6	6.4	9.5	11.9	13.9	15.4	16.6	17.4	17.9	18.0	17.4	15.4	11.9	6.3	-2.5	-11.7	-11.7	-11.7
	16	-11.7	-11.7	-3.8	1.3	5.2	8.4	11.0	13.1	14.9	16.3	17.3	18.1	18.6	18.8	17.9	15.9	12.5	7.4	-.5	-11.7	-11.7
	14	-11.7	-11.7	-5.3	-.2	3.8	7.1	9.9	12.2	14.0	15.6	16.9	17.9	18.7	19.5	19.4	18.5	16.5	13.4	8.9	2.1	-8.8
	12	-11.7	-11.7	-7.0	-1.9	2.3	5.7	8.5	10.9	12.9	14.7	16.1	17.3	18.3	19.6	20.2	20.0	19.0	17.2	14.5	10.5	4.6
	10	-11.7	-11.7	-9.0	-3.7	.5	3.9	6.9	9.4	11.5	13.4	14.9	16.3	17.4	19.1	20.2	20.5	20.3	19.4	17.8	15.3	11.8
	8	-11.7	-11.7	-11.7	-5.9	-1.7	1.9	4.9	7.4	9.7	11.6	13.3	14.8	16.0	18.1	19.4	20.2	20.5	20.2	19.3	17.8	15.6
	6	-11.7	-11.7	-11.7	-8.6	-4.3	-.7	2.3	5.0	7.3	9.3	11.1	12.6	14.0	16.2	17.8	18.9	19.5	19.7	19.3	18.4	16.9
	4	-11.7	-11.7	-11.7	-11.7	-7.9	-4.3	-1.2	1.5	3.8	5.9	7.7	9.3	10.8	13.1	15.0	16.3	17.1	17.5	17.5	17.0	16.0
	2	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-7.2	-4.4	-2.1	.0	1.9	3.5	5.0	7.5	9.4	10.8	11.8	12.3	12.5	12.2	11.5
	0	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7
		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 44. Horizontal rhombic pattern.

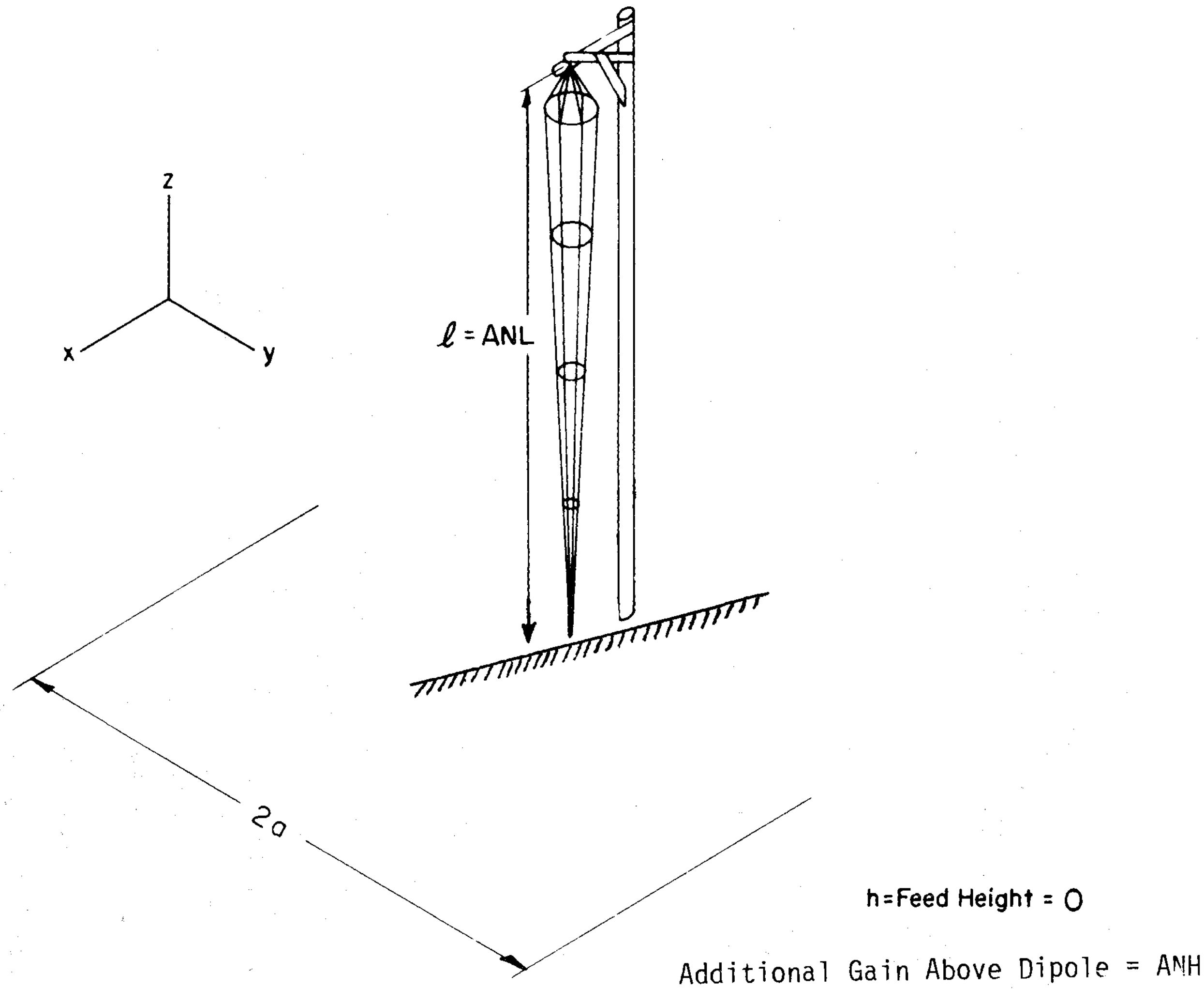

Figure 45. Vertical monopole structure (2).

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ITS- 1 ANTENNA PACKAGE						ANTENNA PATTERN					
FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	VER MONOPOLE	0.000	-.250	0.000	0.000	0.000	0.000	0.000	0.000	.001	4.000

		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
	90	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6
	88	-29.7	-30.0	-30.1	-30.2	-30.2	-30.2	-30.2	-30.2	-30.2	-30.1	-30.1	-30.1	-30.1	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-29.9	-29.9
	86	-23.6	-24.0	-24.1	-24.2	-24.2	-24.2	-24.2	-24.2	-24.1	-24.1	-24.1	-24.1	-24.1	-24.0	-24.0	-24.0	-24.0	-23.9	-23.9	-23.9	-23.9
	84	-20.1	-20.4	-20.6	-20.7	-20.7	-20.7	-20.7	-20.6	-20.6	-20.6	-20.6	-20.6	-20.5	-20.5	-20.5	-20.5	-20.4	-20.4	-20.4	-20.4	-20.4
	82	-17.6	-18.0	-18.1	-18.2	-18.2	-18.2	-18.2	-18.1	-18.1	-18.1	-18.1	-18.1	-18.0	-18.0	-18.0	-18.0	-17.9	-17.9	-17.9	-17.9	-17.9
	80	-15.7	-16.0	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.1	-16.1	-15.1	-16.1	-16.1	-16.0	-16.0	-15.0	-15.0	-16.0	-16.0
	78	-14.1	-14.4	-14.6	-14.7	-14.7	-14.7	-14.6	-14.6	-14.6	-14.6	-14.6	-14.6	-14.5	-14.5	-14.5	-14.5	-14.4	-14.4	-14.4	-14.4	-14.4
	76	-12.8	-13.1	-13.3	-13.3	-13.3	-13.3	-13.3	-13.3	-13.3	-13.3	-13.2	-13.2	-13.2	-13.2	-13.2	-13.1	-13.1	-13.1	-13.1	-13.1	-13.1
	74	-11.6	-11.9	-12.1	-12.2	-12.2	-12.2	-12.2	-12.1	-12.1	-12.1	-12.1	-12.1	-12.1	-12.0	-12.0	-12.0	-12.0	-11.9	-11.9	-11.9	-11.9
	72	-10.6	-10.9	-11.1	-11.2	-11.2	-11.2	-11.2	-11.1	-11.1	-11.1	-11.1	-11.1	-11.0	-11.0	-11.0	-11.0	-11.0	-10.9	-10.9	-10.9	-10.9
E	70	-9.7	-10.0	-10.2	-10.3	-10.3	-10.3	-10.3	-10.2	-10.2	-10.2	-10.2	-10.2	-10.1	-10.1	-10.1	-10.1	-10.1	-10.0	-10.0	-10.0	-10.0
L	68	-8.9	-9.2	-9.4	-9.4	-9.5	-9.5	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4	-9.3	-9.3	-9.3	-9.3	-9.2	-9.2	-9.2	-9.2	-9.2
E	66	-8.1	-8.5	-8.6	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.6	-8.6	-8.5	-8.6	-8.6	-8.5	-8.5	-8.5	-8.5	-8.5	-8.5
V	64	-7.4	-7.8	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0	-7.9	-7.9	-7.9	-7.9	-7.9	-7.8	-7.8	-7.8	-7.8	-7.8
A	62	-6.8	-7.2	-7.3	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.3	-7.3	-7.3	-7.3	-7.3	-7.2	-7.2	-7.2	-7.2	-7.2
T	60	-6.2	-6.6	-6.8	-6.8	-6.9	-6.9	-6.9	-6.8	-6.8	-6.8	-6.8	-6.8	-6.8	-6.7	-6.7	-6.7	-6.7	-6.7	-6.6	-6.6	-6.6
I	58	-5.7	-6.1	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.2	-6.2	-6.2	-6.2	-6.2	-6.1	-6.1	-6.1	-6.1
O	56	-5.2	-5.6	-5.8	-5.8	-5.9	-5.9	-5.9	-5.8	-5.8	-5.8	-5.8	-5.8	-5.8	-5.7	-5.7	-5.7	-5.7	-5.7	-5.7	-5.6	-5.6
N	54	-4.8	-5.2	-5.3	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.2	-5.2	-5.2	-5.2	-5.2
	52	-4.4	-4.7	-4.9	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-4.9	-4.9	-4.9	-4.9	-4.9	-4.8	-4.8	-4.8	-4.8	-4.8
A	50	-4.0	-4.4	-4.5	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.5	-4.5	-4.5	-4.5	-4.5	-4.5	-4.5	-4.4	-4.4
N	48	-3.6	-4.0	-4.2	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.1	-4.1	-4.1	-4.1	-4.1
G	46	-3.3	-3.7	-3.9	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.8	-3.8	-3.8	-3.8	-3.8
L	44	-3.0	-3.4	-3.6	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.5	-3.5
E	42	-2.7	-3.2	-3.4	-3.4	-3.5	-3.5	-3.5	-3.5	-3.5	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3
	40	-2.5	-2.9	-3.1	-3.2	-3.3	-3.3	-3.3	-3.3	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1
I	38	-2.3	-2.8	-3.0	-3.0	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-2.9	-2.9	-2.9	-2.9
N	36	-2.1	-2.6	-2.8	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8
	34	-2.0	-2.5	-2.7	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7
D	32	-1.9	-2.4	-2.6	-2.7	-2.7	-2.8	-2.8	-2.8	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6
E	30	-1.8	-2.3	-2.6	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.6	-2.6	-2.6	-2.6	-2.5	-2.6	-2.6	-2.6
G	28	-1.8	-2.3	-2.6	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6
R	26	-1.8	-2.4	-2.6	-2.7	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7
E	24	-1.9	-2.5	-2.7	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8
E	22	-2.0	-2.6	-2.9	-3.0	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
S	20	-2.2	-2.9	-3.1	-3.3	-3.3	-3.3	-3.4	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.2	-3.2	-3.2	-3.2	-3.2
	18	-2.5	-3.2	-3.5	-3.6	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.5	-3.6
	16	-2.9	-3.6	-3.9	-4.0	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
	14	-3.4	-4.1	-4.5	-4.6	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6
	12	-4.1	-4.8	-5.2	-5.3	-5.4	-5.5	-5.5	-5.5	-5.5	-5.5	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.3
	10	-5.0	-5.8	-6.1	-6.3	-6.4	-6.4	-6.4	-6.5	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.3	-6.3	-6.3
	8	-6.2	-7.1	-7.5	-7.6	-7.7	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7
	6	-8.0	-8.9	-9.3	-9.5	-9.6	-9.6	-9.7	-9.7	-9.7	-9.7	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6
	4	-10.7	-11.7	-12.2	-12.4	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.5	-12.4	-12.4
	2	-16.0	-17.0	-17.5	-17.7	-17.8	-17.9	-17.9	-17.9	-17.9	-17.9	-17.9	-17.9	-17.9	-17.9	-17.9	-17.8	-17.8	-17.8	-17.8	-17.8	-17.8
	0	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6	-50.6
		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

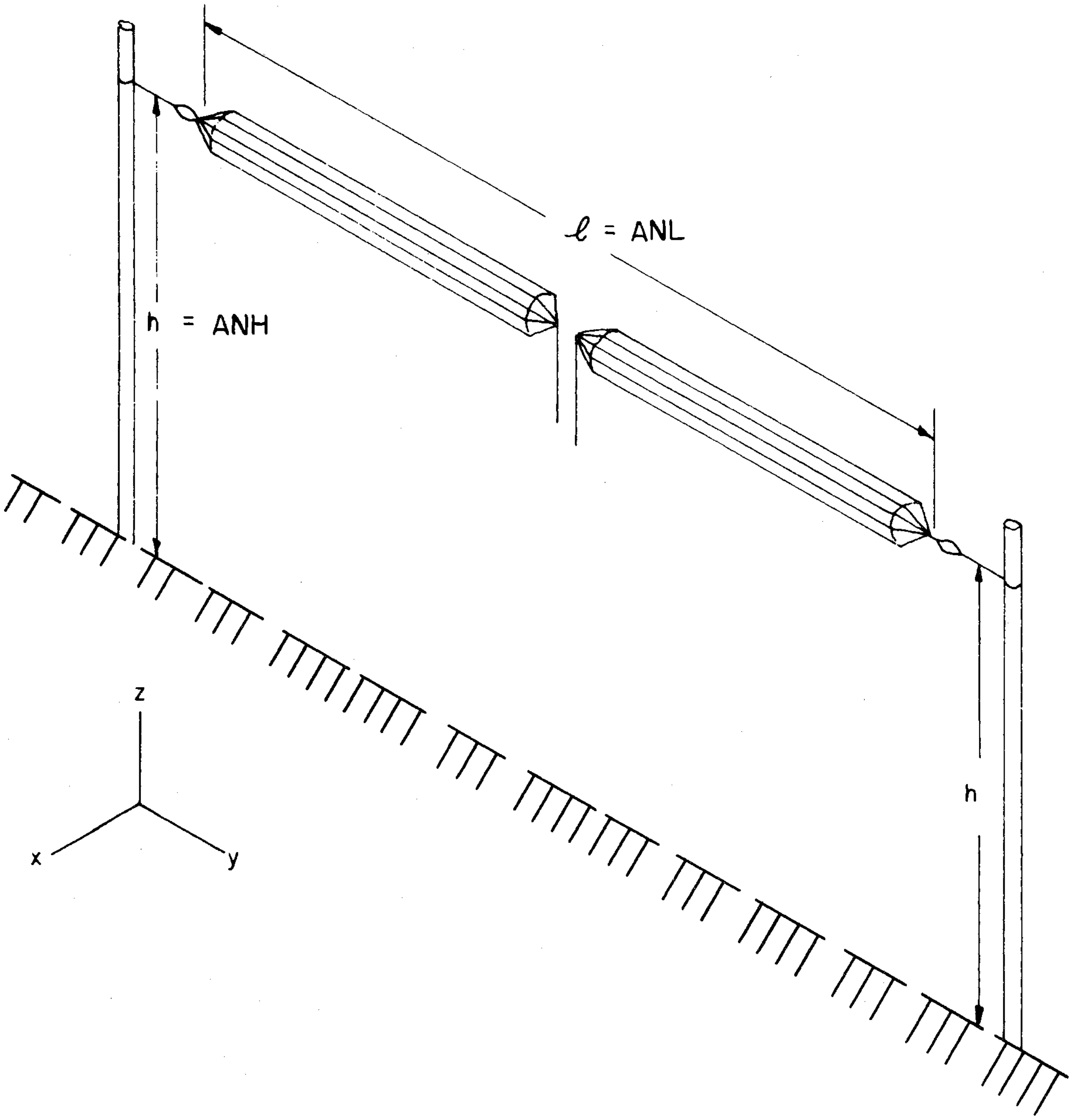
FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 46. Vertical monopole pattern.



True Bearing = AETA
Additional Gain Above 1/2 Wave Horiz. Dipole = AEX(1)

Figure 47. Horizontal dipole structure (3).

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ITS- 1 ANTENNA PACKAGE

ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	HORZ. DIPOLE	-.250	-.500	0.000	0.000	0.000	0.000	0.000	0.000	.001	4.000

ELEVATION ANGLE IN DEGREES	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
90	6.1	5.7	5.4	5.3	5.1	5.1	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
88	6.1	5.7	5.4	5.3	5.1	5.1	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
86	6.1	5.7	5.5	5.3	5.1	5.1	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
84	6.1	5.7	5.5	5.3	5.2	5.1	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
82	6.2	5.8	5.5	5.3	5.2	5.1	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
80	6.2	5.8	5.5	5.3	5.2	5.1	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
78	6.2	5.8	5.5	5.4	5.2	5.1	5.1	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8
76	6.2	5.8	5.6	5.4	5.3	5.2	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8
74	6.3	5.9	5.6	5.4	5.3	5.2	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8
72	6.3	5.9	5.6	5.5	5.3	5.2	5.2	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
E 70	6.3	5.9	5.7	5.5	5.4	5.3	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
L 68	6.4	6.0	5.7	5.5	5.4	5.3	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9
E 66	6.4	6.0	5.8	5.6	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9
V 64	6.4	6.1	5.8	5.6	5.5	5.4	5.3	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
A 62	6.5	6.1	5.8	5.6	5.5	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0
T 60	6.5	6.1	5.9	5.7	5.5	5.4	5.3	5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0
I 58	6.5	6.1	5.9	5.7	5.6	5.5	5.4	5.3	5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0
O 56	6.5	6.2	5.9	5.7	5.6	5.5	5.4	5.3	5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0
N 54	6.5	6.2	5.9	5.7	5.6	5.5	5.4	5.3	5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0
52	6.5	6.2	5.9	5.7	5.6	5.5	5.4	5.3	5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0
A 50	6.5	6.1	5.9	5.7	5.6	5.5	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	4.9	4.9
N 48	6.4	6.1	5.9	5.7	5.6	5.4	5.4	5.3	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9
G 46	6.4	6.1	5.8	5.7	5.5	5.4	5.3	5.3	5.2	5.1	5.1	5.1	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.8
L 44	6.3	6.0	5.8	5.6	5.5	5.4	5.3	5.2	5.1	5.1	5.0	5.0	5.0	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8
E 42	6.2	5.9	5.7	5.5	5.4	5.3	5.2	5.1	5.1	5.0	5.0	4.9	4.9	4.9	4.8	4.8	4.8	4.7	4.7	4.7	4.7
40	6.1	5.8	5.6	5.4	5.3	5.2	5.1	5.0	5.0	4.9	4.9	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6
I 38	5.9	5.7	5.5	5.3	5.2	5.1	5.0	4.9	4.8	4.8	4.8	4.7	4.7	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5
N 36	5.7	5.5	5.3	5.2	5.0	4.9	4.8	4.8	4.7	4.7	4.6	4.6	4.5	4.5	4.4	4.4	4.4	4.4	4.3	4.3	4.3
34	5.5	5.3	5.1	5.0	4.9	4.7	4.7	4.6	4.5	4.5	4.4	4.4	4.4	4.3	4.3	4.2	4.2	4.2	4.2	4.1	4.1
D 32	5.3	5.1	4.9	4.8	4.6	4.5	4.4	4.4	4.3	4.3	4.2	4.2	4.1	4.1	4.0	4.0	4.0	4.0	3.9	3.9	3.9
E 30	5.0	4.8	4.6	4.5	4.4	4.3	4.2	4.1	4.1	4.0	4.0	3.9	3.9	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7
G 28	4.6	4.5	4.3	4.2	4.1	4.0	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4
R 26	4.2	4.1	4.0	3.8	3.7	3.6	3.6	3.5	3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.1	3.1	3.1	3.0	3.0	3.0
E 24	3.8	3.7	3.5	3.4	3.3	3.2	3.1	3.1	3.0	3.0	2.9	2.9	2.9	2.8	2.8	2.7	2.7	2.7	2.6	2.6	2.6
E 22	3.2	3.1	3.0	2.9	2.8	2.7	2.7	2.6	2.5	2.5	2.5	2.4	2.4	2.3	2.3	2.2	2.2	2.2	2.2	2.1	2.1
S 20	2.6	2.6	2.5	2.4	2.3	2.2	2.1	2.1	2.0	1.9	1.9	1.9	1.8	1.8	1.7	1.7	1.7	1.6	1.6	1.6	1.6
18	1.9	1.9	1.8	1.7	1.6	1.5	1.5	1.4	1.3	1.3	1.3	1.2	1.2	1.1	1.1	1.0	1.0	1.0	1.0	.9	.9
16	1.1	1.1	1.0	.9	.8	.8	.7	.6	.6	.5	.5	.5	.4	.4	.3	.3	.3	.2	.2	.2	.2
14	.1	.1	.0	-.0	-.1	-.2	-.2	-.3	-.3	-.4	-.4	-.5	-.5	-.5	-.6	-.6	-.7	-.7	-.7	-.7	-.7
12	-1.0	-1.1	-1.1	-1.2	-1.2	-1.3	-1.3	-1.4	-1.4	-1.5	-1.5	-1.6	-1.6	-1.6	-1.7	-1.7	-1.7	-1.8	-1.8	-1.8	-1.8
10	-2.5	-2.5	-2.5	-2.5	-2.6	-2.6	-2.7	-2.8	-2.8	-2.8	-2.9	-2.9	-2.9	-3.0	-3.0	-3.1	-3.1	-3.1	-3.1	-3.2	-3.2
8	-4.3	-4.2	-4.2	-4.3	-4.3	-4.4	-4.4	-4.5	-4.5	-4.6	-4.6	-4.6	-4.7	-4.7	-4.8	-4.8	-4.8	-4.8	-4.9	-4.9	-4.9
6	-6.6	-6.6	-6.6	-6.6	-6.6	-6.7	-6.7	-6.8	-6.8	-6.9	-6.9	-6.9	-6.9	-7.0	-7.0	-7.1	-7.1	-7.1	-7.2	-7.2	-7.2
4	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0
2	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0
0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0
	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

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
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 48. Horizontal dipole pattern.

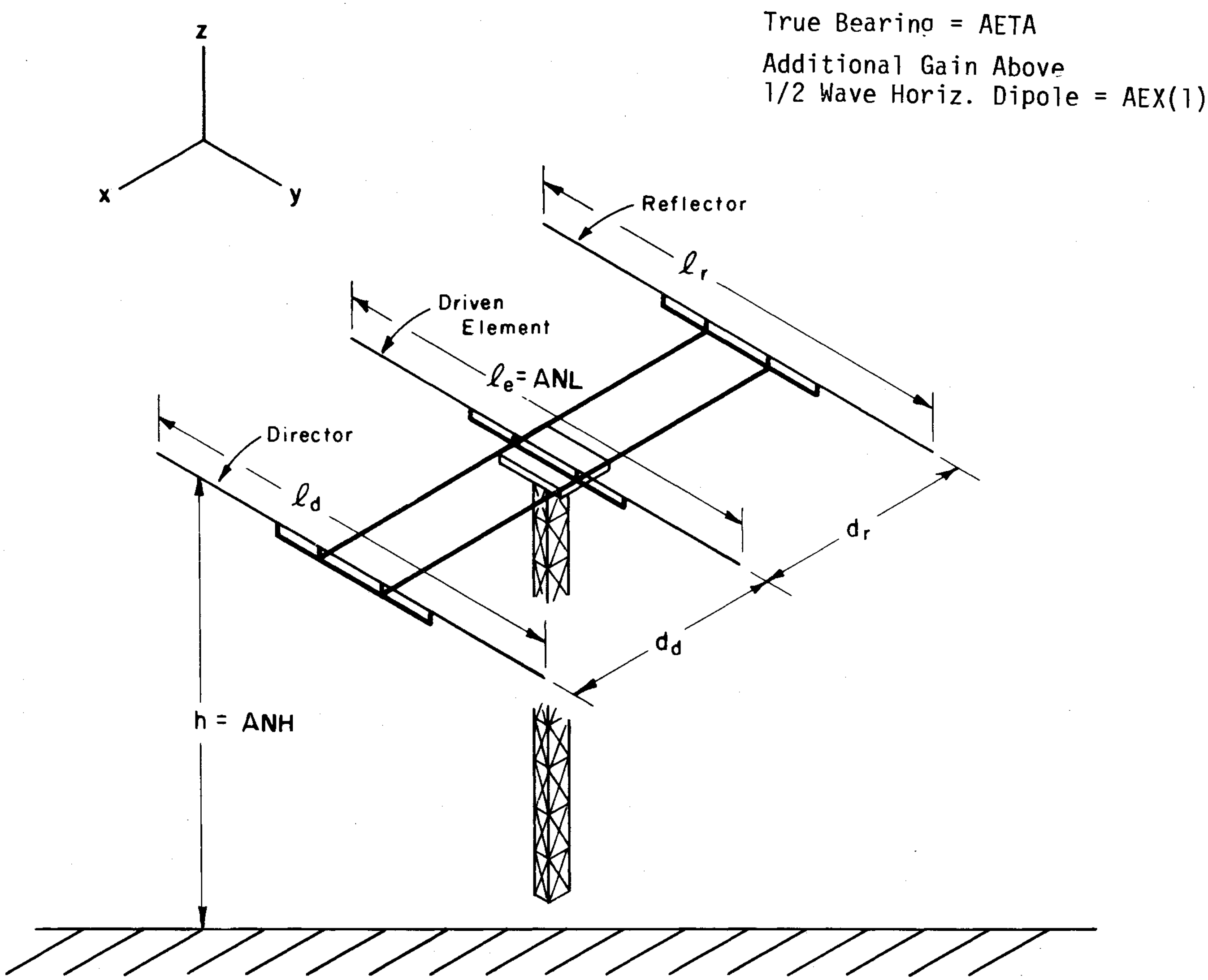

Figure 49. Horizontal Yagi structure (4).

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ITS- 1 ANTENNA PACKAGE ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	HORZ. YAGI	-.250	-.500	0.000	0.000	3.000	0.000	0.000	0.000	.001	4.000

	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
90	9.1	8.7	8.4	8.3	8.1	8.1	8.0	7.9	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
88	9.1	8.7	8.4	8.3	8.1	8.1	8.0	7.9	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
86	9.1	8.7	8.5	8.3	8.1	8.1	8.0	7.9	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
84	9.1	8.7	8.5	8.3	8.2	8.1	8.0	8.0	7.9	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
82	9.2	8.8	8.5	8.3	8.2	8.1	8.0	8.0	7.9	7.9	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
80	9.2	8.8	8.5	8.3	8.2	8.1	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
78	9.2	8.8	8.5	8.4	8.2	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.8	7.8
76	9.2	8.8	8.6	8.4	8.3	8.2	8.1	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.8
74	9.3	8.9	8.6	8.4	8.3	8.2	8.1	8.1	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.8	7.8
72	9.3	8.9	8.6	8.5	8.3	8.2	8.2	8.1	8.1	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9
E 70	9.3	8.9	8.7	8.5	8.4	8.3	8.2	8.1	8.1	8.1	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9	7.9	7.9
L 68	9.4	9.0	8.7	8.5	8.4	8.3	8.2	8.2	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9
E 66	9.4	9.0	8.8	8.6	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.0	8.0	7.9	7.9	7.9
V 64	9.4	9.1	8.8	8.6	8.5	8.4	8.3	8.2	8.2	8.1	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.9
A 62	9.5	9.1	8.8	8.6	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.0	8.0	8.0
T 60	9.5	9.1	8.9	8.7	8.5	8.4	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.0	8.0
I 58	9.5	9.1	8.9	8.7	8.6	8.5	8.4	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.0	8.0
O 56	9.5	9.2	8.9	8.7	8.6	8.5	8.4	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.0	8.0
N 54	9.5	9.2	8.9	8.7	8.6	8.5	8.4	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.0	8.0
52	9.5	9.2	8.9	8.7	8.6	8.5	8.4	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.0	8.0
A 50	9.5	9.1	8.9	8.7	8.6	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.0	7.9	7.9
N 48	9.4	9.1	8.9	8.7	8.6	8.4	8.4	8.3	8.2	8.2	8.1	8.1	8.1	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.9
G 46	9.4	9.1	8.8	8.7	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9	7.8
L 44	9.3	9.0	8.8	8.6	8.5	8.4	8.3	8.2	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.8
E 42	9.2	8.9	8.7	8.5	8.4	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.9	7.8	7.8	7.8	7.7	7.7	7.7	7.7
40	9.1	8.8	8.6	8.4	8.3	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7	7.7	7.7	7.6	7.6	7.6	7.6
I 38	8.9	8.7	8.5	8.3	8.2	8.1	8.0	7.9	7.8	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.5	7.5	7.5	7.5	7.5
N 36	8.7	8.5	8.3	8.2	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.4	7.3	7.3	7.3
34	8.5	8.3	8.1	8.0	7.9	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3	7.2	7.2	7.2	7.2	7.1	7.1
D 32	8.3	8.1	7.9	7.8	7.6	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	7.0	7.0	6.9	6.9	6.9
E 30	8.0	7.8	7.6	7.5	7.4	7.3	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.7	6.7
G 28	7.6	7.5	7.3	7.2	7.1	7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.4	6.4
R 26	7.2	7.1	7.0	6.8	6.7	6.6	6.6	6.5	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.0	6.0	6.0
E 24	6.8	6.7	6.5	6.4	6.3	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.7	5.7	5.7	5.6	5.6	5.6
E 22	6.2	6.1	6.0	5.9	5.8	5.7	5.7	5.6	5.5	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1
S 20	5.6	5.6	5.5	5.4	5.3	5.2	5.1	5.1	5.0	4.9	4.9	4.9	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6
18	4.9	4.9	4.8	4.7	4.6	4.5	4.5	4.4	4.3	4.3	4.3	4.2	4.2	4.1	4.1	4.0	4.0	4.0	4.0	3.9	3.9
16	4.1	4.1	4.0	3.9	3.8	3.8	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.2	3.2
14	3.1	3.1	3.0	3.0	2.9	2.8	2.8	2.7	2.7	2.6	2.6	2.5	2.5	2.5	2.4	2.4	2.3	2.3	2.3	2.3	2.3
12	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.5	1.5	1.4	1.4	1.4	1.3	1.3	1.3	1.2	1.2	1.2	1.2
10	.5	.5	.5	.5	.4	.4	.3	.2	.2	.2	.1	.1	.1	.0	-.0	-.1	-.1	-.1	-.1	-.2	-.2
8	-1.3	-1.2	-1.2	-1.3	-1.3	-1.4	-1.4	-1.5	-1.5	-1.6	-1.6	-1.6	-1.7	-1.7	-1.8	-1.8	-1.8	-1.8	-1.9	-1.9	-1.9
6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.7	-3.7	-3.8	-3.8	-3.9	-3.9	-3.9	-3.9	-4.0	-4.0	-4.1	-4.1	-4.1	-4.2	-4.2	-4.2
4	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.1	-7.1	-7.2	-7.2	-7.2	-7.2	-7.3	-7.3	-7.4	-7.4	-7.4	-7.5	-7.5	-7.5	-7.5
2	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0
0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0
	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

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
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 50. Horizontal Yagi pattern.

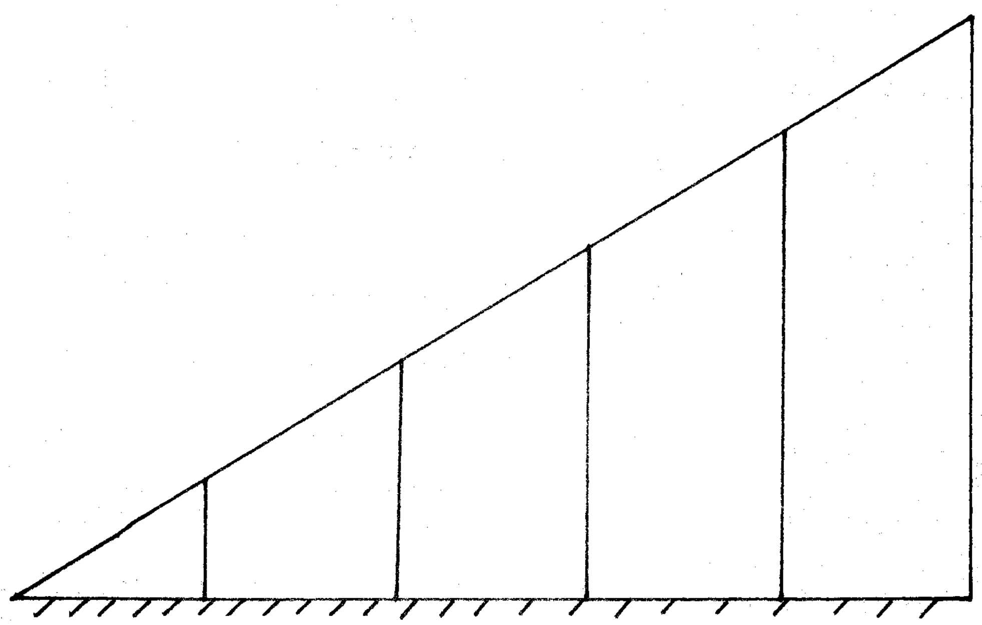

Figure 51. Vertical log periodic structure (5).

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ITS- 1 ANTENNA PACKAGE

ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	V LOG PERIOD	0.000	-.250	0.000	0.000	2.000	0.000	0.000	0.000	.001	4.000

		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
	90	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.5	-10.5	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.5	-10.6
	88	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.5	-10.5	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6
	86	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6
	84	-10.6	-10.6	-10.6	-10.6	-10.5	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.5	-10.5	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6
	82	-10.6	-10.6	-10.6	-10.6	-10.5	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.5	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6
	80	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6
	78	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.5	-10.6	-10.6	-10.6	-10.5	-10.6	-10.6	-10.5	-10.6
	76	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.5	-10.5	-10.6	-10.6	-10.6	-10.5	-10.6	-10.6	-10.6	-10.6
	74	-9.6	-9.9	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.0	-10.0	-9.9	-9.9	-9.9	-9.9
	72	-8.6	-8.9	-9.1	-9.2	-9.2	-9.2	-9.2	-9.1	-9.1	-9.1	-9.1	-9.1	-9.0	-9.0	-9.0	-9.0	-9.0	-8.9	-8.9	-8.9	-8.9
E	70	-7.7	-8.0	-8.2	-8.3	-8.3	-8.3	-8.3	-8.2	-8.2	-8.2	-8.2	-8.2	-8.1	-8.1	-8.1	-8.1	-8.1	-8.0	-8.0	-8.0	-8.0
L	68	-6.9	-7.2	-7.4	-7.4	-7.5	-7.5	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.3	-7.3	-7.3	-7.3	-7.2	-7.2	-7.2	-7.2	-7.2
E	66	-6.1	-6.5	-6.6	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.6	-6.6	-6.5	-6.6	-6.6	-6.5	-6.5	-6.5	-6.5	-6.5	-6.5
V	64	-5.4	-5.8	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-5.9	-5.9	-5.9	-5.9	-5.9	-5.8	-5.8	-5.8	-5.8	-5.8
A	62	-4.8	-5.2	-5.3	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.2	-5.2	-5.2	-5.2	-5.2
T	60	-4.2	-4.6	-4.8	-4.8	-4.9	-4.9	-4.9	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8	-4.7	-4.7	-4.7	-4.7	-4.7	-4.6	-4.6	-4.6
I	58	-3.7	-4.1	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3	-4.2	-4.2	-4.2	-4.2	-4.2	-4.1	-4.1	-4.1	-4.1
O	56	-3.2	-3.6	-3.8	-3.8	-3.9	-3.9	-3.9	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.6	-3.6
N	54	-2.8	-3.2	-3.3	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4	-3.3	-3.3	-3.3	-3.3	-3.3	-3.2	-3.2	-3.2	-3.2	-3.2
	52	-2.4	-2.7	-2.9	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-2.9	-2.9	-2.9	-2.9	-2.9	-2.8	-2.8	-2.8	-2.8	-2.8
A	50	-2.0	-2.4	-2.5	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.4	-2.4
N	48	-1.6	-2.0	-2.2	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.1	-2.1	-2.1	-2.1	-2.1
G	46	-1.3	-1.7	-1.9	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.8	-1.8	-1.8	-1.8	-1.8
L	44	-1.0	-1.4	-1.6	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.5	-1.5
E	42	-.7	-1.2	-1.4	-1.4	-1.5	-1.5	-1.5	-1.5	-1.5	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3
	40	-.5	-.9	-1.1	-1.2	-1.3	-1.3	-1.3	-1.3	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
I	38	-.3	-.8	-1.0	-1.0	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-.9	-.9	-.9	-.9
N	36	-.1	-.6	-.8	-.9	-.9	-.9	-.9	-.9	-.9	-.9	-.9	-.9	-.9	-.9	-.8	-.8	-.8	-.8	-.8	-.8	-.8
	34	-.0	-.5	-.7	-.8	-.8	-.8	-.8	-.8	-.8	-.8	-.8	-.8	-.8	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.7
D	32	.1	-.4	-.6	-.7	-.7	-.8	-.8	-.8	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.6	-.6	-.6	-.6	-.6	-.6
E	30	.2	-.3	-.6	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6
G	28	.2	-.3	-.6	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.6	-.6	-.6	-.6	-.6	-.6	-.6
R	26	.2	-.4	-.6	-.7	-.8	-.8	-.8	-.8	-.8	-.8	-.8	-.8	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.7	-.7
E	24	.1	-.5	-.7	-.9	-.9	-.9	-.9	-.9	-.9	-.9	-.9	-.9	-.9	-.8	-.8	-.8	-.8	-.8	-.8	-.8	-.8
E	22	-.0	-.6	-.9	-1.0	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
S	20	-.2	-.9	-1.1	-1.3	-1.3	-1.3	-1.4	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.2	-1.2	-1.2	-1.2	-1.2
	18	-.5	-1.2	-1.5	-1.6	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6
	16	-.9	-1.6	-1.9	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
	14	-1.4	-2.1	-2.5	-2.6	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6
	12	-2.1	-2.8	-3.2	-3.3	-3.4	-3.5	-3.5	-3.5	-3.5	-3.5	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4	-3.3
	10	-3.0	-3.8	-4.1	-4.3	-4.4	-4.4	-4.4	-4.5	-4.4	-4.4	-4.4	-4.4	-4.4	-4.4	-4.4	-4.4	-4.4	-4.4	-4.3	-4.3	-4.3
	8	-4.2	-5.1	-5.5	-5.6	-5.7	-5.8	-5.8	-5.8	-5.8	-5.8	-5.8	-5.8	-5.7	-5.7	-5.7	-5.7	-5.7	-5.7	-5.7	-5.7	-5.7
	6	-6.0	-6.9	-7.3	-7.5	-7.6	-7.6	-7.7	-7.7	-7.7	-7.7	-7.6	-7.6	-7.6	-7.6	-7.6	-7.6	-7.6	-7.6	-7.6	-7.6	-7.6
	4	-8.7	-9.7	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.5	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6
	2	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.5	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6
	0	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6	-10.6
		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6	-.6
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 52. Vertical log periodic pattern.

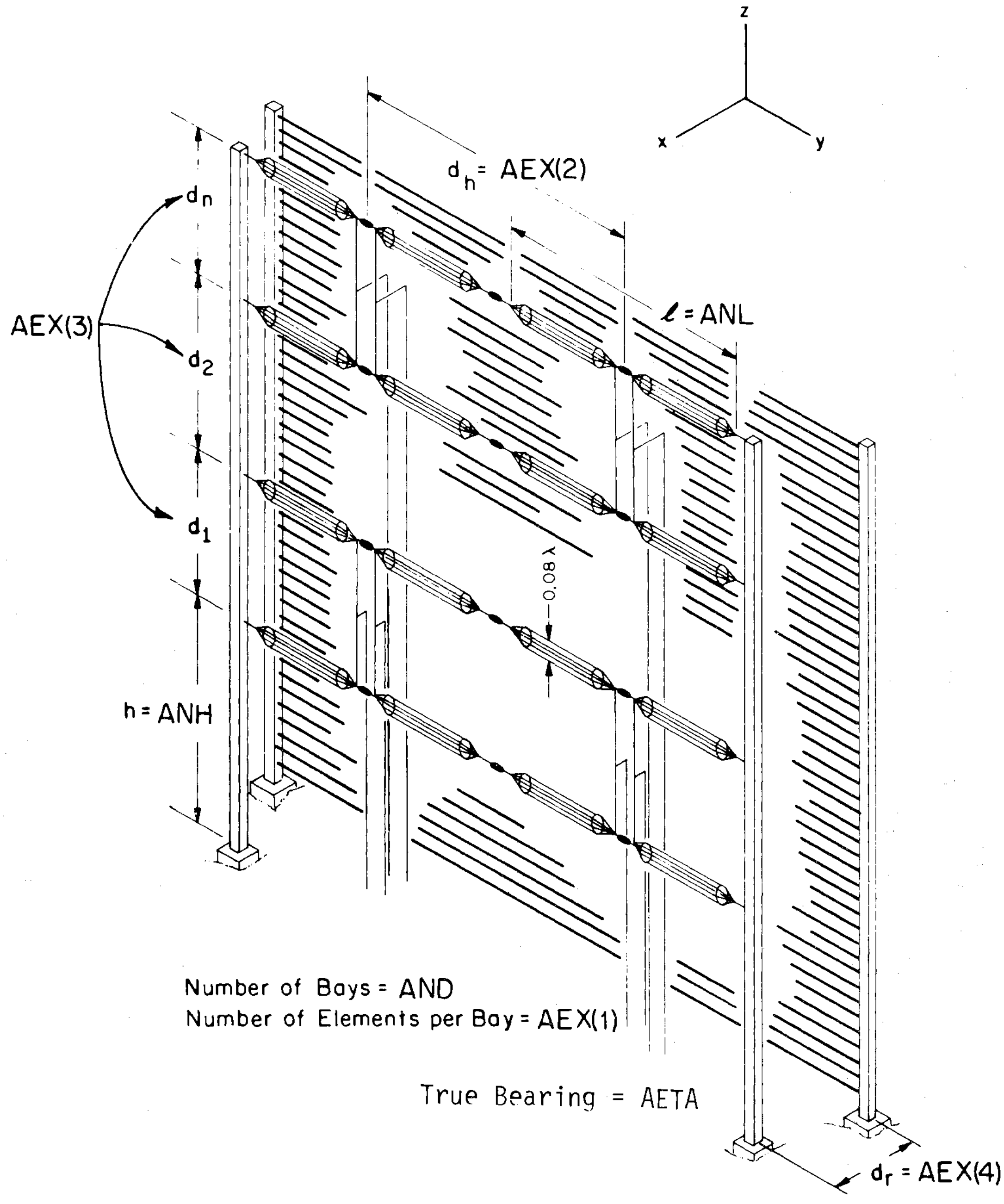

Figure 53. Curtain structure (6).

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ITS- 1 ANTENNA PACKAGE ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	CURTAIN ANT.	16.000	22.000	2.000	0.000	4.000	26.000	13.000	7.000	.001	4.000

		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
	90	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0
	88	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-8.8	-10.0	-10.0	-4.8	-5.1	-10.0	-10.0	-10.0	-10.0
	86	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-9.2	-10.0	-10.0	-10.0	-2.9	-6.8	-9.3	1.2	.7	-4.6	-10.0	-10.0	-10.0
	84	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-8.6	-5.7	-10.0	-10.0	-7.8	.4	-2.9	-6.8	4.7	3.7	-.9	-10.0	-10.0	-10.0
	82	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-6.3	-3.1	-8.9	-10.0	-6.0	2.6	.1	-6.0	7.1	5.6	1.7	-10.0	-10.0	-10.0
	80	-10.0	-10.0	-10.0	-10.0	-10.0	-9.8	-8.6	-4.7	-1.1	-6.1	-10.0	-4.8	4.0	2.7	-6.4	8.8	6.6	3.8	-10.0	-10.0	-10.0
	78	-10.0	-10.0	-10.0	-10.0	-10.0	-8.4	-6.8	-3.4	.6	-3.7	-10.0	-4.2	5.0	4.9	-8.5	10.1	7.0	5.5	-10.0	-10.0	-10.0
	76	-10.0	-10.0	-10.0	-10.0	-10.0	-7.3	-5.3	-2.5	1.9	-1.4	-10.0	-3.9	5.5	6.9	-10.0	10.9	7.0	6.7	-10.0	-10.0	-10.0
	74	-10.0	-10.0	-10.0	-10.0	-10.0	-6.4	-3.9	-1.9	3.0	.6	-10.0	-3.9	5.6	8.7	-10.0	11.3	6.9	7.6	-10.0	-10.0	-10.0
	72	-10.0	-10.0	-10.0	-10.0	-10.0	-5.8	-2.6	-1.4	3.9	2.5	-10.0	-4.0	5.3	10.2	-10.0	11.2	7.1	8.0	-10.0	-10.0	-10.0
E	70	-10.0	-10.0	-10.0	-10.0	-10.0	-5.5	-1.4	-1.1	4.6	4.2	-9.1	-4.3	4.6	11.5	-7.3	10.5	7.9	7.9	-10.0	-10.0	-10.0
L	68	-10.0	-10.0	-10.0	-10.0	-10.0	-5.4	-.4	-.7	5.1	5.7	-3.9	-5.1	3.4	12.5	-3.2	9.1	9.1	7.3	-9.2	-10.0	-7.2
E	66	-10.0	-10.0	-10.0	-10.0	-10.0	-5.6	.5	-.2	5.3	6.9	.1	-7.1	1.9	13.1	.6	6.6	10.1	5.8	-7.7	-10.0	-3.8
V	64	-10.0	-10.0	-10.0	-10.0	-10.0	-6.3	1.3	.5	5.2	7.9	3.2	-10.0	.4	13.4	4.3	2.6	10.6	3.6	-7.0	-10.0	-1.9
A	62	-10.0	-9.0	-10.0	-10.0	-10.0	-7.6	1.8	1.6	4.9	8.7	5.8	-10.0	-.8	13.1	7.6	-4.3	10.3	1.2	-7.1	-10.0	-1.6
T	60	-10.0	-8.2	-9.1	-9.6	-8.4	-9.8	2.1	2.8	4.3	9.1	7.8	-4.8	-2.1	12.3	10.2	-10.0	9.0	.6	-8.2	-10.0	-3.0
I	58	-10.0	-7.3	-7.7	-9.4	-6.8	-10.0	2.2	3.9	3.7	9.1	9.4	1.6	-5.0	10.7	12.1	-9.5	6.5	1.8	-10.0	-10.0	-5.5
O	56	-10.0	-6.5	-6.3	-9.0	-5.5	-10.0	1.8	5.0	3.5	8.8	10.6	5.7	-10.0	8.3	13.2	-3.3	2.1	2.4	-10.0	-10.0	-4.6
N	54	-10.0	-5.7	-4.9	-8.5	-4.5	-10.0	1.0	5.8	4.2	7.9	11.2	8.6	-6.2	4.9	13.5	2.1	-5.6	1.7	-10.0	-10.0	-1.9
	52	-10.0	-5.0	-3.6	-7.6	-3.9	-9.7	-.5	6.3	5.5	6.7	11.3	10.7	2.6	1.4	12.8	6.3	-10.0	-.8	-10.0	-10.0	-1.3
A	50	-10.0	-4.3	-2.3	-6.2	-3.5	-5.5	-3.3	6.3	6.9	5.6	10.7	12.0	7.4	-.8	11.0	8.9	-10.0	-5.7	-10.0	-10.0	-3.4
N	48	-10.D	-3.6	-1.1	-4.5	-3.4	-2.8	-9.0	5.8	8.1	5.7	9.5	12.5	10.4	-4.2	7.7	10.0	-6.3	-10.0	-10.0	-10.0	-9.1
G	46	-10.0	-3.0	.1	-2.5	-3.6	-1.0	-10.0	4.5	8.9	7.2	7.6	12.1	12.2	-10.0	2.7	9.6	-.6	-10.0	-10.0	-10.0	-10.0
L	44	-10.0	-2.5	1.2	-.5	-3.7	.1	-7.4	2.0	8.9	9.0	6.3	10.8	12.9	.8	-2.0	7.5	2.3	-10.0	-10.0	-10.0	-10.0
E	42	-10.0	-2.0	2.2	1.4	-3.1	.6	-1.7	-3.0	8.2	10.3	7.5	8.5	12.4	7.4	-4.5	3.3	3.0	-10.0	-10.0	-10.0	-10.0
	40	-10.0	-1.5	3.1	3.3	-1.3	.4	1.3	-10.0	6.4	10.7	9.7	6.5	10.7	10.7	-10.0	-3.6	1.3	-10.0	-10.0	-10.0	-10.0
I	38	-10.0	-1.1	4.0	4.9	1.3	-.2	2.9	-4.1	2.5	10.2	11.3	8.1	7.6	12.0	-1.0	-8.2	-3.1	-10.0	-10.0	-10.0	-10.0
N	36	-10.0	-.7	4.8	6.4	4.1	-.3	3.4	1.9	-8.0	8.3	11.8	10.7	6.4	11.5	5.9	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0
	34	-10.0	-.4	5.5	7.8	6.6	1.5	2.9	4.6	-4.4	3.8	10.9	12.2	9.5	8.8	8.6	-8.7	-10.0	-10.0	-10.0	-10.0	-10.0
D	32	-10.0	-.2	6.1	9.0	8.8	4.9	1.9	5.5	3.5	-10.0	8.0	12.0	11.8	4.4	8.6	.2	-10.0	-10.0	-10.0	-10.0	-10.0
E	30	-10.0	-.1	6.6	10.1	10.8	8.4	2.9	4.8	6.4	.4	.5	9.9	12.2	6.4	5.6	2.9	-10.0	-10.0	-10.0	-10.0	-8.0
G	28	-10.0	.0	7.0	11.0	12.4	11.3	7.0	3.3	6.9	6.3	-4.8	3.9	10.4	10.0	-.1	1.8	-8.8	-10.0	-10.0	-10.0	-8.2
R	26	-10.0	.0	7.3	11.7	13.8	13.8	11.2	5.5	5.2	7.9	5.8	-10.0	4.5	10.7	3.7	-3.7	-8.9	-10.0	-10.0	-10.0	-10.0
E	24	-10.0	-.1	7.5	12.3	15.0	15.8	14.6	10.9	4.8	6.5	8.3	5.6	-10.0	8.2	6.8	-5.9	-10.0	-10.0	-10.0	-10.0	-10.0
E	22	-10.0	-.2	7.6	12.8	15.9	17.4	17.3	15.3	10.9	4.8	6.9	8.4	5.9	-1.5	5.9	-.7	-10.0	-10.0	-10.0	-10.0	-10.0
S	20	-10.0	-.5	7.6	13.0	16.6	18.7	19.4	18.6	16.2	11.6	5.0	6.3	7.9	-.2	-.9	-1.1	-10.0	-10.0	-10.0	-10.0	-9.2
	18	-10.0	-1.0	7.4	13.1	17.1	19.6	20.9	21.1	20.0	17.5	13.2	6.4	4.1	5.7	-7.4	-8.2	-10.0	-10.0	-10.0	-10.0	-9.3
	16	-10.0	-1.5	7.0	13.0	17.3	20.2	22.1	22.9	22.7	21.6	19.3	15.5	9.7	2.4	1.2	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0
	14	-10.0	-2.3	6.4	12.6	17.2	20.5	22.7	24.1	24.6	24.3	23.2	21.1	18.0	7.2	-3.6	-7.5	-10.0	-10.0	-10.0	-10.0	-7.7
	12	-10.0	-3.2	5.6	12.0	16.8	20.4	23.0	24.7	25.7	26.1	25.7	24.6	22.8	16.6	5.4	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0
	10	-10.0	-4.5	4.5	11.1	16.0	19.8	22.7	24.8	26.2	26.9	27.1	26.6	25.6	21.4	14.0	.8	-10.0	-10.0	-10.0	-10.0	-10.0
	8	-10.0	-6.1	2.9	9.6	14.8	18.8	21.9	24.2	25.9	27.0	27.5	27.4	26.8	23.9	18.0	7.0	-10.0	-6.9	-10.0	-10.0	-10.0
	6	-10.0	-8.4	.8	7.6	12.9	17.0	20.2	22.8	24.6	26.0	26.7	27.0	26.7	24.5	19.6	9.5	-5.9	-.0	-10.0	-10.0	1.5
	4	-10.0	-10.0	-2.5	4.4	9.8	14.0	17.4	20.0	22.1	23.5	24.5	24.9	24.9	23.1	18.7	9.1	-3.9	1.9	-9.7	-10.0	7.2
	2	-10.0	-10.0	-8.3	-1.3	4.1	8.4	11.8	14.5	16.7	18.2	19.3	19.8	19.9	18.4	14.3	4.9	-6.9	-1.1	-10.0	-10.0	5.7
	0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0
		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

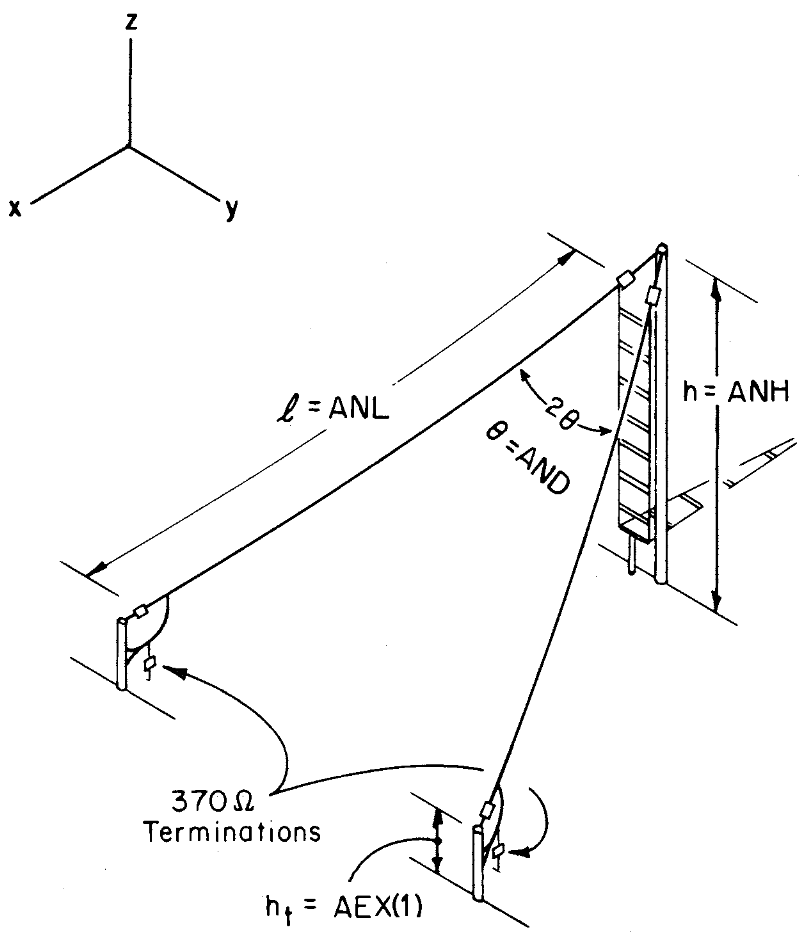
FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

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
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 54. Curtain pattern.



True Bearing = AETA

Figure 55. Sloping vee structure (7).

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ITS- 1 ANTENNA PACKAGE ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	TER SLOP VEE	15.240	121.900	22.500	0.000	1.829	0.000	0.000	0.000	.001	4.000

		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
	90	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7
	88	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-9.3	-11.7	-11.7	-11.7
	86	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7
	84	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-9.8	-11.7	-11.7	-11.7	-11.7	-9.6	-11.7	-11.7
	82	-11.7	-11.7	-9.8	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-9.3	-11.7	-11.7	-11.7	-11.7	-8.5	-11.7	-11.7	-11.7
	80	-11.7	-11.7	-9.6	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-10.0	-11.7	-11.7	-11.7	-9.7	-11.7	-11.7	-11.7	-11.7
	78	-11.7	-11.7	-9.5	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-8.3	-11.7	-11.7
	76	-11.7	-11.7	-9.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-9.3	-11.7	-11.7	-11.7	-8.2	-9.7	-11.7	-11.7
	74	-11.7	-11.7	-11.7	-9.1	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-8.9	-11.7	-8.0	-11.7	-11.7	-11.7	-9.1	-11.7	-8.4	-11.7
	72	-11.7	-11.7	-11.7	-8.3	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-8.6	-11.7	-11.7	-11.7	-11.7	-11.7	-7.1	-11.7	-11.7
E	70	-11.7	-11.7	-11.7	-7.8	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-7.7	-11.7	-8.9	-11.7	-11.7	-8.9	-8.2	-11.7	-8.6
L	68	-10.0	-11.7	-11.7	-7.7	-9.4	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-9.5	-11.7	-8.0	-11.7	-11.7	-7.3	-11.7	-6.2	-11.7
E	66	-9.6	-11.7	-11.7	-7.7	-8.0	-11.7	-11.7	-11.7	-11.7	-11.7	-9.9	-11.7	-11.7	-7.1	-11.7	-11.7	-9.5	-11.7	-6.5	-11.7	-9.6
V	64	-9.2	-11.7	-11.7	-8.1	-7.0	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-9.6	-11.7	-6.0	-11.7	-8.2	-11.7	-11.7	-6.4	-11.7	-6.8
A	62	-8.9	-9.3	-11.7	-8.7	-6.5	-9.2	-11.7	-11.7	-11.7	-11.7	-11.7	-8.2	-11.7	-8.1	-8.5	-11.7	-11.7	-7.1	-11.7	-4.4	-11.7
T	60	-8.6	-8.3	-11.7	-9.4	-6.3	-7.3	-11.7	-11.7	-11.7	-11.7	-11.7	-9.0	-7.2	-11.7	-5.2	-11.7	-9.0	-11.7	-7.4	-8.9	-5.4
I	58	-8.4	-7.5	-11.7	-11.7	-6.4	-6.1	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-6.8	-11.7	-5.9	-9.2	-11.7	-11.7	-5.2	-11.7	-5.2
O	56	-8.2	-6.8	-9.2	-11.7	-6.9	-5.5	-7.6	-11.7	-11.7	-11.7	-11.7	-11.7	-8.8	-6.5	-11.7	-4.8	-11.7	-8.4	-11.7	-3.6	-11.7
N	54	-8.0	-6.2	-7.8	-11.7	-7.6	-5.3	-5.9	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-4.4	-11.7	-5.5	-8.1	-9.7	-11.7	-6.3	-3.4
	52	-7.9	-5.6	-6.6	-9.5	-8.5	-5.5	-4.9	-7.4	-11.7	-11.7	-11.7	-11.7	-11.7	-5.1	-5.3	-11.7	-4.6	-11.7	-6.2	-11.7	-3.5
A	50	-7.8	-5.2	-5.5	-8.0	-9.0	-6.1	-4.5	-5.4	-9.9	-11.7	-11.7	-9.6	-11.7	-8.8	-2.7	-11.7	-6.8	-6.3	-9.5	-4.9	-11.7
N	48	-7.8	-4.8	-4.5	-6.4	-8.7	-6.9	-4.6	-4.3	-6.5	-11.7	-11.7	-11.7	-8.9	-11.7	-3.2	-3.3	-11.7	-5.2	-9.4	-5.3	-4.1
G	46	-7.8	-4.4	-3.7	-5.0	-7.5	-7.5	-5.1	-3.8	-4.6	-8.0	-11.7	-11.7	-8.5	-11.7	-7.0	-1.3	-5.5	-11.7	-5.3	-11.7	-2.8
L	44	-7.8	-4.2	-3.0	-3.7	-5.8	-7.5	-5.9	-4.0	-3.6	-5.1	-9.5	-11.7	-11.7	-7.0	-11.7	-2.6	-.9	-9.1	-8.9	-6.2	-11.7
E	42	-7.9	-4.0	-2.5	-2.6	-4.1	-6.3	-6.5	-4.7	-3.4	-3.6	-5.7	-11.7	-11.7	-5.7	-8.5	-8.1	-.6	-1.2	-11.7	-7.1	-7.1
	40	-8.0	-3.9	-2.0	-1.7	-2.6	-4.5	-6.2	-5.5	-3.8	-3.0	-3.6	-6.1	-11.7	-7.0	-4.2	-11.7	-4.0	.4	-1.6	-11.7	-5.7
I	38	-8.1	-3.8	-1.7	-.9	-1.3	-2.7	-4.7	-5.7	-4.6	-3.2	-2.7	-3.6	-6.2	-11.7	-3.4	-3.8	-11.7	-1.9	1.0	-1.7	-11.7
N	36	-8.3	-3.9	-1.4	-.3	-.3	-1.1	-2.7	-4.6	-5.1	-3.9	-2.8	-2.5	-3.5	-9.9	-5.1	-1.4	-3.7	-8.5	-.8	1.4	-1.3
	34	-8.6	-3.9	-1.3	.1	.6	.2	-.9	-2.6	-4.2	-4.5	-3.5	-2.5	-2.3	-5.5	-8.6	-1.9	-.1	-3.4	-7.3	-.3	1.8
D	32	-8.8	-4.1	-1.2	.5	1.2	1.3	.7	-.5	-2.2	-3.8	-4.1	-3.2	-2.3	-2.8	-7.7	-4.8	.2	1.0	-2.5	-6.9	-.3
E	30	-9.2	-4.2	-1.2	.7	1.7	2.2	2.0	1.3	.0	-1.7	-3.2	-3.7	-3.0	-1.8	-3.8	-7.9	-2.0	1.7	2.1	-1.1	-6.7
G	28	-9.5	-4.5	-1.3	.8	2.1	2.8	3.0	2.7	1.9	.7	-.9	-2.5	-3.2	-2.0	-1.7	-4.6	-6.2	-.2	2.9	3.3	.7
R	26	-10.0	-4.8	-1.5	.7	2.3	3.2	3.7	3.8	3.5	2.7	1.5	.0	-1.5	-2.6	-1.3	-1.7	-4.9	-4.6	.9	3.9	4.4
E	24	-11.7	-5.2	-1.8	.6	2.3	3.5	4.3	4.6	4.6	4.3	3.6	2.5	1.1	-1.7	-1.7	-.7	-1.4	-4.5	-3.5	1.6	4.5
E	22	-11.7	-5.7	-2.2	.4	2.2	3.6	4.5	5.2	5.5	5.5	5.2	4.5	3.6	1.0	-1.3	-.8	.1	-.7	-3.3	-3.0	1.7
S	20	-11.7	-6.3	-2.7	-.0	2.0	3.5	4.6	5.5	6.0	6.3	6.3	6.0	5.5	3.7	1.2	-.4	.3	1.1	.5	-1.6	-2.5
	18	-11.7	-7.0	-3.3	-.5	1.6	3.2	4.5	5.5	6.2	6.7	7.0	7.0	6.9	5.9	4.1	1.9	.8	1.6	2.4	2.1	.6
	16	-11.7	-7.8	-4.0	-1.2	1.0	2.8	4.2	5.3	6.2	5.9	7.3	7.6	7.7	7.3	6.3	4.6	2.9	2.4	3.1	3.9	4.0
	14	-11.7	-8.7	-4.9	-2.0	.3	2.1	3.6	4.9	5.9	6.7	7.3	7.8	8.1	8.2	7.7	6.7	5.3	4.1	4.0	4.8	5.6
	12	-11.7	-9.9	-6.0	-3.0	-.7	1.2	2.8	4.1	5.3	6.2	6.9	7.5	8.0	8.5	8.5	8.0	7.1	6.1	5.4	5.6	6.4
	10	-11.7	-11.7	-7.3	-4.3	-2.0	.0	1.7	3.1	4.3	5.3	6.1	6.9	7.4	8.2	8.5	8.4	8.0	7.3	6.7	6.5	7.0
	8	-11.7	-11.7	-9.1	-6.0	-3.6	-1.6	.1	1.6	2.8	3.9	4.9	5.7	6.3	7.3	7.9	8.1	8.0	7.7	7.2	7.0	7.2
	6	-11.7	-11.7	-11.7	-8.3	-5.9	-3.8	-2.0	-.5	.8	1.9	2.9	3.8	4.5	5.6	6.4	6.8	7.0	6.9	6.6	6.5	6.6
	4	-11.7	-11.7	-11.7	-11.7	-9.2	-7.1	-5.3	-3.7	-2.4	-1.2	-.2	.7	1.5	2.7	3.6	4.2	4.5	4.6	4.5	4.5	4.6
	2	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-9.5	-8.2	-7.0	-5.9	-5.0	-4.2	-2.9	-1.9	-1.2	-.9	-.7	-.6	-.6	-.5
	0	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7
		2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

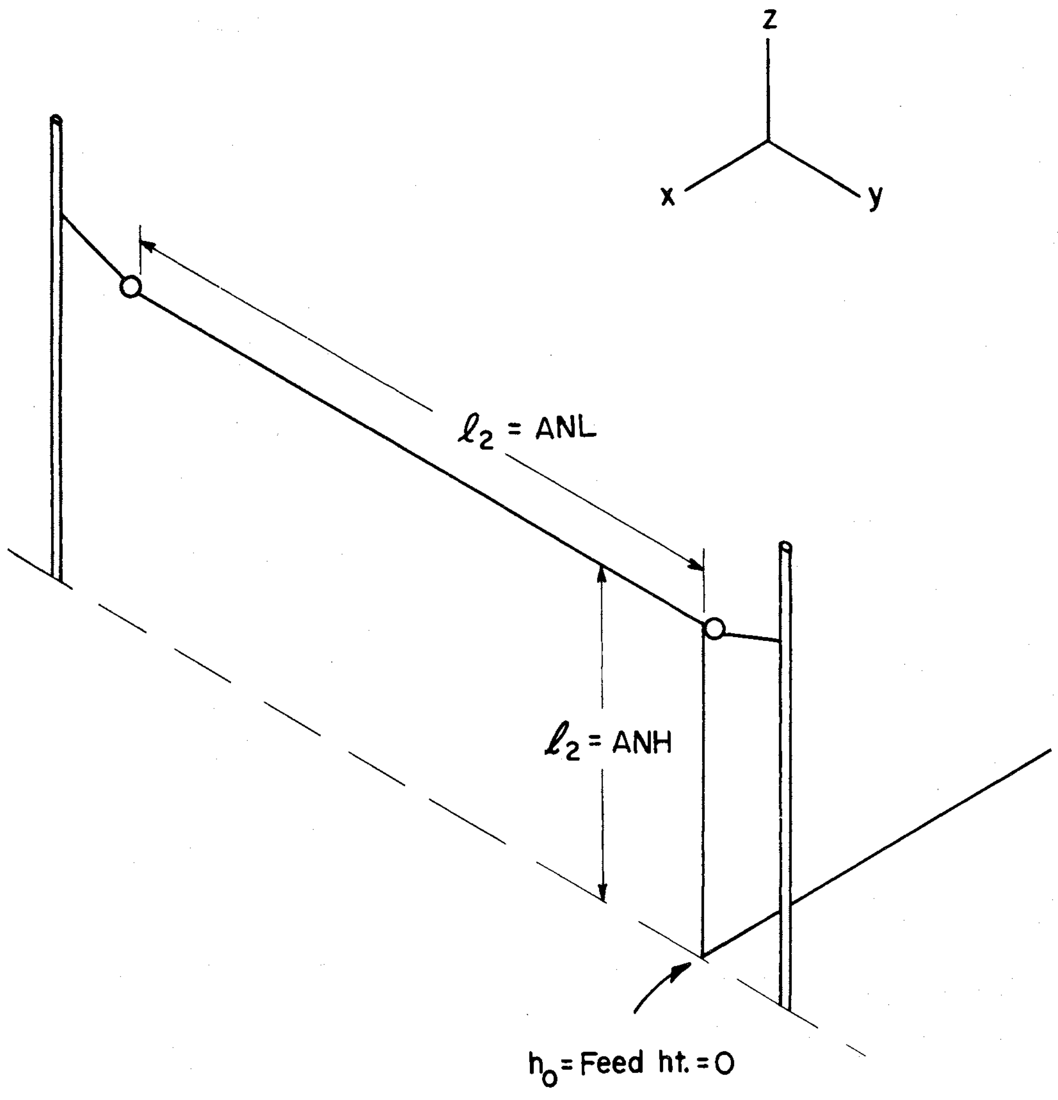
FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 56. Sloping vee pattern.



True Bearing = AETA

Figure 57. Inverted L structure (8).

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ITS- 1 ANTENNA PACKAGE ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	INVERTED L	10.000	21.340	0.000	0.000	0.000	0.000	0.000	0.000	.001	4.000

	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
90	-2.6	7.8	13.3	15.7	16.3	15.0	12.1	7.6	.9	-8.6	-10.0	-10.0	-10.0	-10.0	.0	11.3	11.8	2.1	-10.0	-10.0	-10.0
88	-2.5	7.8	13.3	15.7	16.3	15.0	12.1	7.6	.9	-8.6	-10.0	-10.0	-10.0	-10.0	.0	11.3	11.8	2.1	-10.0	-10.0	-10.0
86	-2.2	7.9	13.3	15.7	16.3	15.0	12.2	7.6	.9	-8.6	-10.0	-10.0	-10.0	-10.0	.0	11.3	11.8	2.1	-10.0	-10.0	-10.0
84	-1.9	7.9	13.3	15.7	16.3	15.0	12.2	7.6	1.0	-8.5	-10.0	-10.0	-10.0	-10.0	-.0	11.3	11.8	2.2	-10.0	-10.0	-10.0
82	-1.4	7.9	13.3	15.7	16.3	15.0	12.2	7.7	1.0	-8.3	-10.0	-10.0	-10.0	-10.0	-.0	11.2	11.8	2.3	-10.0	-10.0	-10.0
80	-.9	8.0	13.3	15.7	16.3	15.0	12.2	7.7	1.1	-8.2	-10.0	-10.0	-10.0	-10.0	-.0	11.1	11.9	2.4	-10.0	-10.0	-10.0
78	-.3	8.0	13.3	15.7	16.3	15.0	12.3	7.8	1.2	-8.0	-10.0	-10.0	-10.0	-10.0	-.0	11.1	11.9	2.5	-9.1	-10.0	-9.4
76	.3	8.1	13.3	15.7	16.3	15.1	12.3	7.8	1.3	-7.8	-10.0	-10.0	-10.0	-10.0	-.0	11.0	11.9	2.6	-7.9	-10.0	-8.2
74	.8	8.1	13.2	15.7	16.3	15.1	12.4	7.9	1.4	-7.5	-10.0	-10.0	-10.0	-9.3	-.0	10.8	11.9	2.8	-6.9	-9.1	-7.3
72	1.4	8.2	13.2	15.7	16.3	15.1	12.4	8.0	1.5	-7.3	-10.0	-10.0	-10.0	-8.4	-.1	10.7	11.9	2.9	-6.0	-7.9	-6.5
E 70	1.9	8.3	13.2	15.6	16.3	15.1	12.5	8.1	1.6	-7.1	-10.0	-10.0	-10.0	-7.6	-.1	10.5	11.8	3.0	-5.3	-6.8	-5.9
L 68	2.4	8.3	13.2	15.6	16.3	15.2	12.5	8.2	1.8	-6.8	-10.0	-10.0	-10.0	-7.0	-.0	10.2	11.8	3.2	-4.6	-5.7	-5.4
E 66	2.9	8.4	13.1	15.6	16.3	15.2	12.6	8.3	1.9	-6.6	-10.0	-10.0	-10.0	-6.4	-.0	9.9	11.7	3.3	-4.1	-4.8	-5.0
V 64	3.4	8.5	13.1	15.6	16.2	15.2	12.6	8.4	2.1	-6.4	-9.8	-9.4	-10.0	-6.0	.0	9.6	11.6	3.4	-3.6	-3.9	-4.7
A 62	3.8	8.5	13.1	15.5	16.2	15.2	12.7	8.5	2.2	-6.2	-9.4	-8.7	-10.0	-5.5	.1	9.1	11.4	3.5	-3.3	-3.1	-4.4
T 60	4.2	8.6	13.0	15.5	16.2	15.2	12.7	8.6	2.4	-5.9	-8.9	-8.1	-9.4	-5.2	.2	8.7	11.2	3.5	-3.0	-2.3	-4.3
I 58	4.6	8.7	13.0	15.4	16.2	15.2	12.8	8.7	2.6	-5.7	-8.5	-7.5	-8.7	-4.9	.3	8.1	10.9	3.6	-2.7	-1.6	-4.1
O 56	4.9	8.7	12.9	15.4	16.2	15.2	12.8	8.8	2.7	-5.5	-8.2	-7.0	-8.0	-4.7	.5	7.5	10.5	3.6	-2.6	-.9	-4.0
N 54	5.2	8.8	12.8	15.3	16.1	15.2	12.9	8.9	2.9	-5.3	-7.9	-6.5	-7.3	-4.5	.7	6.8	10.1	3.5	-2.5	-.3	-3.9
52	5.5	8.8	12.8	15.2	16.1	15.2	12.9	9.0	3.0	-5.2	-7.7	-6.0	-6.7	-4.4	1.0	6.1	9.6	3.4	-2.4	.2	-3.7
A 50	5.8	8.9	12.7	15.1	16.0	15.2	12.9	9.1	3.2	-5.0	-7.5	-5.6	-6.0	-4.3	1.3	5.5	9.0	3.3	-2.5	.6	-3.4
N 48	6.0	8.9	12.6	15.0	15.9	15.2	13.0	9.1	3.3	-4.8	-7.3	-5.2	-5.4	-4.3	1.6	5.1	8.4	3.1	-2.5	1.0	-3.1
G 46	6.2	8.9	12.4	14.9	15.8	15.1	12.9	9.2	3.4	-4.7	-7.2	-4.8	-4.9	-4.2	2.0	5.2	7.8	2.9	-2.7	1.4	-2.8
L 44	6.4	8.9	12.3	14.7	15.7	15.0	12.9	9.2	3.5	-4.6	-7.1	-4.5	-4.4	-4.2	2.4	5.6	7.2	2.8	-2.8	1.6	-2.4
E 42	6.6	8.9	12.2	14.6	15.6	14.9	12.9	9.3	3.6	-4.5	-7.0	-4.2	-3.9	-4.2	2.8	6.5	7.0	2.6	-3.0	1.8	-2.0
40	6.7	8.9	12.0	14.4	15.4	14.8	12.8	9.3	3.7	-4.4	-7.0	-3.9	-3.4	-4.1	3.3	7.5	7.1	2.4	-3.2	1.9	-1.7
I 38	6.8	8.8	11.8	14.2	15.3	14.7	12.7	9.2	3.7	-4.3	-7.0	-3.7	-3.0	-4.1	3.7	8.6	7.5	2.4	-3.4	1.8	-1.4
N 36	6.9	8.8	11.6	14.0	15.1	14.5	12.6	9.2	3.8	-4.3	-7.1	-3.5	-2.6	-4.0	4.0	9.7	8.4	2.5	-3.6	1.8	-1.2
34	6.9	8.7	11.4	13.7	14.8	14.4	12.5	9.1	3.8	-4.3	-7.2	-3.4	-2.2	-3.8	4.4	10.7	9.3	2.7	-3.7	1.6	-1.2
D 32	7.0	8.6	11.1	13.4	14.6	14.1	12.3	9.0	3.7	-4.3	-7.3	-3.3	-1.9	-3.7	4.7	11.6	10.3	3.0	-3.8	1.3	-1.2
E 30	6.9	8.4	10.8	13.1	14.3	13.9	12.1	8.8	3.6	-4.4	-7.5	-3.2	-1.7	-3.5	4.9	12.4	11.3	3.4	-3.8	.9	-1.5
G 28	6.9	8.3	10.5	12.7	13.9	13.6	11.8	8.6	3.5	-4.5	-7.7	-3.2	-1.5	-3.3	5.1	13.0	12.1	3.9	-3.8	.5	-1.9
R 26	6.8	8.0	10.1	12.3	13.5	13.2	11.5	8.4	3.3	-4.6	-8.0	-3.2	-1.4	-3.1	5.2	13.5	12.8	4.4	-3.8	.1	-2.4
E 24	6.7	7.8	9.6	11.8	13.1	12.8	11.2	8.0	3.0	-4.8	-8.3	-3.3	-1.3	-2.9	5.3	13.9	13.4	4.8	-3.8	-.4	-3.1
E 22	6.5	7.5	9.2	11.3	12.6	12.3	10.7	7.7	2.7	-5.1	-8.7	-3.4	-1.3	-2.8	5.2	14.1	13.8	5.1	-3.9	-.9	-4.0
S 20	6.2	7.1	8.6	10.7	12.0	11.7	10.2	7.2	2.3	-5.5	-9.1	-3.7	-1.4	-2.8	5.0	14.2	14.0	5.3	-4.0	-1.3	-4.9
18	5.9	6.6	8.0	10.0	11.3	11.1	9.6	6.6	1.8	-5.9	-9.7	-4.0	-1.6	-2.8	4.7	14.1	14.1	5.4	-4.1	-1.8	-5.8
16	5.4	6.1	7.2	9.2	10.5	10.3	8.9	6.0	1.2	-6.5	-10.0	-4.4	-1.9	-3.0	4.3	13.8	14.0	5.3	-4.4	-2.1	-6.5
14	4.9	5.4	6.3	8.2	9.5	9.4	8.0	5.1	.5	-7.2	-10.0	-5.0	-2.4	-3.3	3.7	13.4	13.6	4.9	-4.9	-2.6	-7.1
12	4.2	4.6	5.3	7.0	8.4	8.3	6.9	4.1	-.5	-8.1	-10.0	-5.7	-3.0	-3.8	2.8	12.6	13.0	4.4	-5.5	-3.1	-7.5
10	3.3	3.6	4.0	5.6	7.0	6.9	5.6	2.9	-1.7	-9.3	-10.0	-6.7	-3.9	-4.6	1.7	11.6	12.0	3.4	-6.4	-3.8	-8.0
8	2.0	2.2	2.4	3.9	5.2	5.2	3.9	1.2	-3.2	-10.0	-10.0	-8.0	-5.2	-5.8	.2	10.2	10.6	2.1	-7.7	-4.8	-8.8
6	.2	.3	.2	1.6	2.9	2.9	1.7	-.9	-5.4	-10.0	-10.0	-9.9	-7.0	-7.5	-2.0	8.1	8.6	.1	-9.5	-6.5	-10.0
4	-2.6	-2.7	-3.0	-1.8	-.5	-.4	-1.6	-4.2	-8.5	-10.0	-10.0	-10.0	-9.9	-10.0	-5.1	4.9	5.5	-3.0	-10.0	-9.2	-10.0
2	-7.8	-8.0	-8.6	-7.6	-6.3	-6.2	-7.3	-9.9	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-.8	-.2	-8.7	-10.0	-10.0	-10.0
0	-15.2	-12.2	-10.8	-10.3	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0
	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

-5.2	-2.2	-.8	-.3	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
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 58. Inverted L pattern.

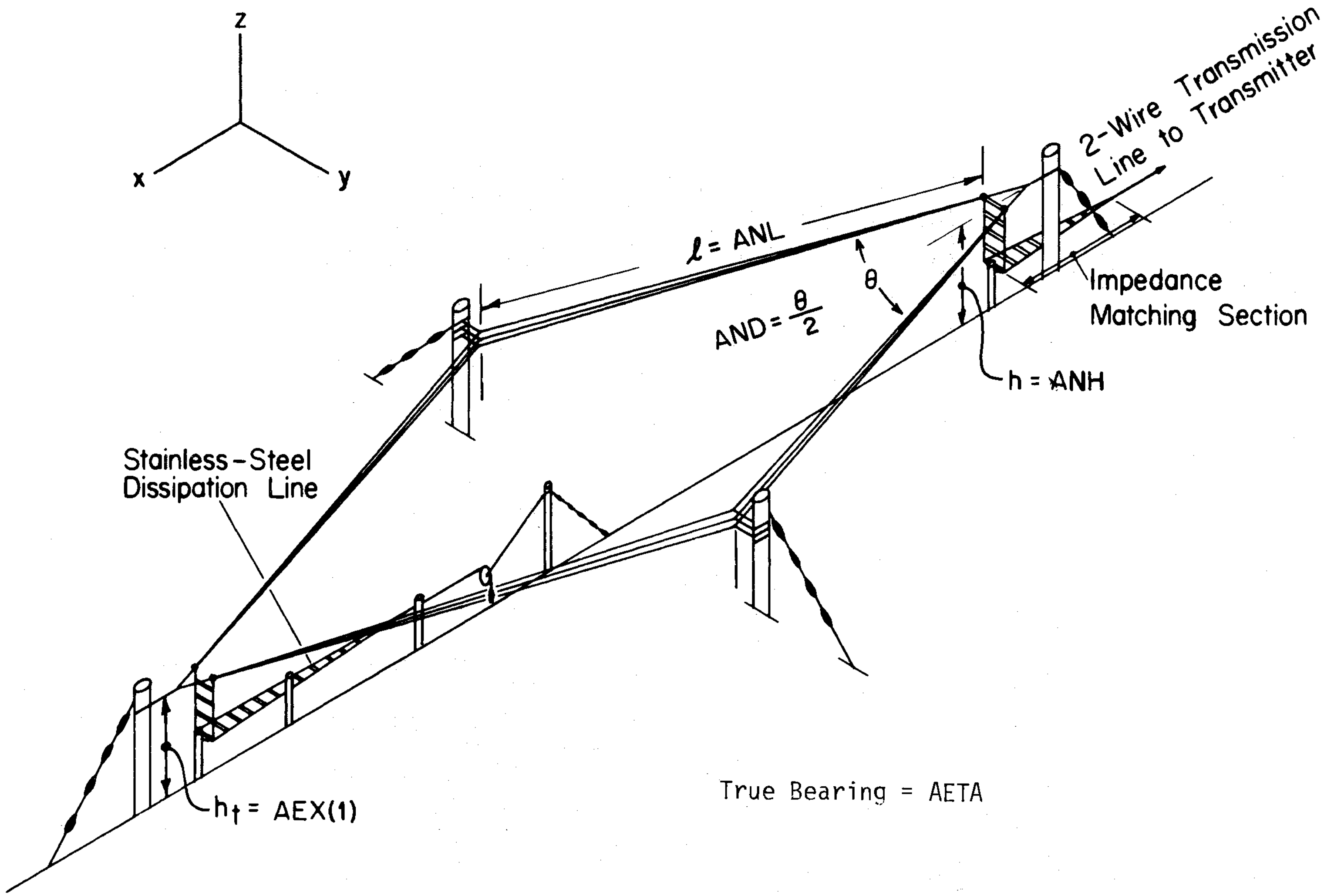

Figure 59. Sloping rhombic structure (9).

ITS- 1 ANTENNA PACKAGE ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	TER SLOP RHM	16.760	88.390	22.500	0.000	8.382	0.000	0.000	0.000	.001	4.000

ELEVATION ANGLE IN DEGREES	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
90	-5.5	-11.7	-11.7	-2.4	-11.7	-11.7	-4.9	-11.7	-11.7	-6.6	-11.7	-11.7	-8.3	-11.7	-5.6	-11.7	-11.7	-8.1	-11.7	-6.9	-6.4
88	-4.9	-11.7	-11.7	-2.3	-7.8	-11.7	-5.8	-8.5	-11.7	-9.1	-8.0	-11.7	-11.7	-9.3	-5.8	-11.7	-5.8	-11.7	-11.7	-4.2	-11.7
86	-4.4	-11.7	-11.7	-2.5	-5.2	-11.7	-7.7	-6.2	-11.7	-11.7	-5.5	-11.7	-11.7	-5.6	-8.9	-11.7	-7.3	-11.7	-5.3	-11.7	-7.4
84	-3.9	-11.7	-11.7	-3.2	-3.3	-11.7	-11.7	-4.9	-11.7	-11.7	-6.2	-8.3	-11.7	-4.5	-11.7	-5.5	-11.7	-9.6	-9.3	-11.7	-2.4
82	-3.5	-9.8	-11.7	-4.3	-2.0	-11.7	-11.7	-4.8	-11.7	-11.7	-11.7	-4.9	-11.7	-6.4	-11.7	-4.6	-11.7	-5.1	-11.7	-4.2	-11.7
80	-3.2	-7.8	-11.7	-5.9	-1.2	-8.6	-11.7	-6.0	-7.0	-11.7	-11.7	-4.9	-6.9	-11.7	-6.0	-8.2	-11.7	-11.7	-11.7	-4.4	-11.7
78	-2.9	-6.1	-11.7	-8.1	-1.0	-5.3	-11.7	-8.7	-4.7	-11.7	-11.7	-8.7	-4.0	-11.7	-3.7	-11.7	-3.8	-11.7	-4.3	-11.7	-2.2
76	-2.6	-4.6	-11.7	-11.7	-1.2	-2.9	-11.7	-11.7	-4.3	-11.7	-11.7	-11.7	-4.2	-9.8	-4.3	-11.7	-6.3	-11.7	-9.1	-11.7	-3.6
74	-2.4	-3.3	-11.7	-11.7	-1.9	-1.3	-10.0	-11.7	-5.6	-5.4	-11.7	-11.7	-8.5	-5.9	-7.6	-4.9	-11.7	-3.9	-11.7	-2.7	-11.7
72	-2.3	-2.2	-11.7	-11.7	-3.3	-.3	-6.1	-11.7	-9.2	-3.6	-11.7	-11.7	-11.7	-2.9	-11.7	-2.6	-11.7	-6.1	-11.7	-5.7	-7.0
E 70	-2.2	-1.2	-9.8	-11.7	-5.3	-.0	-3.1	-11.7	-11.7	-4.1	-5.3	-11.7	-11.7	-2.6	-7.8	-4.2	-7.1	-11.7	-3.2	-11.7	-.5
L 68	-2.2	-.4	-6.9	-11.7	-8.2	-.4	-1.0	-8.7	-11.7	-7.1	-2.9	-9.6	-11.7	-5.7	-3.6	-7.9	-1.9	-11.7	-7.6	-8.8	-6.6
E 66	-2.3	.3	-4.4	-11.7	-11.7	-1.4	.2	-5.0	-11.7	-11.7	-3.3	-3.7	-11.7	-11.7	-1.4	-8.6	-3.2	-6.8	-11.7	-2.1	-11.7
V 64	-2.3	.9	-2.4	-11.7	-11.7	-3.2	.7	-2.0	-9.4	-11.7	-6.8	-1.9	-5.3	-9.2	-2.1	-4.3	-6.9	-1.2	-11.7	-9.1	-2.8
A 62	-2.5	1.4	-.7	-11.7	-11.7	-5.8	.3	-.0	-6.0	-11.7	-11.7	-3.2	-1.7	-7.8	-5.7	-1.0	-8.2	-4.4	-3.2	-11.7	-1.5
T 60	-2.6	1.7	.7	-6.4	-11.7	-9.7	-.8	1.0	-2.6	-8.8	-11.7	-8.8	-1.4	-5.8	-8.1	-.7	-4.3	-7.1	-1.6	-9.6	-8.6
I 58	-2.9	2.0	1.9	-3.3	-11.7	-11.7	-2.9	1.2	-.1	-6.1	-9.0	-11.7	-4.8	-1.6	-6.0	-3.1	-.2	-8.4	-9.1	-.6	-11.7
O 56	-3.1	2.2	2.9	-.8	-11.7	-11.7	-6.1	.4	1.3	-2.5	-8.0	-9.4	-11.7	.3	-3.6	-5.9	.2	-2.6	-6.6	-7.7	-1.0
N 54	-3.5	2.2	3.6	1.2	-6.0	-11.7	-11.7	-1.5	1.7	.3	-5.5	-7.4	-11.7	-1.2	-.3	-4.4	-2.1	1.1	-7.9	-6.7	-3.4
52	-3.8	2.2	4.3	2.9	-2.3	-11.7	-11.7	-4.6	.9	1.8	-1.5	-7.7	-6.4	-8.6	1.5	-1.3	-4.4	.4	.8	-11.7	-9.2
A 50	-4.3	2.2	4.7	4.3	.6	-7.4	-11.7	-9.1	-1.1	2.0	1.3	-3.8	-7.9	-11.7	.1	1.6	-2.3	-2.3	1.7	-.3	-11.7
N 48	-4.7	2.0	5.0	5.3	2.9	-2.8	-11.7	-11.7	-4.4	1.0	2.5	.4	-6.4	-4.6	-6.9	2.5	1.2	-2.8	-.6	2.4	-1.2
G 46	-5.3	1.7	5.2	6.2	4.8	.8	-6.7	-11.7	-9.4	-1.5	2.1	2.5	-.6	-5.8	-8.3	.1	3.2	.7	-2.1	.1	2.8
L 44	-5.8	1.4	5.3	6.8	6.3	3.6	-1.8	-11.7	-11.7	-5.7	.3	2.9	2.5	-11.7	-2.5	-7.6	2.7	3.5	.1	-1.1	.0
E 42	-6.5	1.0	5.2	7.2	7.4	5.8	2.0	-4.2	-11.7	-11.7	-3.3	1.5	3.4	-1.8	-4.7	-3.1	-1.7	4.0	3.6	-.1	-.3
40	-7.1	.5	5.0	7.5	8.2	7.5	5.0	.6	-5.9	-11.7	-8.8	-1.7	2.3	2.9	-11.7	-.7	-3.8	1.4	4.8	3.8	-.1
I 38	-7.8	.0	4.8	7.6	8.8	8.7	7.3	4.3	-.5	-6.7	-11.7	-7.1	-.8	4.3	-.0	-6.6	.7	-2.4	3.1	5.4	4.1
N 36	-8.6	-.6	4.4	7.5	9.2	9.7	9.0	7.1	3.8	-1.0	-6.5	-11.7	-6.2	3.2	4.4	-4.9	-.9	1.4	-.4	4.2	6.0
34	-9.4	-1.3	3.9	7.3	9.4	10.4	10.3	9.3	7.1	3.7	-.8	-5.7	-9.2	-.3	5.1	3.6	-7.0	1.6	2.4	1.3	5.0
D 32	-11.7	-2.1	3.3	7.0	9.4	10.8	11.3	10.9	9.6	7.4	4.1	-.1	-4.4	-6.3	3.1	6.0	2.9	-3.6	3.2	3.5	2.6
E 30	-11.7	-2.9	2.7	6.5	9.2	10.9	11.9	12.0	11.5	10.1	7.9	4.9	1.1	-6.2	-1.9	5.1	6.5	2.8	-.8	4.4	4.8
G 28	-11.7	-3.8	1.9	5.9	8.8	10.9	12.2	12.8	12.8	12.1	10.8	8.8	6.0	-.8	-6.5	1.0	6.4	7.1	3.6	1.0	5.2
R 26	-11.7	-4.8	1.0	5.2	8.3	10.6	12.2	13.2	13.7	13.6	12.9	11.7	9.9	4.6	-1.6	-5.2	2.9	7.3	7.8	4.8	2.1
E 24	-11.7	-5.8	.1	4.4	7.7	10.2	12.1	13.4	14.2	14.5	14.4	13.8	12.7	9.1	3.8	-1.7	-3.7	3.9	7.9	8.6	6.3
E 22	-11.7	-6.9	-.9	3.5	6.9	9.6	11.7	13.2	14.3	15.0	15.3	15.2	14.7	12.5	8.7	3.7	-1.4	-2.6	4.4	8.3	9.4
S 20	-11.7	-8.1	-2.1	2.5	6.0	8.8	11.1	12.9	14.2	15.2	15.8	16.1	16.1	15.0	12.6	8.7	4.0	-.6	-2.0	4.4	8.5
18	-11.7	-9.4	-3.3	1.3	5.0	7.9	10.3	12.3	13.8	15.0	15.9	16.5	16.9	16.7	15.3	12.8	9.1	4.7	.3	-1.6	3.9
16	-11.7	-11.7	-4.6	.0	3.8	6.8	9.4	11.4	13.2	14.6	15.7	16.6	17.2	17.6	17.2	15.7	13.2	9.7	5.5	1.3	-1.1
14	-11.7	-11.7	-6.1	-1.4	2.4	5.6	8.2	10.4	12.3	13.8	15.1	16.2	17.0	18.0	18.2	17.6	16.1	13.8	10.5	6.3	2.1
12	-11.7	-11.7	-7.7	-2.9	.9	4.1	6.8	9.1	11.1	12.8	14.2	15.4	16.4	17.9	18.6	18.6	17.9	16.5	14.3	11.1	7.1
10	-11.7	-11.7	-9.5	-4.7	-.8	2.4	5.2	7.6	9.6	11.4	13.0	14.3	15.4	17.2	18.3	18.8	18.7	17.9	16.6	14.5	11.5
8	-11.7	-11.7	-11.7	-6.9	-2.9	.4	3.2	5.6	7.8	9.6	11.3	12.7	13.9	15.9	17.3	18.1	18.5	18.3	17.5	16.1	14.1
6	-11.7	-11.7	-11.7	-9.5	-5.5	-2.2	.7	3.2	5.3	7.3	9.0	10.5	11.8	13.9	15.5	16.6	17.2	17.4	17.1	16.2	14.8
4	-11.7	-11.7	-11.7	-11.7	-9.1	-5.7	-2.8	-.3	1.9	3.9	5.6	7.2	8.5	10.8	12.5	13.8	14.6	15.0	15.0	14.5	13.5
2	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-8.8	-6.2	-4.0	-2.0	-.3	1.3	2.7	5.1	6.9	8.3	9.2	9.7	9.8	9.5	8.7
0	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7
	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 60. Sloping rhombic pattern.

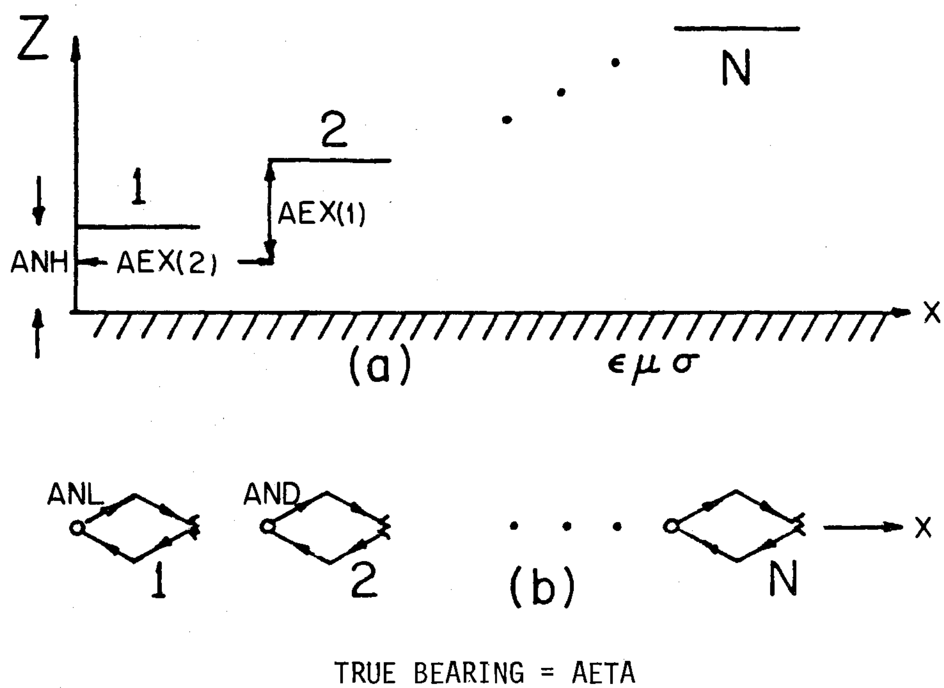

Figure 61. Interlaced rhombic structure (10).

METHOD 15 IONCAP 78.03 PAGE 10

ITS- 1 ANTENNA PACKAGE ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	TER INTR RHM	20.000	114.000	70.000	0.000	4.000	33.000	0.000	0.000	.001	4.000

	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
90	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-6.3	-11.7	-11.7	-7.8	-11.7	-11.7	-11.7	-11.7	-6.3	-8.3	-11.7	-11.7	-9.0	-9.9
88	-9.1	-11.7	-9.7	-11.7	-11.7	-11.7	-11.7	-9.4	-7.3	-11.7	-7.3	-11.7	-11.7	-11.7	-11.7	-6.9	-11.7	-11.7	-11.7	-11.7	-11.7
86	-7.6	-11.7	-9.1	-11.7	-11.7	-11.7	-11.7	-11.7	-4.9	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-6.3	-11.7	-11.7	-11.7
84	-6.2	-11.7	-9.1	-11.7	-11.7	-11.7	-11.7	-11.7	-5.5	-11.7	-11.7	-8.2	-11.7	-8.3	-11.7	-11.7	-5.5	-11.7	-11.7	-11.7	-11.7
82	-4.9	-11.7	-9.5	-11.7	-11.7	-11.7	-11.7	-11.7	-9.2	-6.1	-11.7	-11.7	-9.7	-11.7	-11.7	-8.8	-11.7	-11.7	-5.9	-11.7	-11.7
80	-3.9	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-4.8	-11.7	-11.7	-7.1	-11.7	-11.7	-11.7	-11.7	-9.7	-8.9	-11.7	-11.7
78	-2.9	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-7.0	-7.3	-11.7	-11.7	-11.7	-6.3	-11.7	-11.7	-11.7	-11.7	-3.4	-11.7
76	-2.1	-11.7	-11.7	-9.3	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-4.8	-11.7	-11.7	-7.3	-8.6	-11.7	-11.7	-11.7	-6.7	-9.2	-11.7
74	-1.3	-11.7	-11.7	-8.6	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-6.4	-6.8	-11.7	-3.1	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-3.2
72	-.7	-11.7	-11.7	-8.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-4.4	-11.7	-5.9	-11.7	-8.1	-11.7	-11.7	-11.7	-2.6	-11.7
E 70	-.2	-7.4	-11.7	-9.5	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-6.5	-4.7	-11.7	-3.5	-11.7	-11.7	-11.7	-11.7	-11.7	-7.8
L 68	.3	-4.9	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-3.8	-11.7	-1.9	-11.7	-8.6	-11.7	-11.7	-11.7	-4.2
E 66	.6	-2.8	-11.7	-11.7	-9.8	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-7.9	-9.1	-9.0	-5.3	-11.7	-7.0	-11.7	-11.7	-11.7
V 64	.9	-1.0	-11.7	-11.7	-9.6	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-3.0	-11.7	-1.3	-11.7	-5.2	-11.7	-11.7	-11.7
A 62	1.0	.5	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-3.4	-11.7	-7.4	-3.8	-11.7	-2.1	-11.7	-11.7
T 60	1.1	1.8	-7.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-4.6	-11.7	-.7	-11.7	-7.6	-3.7	-11.7
I 58	1.1	2.8	-4.0	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-3.8	-11.7	-9.6	.2	-11.7	-2.9	-6.9
O 56	1.1	3.7	-1.1	-11.7	-11.7	-11.7	-11.7	-9.5	-11.7	-11.7	-11.7	-11.7	-9.3	-11.7	-9.5	-6.8	-11.7	-1.2	-2.4	-11.7	-1.1
N 54	.9	4.3	1.2	-11.7	-11.7	-11.7	-11.7	-8.4	-7.8	-11.7	-11.7	-11.7	-8.6	-9.9	-11.7	-8.1	-9.4	-11.7	1.5	-6.7	-11.7
52	.7	4.9	3.1	-5.6	-11.7	-11.7	-11.7	-8.9	-4.6	-8.2	-11.7	-11.7	-11.7	-7.0	-11.7	-11.7	-8.4	-11.7	-9.5	1.3	-11.7
A 50	.4	5.2	4.6	-1.5	-11.7	-11.7	-11.7	-11.7	-3.6	-2.9	-9.4	-11.7	-11.7	-7.4	-8.8	-11.7	-11.7	-3.4	-11.7	-5.7	-.7
N 48	.1	5.5	5.9	1.6	-9.5	-11.7	-11.7	-11.7	-4.6	-.6	-2.1	-11.7	-11.7	-9.6	-6.8	-11.7	-11.7	-8.2	-1.5	-11.7	-6.2
G 46	-.4	5.5	6.8	4.1	-3.6	-11.7	-11.7	-11.7	-7.6	-.5	1.4	-1.5	-11.7	-11.7	-9.3	-6.6	-11.7	-11.7	-1.9	-1.1	-11.7
L 44	-.9	5.5	7.5	6.1	.7	-11.7	-11.7	-11.7	-11.7	-2.6	2.2	2.9	-.6	-11.7	-11.7	-7.6	-6.9	-11.7	-11.7	.6	-.9
E 42	-1.4	5.4	8.1	7.6	4.0	-3.9	-11.7	-11.7	-11.7	-6.9	.8	4.2	4.2	-7.8	-11.7	-11.7	-3.0	-6.8	-11.7	-10.0	1.2
40	-2.1	5.1	8.4	8.8	6.5	1.1	-9.4	-11.7	-11.7	-11.7	-3.0	3.2	5.8	2.4	-11.7	-11.7	-8.6	.4	-5.8	-11.7	-11.7
I 38	-2.8	4.7	8.5	9.7	8.5	4.8	-2.1	-11.7	-11.7	-11.7	-11.7	-.5	4.8	7.0	-1.4	-11.7	-11.7	-1.8	3.0	-3.7	-11.7
N 36	-3.6	4.2	8.5	10.3	10.0	7.7	3.0	-5.2	-11.7	-11.7	-11.7	-7.4	1.1	8.2	6.4	-5.9	-11.7	-11.7	1.9	5.1	-.9
34	-4.5	3.6	8.3	10.6	11.1	9.9	6.8	1.3	-7.8	-11.7	-11.7	-11.7	-6.3	6.5	9.6	5.3	-9.7	-11.7	-9.4	4.0	6.9
D 32	-5.4	2.9	7.9	10.7	11.9	11.5	9.6	6.0	.1	-9.3	-11.7	-11.7	-11.7	1.6	9.4	10.2	4.4	-11.7	-11.7	-8.2	4.7
E 30	-6.4	2.1	7.4	10.6	12.3	12.7	11.8	9.5	5.6	-.4	-9.6	-11.7	-11.7	-8.2	5.9	11.0	10.5	4.2	-11.7	-11.7	-11.7
G 28	-7.5	1.2	6.8	10.4	12.5	13.4	13.3	12.0	9.6	5.7	-.1	-8.6	-11.7	-11.7	-1.9	8.4	12.1	11.0	5.0	-8.6	-11.7
R 26	-8.7	.2	6.0	9.9	12.4	13.9	14.4	13.9	12.5	10.0	6.3	1.0	-6.5	-11.7	-11.7	1.4	9.8	12.8	11.9	6.7	-4.0
E 24	-11.7	-.9	5.1	9.3	12.1	14.0	15.0	15.2	14.6	13.2	10.9	7.5	2.8	-11.7	-11.7	-11.7	2.9	10.4	13.4	13.0	9.1
E 22	-11.7	-2.1	4.1	8.4	11.6	13.8	15.2	16.0	16.0	15.5	14.2	12.2	9.2	-.1	-11.7	-11.7	-11.7	3.1	10.5	13.8	14.2
S 20	-11.7	-3.5	2.9	7.5	10.9	13.4	15.2	16.3	16.9	17.0	16.5	15.4	13.7	8.1	-1.7	-11.7	-11.7	-11.7	2.0	9.8	13.8
18	-11.7	-4.9	1.6	6.3	9.9	12.7	14.8	16.3	17.3	17.9	17.9	17.6	16.7	13.5	7.8	-1.6	-11.7	-11.7	-11.7	-.5	8.3
16	-11.7	-6.5	.1	5.0	8.8	11.8	14.1	15.9	17.3	18.2	18.7	18.9	18.7	17.2	14.0	8.6	.2	-11.7	-11.7	-11.7	-5.1
14	-11.7	-8.2	-1.5	3.5	7.5	10.6	13.2	15.2	16.8	18.1	19.0	19.6	19.8	19.5	17.9	15.0	10.4	3.4	-7.2	-11.7	-11.7
12	-11.7	-11.7	-3.3	1.9	5.9	9.2	11.9	14.2	16.0	17.5	18.7	19.6	20.2	20.8	20.4	19.0	16.4	12.6	7.0	-1.2	-11.7
10	-11.7	-11.7	-5.3	-.1	4.1	7.5	10.4	12.8	14.8	16.5	17.9	19.0	20.0	21.2	21.6	21.2	20.0	17.9	14.8	10.4	4.1
8	-11.7	-11.7	-7.6	-2.3	2.0	5.5	8.4	10.9	13.1	14.9	16.5	17.9	19.0	20.7	21.7	22.0	21.7	20.7	19.1	16.5	12.9
6	-11.7	-11.7	-11.7	-5.0	-.7	2.9	5.9	8.5	10.8	12.7	14.5	15.9	17.2	19.3	20.7	21.5	21.8	21.5	20.7	19.3	17.1
4	-11.7	-11.7	-11.7	-8.7	-4.3	-.7	2.4	5.1	7.4	9.4	11.2	12.8	14.2	16.5	18.2	19.3	20.0	20.2	19.9	19.1	17.7
2	-11.7	-11.7	-11.7	-11.7	-11.7	-6.7	-3.6	-.9	1.5	3.6	5.5	7.1	8.6	11.0	12.8	14.2	15.0	15.5	15.5	15.0	14.1
0	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7
	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 62. Interlaced rhombic pattern.

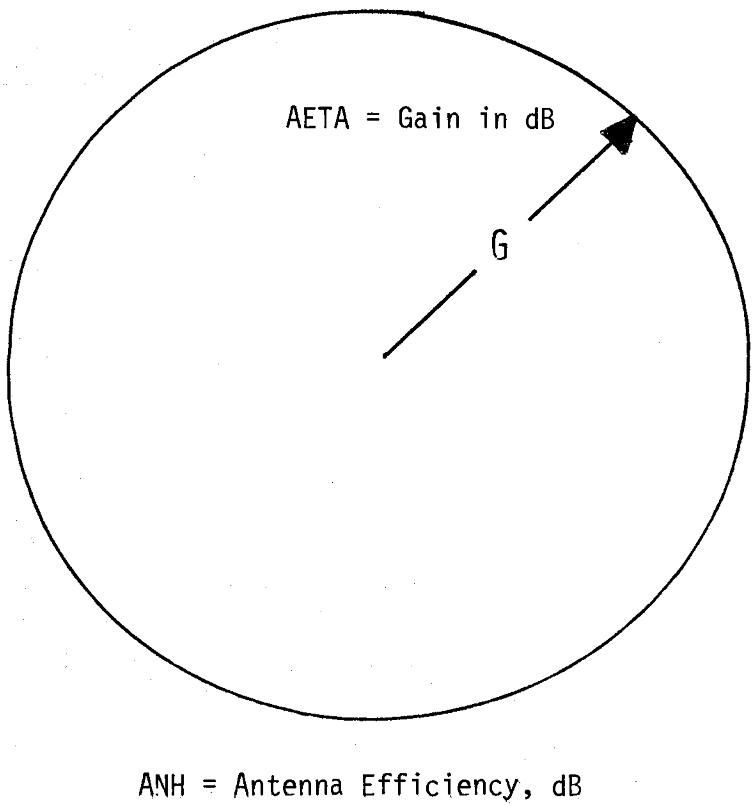

Figure 63. Constant gain pictorial pattern (12).

ITS- 1 ANTENNA PACKAGE ANTENNA PATTERN

FREQUENCY RANGE	ANTENNA TYPE	HEIGHT	LENGTH	ANGLE	AZIMUTH	EX(1)	EX(2)	EX(3)	EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0	CONST. GAIN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	4.000

	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
90	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
88	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
86	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
84	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
82	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
80	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
78	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
76	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
74	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
72	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
E 70	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
L 68	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
E 66	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
V 64	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
A 62	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
T 60	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
I 58	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
O 56	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
N 54	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
52	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
A 50	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
N 48	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
G 46	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
L 44	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
E 42	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
40	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
I 38	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
N 36	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
34	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
D 32	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
E 30	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
G 28	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
R 26	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
E 24	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
E 22	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
S 20	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
18	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
16	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
14	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
12	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
10	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
8	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
6	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
4	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
2	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

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
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 64. Constant gain pattern.

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ITS- 1 ANTENNA PACKAGE							ANTENNA PATTERN													
FREQUENCY RANGE		ANTENNA TYPE			HEIGHT	LENGTH		ANGLE		AZIMUTH		EX(1)		EX(2)		EX(3)		EX(4)	CONDUCT.	DIELECT.
2.0 TO 30.0		CONST. GAIN			-1.870	0.000		0.000		0.000		0.000		0.000		0.000		0.000	.001	4.000

	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30
90	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
88	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
86	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
84	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
82	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
80	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
78	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
76	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
74	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
72	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
E 70	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
L 68	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
E 66	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
V 64	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
A 62	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
T 60	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
I 58	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
O 56	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
N 54	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
52	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
A 50	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
N 48	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
G 46	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
L 44	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
E 42	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
40	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
I 38	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
N 36	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
34	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
D 32	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
E 30	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
G 28	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
R 26	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
E 24	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
E 22	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
S 20	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
18	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
16	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
14	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
12	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
10	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
8	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
6	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
4	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
2	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
0	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

ANTENNA EFFICIENCY

-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9
2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30

FREQUENCY IN MEGAHERTZ

Figure 65. Constant gain receiver antenna with antenna efficiency.

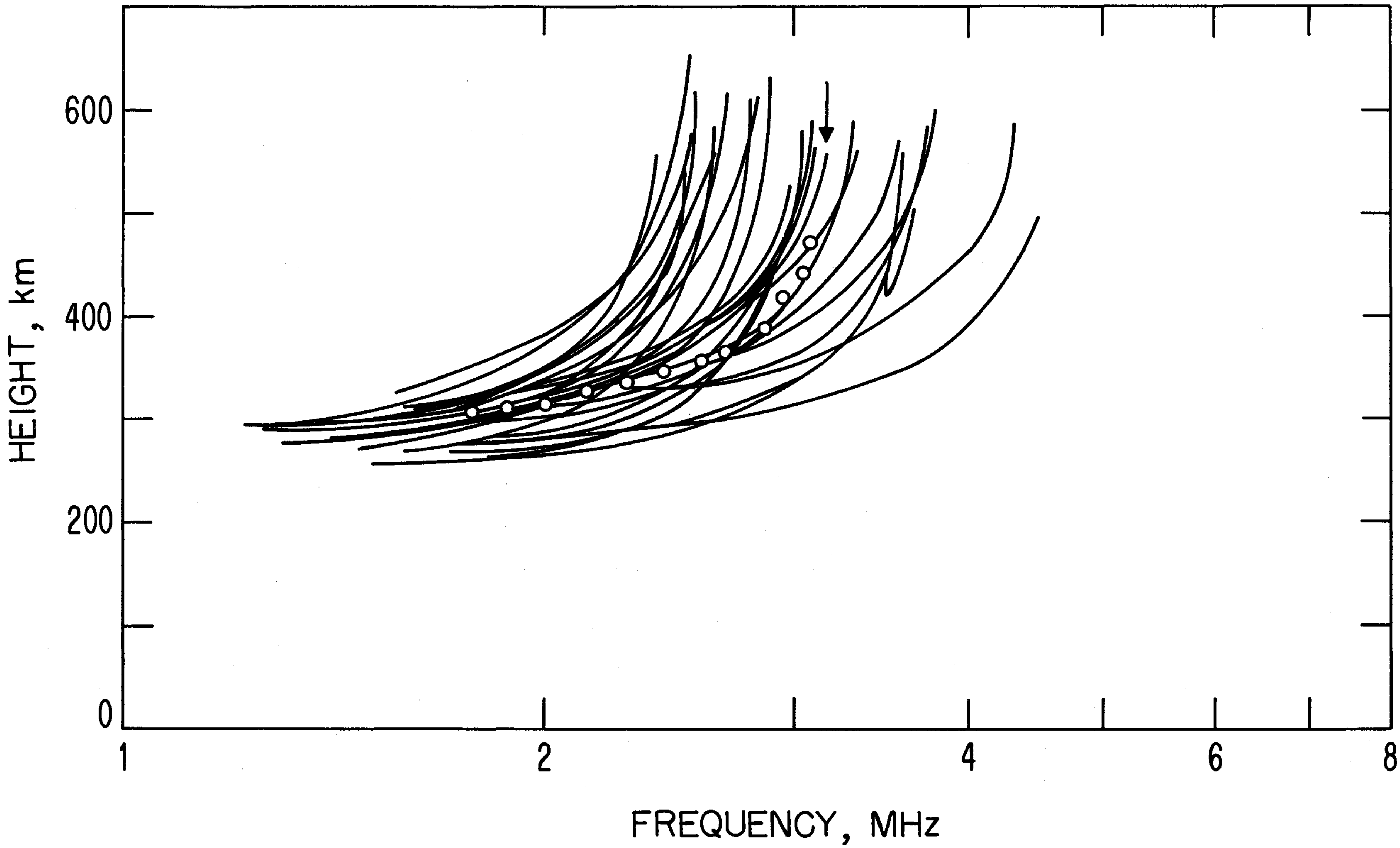


Figure 66. Comparison of predicted vertical incidence ionograms compared to observed ionograms (Boulder, Colorado, night, June).

Table 1. IONCAP Files

	FILE NAME	TYPE	USE*	MNEMONIC	LOGICAL UNIT	USUAL DEVICE	TASK
1)	PRIMARY INPUT FILE	BCD	W/P	LUI/LU5**	5	CARDS	INPUT
2)	PRIMARY OUTPUT FILE	BCD	W/P	LUO/LU6**	6	PRINTER	OUTPUT
3)	LONG TERM IONOSPHERIC DATA BASE FILE	BINARY	P	LU2	2	DISK/TAPE	INPUT
4)	AUXILIARY INPUT FILE	BCD	W/P	LU15	15	CARDS/DISK	INPUT
5)	AUXILIARY OUTPUT FILE	BCD	W/P	LU16	16	PRINTER/DISK	OUTPUT
6)	COMMON MUFS FILE	BINARY	W/P	LU20	20	DISK/TAPE	OUTPUT
7)	ANTENNA OUTPUT FILE	BINARY	W/P	LU25	25	DISK/TAPE	OUTPUT
8)	ANTENNA INPUT FILE	BINARY	P	LU26	26	DISK/TAPE	INPUT
9)	PROCEDURE FILE	BCD	S	LU35	35	DISK	INPUT/OUTPUT
10)	DEBUG OUTPUT FILE***	BCD	NONE	LU61	61	PRINTER	OUTPUT

* S = scratch file; P = permanent file; W = working file; W/P = working or permanent file, user options dictate the necessity of file denoted by W/P.

** Default card image input file is LU5 but may be changed by the user to the auxiliary input file LU15. Default output file is system output LU6 but may be changed by the user to the auxiliary output file LU16.

*** The debug output file was implemented during the development phase of IONCAP. This file is not generally made available to the user.

Table 2. Valid Name Identifiers

IDENTIFIER	DESCRIPTION OF INPUT PARAMETERS
METHOD	Program run option and beginning page number
MONTH	Year and a list of up to 12 months
MONTHLOOP	Year and months specified in a loop
SUNSPOT	List of sunspots (all months are run for each)
CIRCUIT	Transmitter-receiver locations
SYSTEM	Power, noise, min. angle, req. reliability, SNR, time delay and power increment for multipath
TIME	Time of day loop (and indicator for LMT or UT)
ANTENNA	Transmitter or receiver, antenna type and parameters
FREQUENCY	Operating frequencies
LABEL	Alphanumeric label for identification
INTEGRATE	.GE. 0 will do a fast integration when no F1 is present
EXECUTE	Execute program with parameters currently set
SAMPLE	Optional geophysical samples (for a specified area)
EFVAR	Optional E, F1 and F2 parameters (for a specified area)
ESVAR	Optional Es parameters (for a specified area)
EDP	True heights and electron density (for a specified area)
AUXIN	Read input card images from an alternate file
AUXOUT	Write program output to an alternate file
ANTOUT	Write antenna patterns on a file
OUTGRAPH	Request output of several methods
COMMENT	Comment card in user defined input
FREEFORM	Input is freeform card images (NOT IMPLEMENTED)
PROCEDURE	Definition of an input procedure
END	Termination of an input procedure definition
NEXT	End of month/sunspot loop
QUIT	Termination of program execution
FPROB	Critical frequency multipliers
TOPLINES	User specified heading lines (for method 23)
BOTLINES	User specified output lines (for method 23)
DEBUG	Write debug output used for program development
(USER DEFINED PROCEDURE NAME)	Replace procedure name with its definition

Table 3. Available Output Methods

METHOD	DESCRIPTION OF METHOD
1	Ionospheric parameters
2	Ionograms
3	MUF-FOT lines (nomogram)
4	MUF-FOT graph
5	HPF-MUF-FOT graph
6	MUF-FOT-Es graph
7	FOT-MUF table (full ionosphere)
8	MUF-FOT graph
9	HPF-MUF-FOT graph
10	MUF-FOT-ANG graph
11	MUF-FOT-Es graph
12	MUF by magnetic indices, K (not implemented)
13	Transmitter antenna pattern
14	Receiver antenna pattern
15	Both transmitter and receiver antenna patterns
16	System performance (S.P.)
17	Condensed system performance, reliability
18	Condensed system performance, service probability
19	Propagation path geometry
20	Complete system performance (C.S.P.)
21	Forced long path model (C.S.P.)
22	Forced short path model (C.S.P.)
23	User selected output lines (set by TOPLINES and BOTLINES)
24	MUF-REL table
25	All modes table
26	MUF-LUF-FOT table (nomogram)
27	FOT-LUF graph
28	MUF-FOT-LUF graph
29	MUF-LUF graph
30	Create binary file of variables in "COMMON /MUFS/" (allows the user to save MUFs-LUFs for printing by a separate user written program)

Table 4. Required SNR's for Radiotelephone Service

Radio Telephone Description	GRADE OF SERVICE*			
	Operator-to-Operator**		Good Commercial Quality	
	No Diversity	Dual Diversity	No Diversity	Dual Diversity
6A3 Double Sideband - AM	51	48	75	70
3A3 Single Sideband - AM				
3A3a (reduced carrier)	49	46	73	68
3A3j (suppressed carrier)	48	45	72	67
6A3 Independent Sideband - AM				
6A3b (2-voice channels)	50	47	74	69
9A3b (3-voice channels)	50	47	74	69
12A3b (4-voice channels)	51	48	75	70

*Required Signal-to-Noise Ratio in occupied bandwidth relative to noise in a 1 Hz bandwidth (dB).

**For 90% intelligibility of related words.

Table 5. Required SNR's for Radioteletype Service

Radio Teletype Description	GRADE OF SERVICE* Character Error Rate**					
	10^{-2}		10^{-3}		10^{-4}	
	No Diversity	Dual Diversity	No Diversity	Dual Diversity	No Diversity	Dual Diversity
1.1F1 FSK, 60 WPM, 1500-Hz filter						
Start-Stop	55	51	62	58	68	63
Synchronous	50	47	59	54	65	60
3A7j SSB, Suppressed carrier, 16-teletype subchannels, each subchannel ± 42.5 Hz FSK, 110-Hz filter, 100 WPM, 5 unit						
Start-Stop	63	59	70	65	76	70
Synchronous	58	54	66	62	73	68
6A9b ISB, 1-voice channel and 16-teletype subchannels, each subchannel ± 42.5 Hz, FSK, 110-Hz filter, 100 WPM						
Start-Stop	64	60	71	66	77	71
Synchronous	59	55	67	63	74	69
12A9b ISB, 2-voice channels and 32-teletype subchannels, each subchannel ± 42.5 Hz, FSK, 110-filter, 100 WPM						
Start-Stop	66	62	73	68	79	73
Synchronous	61	57	69	65	76	71

*Required Signal-to-Noise Ratio in occupied bandwidth relative to noise in a 1 Hz bandwidth (dB).
**5-unit code, no error control schemes.
Power assumed equally divided between channels.

Table 6. Typical Values of Ground Electrical Characteristics

GROUND TYPE	CONDUCTIVITY	DIELECTRIC CONSTANT
Sea Water	5.0 mhos/m	80
Good Ground	0.01	10
Poor Ground and Sea Ice	0.001	4
Polar Ice Cap	0.0001	1
Fresh Water	0.002	80

Table 7. Output Combinations for the OUTGRAPH Card

METHOD CARD	OUTGRAPH CARD
PROGRAM TASK OPTION*	ADDITIONAL OUTPUT AVAILABLE FOR THE SPECIFIED TASK OPTION (SPECIFIED ON OUTGRAPH CARD)
3	4 5 6
4	3 5 6
5	3 4 6
6	3 4 5
7	8 to 11
8	9 to 11
9	8, 10, 11
10	8, 9, 11
11	8 to 10
16 TO 25	8 to 11, 26 to 29**
26	8 to 11, 27 to 29
27	8 to 11, 26, 28, 29
28	8 to 11, 26 to 29
29	8 to 11, 26 to 28
30	

* Optimal program task options for additional output.

** LUF values set by first frequency in the frequency complement which has a computed reliability that is greater than or equal to the required system reliability. If none of the computed reliabilities are at least as large as that required, the frequency with the greatest reliability is chosen and a designator is printed to indicate the reliability. (Note that this occurs only when the user specifies 26 to 29 on the OUTGRAPH card and 16 to 25 on the METHOD card. The actual computed values for LUF are printed when the user specifies 26 to 29 on the OUTGRAPH card and 26 to 29 on the METHOD card.)

Table 8. Header Line Options for the TOPLINES Card

LINTP	DESCRIPTION OF HEADER LINE
1	Month, year, and sunspot number
2	Alphanumeric information on the label card
3	Transmitter and receiver information consisting of coordinates, azimuth, and great circle distance (in kilometers and nautical miles)
4	Minimum take-off angle (in degrees)
5	Transmitter antenna information consisting of the operating frequency range, antenna type (in mnemonics), height*, length*, off azimuth angle, conductivity, dielectric constant as well as other antenna characteristics
6	Receiver antenna information consisting of the operating frequency range, antenna type (in mnemonics), height*, length*, off azimuth angle, conductivity, dielectric constant as well as other antenna characteristics
7	Power, 3 MHz man-made noise, required reliability and required SNR
8	Multipath power tolerance and delay time tolerance

* Height and length given in meters if positive and wavelength if negative.

Table 9. System Performance Output Line Options for the BOTLINES Card

LINBD	OUTPUT MNEMONIC	VARIABLE DESCRIPTION
1	MODE*	Number of hops for MUF and mode type
	MODE**	Mode type at transmitter end and at receiver end
2	ANGLE*	Radiation angle at transmitter, degrees
	ANGLE**	Radiation angle at transmitter and receiver end, degrees
3	DELAY	Time delay most reliable mode (MRM), milliseconds
4	V HITE	Virtual height MRM, kilometers
5	F DAYS	Prob. operating frequency exceeds the predicted MUF
6	LOSS	Median system loss, MRM, dB
7	DBU	Field strength, median, dBu
8	S DBW	Signal power, median, dBw
9	N DBW	Noise strength, median, dBw
10	SNR	Median SNR, dB
11	RPWRG	Required power gain for MRM, dB
12	REL	Reliability
13	MPROB	Multipath probability (short paths only)
14	SPRB	Service probability
15	SIGLW	Signal (loss), lower decile, dB
16	SIGUP	Signal (loss), upper decile, dB
17	VHFDBU	VHF field strength, median, dBu
18	VHFLW	VHF field strength, lower decile, dB
19	VHFUP	VHF field strength, upper decile, dB
20	VHFMOD	VHF mode type
21	SNRLW	SNR, lower decile, dB
22	SNRUP	SNR, upper decile, dB

* if short path
** if long path

Table 10. System Performance Output Line Options as Preset by the Method Number

METHOD	LINES	DESCRIPTION
16	1 to 13	Detailed system performance
17	1, 2, 5, 7, 10, 12	Condensed S. P. with reliability
18	1, 2, 5, 7, 10, 14	Condensed S. P. with service prob.
19	1, 2, 3, 4, 5	Propagation path geometry
20	1 to 22 (all)	Complete S. P. output
21	1 to 16	Force long path submodule
22	1 to 16	Force short path submodule

Table 11. Input Data Required for HF Systems Performance Predictions

1. GENERAL INFORMATION

NAME: ____; COMPANY: ____; ADDRESS: ____;

CITY: ____; STATE: ____; ZIP CODE: ____; AND TELEPHONE NUMBER: ____.

(A) YEAR ____ OR PERIOD OF SOLAR CYCLE ____; SUNSPOT NUMBER ____,

(B) MONTHS (Circle) J F M A M J J A S O N D; DAY OF MONTH ____,

(C) TRANSMITTER SITE CHARACTERISTICS: σ ____ MHOS/m, ε ____ OR

(D) RECEIVER SITE CHARACTERISTICS: σ ____ MHOS/m, ε ____ OR

	CHECK ONE*			
	SEA WATER	GOOD GROUND	FAIR GROUND	POOR GROUND
(C)	____	____	____	____.
(D)	____	____	____	____.

* Each antenna requires specification of its local ground electrical characteristics per numbers 1(C) and 1(D).

2. PROGRAM CONTROL INFORMATION

(A) Type of tabulation (method) desired 1 to 30.

(B) Beginning hour of calculation ____ (do not use zero UT).

(C) Ending hour of calculation ____.

(D) Every ____ hours UT or LMT ____.

(E) Antenna Pattern: None ____ Transmitter ____ Receiver ____ Both ____.

(F) Great Circle Path: Short ____ OR Long ____.

(G) Header Lines

(H) S.P. Lines

3. FREQUENCY COMPLEMENT

____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ MHz

A typical complement covering the frequency range is 2, 3, 5, 7, 9, 12, 15, 22, 26, 30 MHz.

4. CIRCUIT AND SYSTEM PERFORMANCE

(A) Transmitter Location Name ____, Latitude ____, Longitude ____. (C) Minimum Takeoff Angle ____

(B) Receiver Location Name ____, Latitude ____, Longitude ____. (D) Transmitter Power ____ kw.

(E) Required S/N Ratio ____ dB OR Required Service ____.

(F) Manmade Noise at Receiving Site ____ DBW/MHZ at 3 MHz OR Industrial ____, Residential ____, Rural ____, Remote Unpopulous ____.

(G) Circuit Reliability Required for LUF or Service Probability Computation ____%. (H) Is Multipath Computation Required: Yes ____ No ____.

(I) Minimum Tolerable Power Ratio Between Multiple Modes ____ dB. (J) Maximum Tolerable Time Delay Between Multiple Modes ____ ms.

6. TRANSMITTING ANTENNAS			7. RECEIVING ANTENNAS		
TYPE	FREQUENCY - MHz		TYPE	FREQUENCY - MHz	
	Begin	End		Begin	End

Table 12. Antenna Data Required for HF Systems Performance Predictions

5. ANTENNA PARAMETERS (TRANSMITTING OR RECEIVING) - All dimensions must be in meters, wavelengths, or degrees unless otherwise stated. Electrical lengths and heights rather than physical lengths and heights should be specified.

Type 1 Terminated Rhombic

feed height _____ meters (wavelength if negative)
leg length _____ meters (wavelength if negative)
tilt angle _____ degrees
true bearing _____ degrees, east of north

Type 2 Vertical Monopole

height _____ meters (wavelength if negative)
additional gain above dipole _____ dB

Type 3 Horizontal Dipole

feed height _____ meters (wavelength if negative)
length _____ meters (wavelength if negative)
true bearing _____ degrees, east of north
additional gain above 1/2 wave horiz. dipole _____ dB

Type 4 Horizontal Yagi

feed height _____ meters (wavelength if negative)
driven element length _____ meters (wavelength if negative)
true bearing _____ degrees, east of north
additional gain above 1/2 wave horiz. dipole _____ dB

Type 5 Vertical Log Periodic Array of Monopoles (estimated using a 1/4 wave monopole)

height -.25 (wavelengths)
additional gain above 1/4 wave vertical _____ dB

Type 6 Curtain Antenna

antenna element length _____ meters
antenna height to first element _____ meters
number of bays _____
number of elements per bay _____
distance between element centers _____ meters
vertical spacing of elements _____ meters
distance from screen _____ meters
true bearing _____ degrees, east of north

Type 7 Terminated Sloping Vee

feed height _____ meters
leg length _____ meters
terminated height _____ meters
half apex angle _____ degrees
true bearing _____ degrees, east of north

Type 8 Inverted L

vertical height _____ meters
horizontal length _____ meters
true bearing _____ degrees, east of north

Type 9 Sloping Rhombic

feed height _____ meters
leg length _____ meters
half large interior angle _____ degrees
termination height _____ meters
true bearing _____ degrees, east of north

Type 10 Interlaced Rhombic

feed height _____ meters
leg length _____ meters
vertical displacement _____ meters
horizontal feed point displacement _____ meters
half large interior angle _____ degrees
true bearing _____ degrees, east of north

Type 12 Constant Gain

gain above an isotropic _____ dB
antenna efficiency _____ dB

Table 13. Input Data Required for Output Methods

DATA #	DESCRIPTION	OUTPUT/RUN TYPES			
		IONOSPHERIC PARAMETERS 1, 2	ANTENNAS 13, 14, 15	MUFS 3 TO 12	SYSTEM PERFORMANCE 16 TO 29
1. A	YEAR OR SSN	R		R	R
B	MONTH	R		R	R
C	TRANSMITTER SITE, σ, ε		R		R
D	RECEIVER SITE, σ, ε		R		R
2. A	METHOD	R	R	R	R
B	BEGINNING HOUR	R		R	R
C	END HOUR	R		R	R
D	HOUR INCREMENT	R		R	R
E	ANTENNA PATTERN				R
F	GREAT CIRCLE PATH	R		R	R
G	HEADER LINES				?
H	SYS. PER. LINES				?
3.	FREQUENCY COMP.				R
4. A	TRANSMITTER SITE	R	*	R	R
B	RECEIVER SITE	R	**	R	R
C	MIN. TAKE-OFF ANGLE			R	R
D	POWER				R
E	REQUIRED SNR				R
F	NOISE				R
G	REQUIRED RELIABILITY				?
H	MULTIPATH				?
I	MULTIPATH POWER				?
J	MULTIPATH TIME				?
5.	ANTENNA TYPES		R		R
6.	TRANSMITTING ANTENNAS		R		R
7.	RECEIVING ANTENNAS		R		R

where R denotes required
? required only if that output is requested

* Transmitter site is an optional requirement for Methods 13 and 15 if the transmitter antenna orientation is not off-azimuth from path.

** Receiver site is an optional requirement for Methods 14 and 15 if the receiver antenna orientation is not off-azimuth from path.

Table 14. Data Input Card Formats (I)

	NAME	VARIABLES	VALUES	COMMENTS
1.	METHOD	METHOD, NPAGO	1, 1	SET PROGRAM RUN OPTION AND PAGE NUMBERING.
2.	MONTH	NYEAR, MONTHS (12)	1977, 6, 12	SET YEAR AND UP TO 12 MONTHS IN TABLE.
3.	MONTHLOOP	NYEAR, MINIT, MFINAL, MINC	1977, 6, 12, 6	SET YEAR AND MONTH LOOP.
4.	SUNSPOT	SUNSP(12)	10., 110.	SUNSPOT NUMBERS. ALL MONTHS ARE RUN FOR ALL SSN'S.
5.	CIRCUIT	TLATD, ITLAT, TLONGD, ITLONG, RLATD, IRLAT, RLONGD, IRLONG, NPSL	40.03, N, 105.3, W, 30.67, N, 90.25, W	CIRCUIT. TRANSMITTER LOCATION. RECEIVER LOCATION. LONG OR SHORT PATH.
6.	SYSTEM	PWR, XNOISE, AMIND, XLUFP, RSN, PMP, DMPX	1.0, -4., 3.0, 90., 55., 10., 0.85	REQUIRED SYSTEM PARAMETERS. POWER. MAN MADE NOISE. MIN. ANGLE. RELIABILITY. SNR. POWER AND TIME DELAY FOR MULTIPATH.
7.	TIME	IHRO, IHRE, IHRS, ITIM	4, 24, 4, -1	TIME OF DAY. START. STOP. INC. LMT OR UT (≥ 0).
8.	ANTENNA	IAT, IANTR, AETA, ASIG, AEPS, AND, ANL, ANH, AEX(1), AEX(2), AEX (3), AEX (4), AFOB, IAIN	1, 1, 0., .001, 4., , , -.5	
9.	FREQUENCY	FREL (11)	3., 5., 7., 10., 13., 16., 20., 25., 30., 35.	FREQUENCIES. THIS SET WILL INSERT FOT.
10.	LABEL	ITRAN (1), ITRAN(2), IRCVR (1), IRCVR(2)	BOULDER, CO TO ST. LOUIS, MO	ALPHANUMERIC LABEL FOR IDENTIFICATION.
11.	INTEGRATE	INTEG	1	IF NON-NEGATIVE FAST INTEGRATION FOR E-F2 (NO F1) PROFILES.
12.	EXECUTE	KRUN		EXECUTE PROGRAM WITH CARDS READ IN. LE.0 ALL LAYERS. EQ. 1 E. F1. F2. ONLY. EQ. 2 Es ONLY; GE. 3 NO USE OF MAPS.
13.	SAMPLE	I, SLAT, ISLAT, SLONG, ISLONG, SGLAT, ISGLAT, RD(I), GYZ(I), CLCK(I), GMDIP(I), ARTIC(I), SIGPAT (I), EPSPAT(I)	1, 39.6, N, 97.7, W, 49.4, N, 650.6, 1.4, 4., 53., 1., .001, 4.0	GEOPHYSICAL SAMPLES AT AREA I.
14.	EFVAR	I, FI(1,I), YI(1,I), HI(1,I), FI (2,I), YI (2,I), HI(2,I), FI (3,I), YI (3,I), HI (3,I)	1, 0.61, 20., 110., 0., 0., 0., 4.1, 75.6, 338.7	E. F1. F2. PARAMETERS AT AREA I.
15.	ESVAR	I, FS(1,I), FS(2,I), FS(3,I), HS(I)	1, 0.8, 1.2, 2.5, 110.	Es PARAMETERS AT AREA I.

Table 15. Date Input Card Formats (II)

	NAME	VARIABLE	COMMENTS
16.	EDP	JSAMP: 1; ITEMP: ON	FOR ITEMP ≠ 3HOFF, NEXT 4 CARDS ARE TRUE HEIGHTS (16F5.2) AND NEXT 4 ARE f_N^2 (16F5.2) TO BE ELECTRON DENSITY PROFILE FOR AREA I.
17.	AUXIN	ITEMP: OFF	READ CARDS FROM ALTERNATE FILE.
18.	AUXOUT	ITEMP: ON	OUTPUT TO ALTERNATE FILE.
19.	ANTOUT	ITEMP: OFF	ANTENNA PATTERNS ARE TO BE OUTPUT.
20.	OUTGRAPH	KTOUT (I2): 8, 10, 9	COMBINE OUTPUT METHODS, E. G. LINES AND GRAPHS.
21.	COMMENT	THIS IS A SAMPLE COMMENT CARD	ALLOWS COMMENT IN INPUT STREAM.
22.	FREEFORM	ITEMP: OFF	WILL BE USED TO INDICATE FREE FORM INPUT.
23.	PROCEDURE	USER DEFINED NAME: NAME	SET A PROCEDURE, E. G., A BLOCK OF CIRCUIT CARDS CAN BE REPEATED BY INSERTING THE CARD "CIRCUITS."
24.	END		DENOTES END OF PROCEDURE.
25.	NEXT		END OF MONTH AND SUNSPOT LOOP.
26.	QUIT		END PROGRAM EXECUTION.
27.	FPROB	E PSC (1): 1.; F1 PSC (2): 1.; F2 PSC (3): 1.; Es PSC (4): 1.	EACH CRITICAL FREQUENCY IS MULTIPLIED BY A PSC. FOR MEDIAN LOSSES USE PSC(4) = 0.7, REST AS 1.0.
28.	TOPLINES	LINTP (I4): 1, 2, 3, 4	OVERIDE METHOD, PRINT TOP LINES SPECIFIED.
29.	BOTLINES	LINBD (I4): 1, 2, 4, 7, 15, 16, 17, 18, 19, 20	OVERIDE METHOD, PRINT LINES SPECIFIED.
30.	DEBUG	ITEMP: OFF	DEBUG OUTPUT FOR PROGRAM DEVELOPMENT.
31.	EDP		

Table 16. Antenna Data Input Card Formats

Card (cols 1–10)	T or R T=1	Type	Bearing (Gain)	Sigma (Optnl)	Epsilon (Optnl)	Tilt Angle (No. of Bays)	Length ("-" is in wave Length)	Height	EX(1)	EX(2)	EX(3)	EX(4)	AFQB	IAIN
COMMENT														
COMMENT	ITSA-1 ANTENNA PACKAGE (REVISED 1977)													
COMMENT														
COMMENT	TERMINATED RHOMBIC TRANSMITTER ANTENNA													
ANRENNA	1	1		.001	4.00	67.5	88.39	16.76						
COMMENT	VERTICAL MONOPOLE RECEIVER ANTENNA													
ANTENNA	2	2		.001	4.0		-0.25						30.	1
COMMENT	HORIZONTAL DIPOLE TRANSMITTER ANTENNA													
ANTENNA	1	3		.001	4.0		-.5	-.25	0.0				30.	1
COMMENT	HORIZONTAL YAGI RECEIVER ANTENNA													
ANTENNA	2	4		.001	4.0		-.5	-.25	3.0					
COMMENT	VERTICAL LOG PERIODIC ARRAY OF MONOPOLES TRANSMITTER ANTENNA													
ANTENNA	1	5		.001	4.		-.25		2.					
COMMENT	CURTAIN RECEIVER ANTENNA													
ANTENNA	2	6		.001	4.0	2.0	22.	16.	4.0	26.	13.	7.	30.	1
COMMENT	TERMINATED SLOPING VEE TRANSMITTER ANTENNA													
ANTENNA	1	7	0.0	.001	4.0	22.5	121.9	15.24	1.829				30.	1
COMMENT	INVERTED L RECEIVER ANTENNA													
ANTENNA	2	8		.001	4.0		21.34	10.0					30.	1
COMMENT	TERMINATED SLOPING RHOMBIC TRANSMITTER ANTENNA													
ANTENNA	1	9		.001	4.0	22.5	88.39	16.76	8.382					
COMMENT	INTERLACED RHOMBIC RECEIVER ANTENNA													
ANTENNA	2	10		.001	4.	70.	114.	20.	4.	33.				
COMMENT	CONSTANT GAIN TRANSMITTER ANTENNA													
ANTENNA	1	12	10.	.001	4.			0.						

Table 17. Binary Data File Structure

BLOCK	NAME	RECORDS	SIZE
1	YEAR	1	1468
2	WINTER	2, 3	1548 + 2796 = 4344
3	JANUARY	4, 5, 6, 7	914 + 1100 + 1278 + 1976 = 5268
4	FEBRUARY	8, 9, 10, 11	
5	SPRING	12, 13	
6	MARCH	14, 15, 16, 17	
7	APRIL	18, 19, 20, 21	
8	MAY	22, 23, 24, 25	
9	SUMMER	26, 27	
10	JUNE	28, 29, 30, 31	
11	JULY	32, 33, 34, 35	
12	AUGUST	36, 37, 38, 39	
13	FALL	40, 41	
14	SEPTEMBER	42, 43, 44, 45	
15	OCTOBER	46, 47, 48, 49	
16	NOVEMBER	50, 51, 52, 53	
17	WINTER	54, 55	
18	DECEMBER	56, 57, 58, 59	

Table 18. Year Data Block.

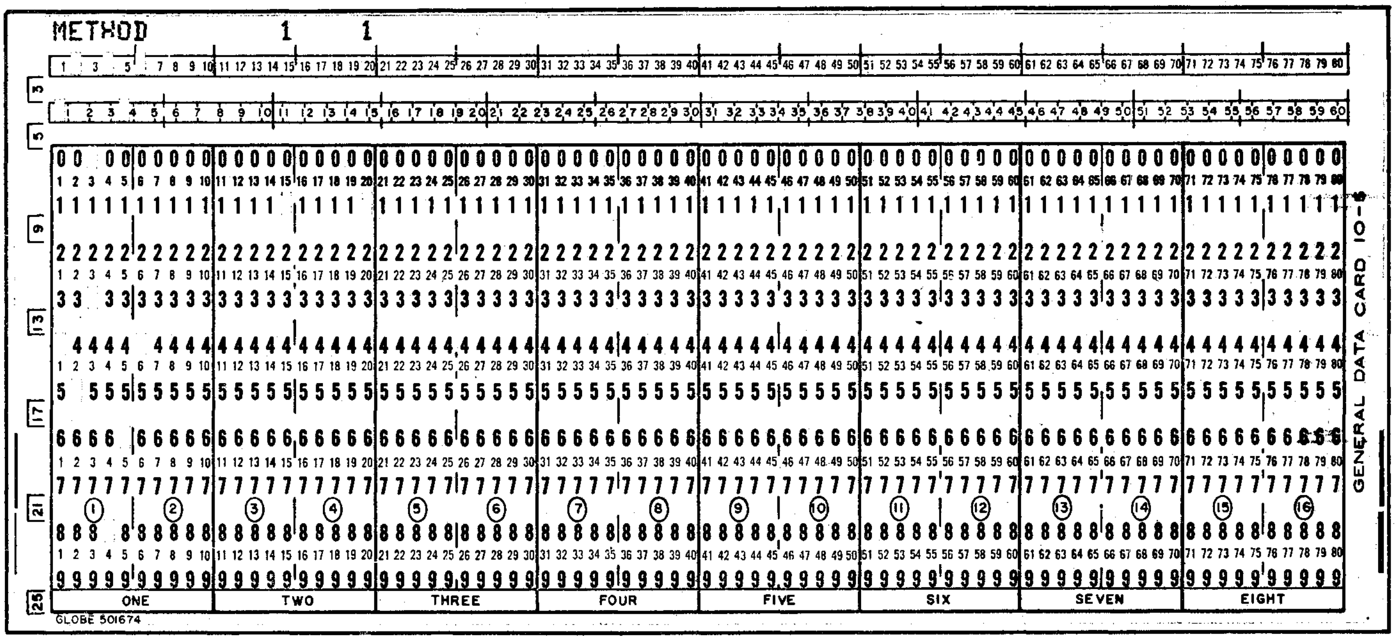
VARIABLE	DESCRIPTION	SOURCE	LISTING
XF1COF(10, 7)	foF1 and Xmax	Rosich, Jones, 1973	Same
FAKMAP(29, 16)	Land mass map	Lucas, Haydon, 1966	Spogen, et al., 1967
XPMAP(29,16.2)	h_mF2/ymF2 ratio	Lucas, Haydon, 1966	Spogen, et al., 1967
ABMAP(2, 3)	"	"	

Table 19. Season Data Block.

VARIABLE	DESCRIPTION	SOURCE	LISTING
F2D(16, 6, 6)	F2(3000) MUF Deciles	Lucas, Haydon, 1966	Same
DUD(5, 12, 5)	Noise deciles	Lucas, Harper, 1965	Same
FAM(14, 12)	Noise frequency dependence	Lucas, Harper, 1965	Same
SYS(9, 16, 6)	Signal level deciles	Lucas, Haydon, 1966	Same
PERR(9, 4, 6)	Prediction errors		
FAKP(29, 16, 6)	Atmospheric noise	Lucas, Harper, 1965	Same
FAKABP(2, 6)	"	"	"

Table 20. Month Data Block

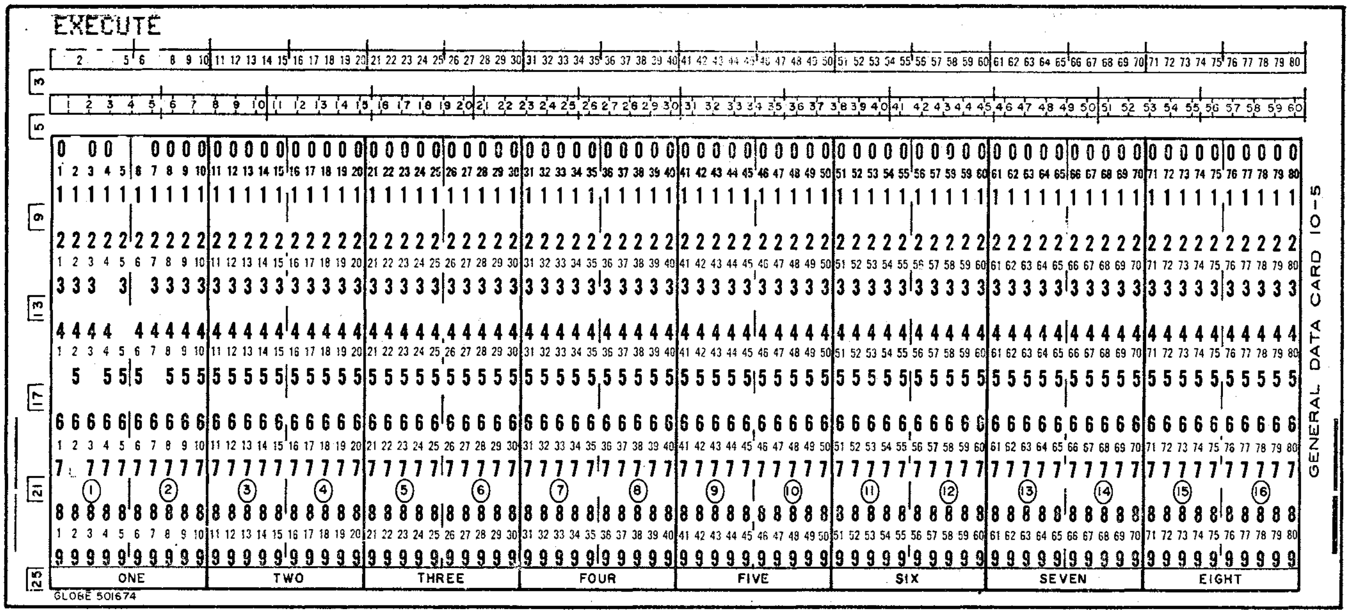
VARIABLE	DESCRIPTION	SOURCE	LISTING
IKIM(10, 6)	Summation limits for series below	as below	as below
XESMCF(7, 61, 2)	Median foEs	Leftin, et al., 1968	Partial in same
XESLCF(5, 55, 2)	Lower Decile foEs	Leftin, et al., 1968	Partial (seasons) in same
XESUCF(5, 55, 2)	Upper Decile foEs	"	"
XFM3CF(9, 49, 2)	Median F2 M(3000)	CCIR, 1966	Same
XERCOF(9, 22, 2)	Median foE	Leftin, 1976	None
XF2COF(13, 76, 2)	Median foF2	CCIR, 1966	Same



METHOD Control Card (3.3.1)

Columns	Name	Format	Description of Input Data
1-10		A10	"METHOD" control card identifier
11-15	Method	I5	Program task option, 1 to 30
16-20	NPAGO	I5	Starting page number on output file. (Note if NPAGO
			$\leq$ 0 then initial page is set to default of one.)

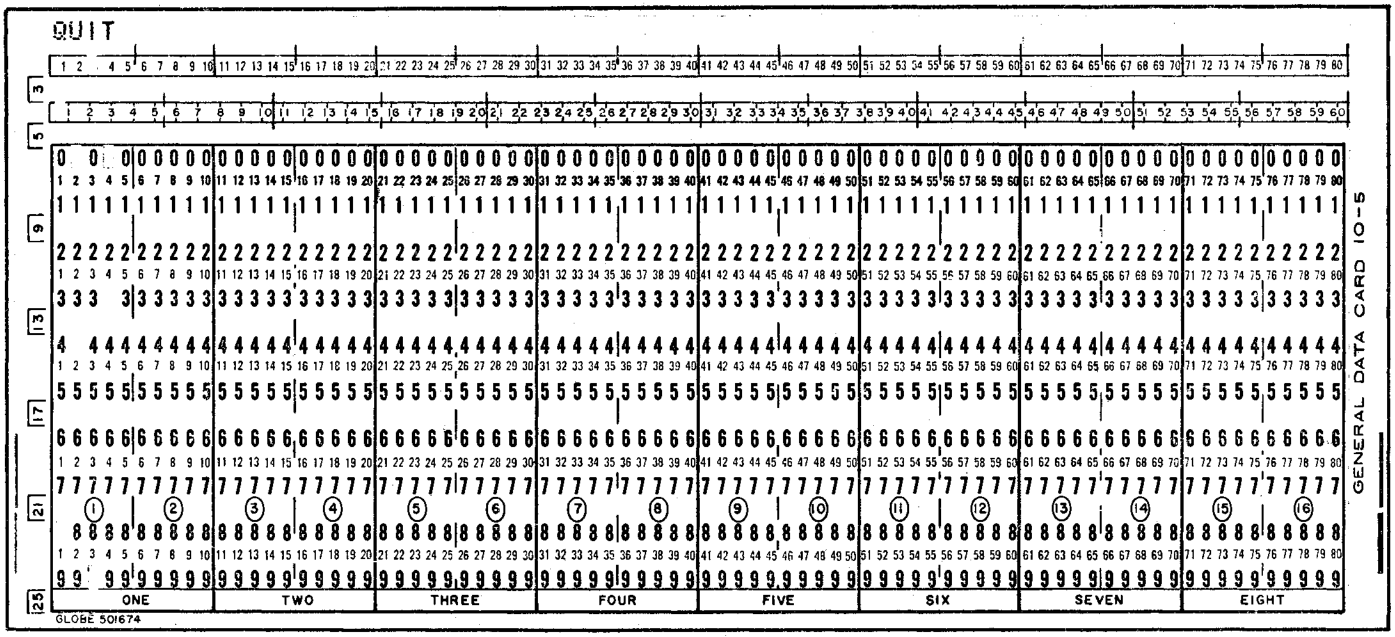
Control Card 1. METHOD card



EXECUTE Control Card (3.3.1)

Columns	Name	Format	Description of Input Data
1-10		A10	"EXECUTE" control card identifier
11-15	KRUN	I5	3 = no indices calculation; 2 = Es indices only; 1 = E,
			F1, F2 indices only; 0 = E, F1, F2, Es indices.
			(default is KRUN = 0 which indicates indices are calculated
			for each ionospheric layer)

Control Card 2. EXECUTE card

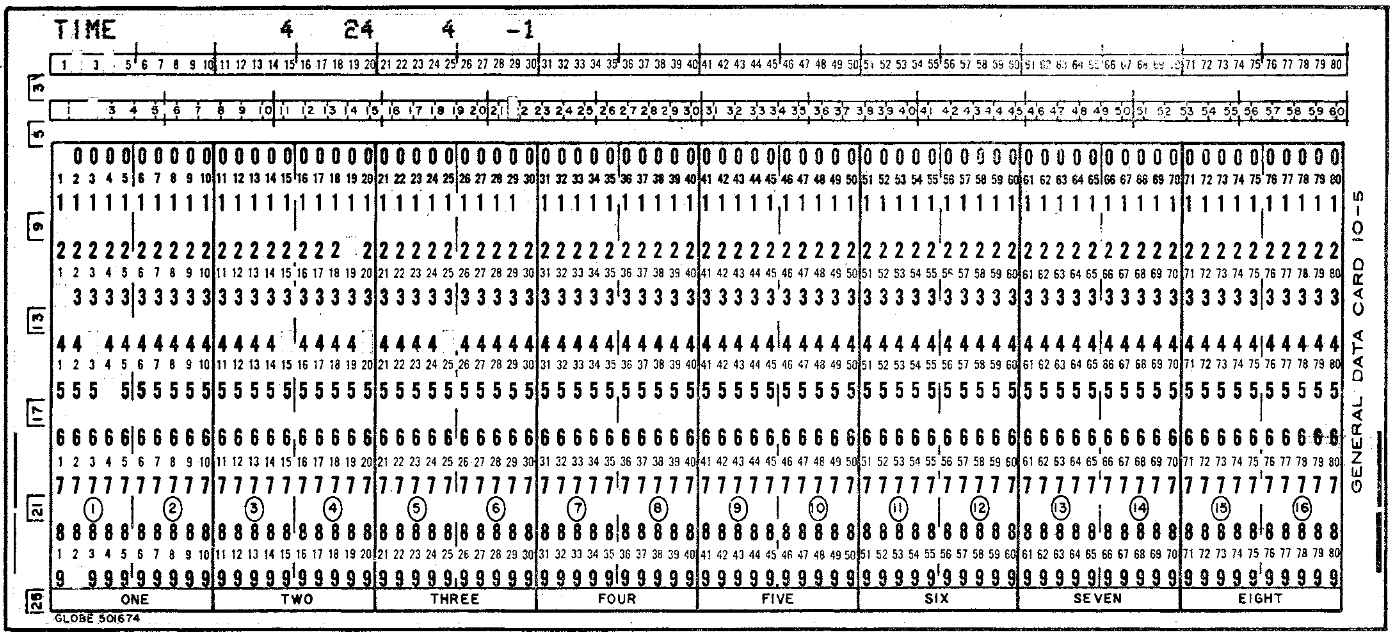


QUIT Control Card (3.3.1)

Columns	Name	Format	Description of Input Data
1-10		A10	"QUIT" control card identifier

NOTE: THIS CARD MUST BE PRESENT AND MUST BE THE LAST CARD ON THE INPUT FILE.

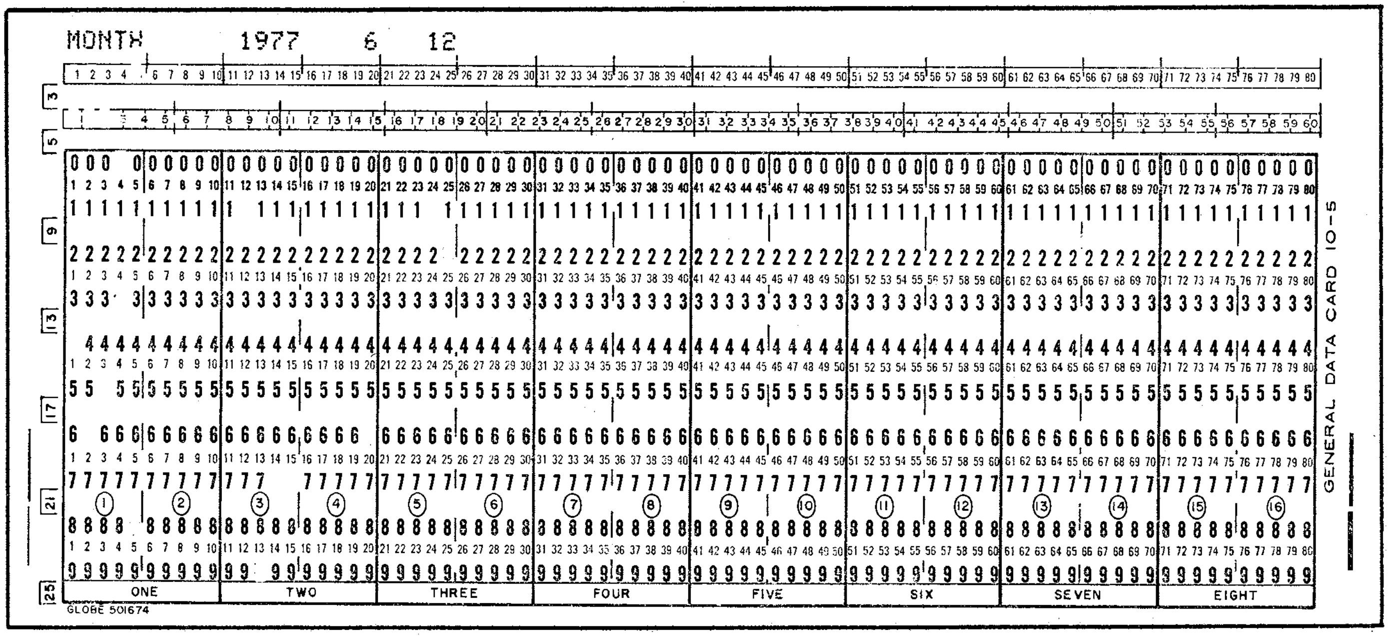
Control Card 3. QUIT card



TIME Control Card (3.3.2)

Columns	Name	Format	Description of Input Data
1-10		A10	"TIME" control card identifier
11-15	IHRO	I5	Start time, hours
16-20	IHRE	I5	Stop time, hours
21-25	IHRS	I5	Hour increment, hours
26-30	ITIM	I5	If negative LMT at transmitter, otherwise UT

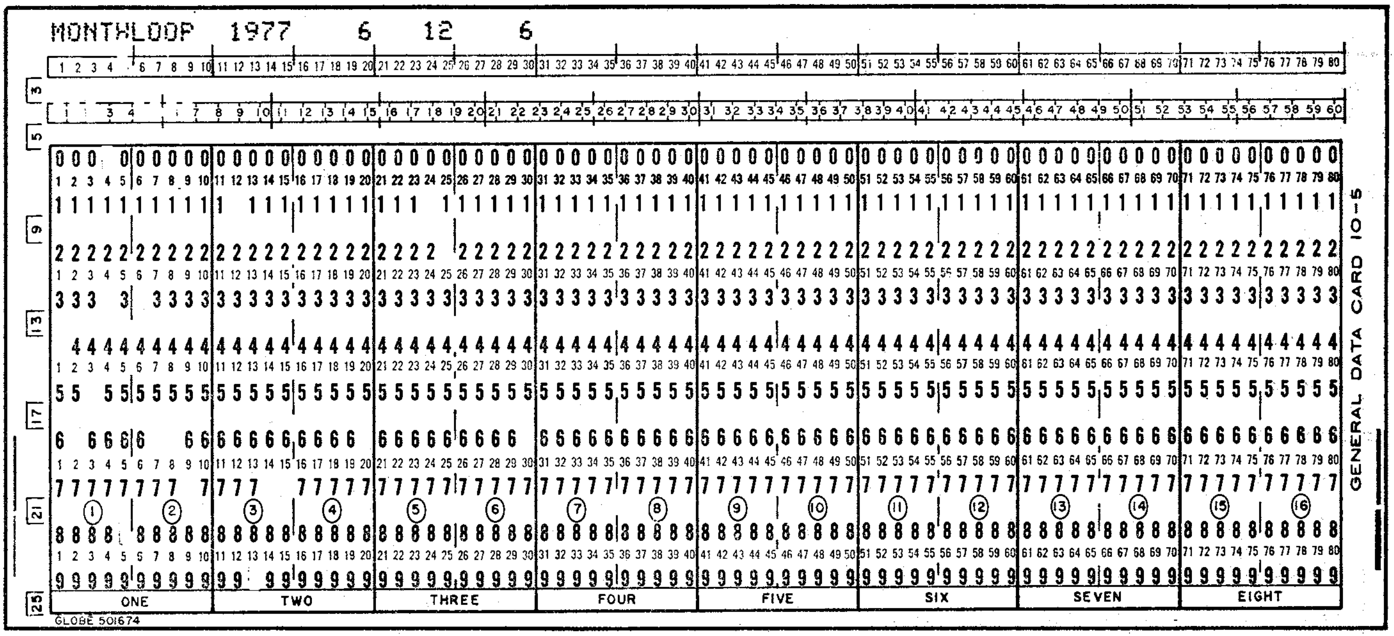
Control Card 4. TIME card



MONTH Control Card (3.3.2)

Columns	Name	Format	Description of Input Data
1-10		A10	"MONTH" control card identifier
11-15	NYEAR	I5	Year
16-20	MONTHS(1)	I5	an array of up to 12 months where January is represented by
21-25	MONTHS(2)	I5	1, February is represented by 2, etc.
26-30	MONTHS(3)	I5	
31-35	MONTHS(4)	I5	
36-40	MONTHS(5)	I5	
41-45	MONTHS(6)	I5	
46-50	MONTHS(7)	I5	
51-55	MONTHS(8)	I5	
56-60	MONTHS(9)	I5	
61-65	MONTHS(10)	I5	
66-70	MONTHS(11)	I5	
71-75	MONTHS(12)	I5	

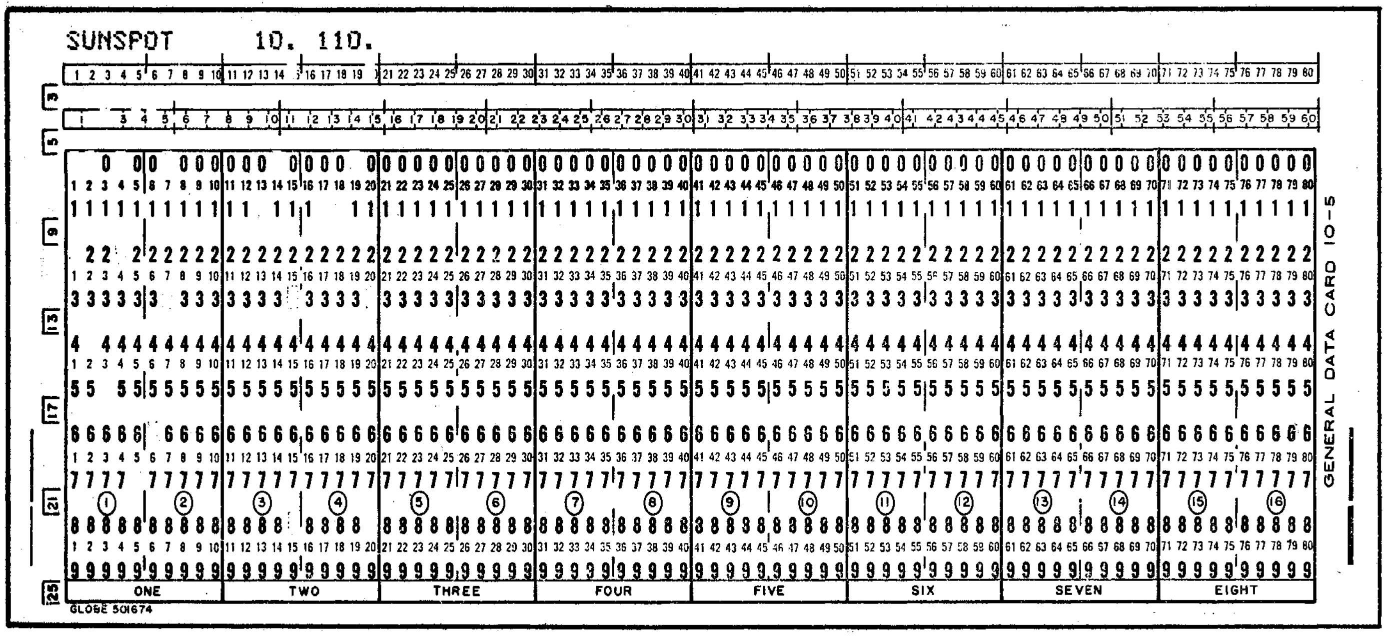
Control Card 5. MONTH card



MONTHLOOP Control Card (3.3.2)

Columns	Name	Format	Description of Input Data
1-10		A10	"MONTHLOOP" control card identifier
11-15	NYEAR	I5	Year
16-20	MINIT	I5	Starting month number; 1 is January, 2 is February etc.
21-25	MFINAL	I5	Last month number
26-30	MINC	I5	Increment

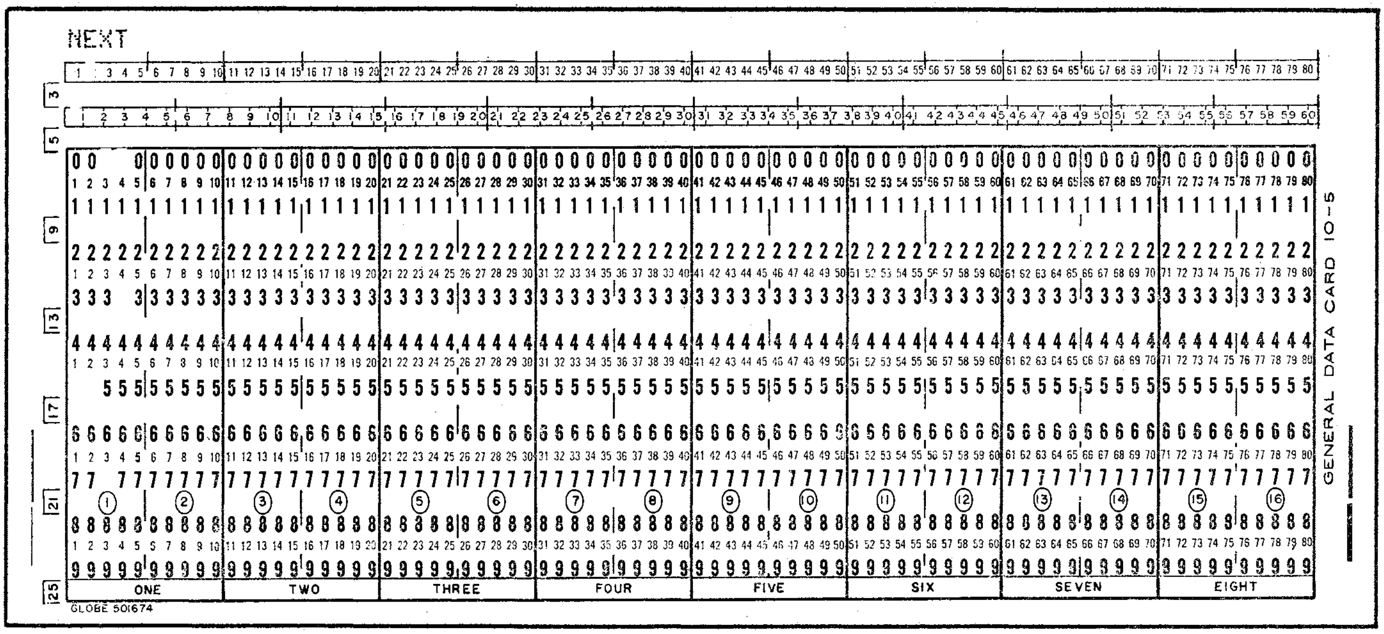
Control Card 6. MONTHLOOP card



SUNSPOT Control Card (3.3.2)

Columns	Name	Format	Description of Input Data
1-10		A10	"SUNSPOT" control card identifier
11-15	SUNSP(1)	F5.1	An array of up to
16-20	SUNSP(2)	F5.1	12 sunspot numbers.
21-25	SUNSP(3)	F5.1	
26-30	SUNSP(4)	F5.1	
31-35	SUNSP(5)	F5.1	
36-40	SUNSP(6)	F5.1	
41-45	SUNSP(7)	F5.1	
46-50	SUNSP(8)	F5.1	
51-55	SUNSP(9)	F5.1	
56-60	SUNSP(10)	F5.1	
61-65	SUNSP(11)	F5.1	
66-70	SUNSP(12)	F5.1	
			May be negative; only the first sunspot number. SUNSP(1),
			may be 0.0.

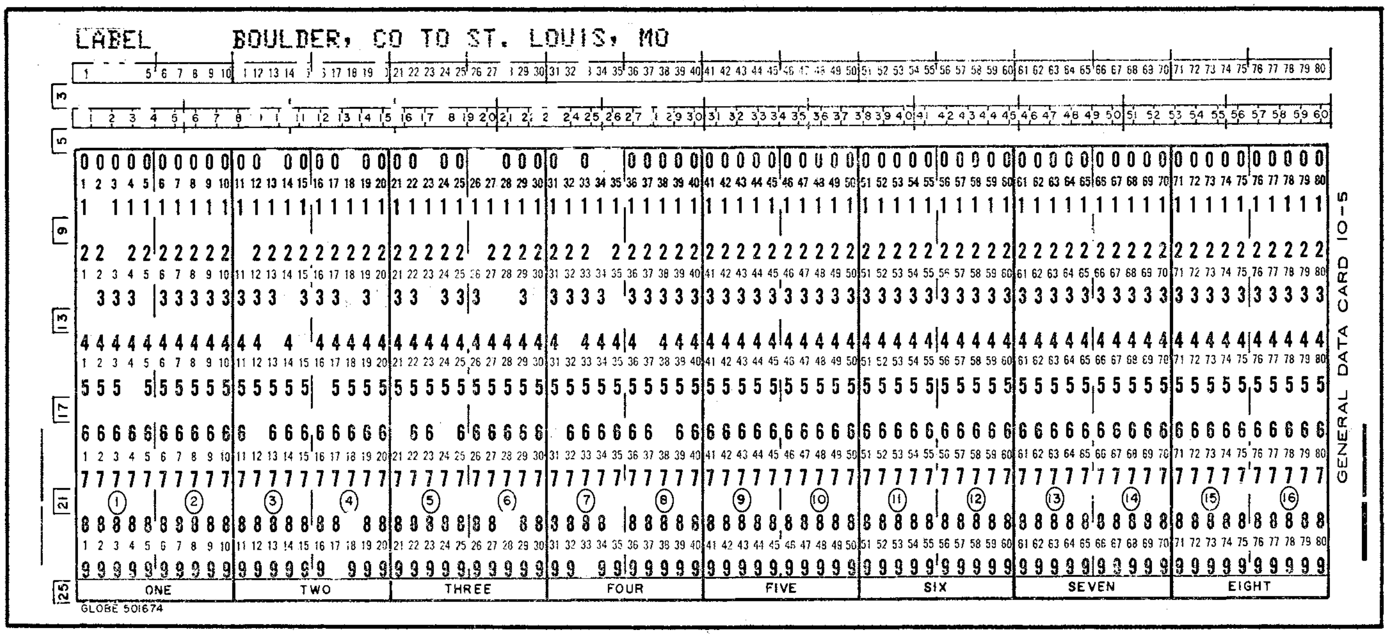
Control Card 7. SUNSPOT card



NEXT Control Card (3.3.2)

Columns	Name	Format	Description of Input Data
1-10		A10	"NEXT" control card identifier
			Indicates end of a month-sunspot loop

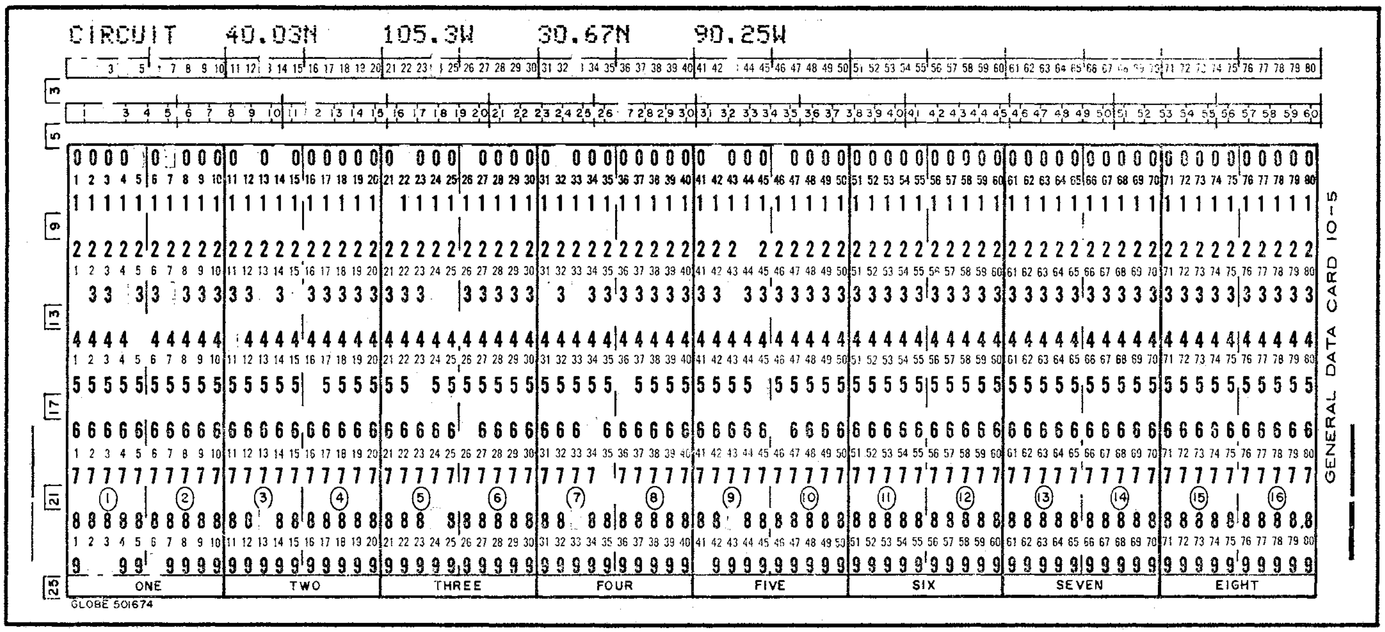
Control Card 8. NEXT card



LABEL Control Card (3.3.3)

Columns	Name	Format	Description of Input Data
1-10		A10	"LABEL" control card identifier
11-20	ITRAN(1)	A10	For output identification only
21-30	ITRAN(2)	A10	For output identification only
31-40	IRCVR(1)	A10	For output identification only
41-50	IRCVR(2)	A10	For output identification only

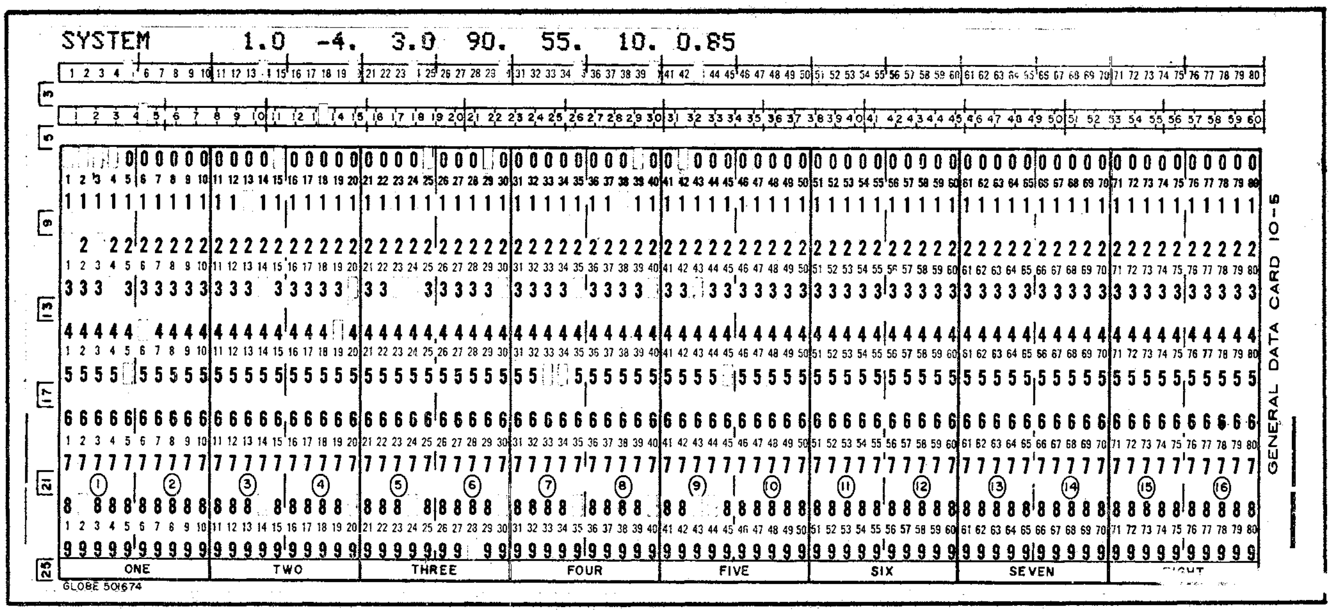
Control Card 9. LABEL card



CIRCUIT Control Card (3.3.3)

Columns	Name	Format	Description of Input Data
1-10		A10	"CIRCUIT" control card identifier
11-15	TLATD	F5.2	Latitude of transmitter, degrees
16	ITLAT	A1	N = north, S = south
21-25	TLONGD	F5.2	Longitude of transmitter, degrees
26	ITLONG	A1	E = east, W = west
31-35	RLATD	F5.2	Latitude of receiver, degrees
36	IRLAT	A1	N = north, S = south
41-45	RLONGD	F5.2	Longitude of receiver, degrees
46	IRLONG	A1	E = east, W = west
51-55	NPSL	I5	Use long great circle path if = 1
			(default is NPSL = 0 which specifies that the shortest
			distance between transmitter and receiver is used as circuit path)

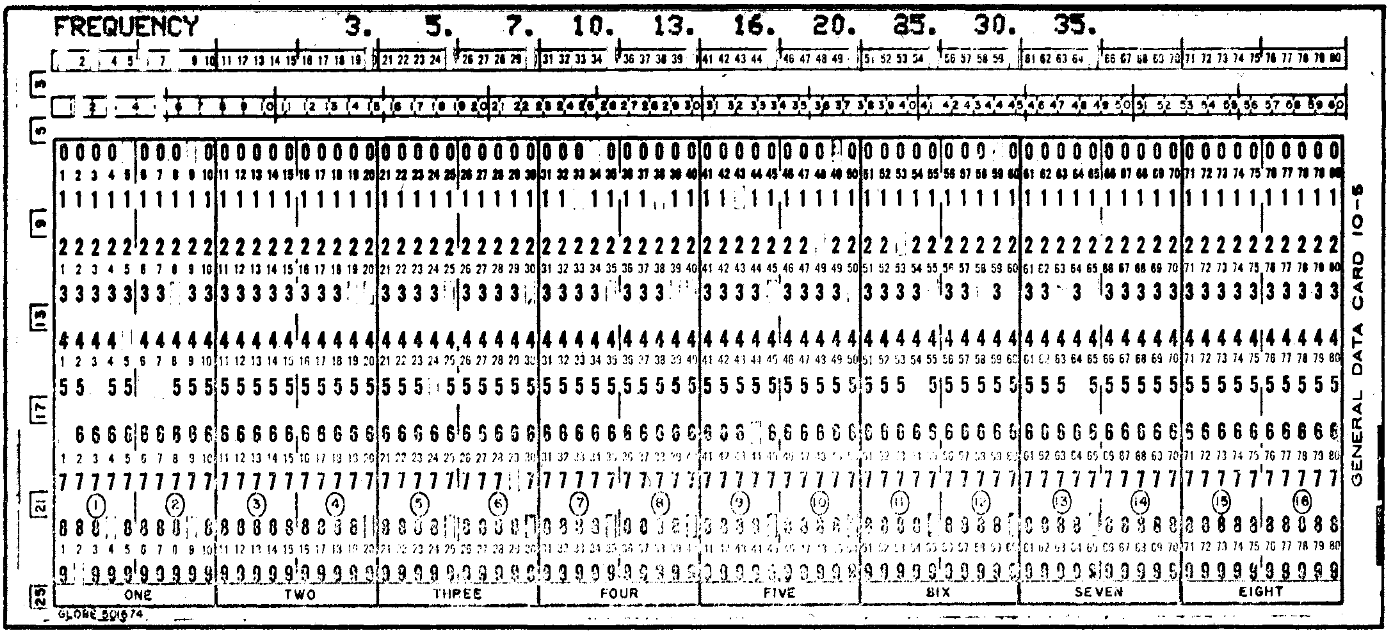
Control Card 10. CIRCUIT card



SYSTEM Control Card (3.3.3)

Columns	Name	Format	Description of Input Data
1-10		A10	"SYSTEM" control card identifier
11-15	PWR	F5.2	Transmitter power, kilowatts
16-20	XNOISE	F5.0	Man-made noise in dB below a watt (-dBW);-1 is industrial (125),
			-2 is residential (136), -3 is rural (148), -4 is remote (164)*
21-25	AMIND	F5.2	Minimum radiation angle, degrees
26-30	XLUFP	F5.0	Required reliability, percent
31-35	RSN	F5.2	Required SNR, dB
36-40	PMP	F5.2	Multipath power tolerance, dB
41-45	DMPX	F5.2	Multipath time delay increment, milliseconds
			*The user may indicate other man-made noise values by
			specifying a positive value in this field.

Control Card 11. SYSTEM card

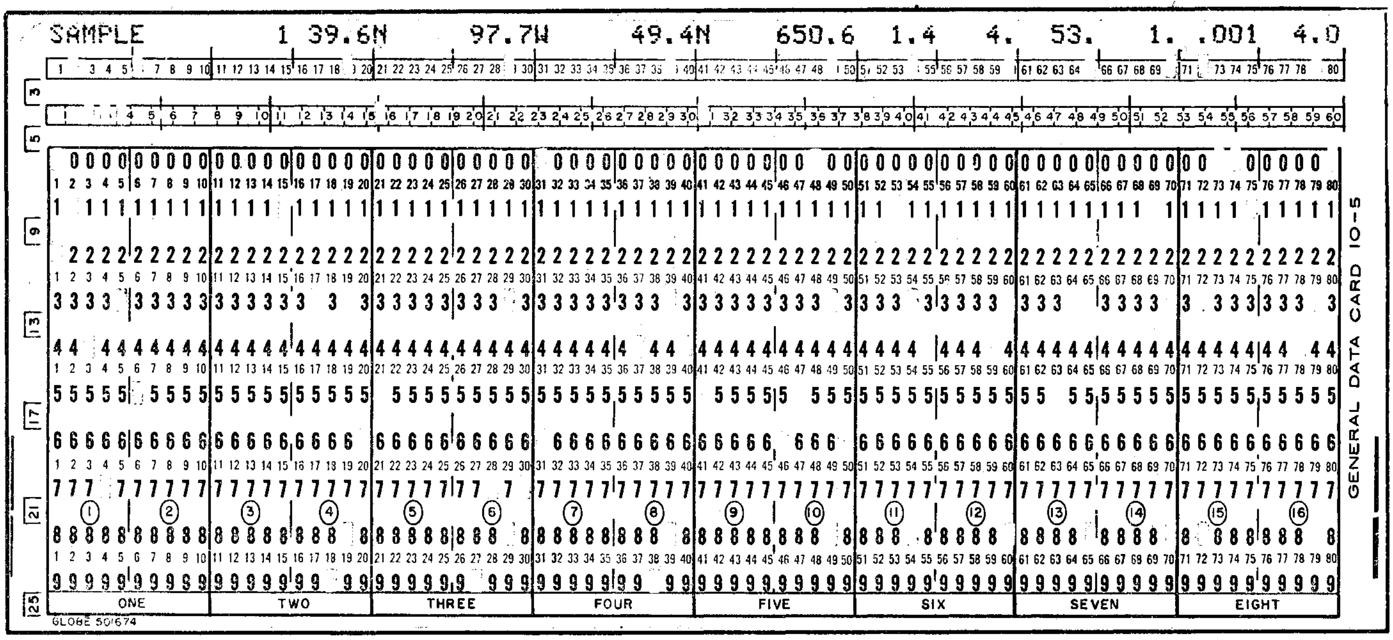


FREQUENCY Control Card (3.3.3)

Columns	Name	Format	Description in Input Data
1-10		A10	"FREQUENCY" control card identifier
11-15	FREL(1)	F5.2	Array of up to 11 frequencies, MHz,
16-20	FREL(2)	F5.2	if FREL(1) is zero, then the FOT replaces FREL(1)
21-25	FREL(3)	F5.2	
26-30	FREL(4)	F5.2	
31-35	FREL(5)	F5.2	
36-40	FREL(6)	F5.2	
41-45	FREL(7)	F5.2	
46-50	FREL(8)	F5.2	
51-55	FREL(9)	F5.2	
56-60	FREL(10)	F5.2	
61-65	FREL(11)	F5.2	

Up to eleven values on this card are used. A nonpositive value terminates the frequency loop. If card is blank a complement is calculated for each hour.

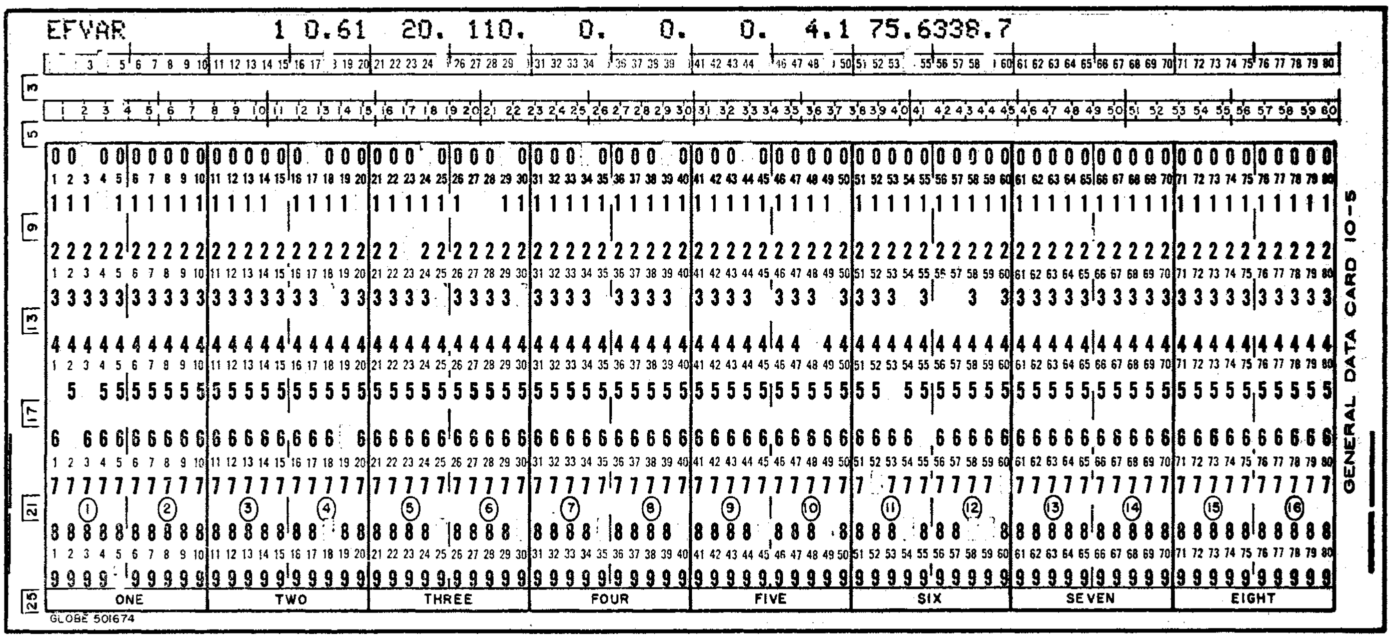
Control Card 12. FREQUENCY card



SAMPLE Control Card (3.3.4)

Columns	Name	Format	Description in Input Data
1-10		A10	"SAMPLE" control card identifier
11-15	I	I5	Sample area 1 to 5
16-20	SLAT	F5.2	Geographic latitude, degrees
21	ISLAT	A1	N = North, S = South
26-30	SLONG	F5.2	Geographic longitude, degrees
31	ISLONG	A1	E = East, W = West
36-40	SGLAT	F5.2	Geomagnetic latitude, degrees
41	ISGLAT	A1	N = North, S = South
46-50	RD(I)	F5.0	Distance from transmitter, km
51-55	GYZ(I)	F5.2	Gyrofrequency, MHz
56-60	CLCK(I)	F5.2	Local mean time
61-65	GMDIP(I)	F5.2	Geomagnetic dip angle
66-70	ARTIC(I)	F5.2	Auroral loss, dB
71-75	SIGPAT(I)	F5.2	Ground conductivity, mhos/m
76-80	EPSPAT(I)	F5.2	Relative dielectric constant

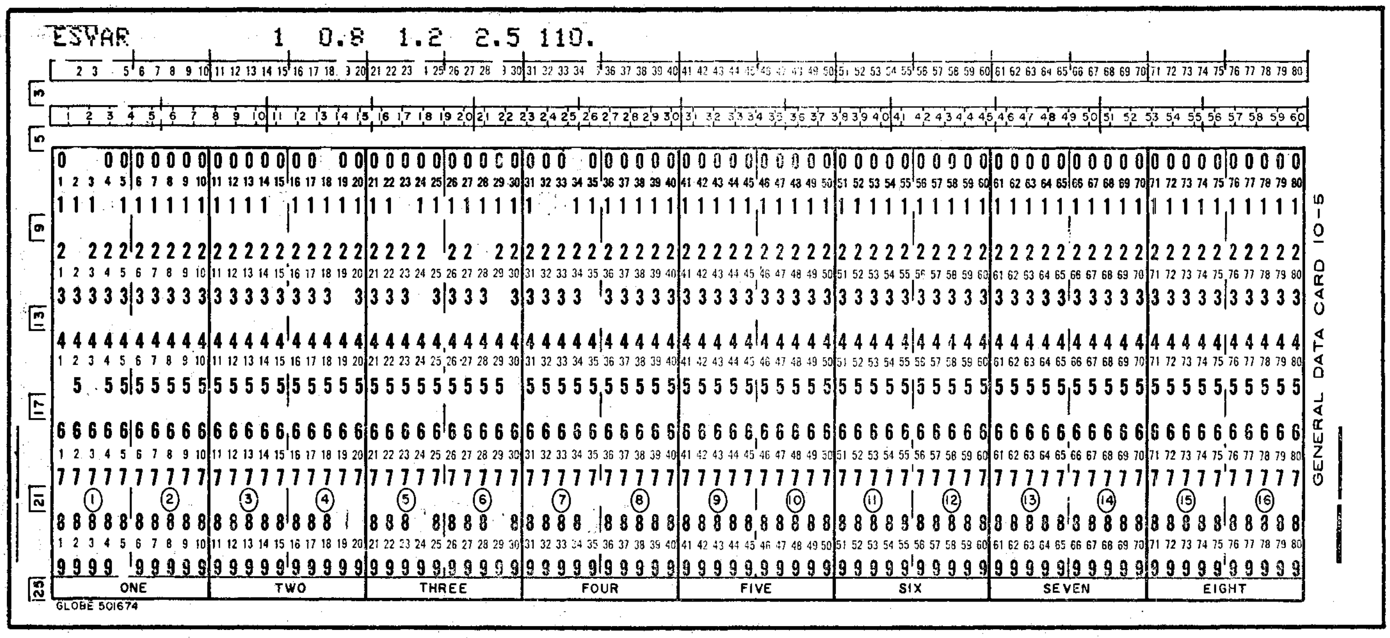
Control Card 13. SAMPLE card



EFVAR Control Card (3.3.4)

Columns	Name	Format	Description in Input Data
1-10		A10	"EFVAR" control card identifier
11-15	I	I5	Sample area 1 to 5
16-20	FI(1,I)	F5.2	foE, MHz
21-25	YI(1,I)	F5.1	ymE, km
26-30	HI(1,I)	F5.1	hmE, km
31-35	FI(2,I)	F5.2	foF1, MHz
36-40	YI(2,I)	F5.1	ymF1, km
41-45	HI(2,I)	F5.1	hmF1, km
46-50	FI(3,I)	F5.2	foF2, MHz
51-55	YI(3,I)	F5.1	ymF2, km
56-60	HI(3,I)	F5.1	hmF2, km

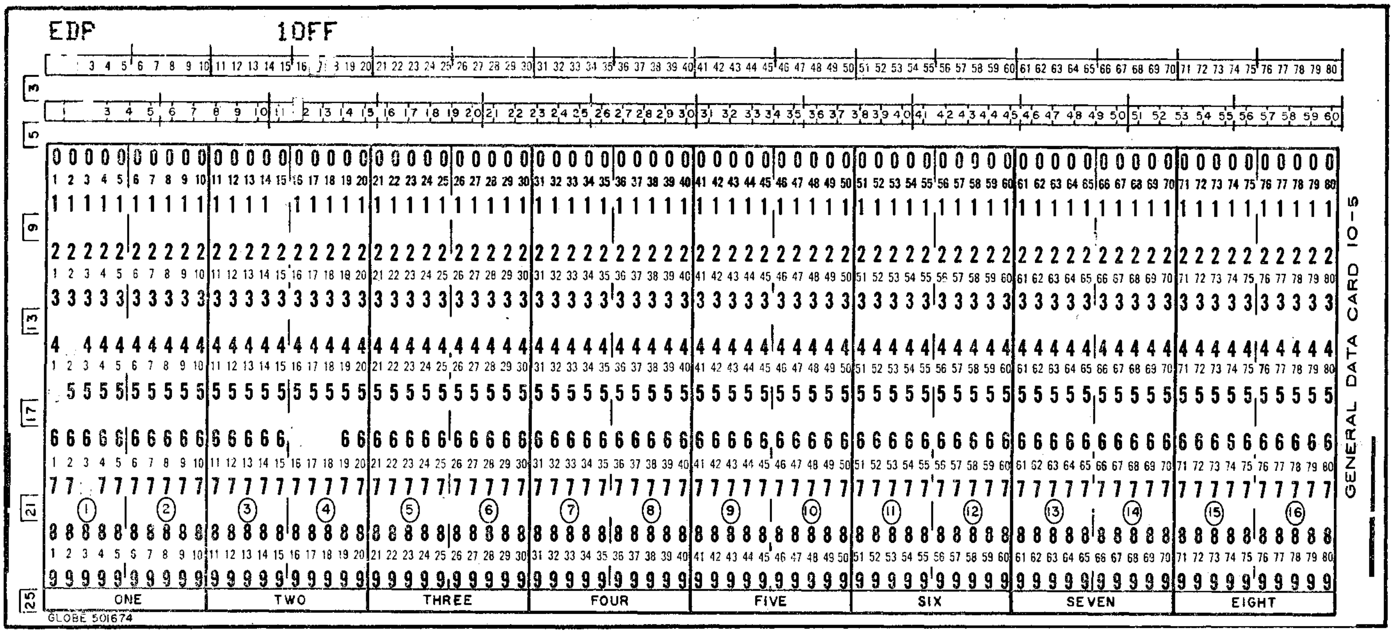
Control Card 14. EFVAR card



ESVAR Control Card (3.3.4)

Columns	Name	Format	Description of Input Data
1-10		A10	"ESVAR" control card identifier
11-15	I	I5	Sample area 1 to 5
16-20	FS(1,I)	F5.2	foEs, lower decile, MHz
			= lowest value, e.g., 2.
21-25	FS(2,I)	F5.2	foEs median, e.g., 4., MHz
26-30	FS(3,I)	F5.1	foEs upper decile, MHz
			= highest value, e.g., 6.
31-35	HS(I)	F5.1	Virtual height of reflection, km, e.g., 110

Control Card 15. ESVAR card



EDP Control Card (3.3.4)

Columns	Name	Format	Description of Input Data
1-10		A10	"EDP" control card identifier
11-15	JSAMP	I5	Must = 1 (limitation on current implementation)
16-25	ITEMP	A10	If "OFF" return to use calculated EDP
			If not "OFF" followed by 8 cards; first four contain
			heights, second four contain square of plasma frequency

Control Card 16. EDP card

Data for external electron density profile (3.3.4)

Columns	Name	Format	Description of Input Data
1-5	HTR(1)	F5.2	True heights, kilometers
6-10	HTR(2)	F5.2	
	⋮		

Four cards containing 50 values.

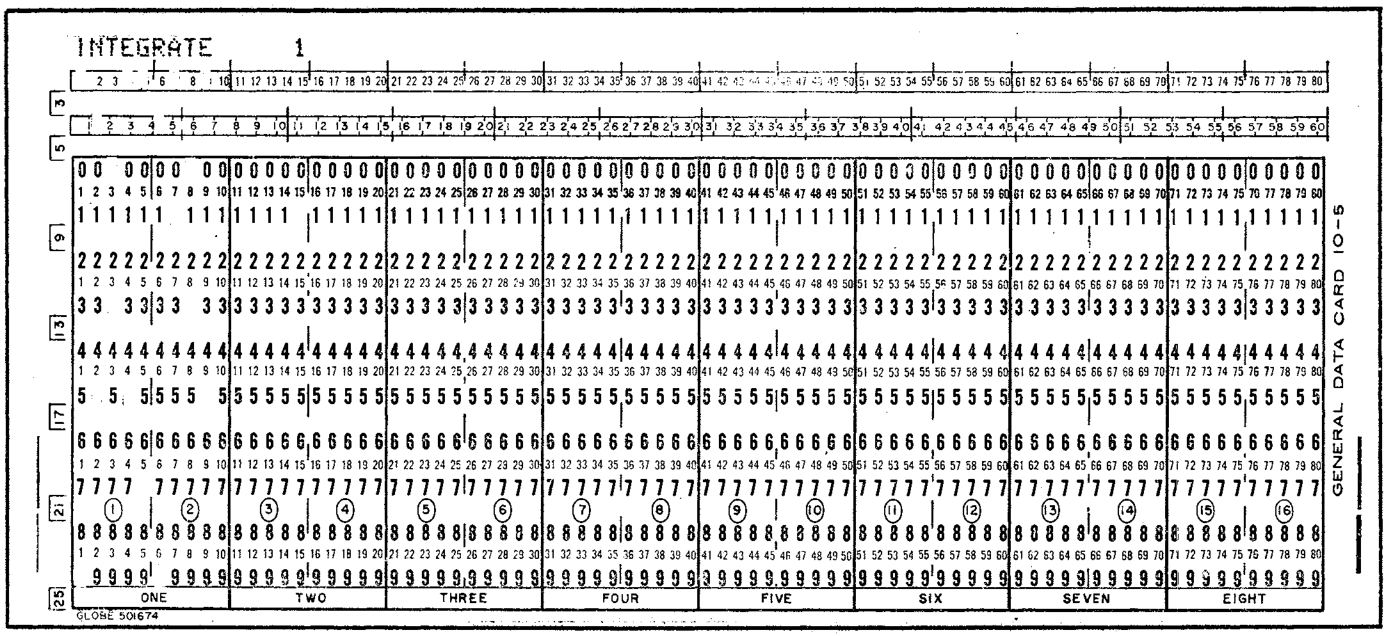
Control Card 17. Electron density cards, true height

Data for external electron density profile (3.3.4)

Columns	Name	Format	Description of Input Data
1-5	FNSQ(1)	F5.2	Plasma frequency squared $(\mathrm{MHz})^2$
6-10	FNSQ(2)	F5.2	
	⋮		

Four cards containing 50 values.

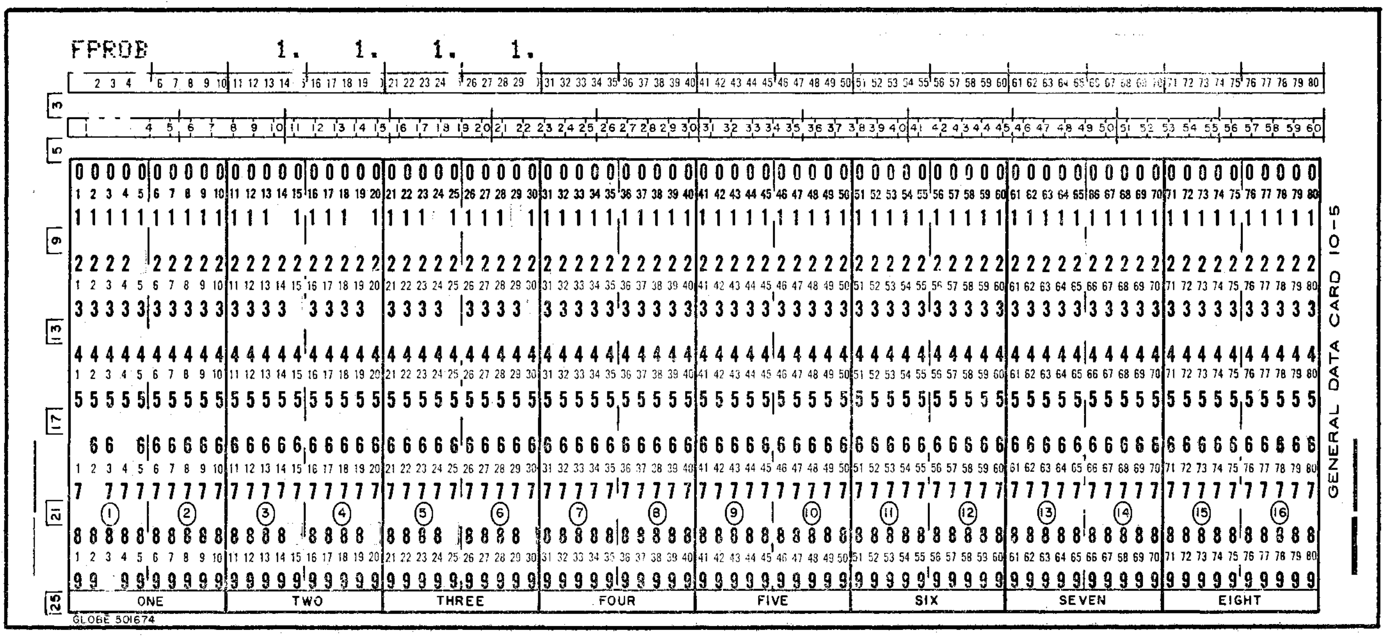
Control Card 18. Electron density cards, square of plasma frequency



INTEGRATE Control Card (3.3.4)

Columns	Name	Format	Description of Input Data
1-10		A10	"INTEGRATE" control card identifier
11-15	INTEG	I5	$\geq$ 0 indicates fast integration; < 0 indicates
			Gaussian integration
	-OR-		
11-20	ITEMP	A10	"OFF" indicates return to fast integration

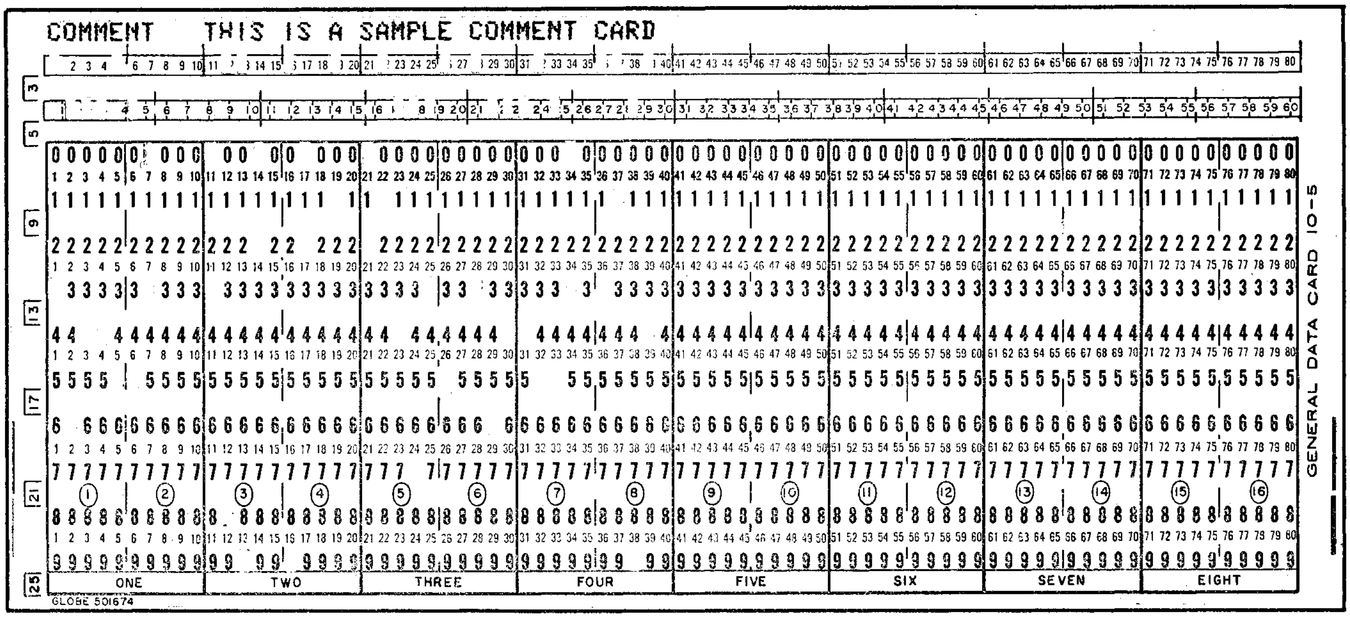
Control Card 19. INTEGRATE card



FPROB Control Card (3.3.4)

Columns	Name	Format	Description of Input Data
1-10		A10	"FPROB" control card identifier
11-15	PSC(1)	F5.1	Multiplier for foE > 0
16-20	PSC(2)	F5.1	Multiplier for foF1
21-25	PSC(3)	F5.1	Multiplier for foF2 > 0
26-30	PSC(4)	F5.1	Multiplier for foEs
	-OR-		
11-20	ITEMP	A10	"OFF" returns to default values of 1.0, 1.0, 1.0, 0.7
			The value for foE and foF2 must be positive. The F1 layer
			can be removed by setting the multiplier for foF1 to 0.
			The Es layer can be removed as a separater layer in the
			same manner.

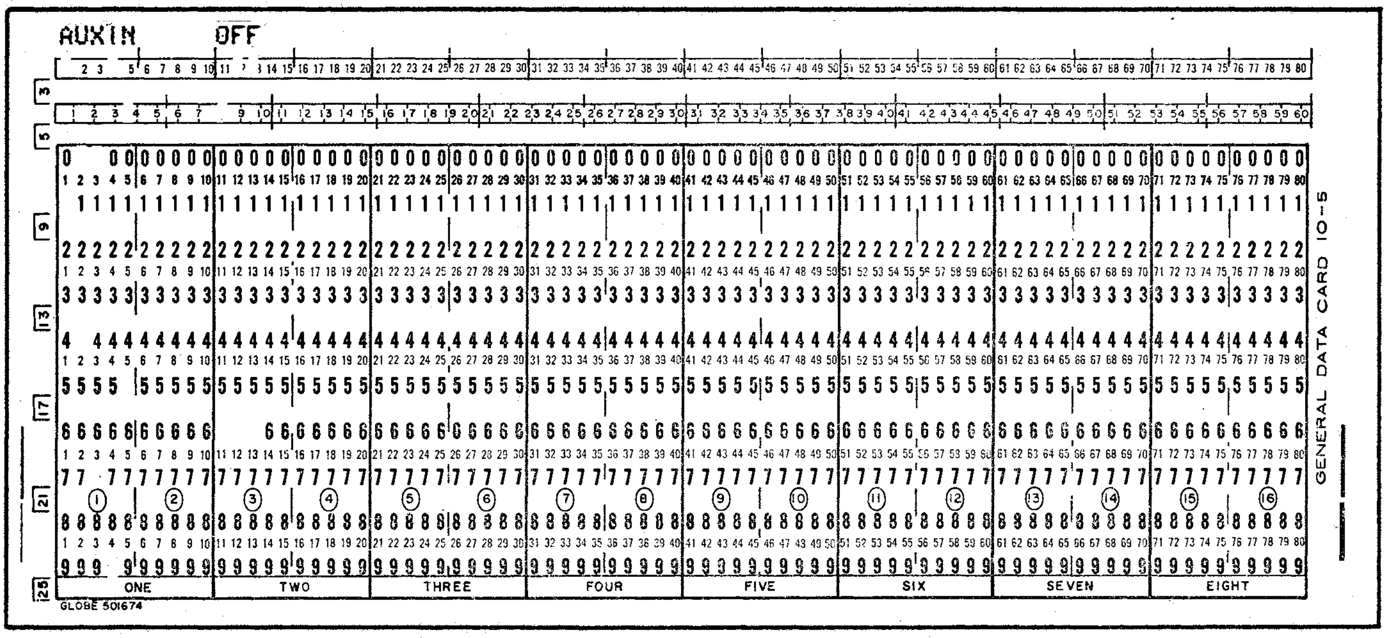
Control Card 20. FPROB card



COMMENT control Card (3.3.5)

Columns	Name	Format	Description of Input Data
1-10		A10	"COMMENT" control card identifier
11-80			User inserts description of the input file or other remarks
			and comments; not internally read by program

Control Card 21. COMMENT card



AUXIN Control Card (3.3.5)

Columns	Name	Format	Description of Input Data
1-10		A10	"AUXIN" control card identifier
11-20	ITEMP	A10	If = "OFF" return to user defined input file LU5 otherwise
			program uses LU15 as user defined input file

Control Card 22. AUXIN card

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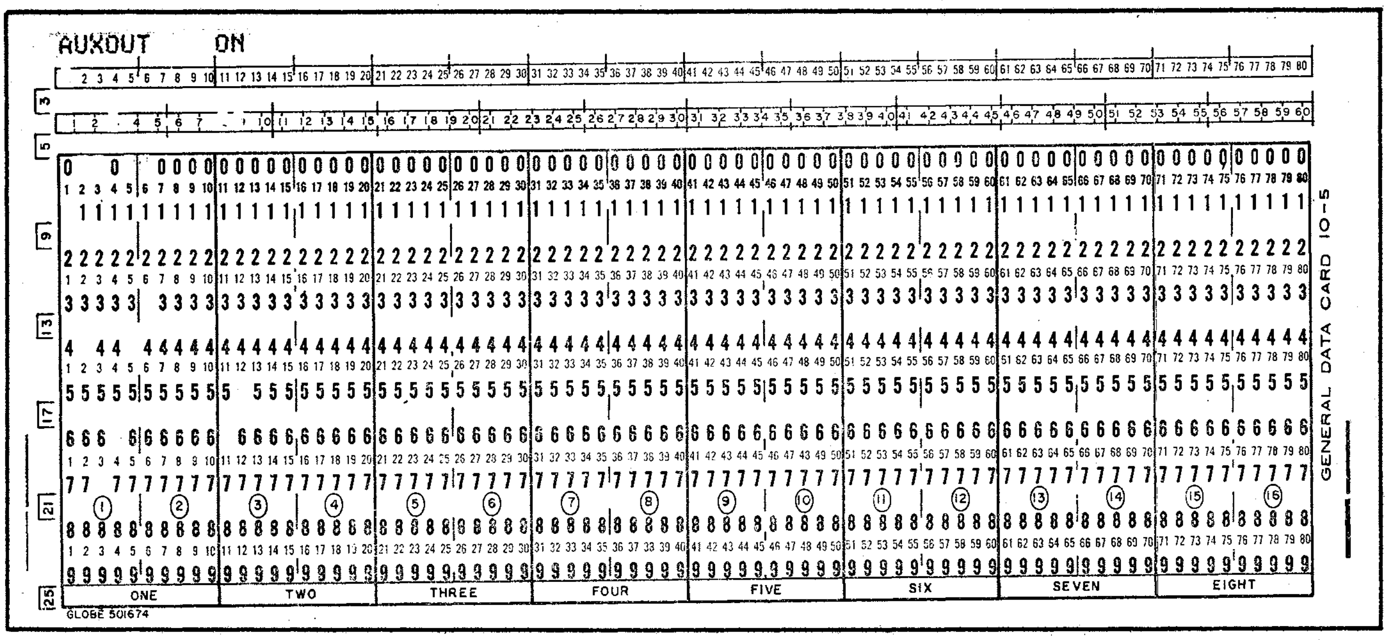
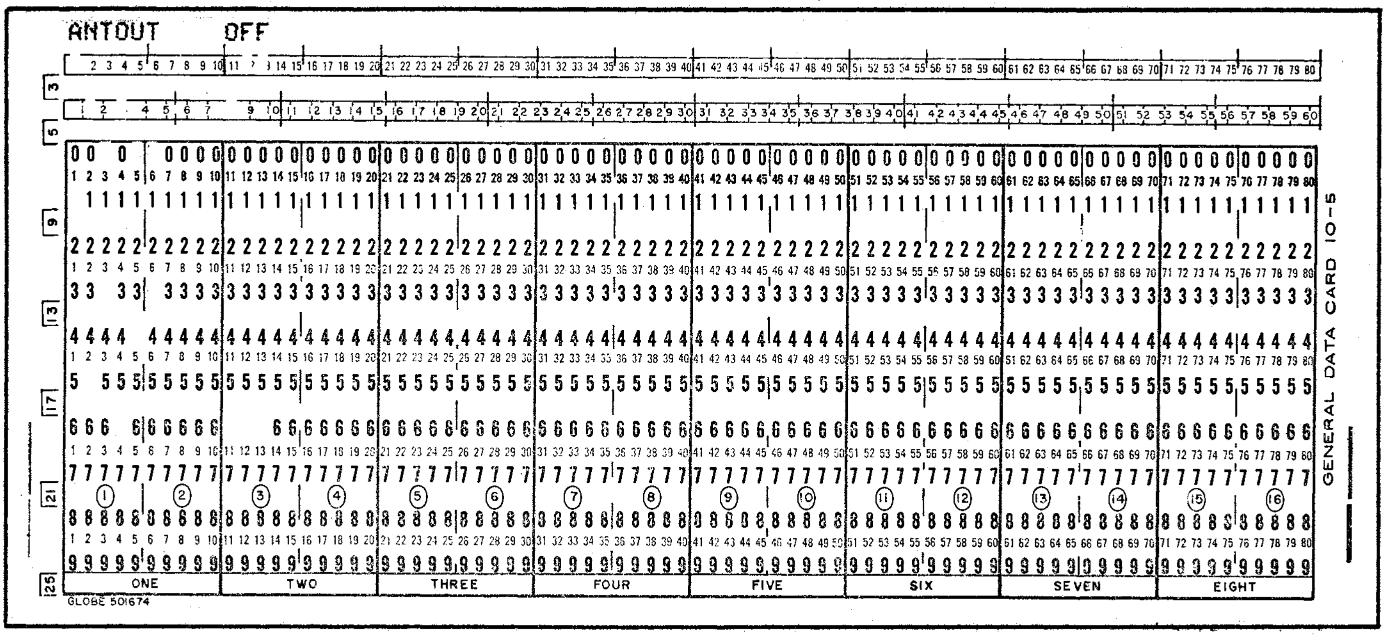


AUXOUT Control Card (3.3.5)

Columns	Name	Format	Description of Input Data
1-10		A10	"AUXOUT" control card identifier
11-20	ITEMP	A10	If = "OFF" return line printer output to default LU6,
			otherwise program uses line printer image output to LU16.

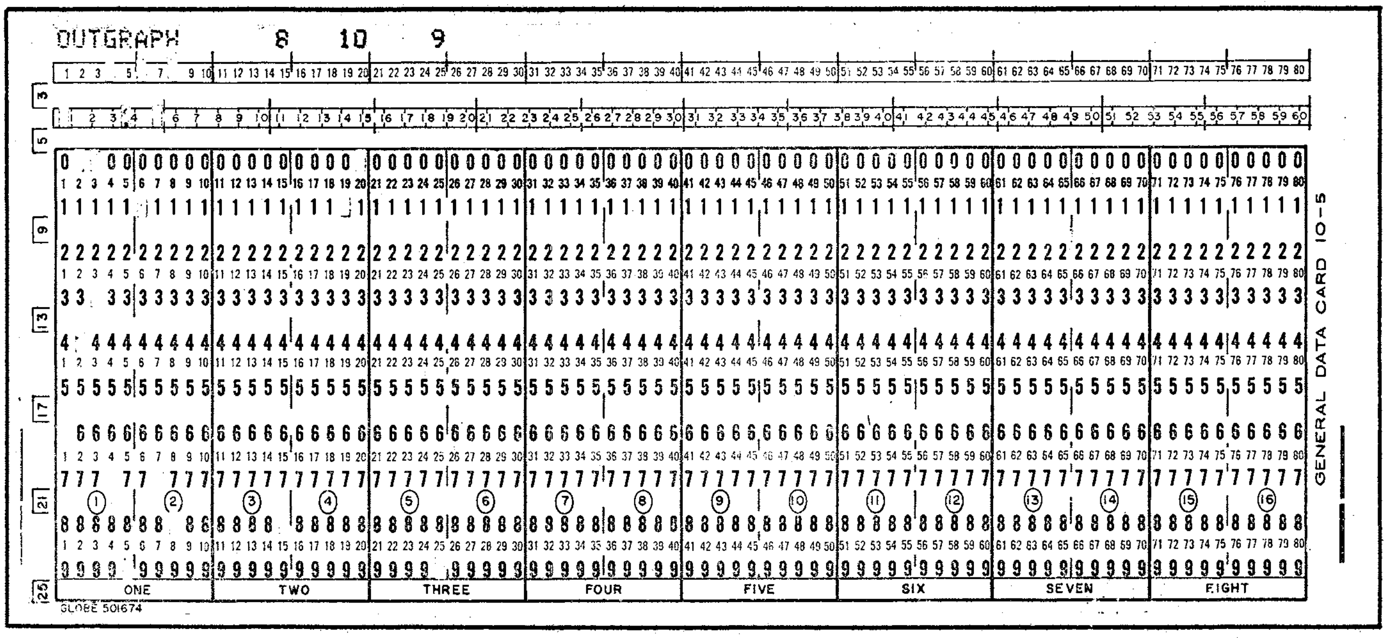
Control Card 23. AUXOUT card



ANTOUT Control Card (3.3.5)

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTOUT" control card identifier
11-20	ITEMP	A10	If = "OFF" do not output any antenna patterns, otherwise
			pattern will be output to LU25.

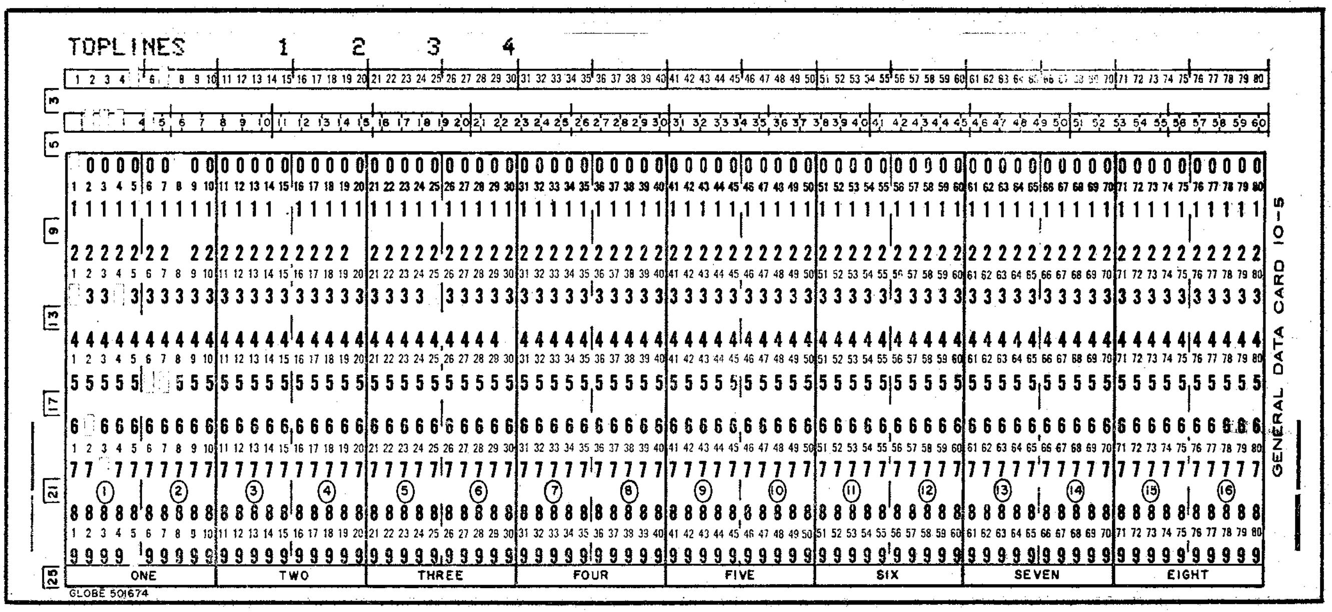
Control Card 24. ANTOUT card



OUTGRAPH Control Card (3.3.5)

Columns	Name	Format	Description of Input Data
1-10		A10	"OUTGRAPH" control card identifier
11-15	KTOUT(1)	I5	Indicates additional "methods" of desired graphical output
16-20	KTOUT(2)	I5	(specify 1 to 12 methods)
21-25	KTOUT(3)	I5	
26-30	KTOUT(4)	I5	(See Table 7 for valid output combinations.)
31-35	KTOUT(5)	I5	
36-40	KTOUT(6)	I5	
41-45	KTOUT(7)	I5	
46-50	KTOUT(8)	I5	
51-55	KTOUT(9)	I5	
56-60	KTOUT(10)	I5	
61-65	KTOUT(11)	I5	
66-70	KTOUT(12)	I5	
	-OR-		
11-20	ITEMP	A10	If = "OFF", stop additional output

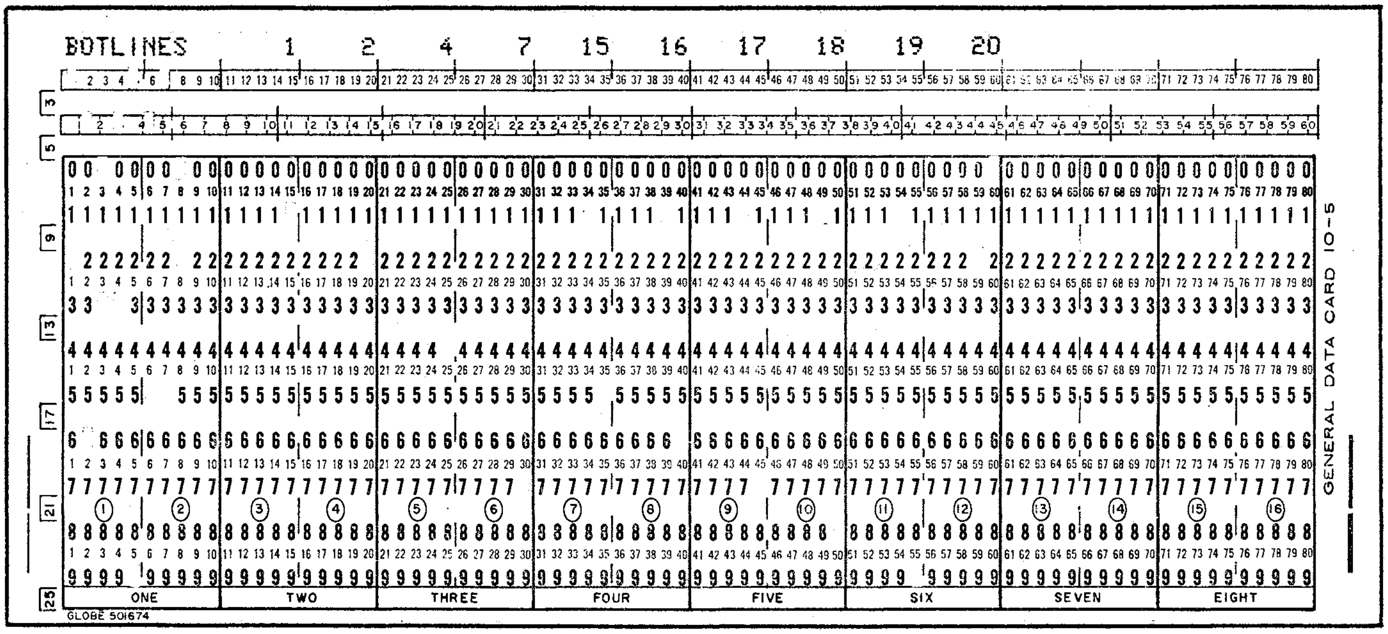
Control Card 25. OUTGRAPH card



TOPLINES Control Card (3.3.5)

Columns	Name	Format	Description of Input Data
1-10		A10	"TOPLINES" control card identifier
11-15	LINTP(1)	I5	Header line number; 1 to 8 (refer to table 8 for description)
16-20	LINTP(2)	I5	Program will print those header lines specified when
21-25	LINTP(3)	I5	method 23 is used.
26-30	LINTP(4)	I5	
31-35	LINTP(5)	I5	
36-40	LINTP(6)	I5	
41-45	LINTP(7)	I5	
46-50	LINTP(8)	I5	
51-55	LINTP(9)	I5	
56-60	LINTP(10)	I5	
61-65	LINTP(11)	I5	
66-70	LINTP(12)	I5	
71-75	LINTP(13)	I5	
76-80	LINTP(14)	I5	
11-20	ITEMP	A10	"OFF" indicates to discontinue printing the header line(s) specified on a previous "TOPLINES" card

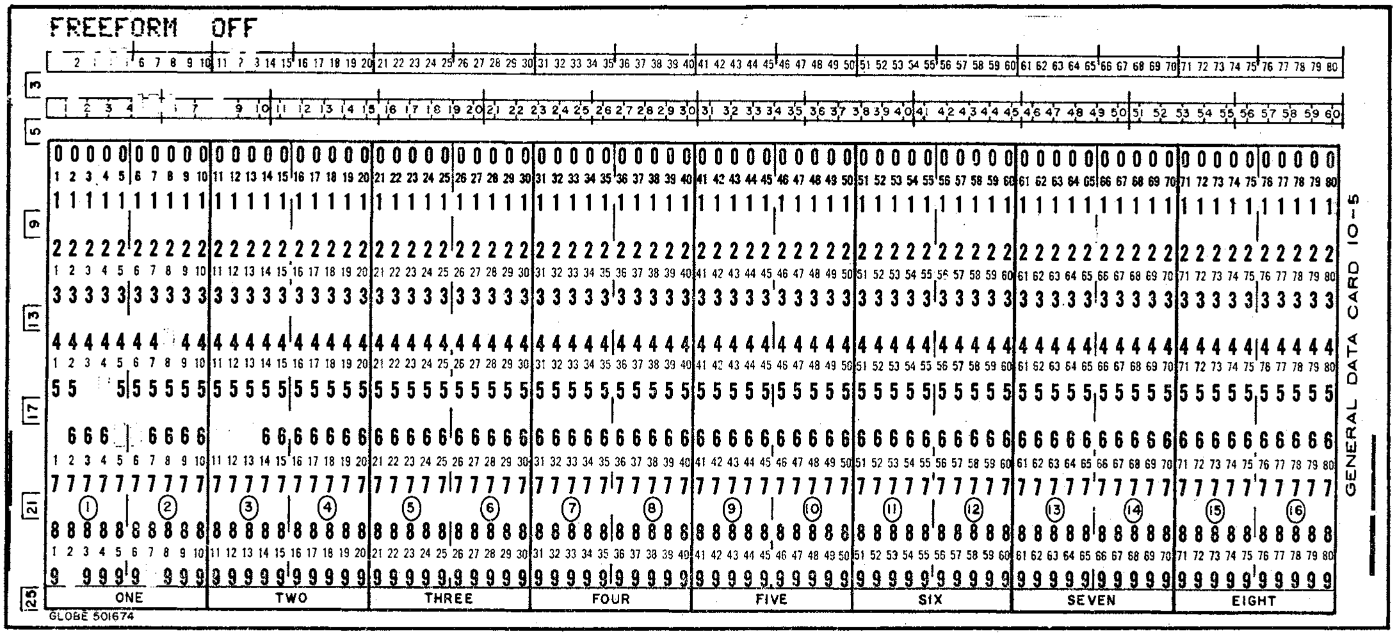
Control Card 26. TOPLINES card



BOTLINES Control Card (3.3.5)

Columns	Name	Format	Description of Input Data
1-10		A10	"BOTLINES" control card identifier
11-15	LINBD(1)	I5	Line number, 1 to 22 (indicate parameter to output, see
16-20	LINBD(2)	I5	Table 9) when method 23 is used
21-25	LINBD(3)	I5	
26-30	LINBD(4)	I5	
31-35	LINBD(5)	I5	
36-40	LINBD(6)	I5	
41-45	LINBD(7)	I5	
46-50	LINBD(8)	I5	
51-55	LINBD(9)	I5	
56-60	LINBD(10)	I5	
61-65	LINBD(11)	I5	
66-70	LINBD(12)	I5	
71-75	LINBD(13)	I5	
76-80	LINBD(14)	I5	
11-20	ITEMP	A10	"OFF" indicates to discontinue printing the parameter(s) specified on a previous "BOTLINES" card

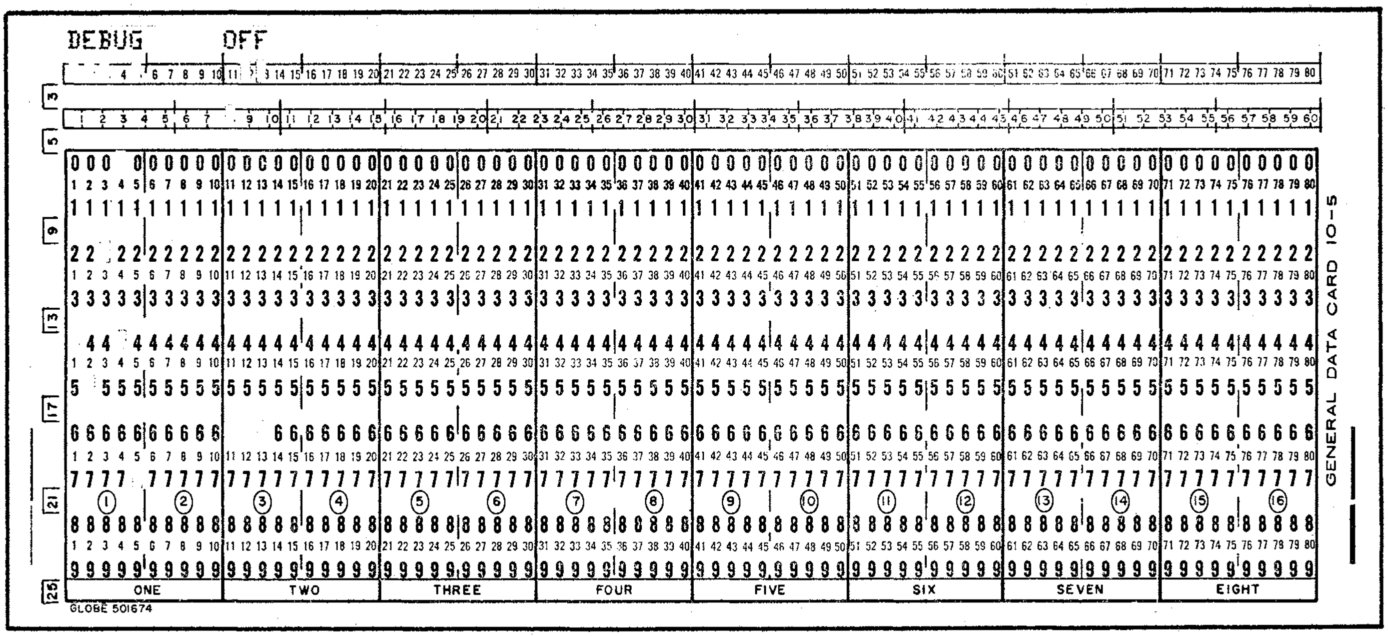
Control Card 27. BOTLINES card



FREEFORM Control Card

Columns	Name	Format	Description of Input Data
1-10		A10	"FREEFORM" control card identifier
			Do not use! Freeform analyser not currently implemented
			in version 78.03. Usage causes program execution to
			terminate.

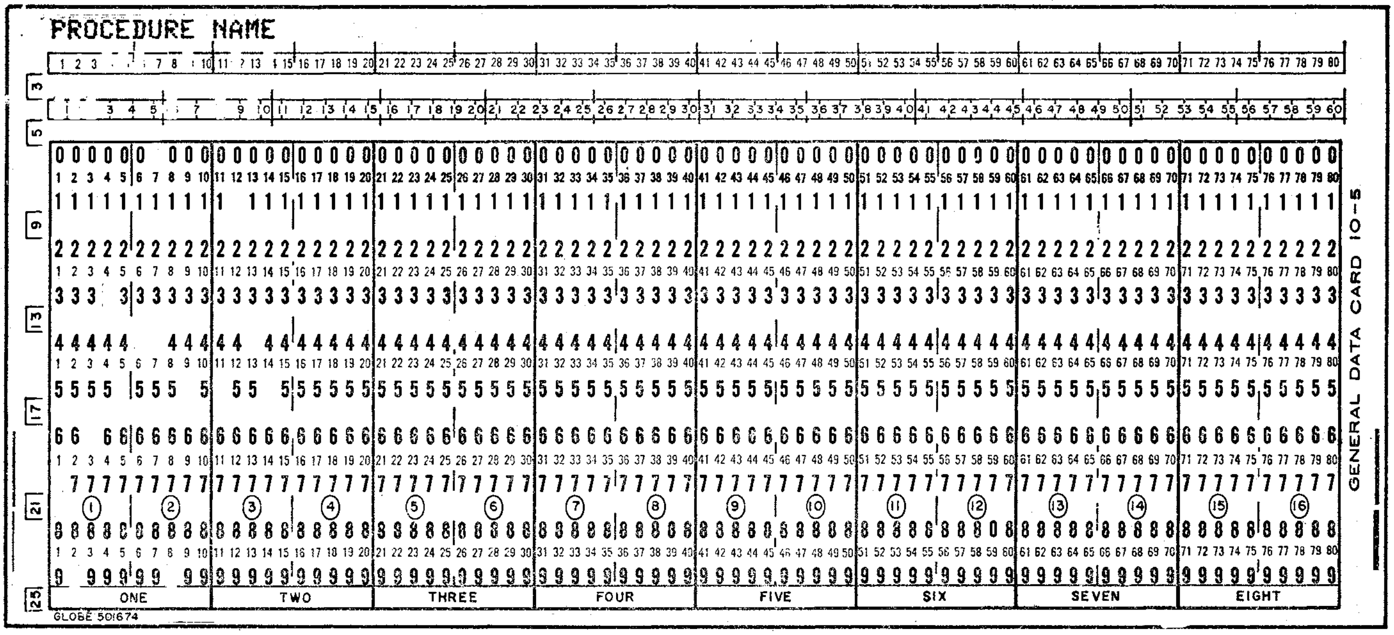
Control Card 28. FREEFORM card



DEBUG Control Card (3.3.5)

Columns	Name	Format	Description of Input Data
1-10		A10	"DEBUG" control card identifier
			Do not use! For program development only, not available
			to most users. Usage has no effect on program execution
			to users where the option is not available.

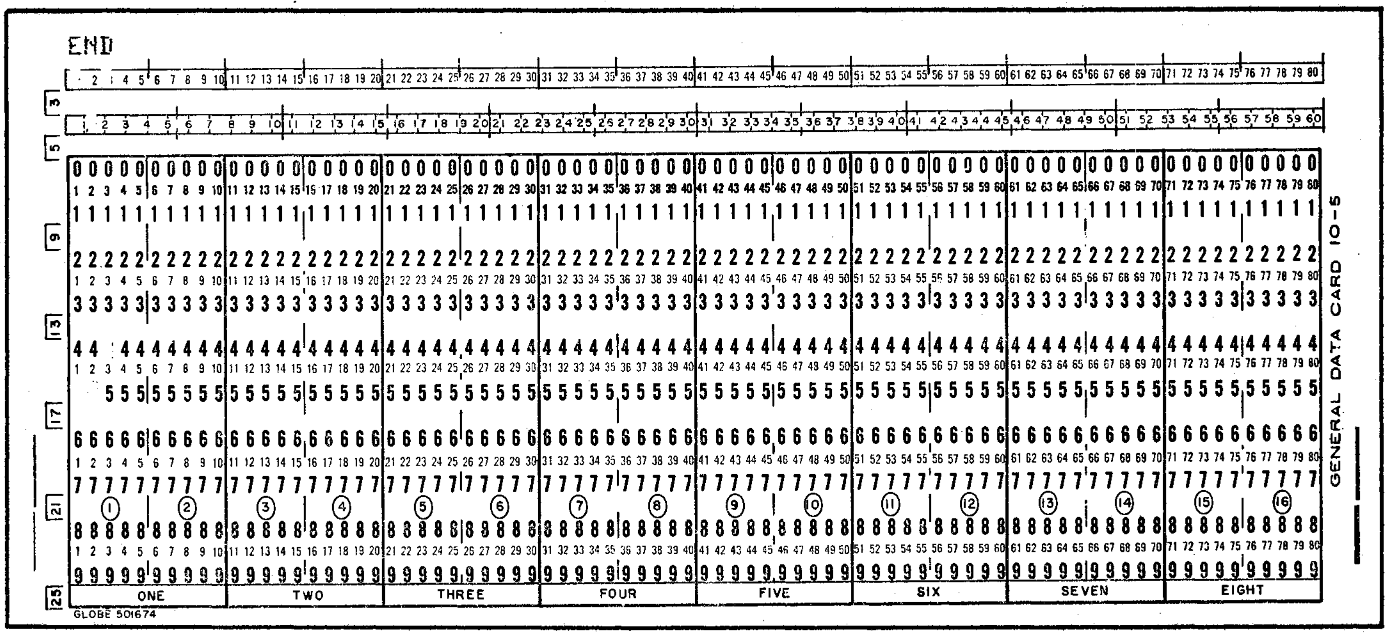
Control Card 29. DEBUG card



PROCEDURE Control Card (3.3.6)

Columns	Name	Format	Description of Input Data
1-10		A10	"PROCEDURE" control card identifier
11-20	ITEMP	A10	User defined procedure name. Procedure definition follows this card with a set of control cards terminating with an END card. During program execution, when a control card is encountered with ITEMP in colums 1-10 the entire set will be inserted.

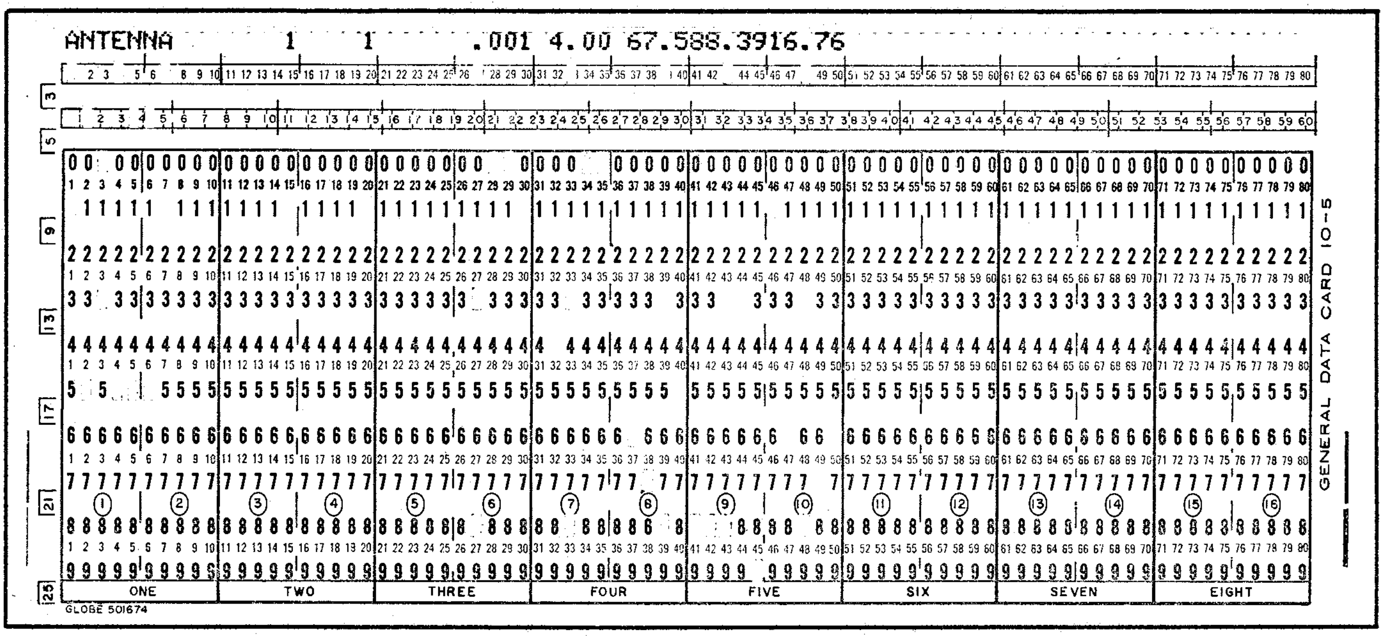
Control Card 30. PROCEDURE card



END Control Card (3.3.6)

Columns	Name	Format	Description of Input Data
1-10		A10	"END" control card identifier
			Indicates end of a procedure definition (all cards between
			PROCEDURE control cards and END card constitute procedure
			definition)

Control Card 31. END card



ANTENNA CARD, TERMINATED RHOMBIC

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 1
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	Antenna type = 1
21-25	AETA	F5.1	Bearing of antenna, degrees, E of N
26-30	ASIG	F5.1	Ground conductivity, mhos/m
31-35	AEPS	F5.1	Relative dielectric constant
36-40	AND	F5.1	Tilt angle, degrees (1/2 the large interior angle)
41-45	ANL	F5.1	Antenna leg length, meters (wavelengths if negative)
46-50	ANH	F5.1	Antenna height, meters (wavelengths if negative)
51-55			Not used for this antenna
56-60			Not used for this antenna
61-65			Not used for this antenna
66-70			Not used for this antenna
71-75	AFQB	F5.1	Ending frequency when more than one antenna is used
76-80	IAIN	I5	Antenna number indicator (each transmitter or receiver antenna can be defined by up to three different antennas
			over the frequency range; default is one, if IAIN is left blank.

Control Card 32. Terminated rhombic card

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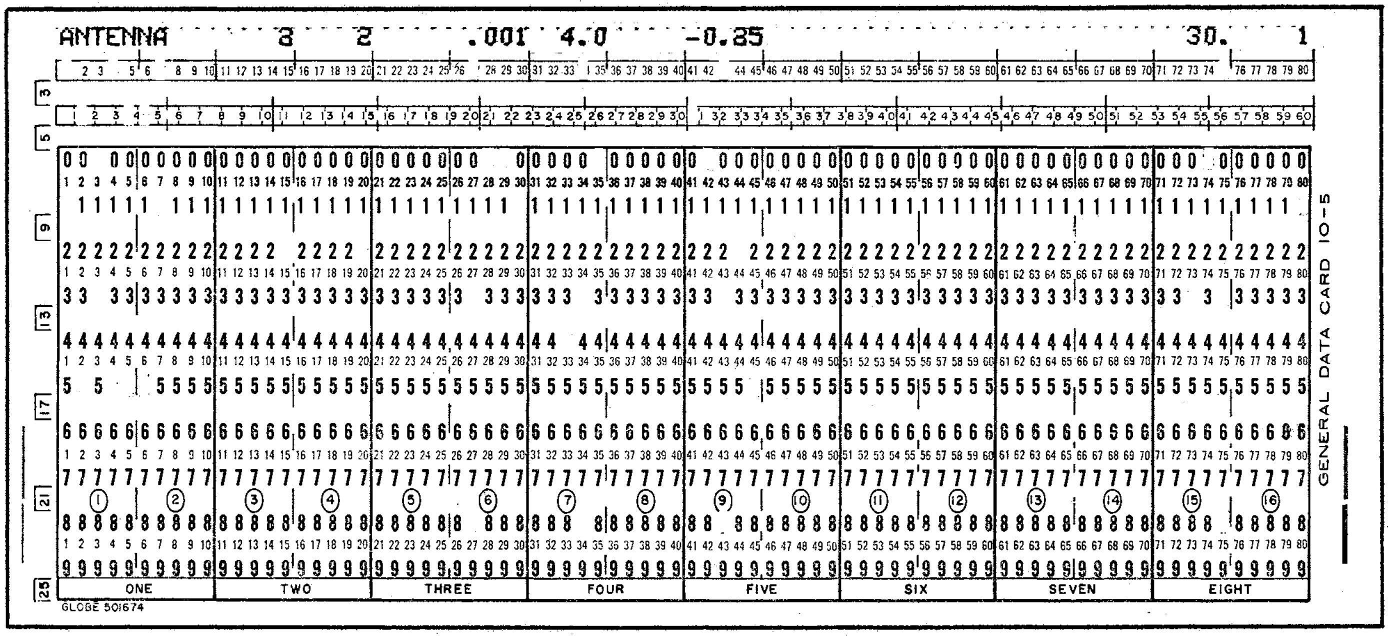
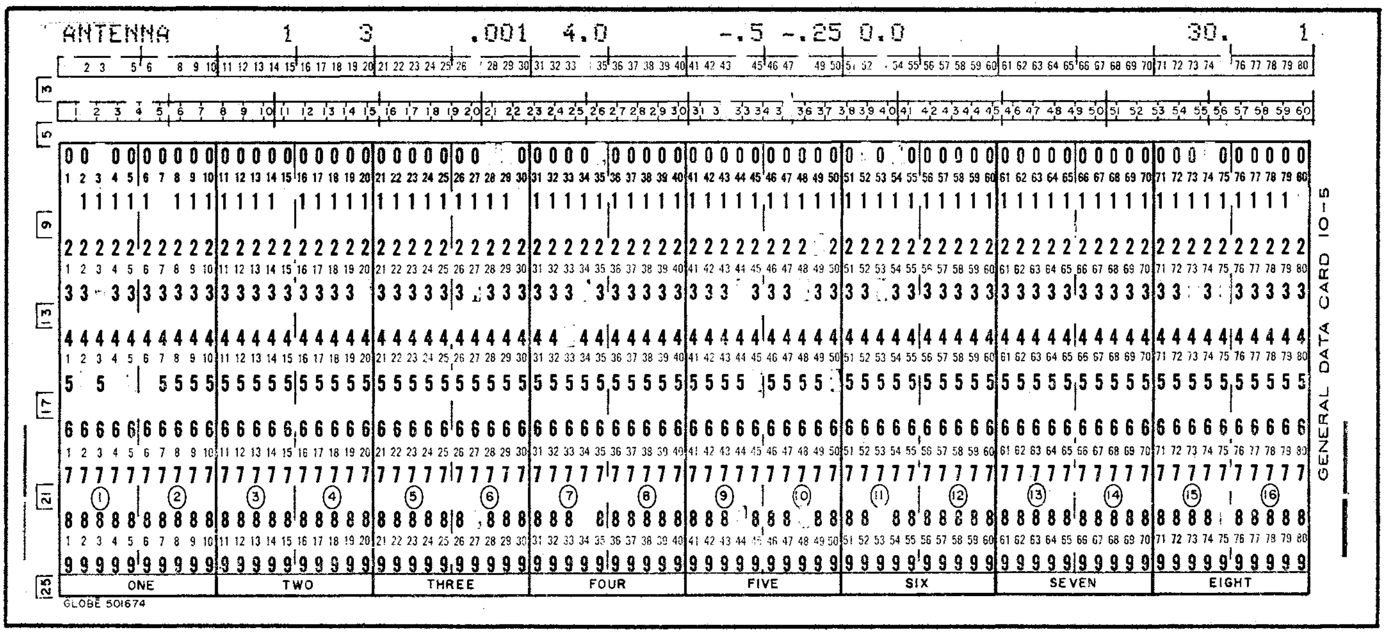


ANTENNA CARD, VERTICAL MONOPOLE

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 2
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	antenna type = 2
21-25			Not used for this antenna
26-30	ASIG	F5.1	ground conductivity, mhos/m
31-35	AEPS	F5.1	relative dielectric constant
36-40			Not used for this antenna
41-45	ANL	F5.1	antenna height, meters (wavelengths if negative)
46-50	ANH	F5.1	gain above a dipole, dB
51-55			Not used for this antenna
56-60			Not used for this antenna
61-65			Not used for this antenna
66-70			Not used for this antenna
71-75	AFQB	F5.1	Ending frequency when more than one antenna is used
76-80	IAIN	I5	Antenna number indicator (each transmitter or receiver antenna can be defined by up to three different antennas over the frequency range; default is one, if IAIN is left blank.

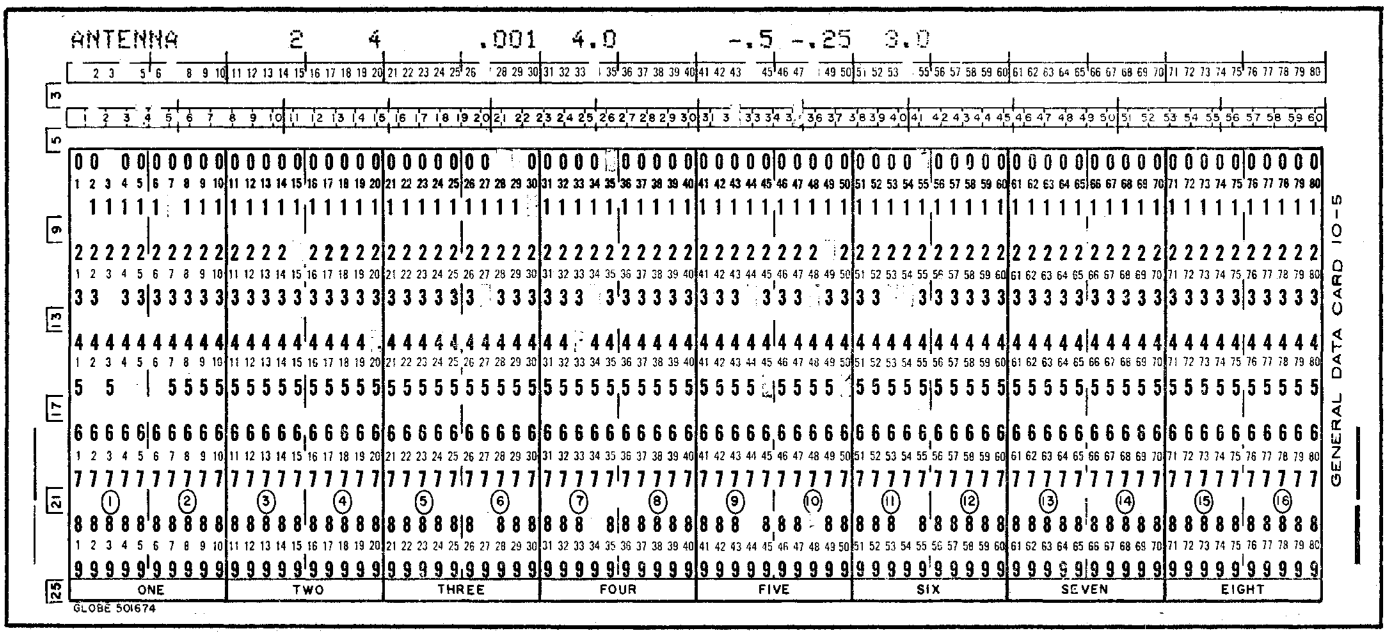
Control Card 33. Vertical monopole card



ANTENNA CARD, HORIZONTAL DIPOLE

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 3
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	antenna type = 3
21-25	AETA	F5.1	bearing, degrees E of N
26-30	ASIG	F5.1	ground conductivity, mhos/m
31-35	AEPS	F5.1	relative dielectric constant
36-40			Not used for this antenna.
41-45	ANL	F5.1	antenna length, meters (wavelengths if negative)
46-50	ANH	F5.1	antenna height, meters (wavelengths if negative)
51-55	AEX(1)	F5.1	gain above 1/2 wavelength horizontal dipole, dB
56-60			Not used for this antenna.
61-65			Not used for this antenna.
66-70			Not used for this antenna.
71-75	AFQB	F5.1	Ending frequency when more than one antenna is used
76-80	IAIN	I5	Antenna number indicator (each transmitter or receiver antenna can be defined by up to three different antennas over the frequency range; default is one, if IAIN is left blank.

Control Card 34. Horizontal dipole card



ANTENNA CARD, HORIZONTAL YAGI

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 4
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	antenna type = 4
21-25	AETA	F5.1	bearing of antenna, degrees E of N
26-30	ASIG	F5.1	ground conductivity, mhos/m
31-35	AEPS	F5.1	relative dielectric constant
36-40			Not used for this antenna.
41-45	ANL	F5.1	antenna length, meters (wavelengths if negative)
46-50	ANH	F5.1	antenna height, meters (wavelengths if negative)
51-55	AEX (1)	F5.1	gain above 1/2 wavelength horizontal dipole, dB
56-60			Not used for this antenna.
61-65			Not used for this antenna.
66-70			Not used for this antenna.
71-75	AFQB	F5.1	Ending frequency when more than one antenna is used
76-80	IAIN	I5	Antenna number indicator (each transmitter or receiver antenna can be defined by up to three different antennas
			over the frequency range; default is one, if IAIN is left blank.

Control Card 35. Horizontal Yagi card

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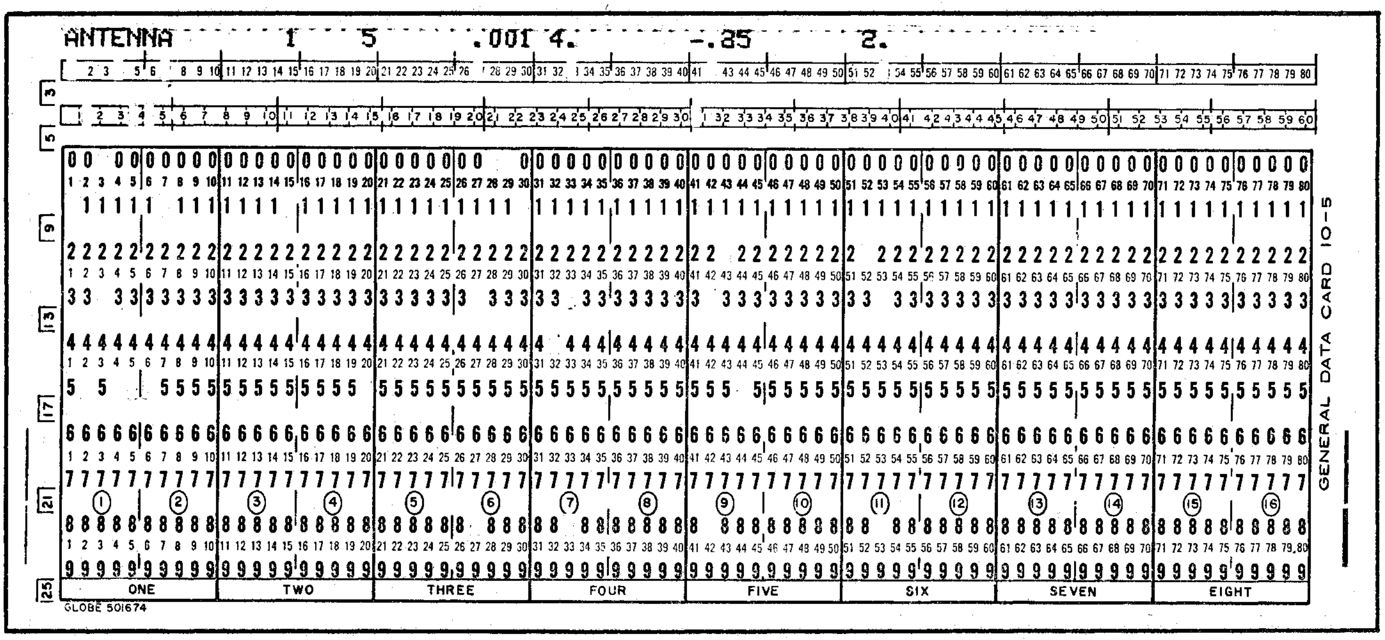
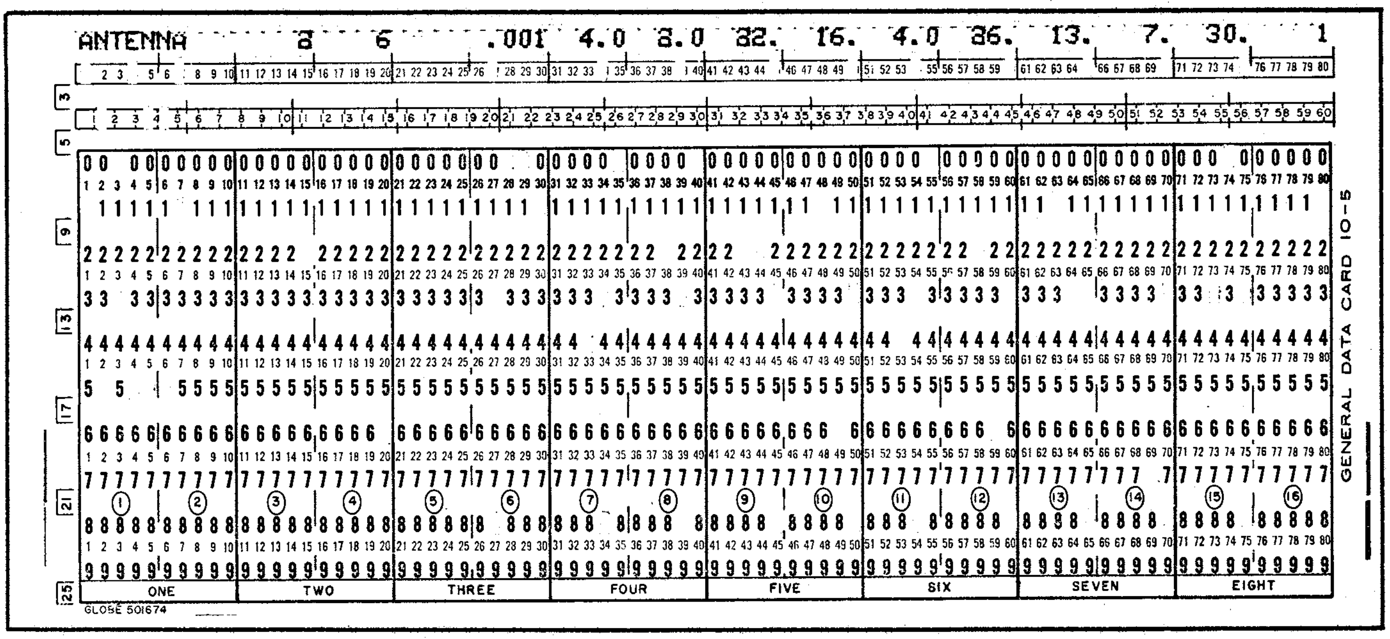


ANTENNA CARD, VERTICAL LOG PERIODIC ARRAY OF MONOPOLES

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 5
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	antenna type = 5
21-25			Not used for this antenna.
26-30	ASIG	F5.1	ground conductivity, mhos/m
31-35	AEPS	F5.1	relative dielectric constant
36-40			Not used for this antenna.
41-45	ANL	F5.1	antenna height, must be 1/4 wavelength (-.25)
46-50			Not used for this antenna.
51-55	AEX (1)	F5.1	gain above a 1/4 wavelength vertical
56-60			Not used for this antenna.
61-65			Not used for this antenna.
66-70			Not used for this antenna.
71-75	AFQB	F5.1	Ending frequency when more than one antenna is used
76-80	IAIN	I5	Antenna number indicator (each transmitter or receiver antenna can be defined by up to three different antennas
			over the frequency range; default is one, if IAIN is left blank.

NOTE: The vertical log periodic array of monopoles is estimated from a 1/4 wave vertical monopole plus additional gain.

Control Card 36. Vertical log periodic card

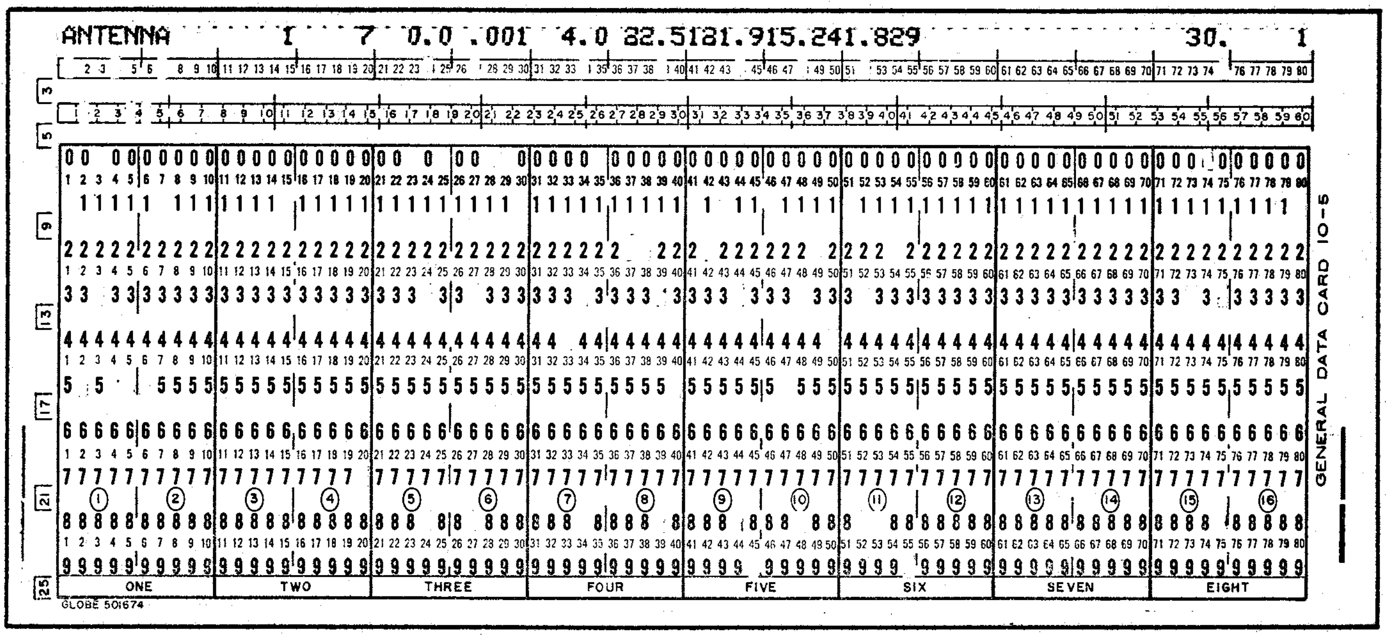


ANTENNA CARD, CURTAIN ANTENNA

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 6
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	antenna type = 6
21-25	AETA	F5.1	antenna bearing degrees E of N
26-30	ASIG	F5.1	ground conductivity, mhos/m
31-35	AEPS	F5.1	relative dielectric constant
36-40	AND	F5.1	number of bays
41-45	ANL	F5.1	antenna element length, meters
46-50	ANH	F5.1	antenna height to first element, meters
51-55	AEX (1)	F5.1	number of elements per bay
56-60	AEX (2)	F5.1	distance between elements centers, meters
61-65	AEX (3)	F5.1	vertical spacing of elements, meters
66-70	AEX (4)	F5.1	distance from screen, meters
71-75	AFQB	F5.1	ending frequency when more than one antenna is used
76-80	IAIN	I5	Antenna number indicator (each transmitter or receiver antenna can be defined by up to three different antennas over the frequency range; default is one, if IAIN is left blank.

Control Card 37. Curtain card

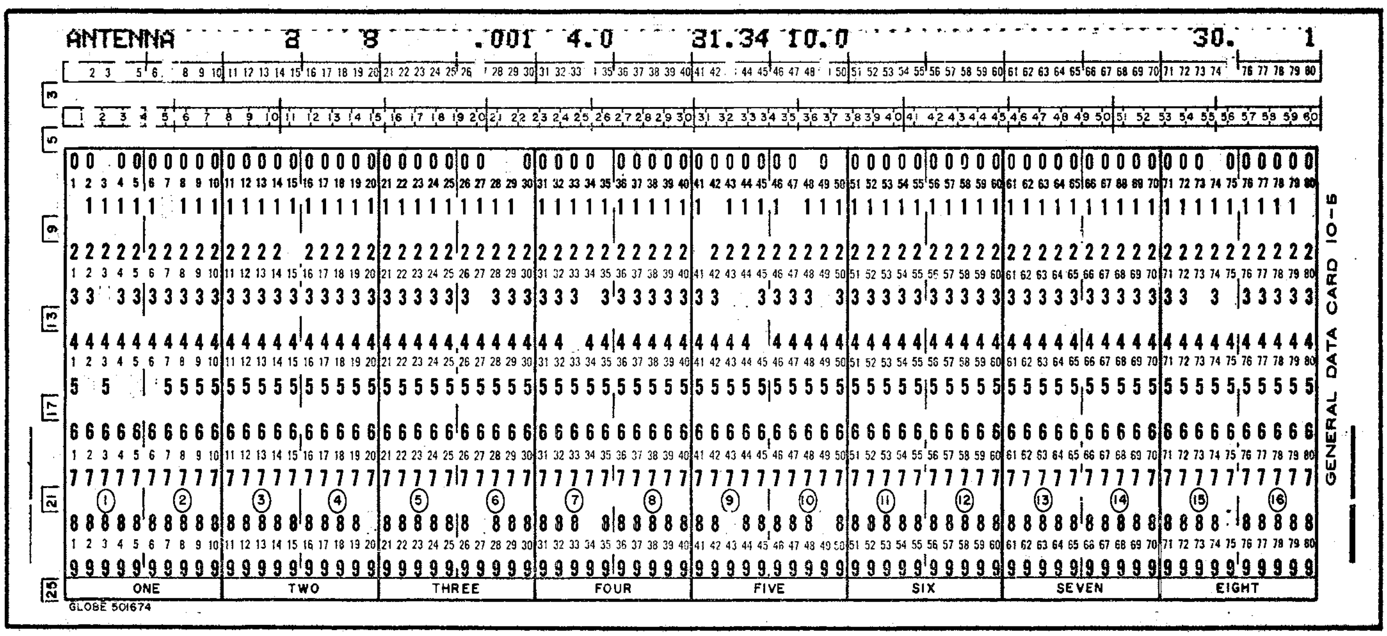
USCOMM - ERL



ANTENNA CARD, TERMINATED SLOPING VEE

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 7
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	antenna type = 7
21-25	AETA	F5.1	bearing of antenna degrees E of N
26-30	ASIG	F5.1	ground conductivity, mhos/m
31-35	AEPS	F5.1	relative dielectric constant
36-40	AND	F5.1	1/2 apex angle in plane of wires
41-45	ANL	F5.1	antenna leg length, meters
46-50	ANH	F5.1	antenna height, meters
51-55	AEX (1)	F5.1	terminated height
56-60			Not used for this antenna.
61-65			Not used for this antenna.
66-70			Not used for this antenna.
71-75	AFQB	F5.1	ending frequency when more than one antenna is used
76-80	IAIN	I5	Antenna number indicator (each transmitter or receiver antenna can be defined by up to three different antennas over the frequency range; default is one, if IAIN is left blank.

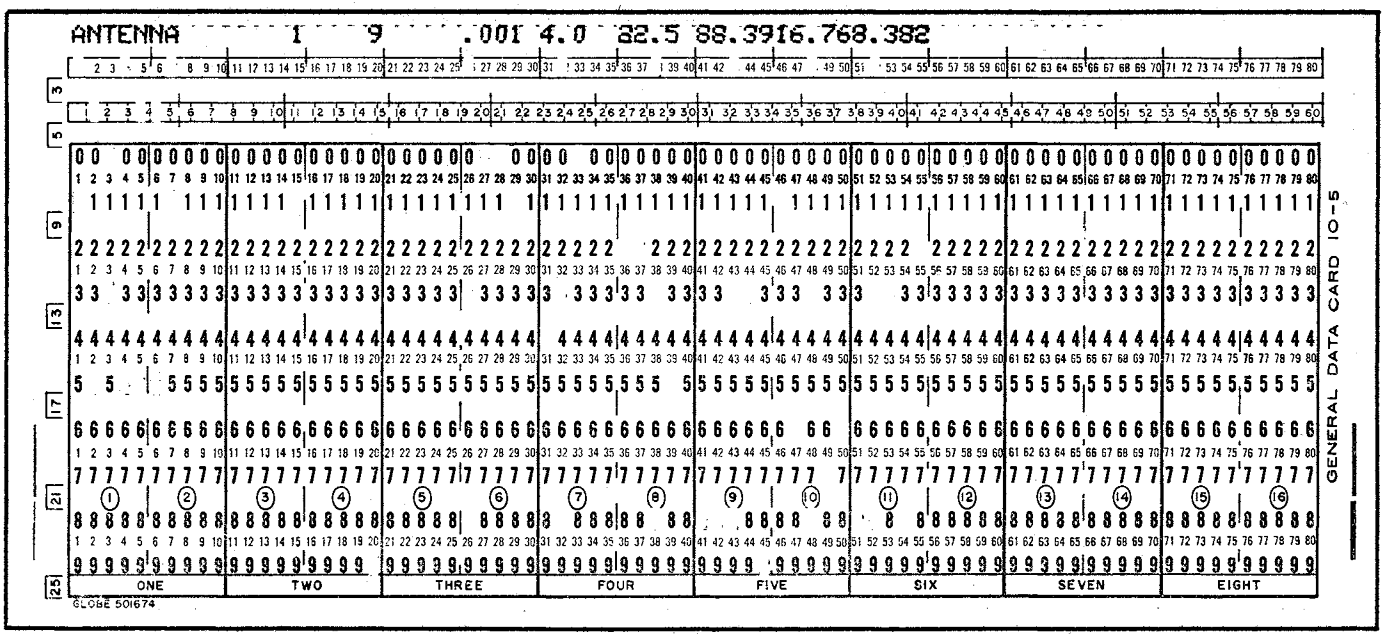
Control Card 38. Sloping vee card



ANTENNA CARD, INVERTED L

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 8
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	antenna type = 8
21-25	AEAT	F5.1	antenna bearing degrees E of N
26-30	ASIG	F5.1	ground conductivity, mhos/m
31-35	AEPS	F5.1	relative dielectric constant
36-40			Not used for this antenna.
41-45	ANL	F5.1	antenna length, meters
46-50	ANH	F5.1	antenna height, meters
51-55			Not used for this antenna.
56-60			Not used for this antenna.
61-65			Not used for this antenna.
66-70			Not used for this antenna.
71-75	AFQB	F5.1	Ending frequency when more than one antenna is used
76-80	IAIN	I5	Antenna number indicator (each transmitter or receiver antenna can be defined by up to three different antennas over the frequency range; default is one, if IAIN is left blank.

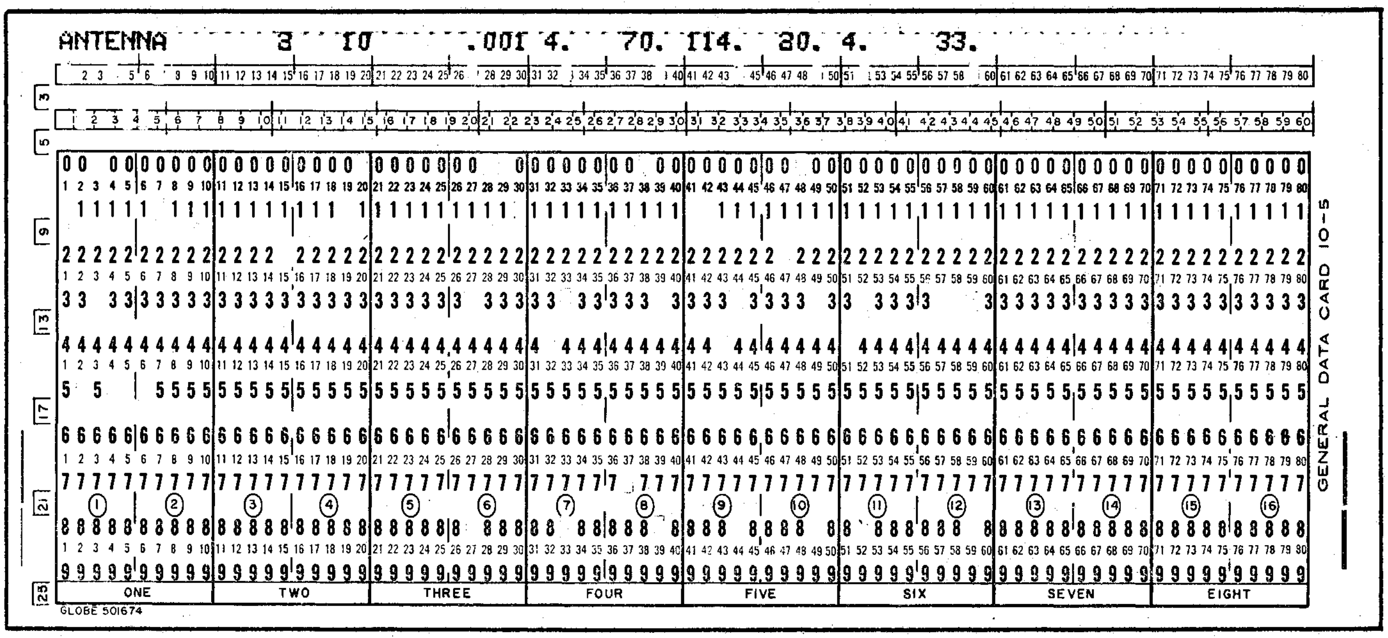
Control Card 39. Inverted L card



ANTENNA CARD, TERMINATED SLOPING RHOMBIC

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 9
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	antenna type = 9
21-25	AETA	F5.1	antenna bearing degrees E of N
26-30	ASIG	F5.1	ground conductivity, mhos/m
31-35	AEPS	F5.1	relative dielectric constant
36-40	AND	F5.1	1/2 large interior angle in plane of wire
41-45	ANL	F5.1	leg length, meters
46-50	ANH	F5.1	antenna height meters
51-55	AEX (1)	F5.1	terminate height, meters
56-60			Not used for this antenna.
61-65			Not used for this antenna.
66-70			Not used for this antenna.
71-75	AFQB	F5.1	Ending frequency when more than one antenna is used
76-80	IAIN	I5	Antenna number indicator (each transmitter or receiver antenna can be defined by up to three different antennas
			over the frequency range; default is one, if IAIN is left blank.

Control Card 40. Sloping rhombic card

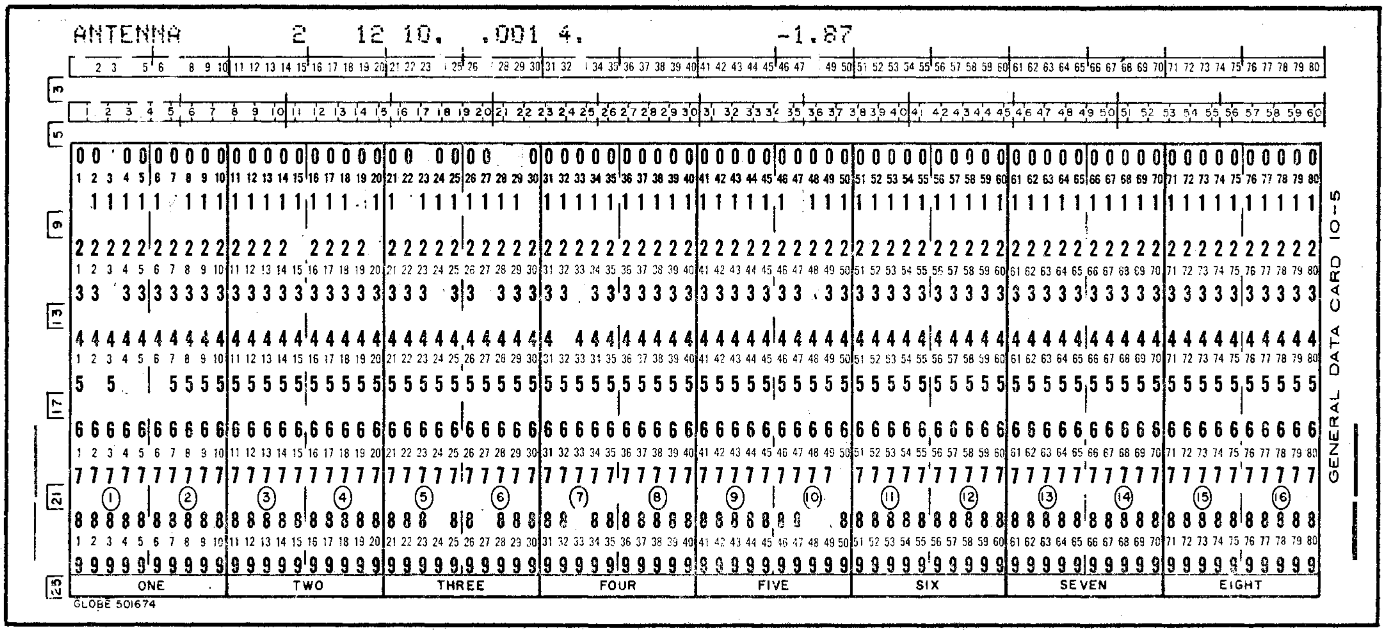


ANTENNA CARD, INTERLACED RHOMBIC

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 10
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	antenna type = 10
21-25	AETA	F5.1	antenna bearing degrees E of N
26-30	ASIG	F5.1	ground conductivity, mhos/m
31-35	AEPS	F5.1	relative dielectric constant
36-40	AND	F5.1	1/2 large interior angle in plane of wire, degrees
41-45	ANL	F5.1	leg length, meters
46-50	ANH	F5.1	lower antenna height, meters
51-55	AEX (1)	F5.1	vertical displacement, meters
56-60	AEX (2)	F5.1	horizontal feed point displacement, meters
61-65			Not used for this antenna.
66-70			Not used for this antenna.
71-75	AFQB	F5.1	Ending frequency when more than one antenna is used
76-80	IAIN	I5	Antenna number indicator (each transmitter or receiver antenna can be defined by up to three different antennas
			over the frequency range; default is one, if IAIN is left blank.

Control Card 41. Interlaced rhombic card

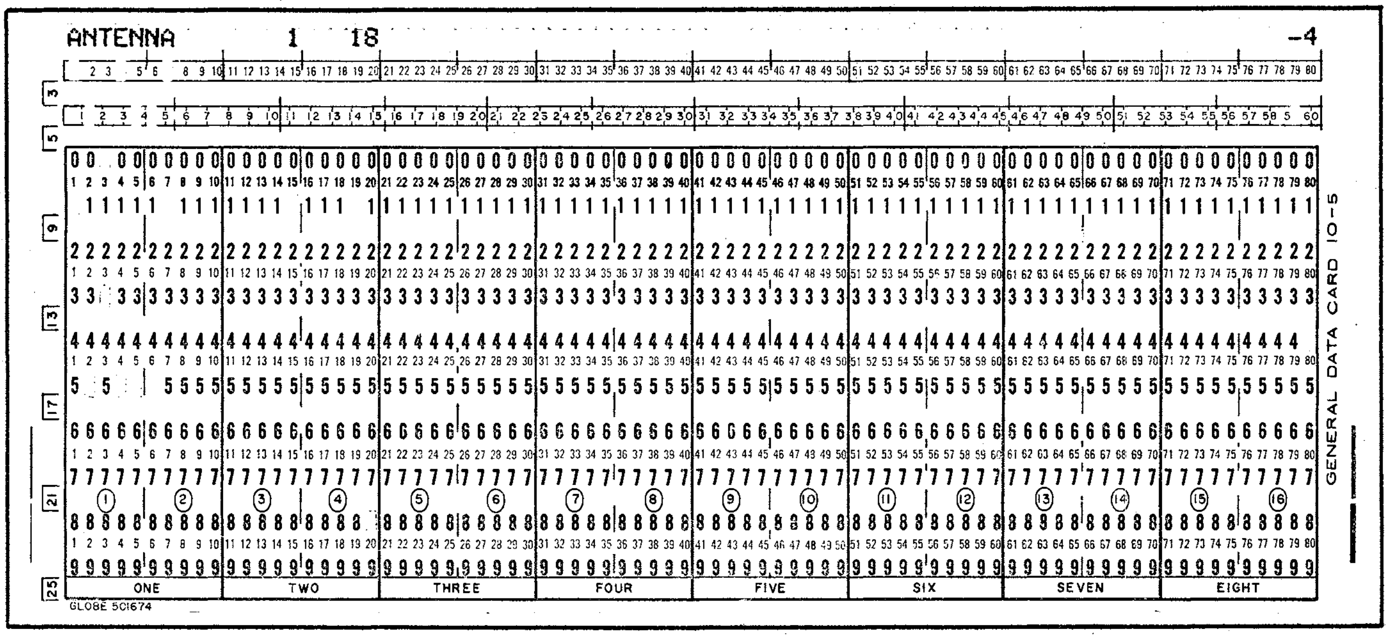
USCOMM - ERL



ANTENNA CARD, CONSTANT GAIN

Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 12
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	antenna type = 12
21-25	AETA	F5.1	gain above isotropic, dB
26-30	ASIG	F5.1	ground conductivity, mhos/m
31-35	AEPS	F5.1	relative dielectric constant
36-40			Not used for this antenna.
41-45			Not used for this antenna.
46-50	ANH	F5.1	antenna efficiency, dB
51-55			Not used for this antenna.
56-60			Not used for this antenna.
61-65			Not used for this antenna.
66-70			Not used for this antenna.
71-75	AFQB	F5.1	Ending frequency when more than one antenna is used
76-80	IAIN	I5	Antenna number indicator (each transmitter or receiver antenna can be defined by up to three different antennas over the frequency range; default is one, if IAIN is left blank.

Control Card 42. Constant gain card



Columns	Name	Format	Description of Input Data
1-10		A10	"ANTENNA" 18
11-15	IAT	I5	1 for transmitter, 2 for receiver
16-20	IANTR	I5	antenna type = 18
21-25			
26-30			
31-35			
36-40			Columns 21-55 not used for this antenna.
41-45			
46-50			
51-55			
56-60			Antenna type 18 (a). If IAIN ≥ 0, then IAIN indicates
61-65			the number of antennas to skip forward from present
66-70			position on the antenna file (LU26) before reading the
71-75			desired pattern (b) IF IAIN < 0, then the antenna file
76-80	IAIN	I5	is rewound before searching for the antenna pattern.
			The pattern that is used is |IAIN| on the antenna file.

Control Card 43. Antenna pattern read from file

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report describes the operation and use of the Ionospheric Communications Analysis and Prediction Program (IONCAP). The computer program is an integrated system of subroutines designed to predict high-frequency (HF) skywave system performance and analyze ionospheric parameters. These computer-aided predictions may be used in the planning and operation of high-frequency communication systems using skywaves.

This report contains instructions for the use of IONCAP. A description of the input data requirements, including data definition, organization, and instructions for setup of the various analysis tasks, is presented. Procedures and formats are given for preparing the input data and executing the program. The various outputs are presented and described with an interpretation of the analysis results.

16. Key Words *(Alphabetical order, separated by semicolons)*
communications; computer model; high frequency; ionosphere; LUF; MUF; skywave; user's manual

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