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Revised Program FOOTPRINTS User's Manual

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PREFACE

The work to revise and modify the computer-based model described by this report was accomplished as part of the Fiscal Year 1982 Satellite Support provided by the Institute for Telecommunication Sciences to the National Telecommunications and Information Administration under the Systems Technology Programs. The material reported here is a continuation of the work performed earlier by E. J. Haakinson, D. E. Skinner, K. P. Spies, and G. J. Bridgewater. Previous related reports are as follows:

"Automatic Computing and Plotting of Geostationary Satellite Earth Footprints: Program Footprints User's Manual," E. J. Haakinson, D. E. Skinner, K. P. Spies, and G. J. Bridgewater, OT Report 77-120, April 1977.

"Calculation of Geostationary Satellite Footprints for Certain Idealized Antennas," K. P. Spies and E. J. Haakinson, NTIA Report 80-51, October 1980.

Management and technical supervision at the National Telecommunications and Information Administration, Institute for Telecommunication Sciences, in Boulder, Colorado, was provided by Dr. P. M. McManamon, Acting Deputy Director for the Systems and Networks Division. Technical direction was provided by Mr. R. D. Jennings, Chief of the Satellite Network Analysis Group.

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REVISED PROGRAM FOOTPRINTS USER'S MANUAL

K. J. Gamauf*

This report describes use of the revised computer program FOOTPRINTS. The program automatically computes and plots earth footprints and service area polygons on a map projection of the earth's surface. The program can be used as a design tool to maximize geostationary satellite antenna coverage over a particular portion of the earth's surface and to limit potential interference in adjacent areas.

This program is a revised version of a program written several years ago at the Institute for Telecommunication Sciences. The program can accommodate a broad range of user-supplied input details ranging from minimal information to very specific antenna pattern data. The program is written in the FORTRAN IV computer language for use in an interactive (time-sharing) mode on a CDC 170/750 computer.

This manual provides a general description of the FOOTPRINTS program, explains the execution of the program, including the input of the required information, and interprets the program output. Sample executions of the program also are provided.

Key words: Broadcasting Satellite Service; computer program; footprints; geostationary satellite; service area

1. INTRODUCTION

1.1 Purpose of Program FOOTPRINTS

Radiation from transmitting antennas on satellites illuminates the earth's surface. Depending on the characteristics of the satellite's antenna, the illumination can be broad enough to cover the visible earth with a nearly constant power spacial density, or the illumination can be very intense on a particular region of the earth's surface. In either case, the fields radiated by the satellite antenna can be described by contours of constant power spacial density or contours of constant antenna gain intersecting the earth's surface. These contours commonly are called "earth footprints" or simply footprints.

Footprints, as depicted on maps of the world, are utilized by satellite communication system designers and spectrum managers to: 1) maximize the satellite's coverage to a particular region or section of the earth's surface, and 2) minimize the effects of interference to other telecommunication systems. In the initial stages of the satellite development, designers and spectrum managers

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may know very little about the satellite and its antenna characteristics. As the system evolves however, the final design values become established and detailed antenna patterns become available. A desirable engineering aid to have during the satellite's design process is the ability to quickly plot footprints on maps of the earth's surface. With this aid, the designers and spectrum managers can evaluate satellite system design trade-offs to determine how the trade-offs will affect the footprints and ultimately, the satellite's coverage and/or potential interference.

As such an aid, a computer program, named FOOTPRINTS, was developed at the Institute for Telecommunication Sciences (ITS) several years ago to automatically compute and plot footprints from geostationary satellites. The program was written in Fortran V to operate on a UNIVAC 1108 computer (see Haakinson, Skinner, Spies, and Bridgewater, 1977). This program has been converted to Fortran IV to operate on the CDC 170/750 computer at ITS in Boulder, Colorado. Along with the conversion of the program, several features were added to enhance the program. Some of these enhancements of the program include higher resolution map projections with political boundaries, up to 15 footprints per map, optional file input of the set-up data, two additional map projections, two additional antenna models, and the plotting of service area polygons on the map projections along with the footprints.

The user calls for and communicates with the FOOTPRINTS program via an interactive (time-share) computer terminal. The FOOTPRINTS program operates in a "question-answer" interactive mode and will ask the user to supply information about the satellite's position, its antenna characteristics, the aim point, etc. This is repeated for all of the antennas on a particular plot. The program then will compute all of the footprints for the antennas and superimpose them, along with any service area polygons to be plotted, on a map of the earth's surface. All of this information is then sent to the microfilm plotter which then plots the results.

1.2 Scope of the User's Manual

This user's manual of the revised version of the FOOTPRINTS program is structured along the same lines as the user's manual to the original version of the FOOTPRINTS program (Haakinson, Skinner, Spies, and Bridgewater, 1977). Although many items in the original manual are still valid in this manual, they are repeated here in order to make this manual complete. Since the section describing the user-supplied antenna pattern (point-pattern mode) is essentially unchanged, it is repeated in this manual in its entirety as the Appendix. All of the other sections of the original manual had at least some minor changes, due to the added features or the conversion of the program to the CDC 170/750 computer, which are integrated into this manual. The mathematical derivation for the calculation of the satellite earth footprints is given in Spies and Haakinson (1980). Figure 1 shows graphically the method for generating the satellite antenna footprints.

This manual matches the user's needs to the program's capabilities by describing the types of information or parameter values that are required from the user. Guidelines for reasonable parameter values are given when values are unknown or undefined to the user. There are sections describing the map projections, satellite antenna models, and the service area polygons. There are other sections which list for the user all possible questions that he/she may encounter when using the program, how to log on and off the computer, and how to set up the required data files for the program. Finally, several sample program executions are given, including the responses to the questions asked during the execution and the resultant footprint plots.

2. PROGRAM DESCRIPTION

2.1 Overview

The original program FOOTPRINTS was designed to accept a broad range of information from the user. The additional development of the program has not changed this, but only added more versatility to the program. If the user knows very little about the antenna system on the satellite, he/she supplies a minimal amount of information and the program will use preselected information (default values) for parameters not supplied by the user. On the other hand, the user can supply very detailed information about the antenna pattern or antenna systems, and the program will utilize the data to compute the footprints from the satellite.

The program's primary capabilities are as follows:

1. Footprints from geostationary satellites can be plotted.
2. The footprints are superimposed on map projections of the world showing geographical and political boundaries, on map projections of the United States showing state boundaries, or on map projections of user specified portions of the earth.

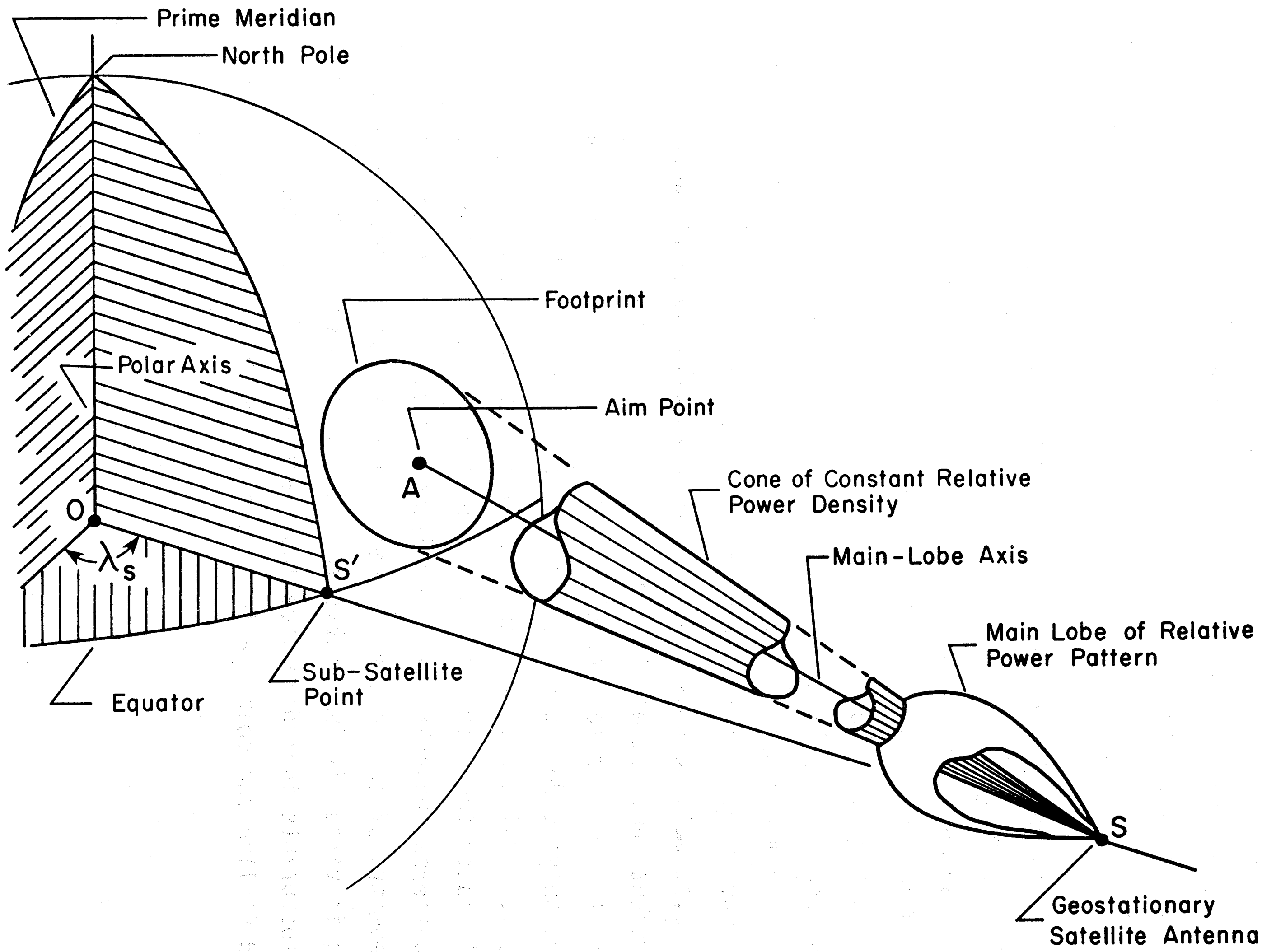


Figure 1. Method for generating geostationary satellite antenna footprints (Spies and Haakinson, 1980).

3. The maps and footprints may be plotted using one of ten standard map projections.
4. Footprints can be computed and plotted using any of four common or two specialized types of satellite antennas. The user supplies the antenna's characteristics and the program computes the footprint patterns.
5. Footprints can also be plotted from user-supplied antenna radiation pattern data (point-pattern mode).
6. Service area polygons can be plotted on the map projections along with the footprints.
7. Multiple antennas on the same satellite, multiple aim points, and multiple map projections may be chosen by the user for each program execution (up to 15 footprints per map).

Although the program FOOTPRINTS has been designed to be quite flexible for the user, there are limitations as follows:

1. Nongeostationary satellite footprints cannot be plotted. These footprints would only be, at best, "snapshots", since at the next moment, both satellite and footprint would have moved.
2. Footprints are computed and plotted from the antenna's main-beam pattern only; side lobes are not included. The main-beam patterns, as simulated by the antenna gain function models, very closely match the actual antenna's measured pattern. The side lobe patterns, however, are very dependent upon the antenna and the geometry of the devices on the satellite next to the antenna, making it virtually impossible to model side lobes accurately. When footprints including side lobes are required, the user should utilize the point-pattern mode of FOOTPRINTS.
3. The point-pattern mode utilizes pattern data supplied by the user to plot footprints. The program will not smooth or fit a function to the data, and the program will not interpolate between user-supplied pattern contours to compute additional contours.

2.2 Map Projections

The parallel (line of constant latitude) and the meridian (line of constant longitude) system of the earth can be drawn on a sphere or globe, but if the surface of the globe is to be flattened onto a two-dimensional surface, then the system of parallels and meridians will become distorted. If only a small part of the globe is to be represented on a flat paper, then the distortion is not noticeable or bothersome. However, when a large portion of the earth is to be shown or "projected" onto a plane surface, the distortion can be so great as to make geographical boundaries unrecognizable. Thus, it is desirable to choose projections which convey the most information about footprints and their relationship to world political boundaries.

The user of the FOOTPRINTS program can select any of the following map projections:

- Mercator
- Cylindrical Equidistant
- Mollweide
- Alber's Equal Area Conic
- Bi-Parallel Conformal Conic
- Stereographic
- Orthographic
- Lambert Equal Area
- Azimuthal Equidistant
- Gnomonic.

For each projection, the program gives the user a choice of three map options:

"WORLD MAP"	The World Map displays the largest possible portion of the earth's surface within the limitations of the projection.
"U.S. MAP"	The U.S. Map displays the continental United States only, including the state boundaries.
"ENLARGED MAP"	The Enlarged Map displays an area within coordinate boundaries specified by the user.

Brief discussions of the various projections and their uses are presented below. Samples of each projection showing the world map are given in Figures 2 through 11. For more complete descriptions of the projections, see the cartography references (Robinson, Sale, and Morrison, 1978; McDonnell, 1979; Richardus and Adler, 1972) and the graphics package manual (Integrated Software Systems Corporation, 1981) of the CDC 170/750 computer system.

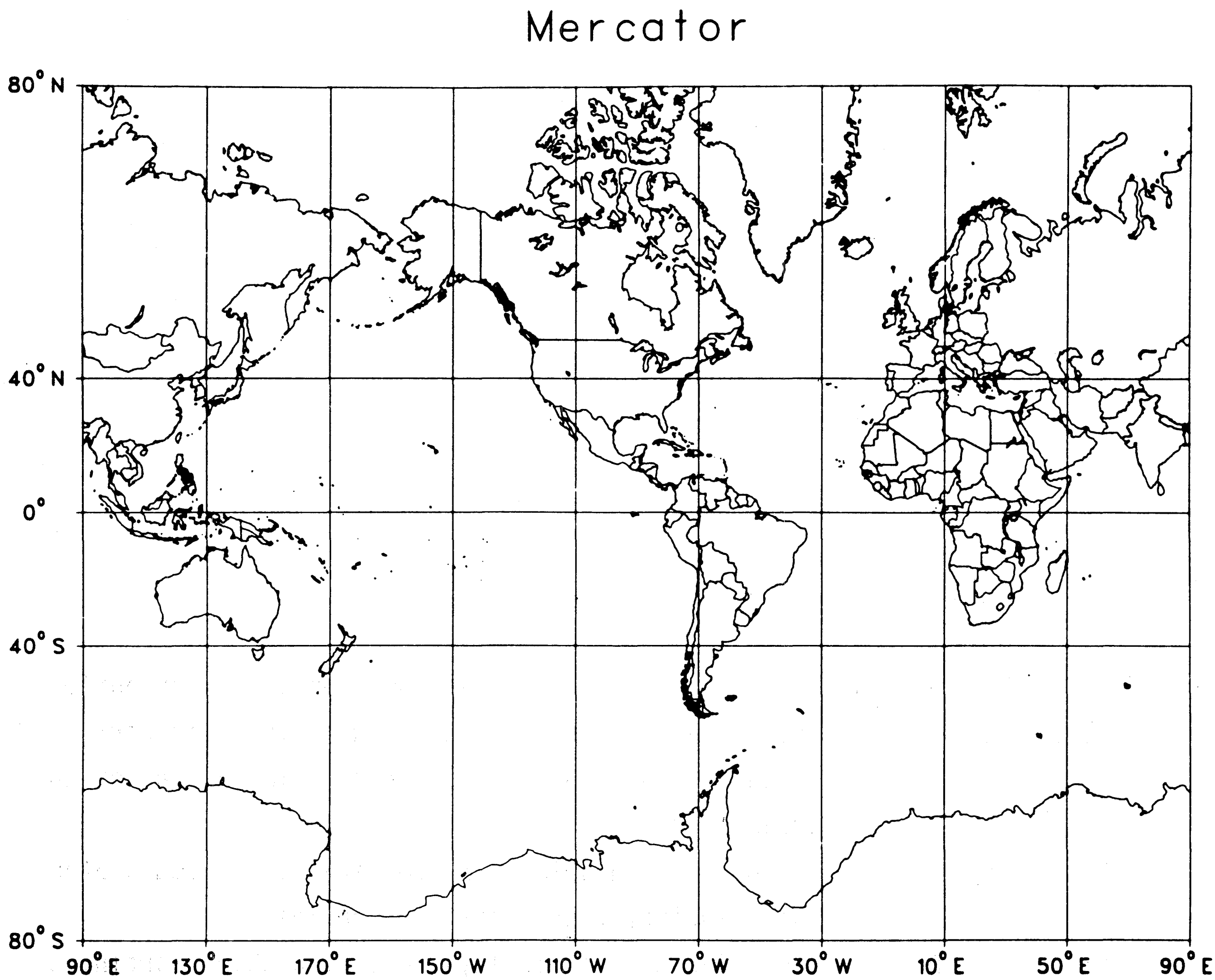


Figure 2. Mercator projection of the world map.

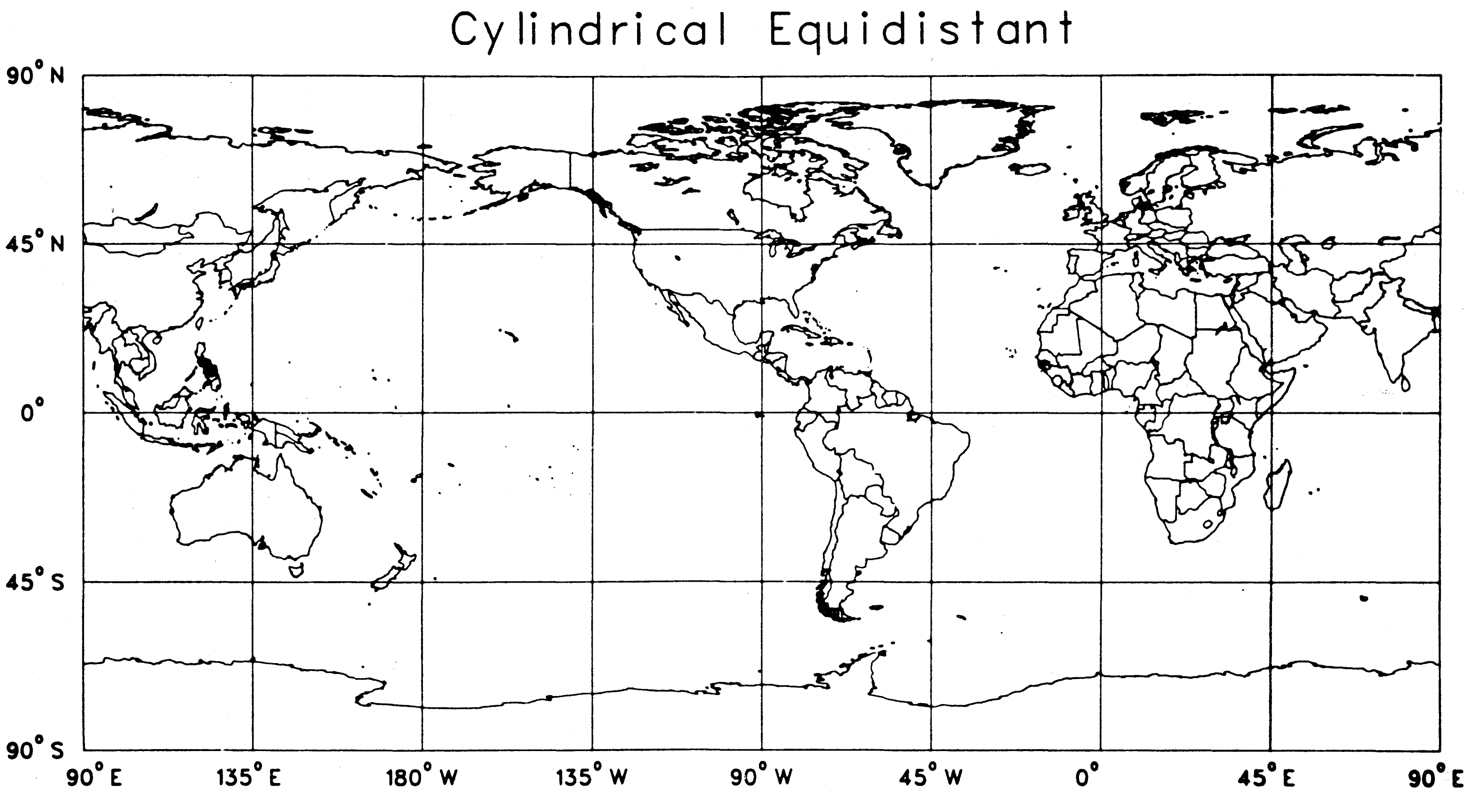


Figure 3. Cylindrical equidistant projection of the world map.

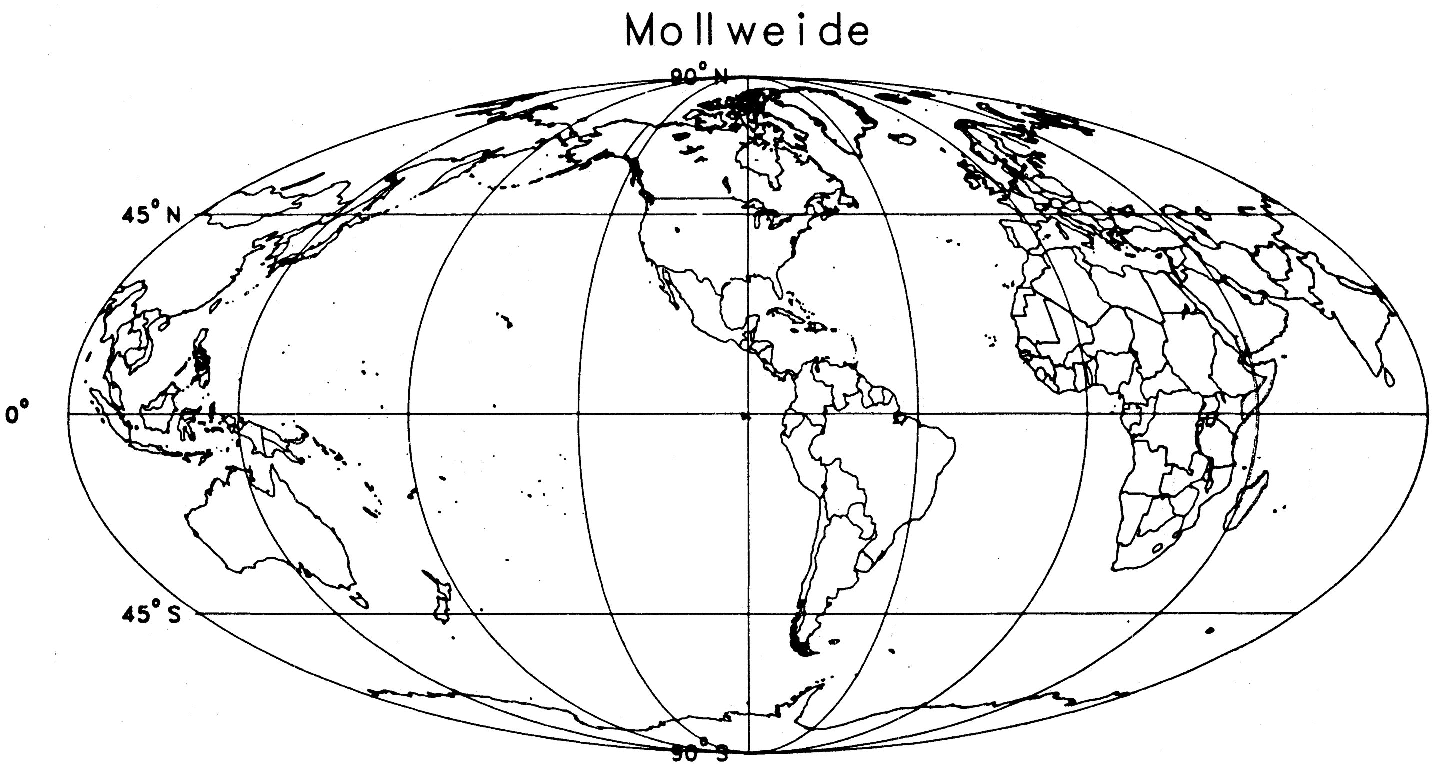


Figure 4. Mollweide projection of the world map.

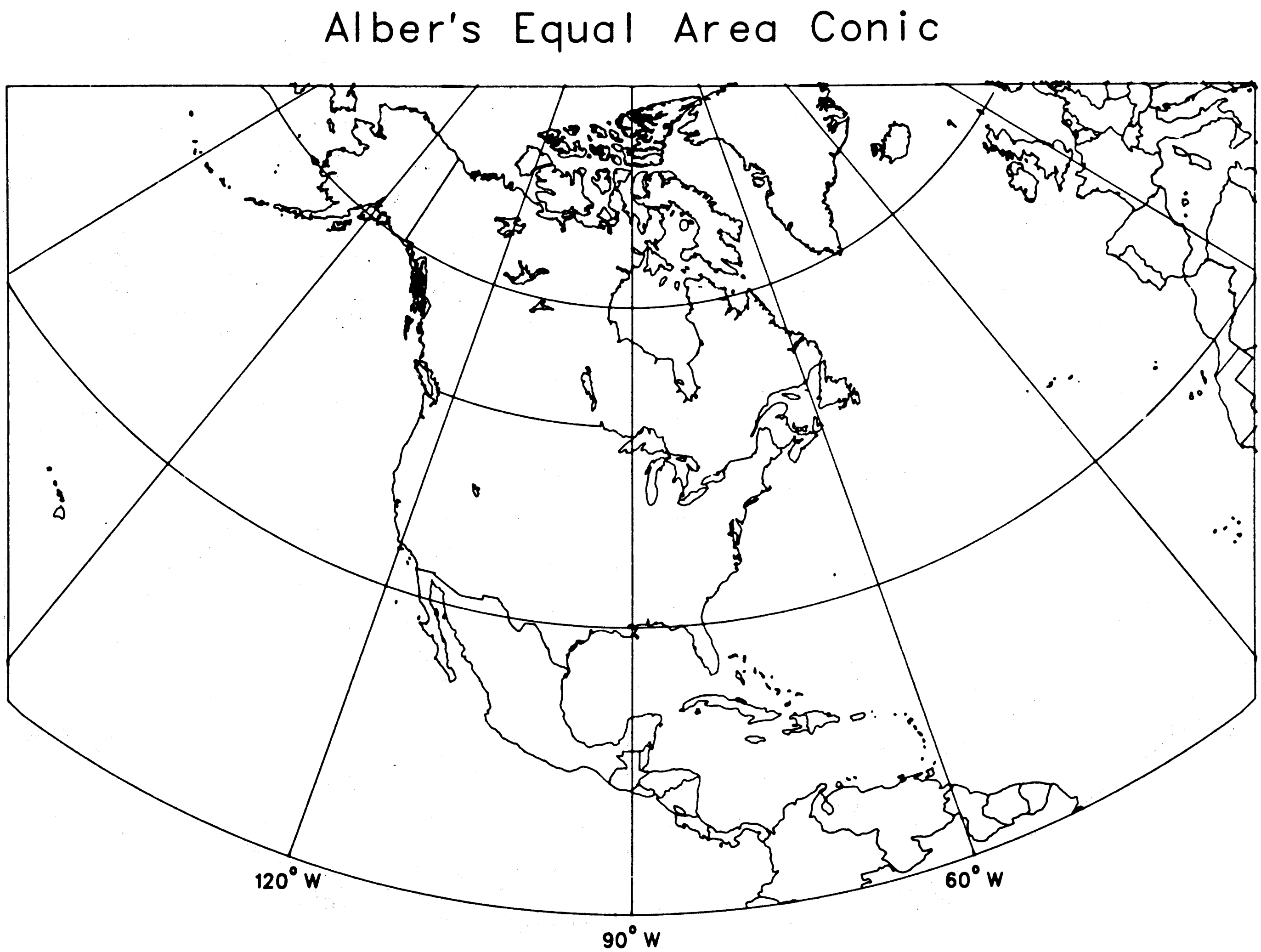


Figure 5. Alber's equal area conic projection of the world map.

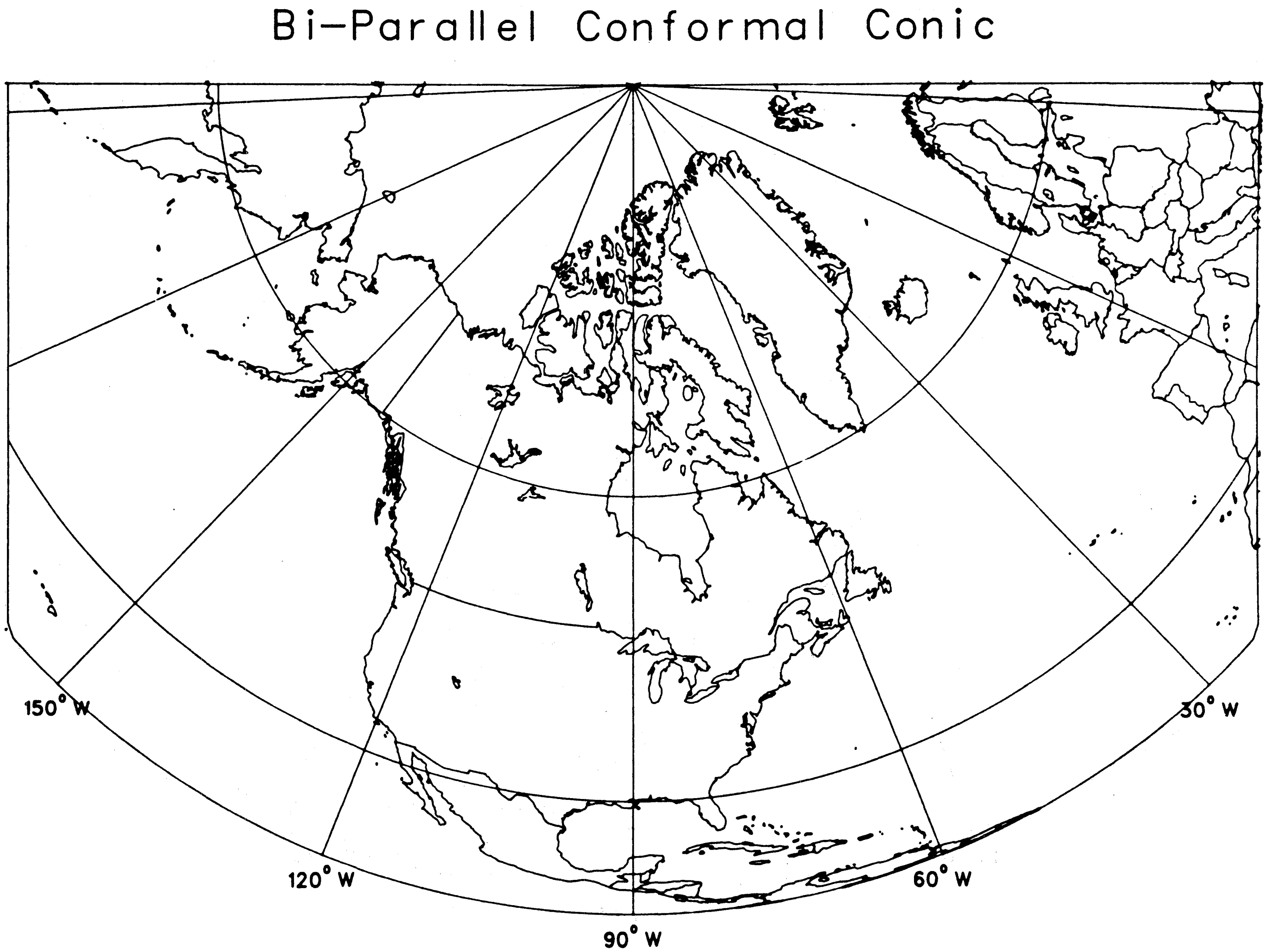


Figure 6. Bi-parallel conformal conic projection of the world map.

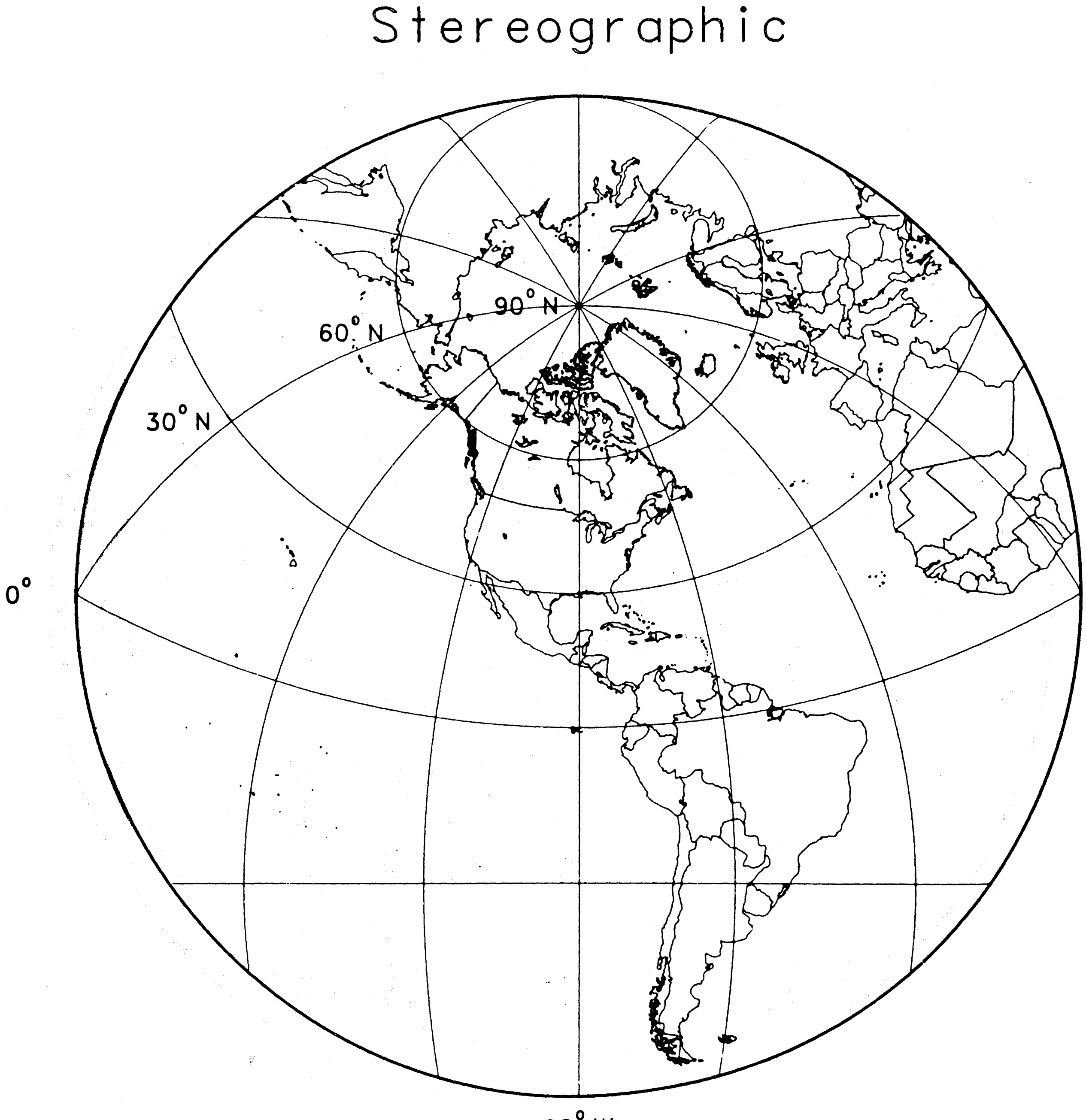


Figure 7. Stereographic projection of the world map.

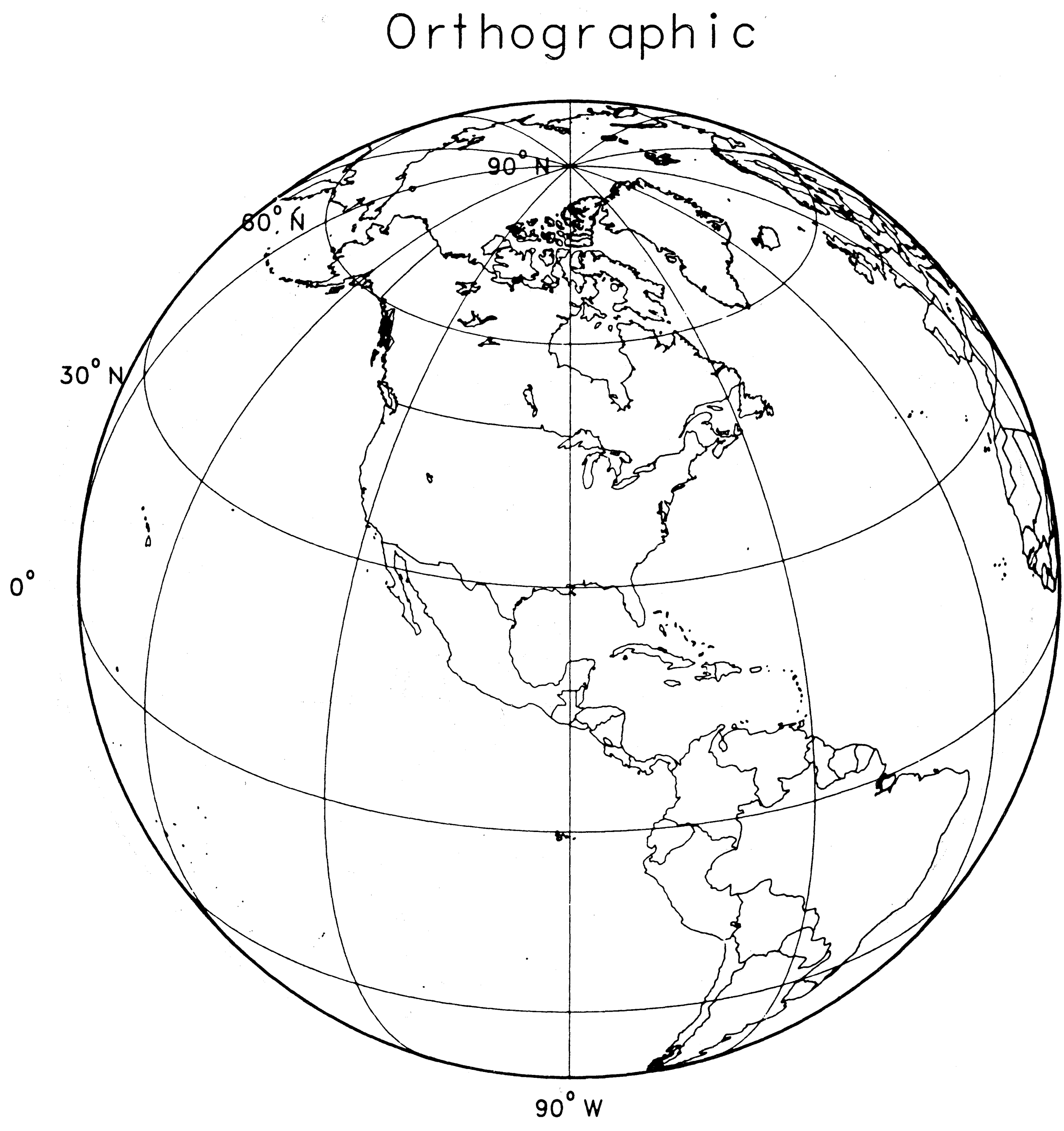


Figure 8. Orthographic projection of the world map.

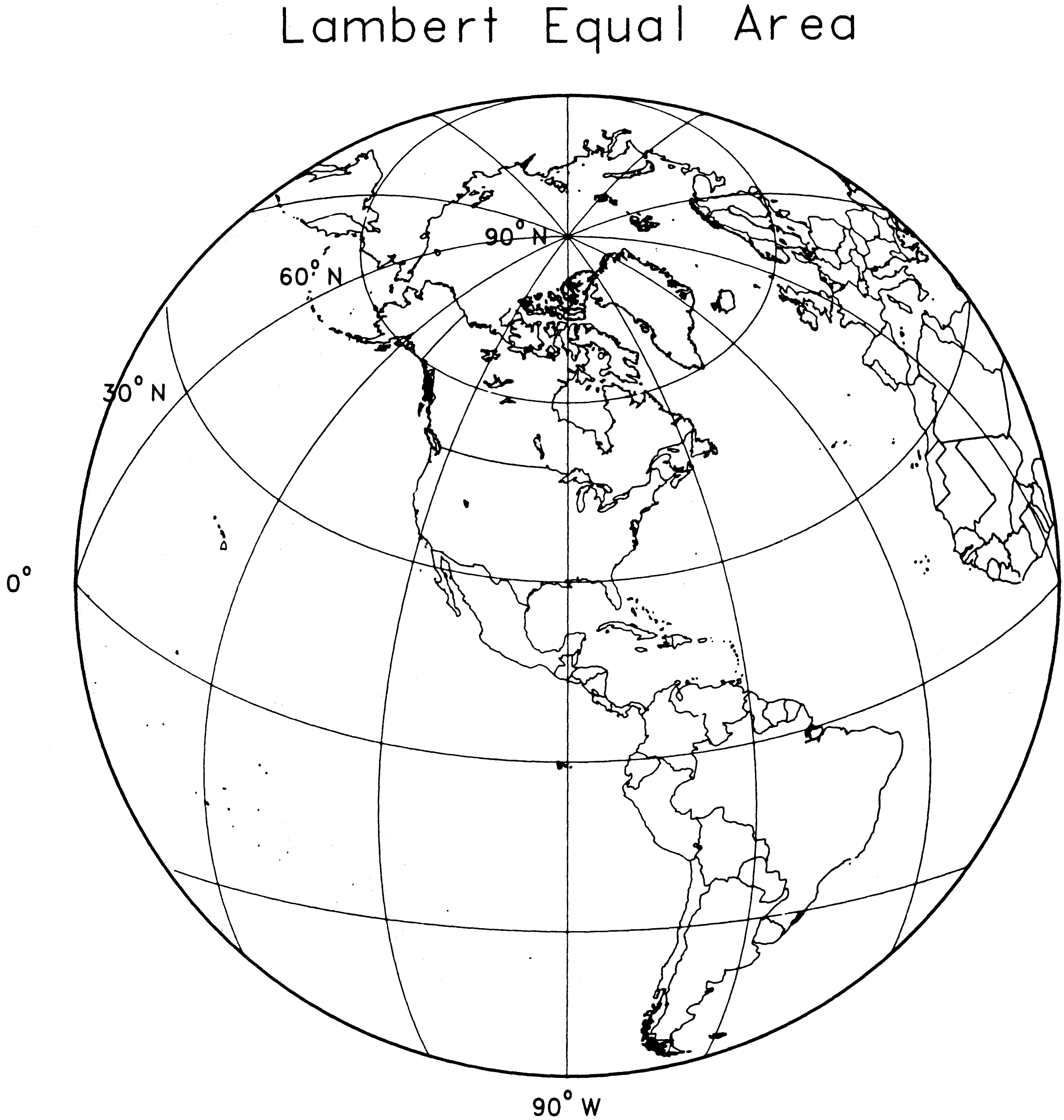


Figure 9. Lambert equal area projection of the world map.

Azimuthal Equidistant

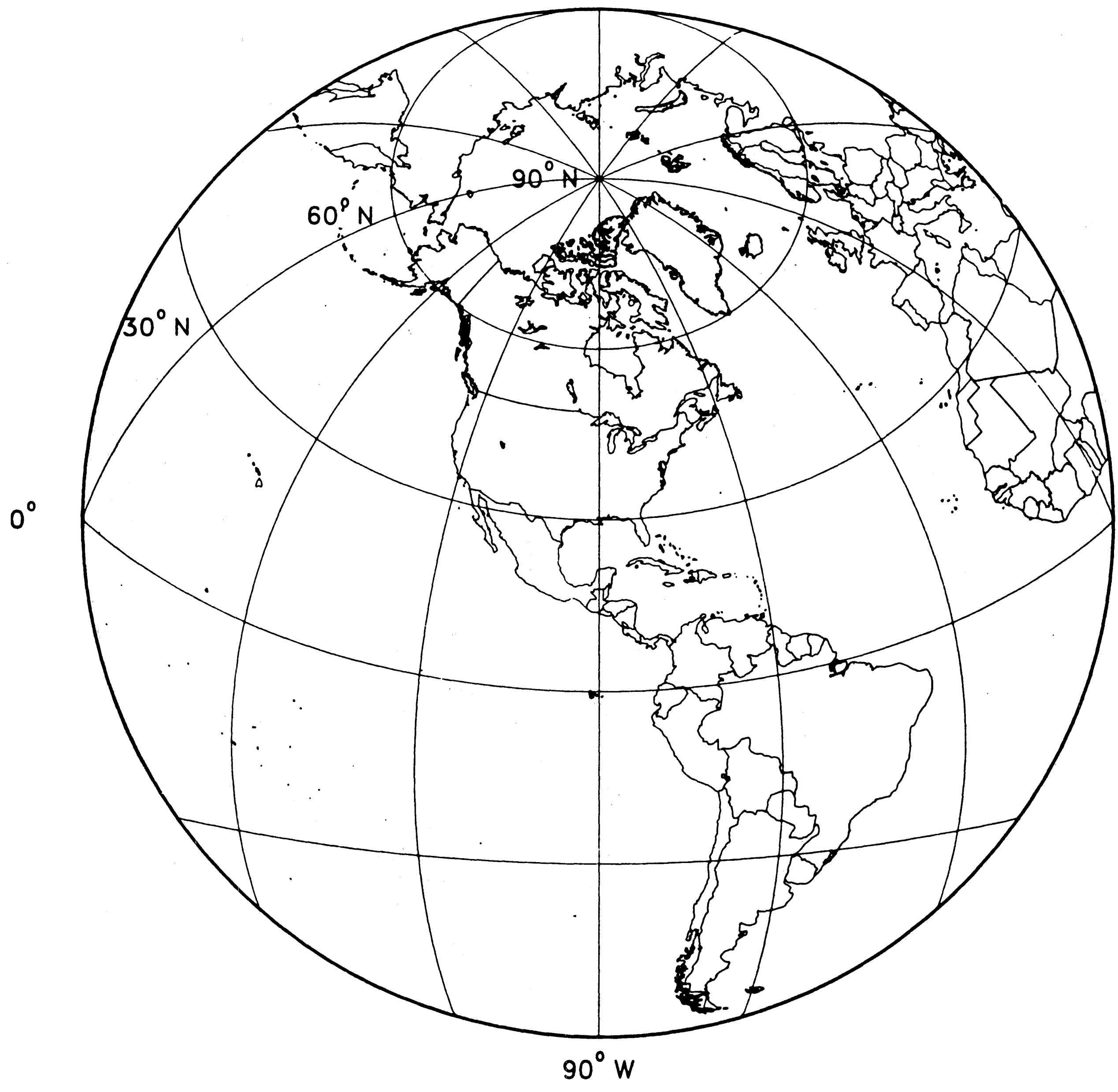


Figure 10. Azimuthal equidistant projection of the world map.

Gnomonic

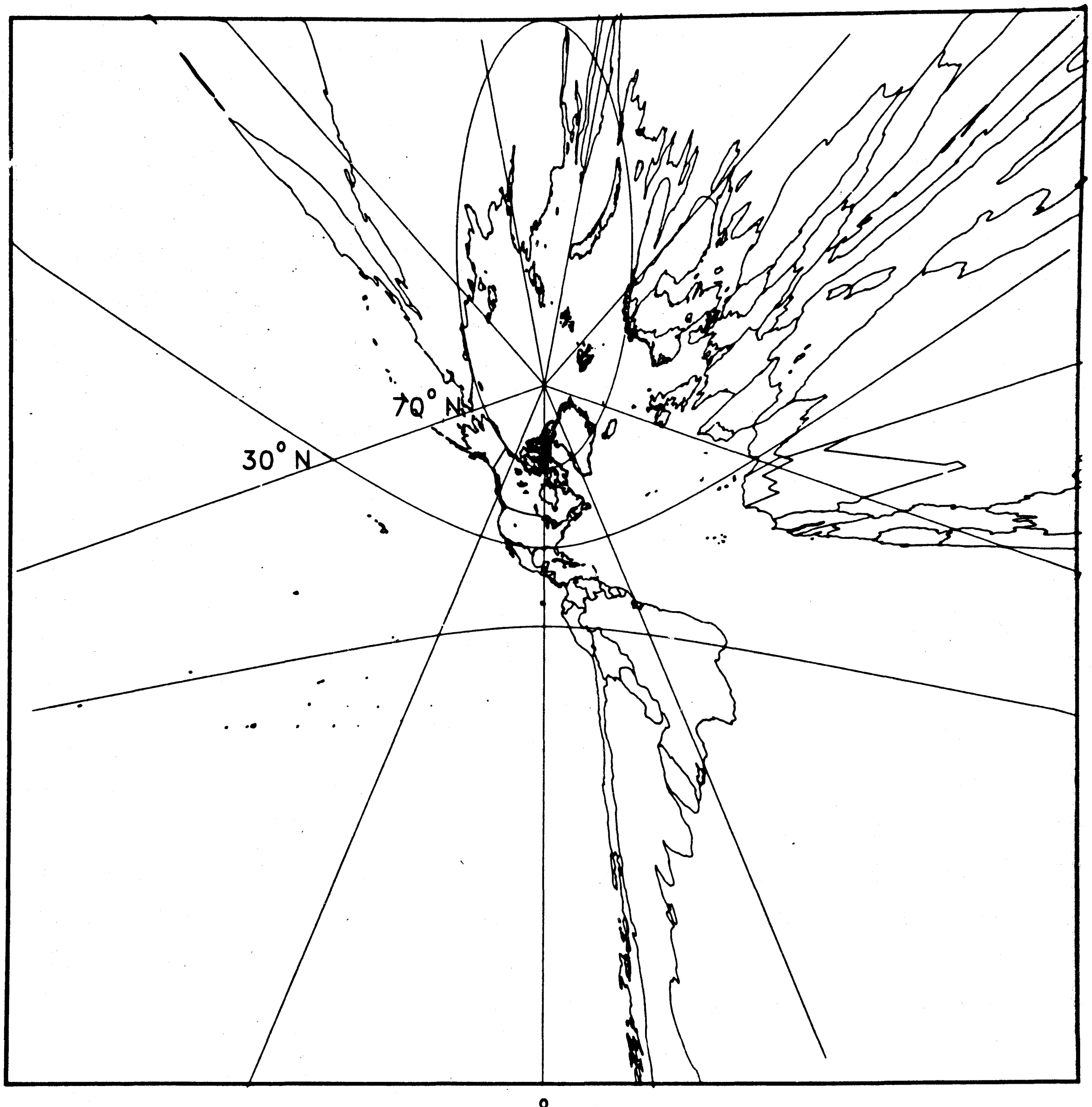


Figure 11. Gnomonic projection of the world map.

MERCATOR

The Mercator projection is a cylindrical projection that is the most frequently used for displaying footprint contours on the earth's surface. It is rectangular in appearance displaying all meridians and parallels as perpendicular straight lines. The Mercator projection has the property that at any point, the scale is the same in all directions. As one moves closer to the poles on a globe, the longitude lines become closer to one another, but as they are drawn on a two-dimensional Mercator projection, these longitude lines are separated by a constant distance regardless of the latitude. To compensate for the constant separation of the longitude lines, the latitude lines become spaced further apart as one approaches the poles. In fact at the poles themselves, the separation between adjacent lines of latitude becomes infinite. Therefore, although the Mercator projection is good for navigation because bearings may be read simply with a protractor, the expansion of the scale as one approaches the poles gives the illusion of larger areas than actually exist. Hence the Mercator projection is conformal (preserves shape) and not equal area (does not preserve size). The world map displays the full 360 degrees of longitude, but only latitudes within the limits ± 80 degrees. This projection is suited particularly for displaying footprints covering large areas of the earth.

CYLINDRICAL EQUIDISTANT

The cylindrical equidistant projection does not really project the data at all; it simply displays the coodinates as they are. The latitude lines meet the longitude lines at right angles and, as the name implies, the latitude and longitudes are separated by equal distances. The projection is rectangular in appearance. The world map displays the full 360 degrees of longitude and 180 degrees of latitude. This projection is mainly used for small areas near the equator.

MOLLWEIDE

The Mollweide projection is an elliptical presentation of the entire earth's surface. The Mollweide projection is equal area, but not conformal, with lines of constant latitude that are parallel. The lines of constant longitude appear as ellipses equally spaced at the equator. Although the Mollweide projection is not badly distorted near the equator, close to the poles it tends to distort severely. This projection is frequently used for illustrating geographic distributions.

ALBER'S EQUAL AREA CONIC

The Alber's equal area conic projection, as in all conic projections, involves transferring the map onto an imaginary cone fitted over the globe. It uses two parallels common to both the cone and sphere, which are known as the reference parallels. The meridians are straight lines which, when extrapolated, intersect at either the North or South Pole, depending on the hemisphere of the map. The parallels appear as segments of concentric circles whose centers lie at the North or South Pole. The latitude limits of this projection, and all conic projections in general, can not lie on or cross the equator. The spacing of the meridian radii and the parallel circle segments of this projection is such as to preserve local area on the globe. An interesting feature of this projection is that although local scale is not preserved, the meridian radii and parallel circles are still orthogonal so that angle is preserved. This property makes this projection extremely useful for maps of limited areas.

BI-PARALLEL CONFORMAL CONIC

The bi-parallel conformal conic projection is similar to the Alber's equal area conic projection, except that the separation of the meridians and parallels is such as to preserve local scale and thus the projection is forced to be conformal since the parallel circles and the meridian radii are orthogonal. As in other conic projections, the latitude limits can not lie on or cross the equator. Since this projection is conformal, it is most useful for local navigation.

STEREOGRAPHIC

The stereographic projection is an azimuthal projection, and as is basically true for all azimuthal projections, it is based on the concept of placing the globe tangent to a plane. The two-dimensional surface onto which the map is to be projected is referred to as the plane of projection. The various techniques for azimuthal projection all involve extending rays from the globe to the plane of projection in some prescribed manner. The point at which the globe touches the plane of projection is defined as the map pole. The stereographic projection is conformal and can display one-half of the earth's surface from any reference point (map pole) specified by the user. Directions from the reference point are true and all circles on the earth remain as circles on the projection. Of all the projections discussed in this report, the stereographic projection probably gives the most accurate representation of geographical features over a large portion of the earth. As a result it is often used for maps of large areas up to an entire hemisphere.

ORTHOGRAPHIC

The orthographic projection is an azimuthal projection that displays the earth as seen from an infinite distance. This projection shows one-half of the earth's surface centered on any reference point (map pole) that the user wishes to specify. This projection is the true perspective view of the earth. Since geographic features near the periphery are greatly distorted, the orthographic projection is most useful for displaying footprints of relatively narrow beam antennas. The projection is not conformal; however, when used to display small areas, such as the U.S., the scale factor over the map surface is reasonably uniform.

LAMBERT EQUAL AREA

The Lambert equal area projection is an azimuthal projection that will show one-half of the earth's surface from any reference point (map pole) specified by the user. Lengths on the map plane correspond to lengths on the surface of the sphere, except that the spacing of the arcs is altered in such a way as to preserve the areas of the concentric rings about the map pole in going from the globe surface to the map plane. This projection has the property that azimuths to any point on the earth from the map pole are true. As its name implies, this projection is equal area and is frequently used for analyzing population densities on large maps.

AZIMUTHAL EQUIDISTANT

The azimuthal equidistant projection is an azimuthal projection that will show one-half of the earth's surface from any reference point (map pole) specified by the user. Lengths on the map plane correspond to lengths on the surface of the sphere. This projection is not conformal or equal area, but as its name implies, all azimuths to any point on the earth from the map pole are true. This projection is often used for polar projections in which the map pole coincides with the North or South Pole and is useful for checking radio propagation paths.

GNOMONIC

The gnomonic projection is an azimuthal projection that is limited to a total latitude and longitude span of 160 degrees centered about any reference point (map pole) specified by the user. The gnomonic projection is a view of the earth as seen from the center looking outward. This projection is neither conformal nor equal area and it distorts the map very badly near the corners, thus limiting the useful area to the center of the map. It does have one very important property, however, namely that a straight line on a gnomonic map lies on a great circle, which is the shortest path between two points on the surface of a globe. Because of this projection's lack of other important properties, its primary use is for navigation.

Table 1 lists each of the map projections and some parameter value guidelines that may be helpful to the user during the specification of the footprints map. For the world map, the table gives the reference point limits for each projection and suggests height and width dimensions of the footprint's microfilm output. For the U.S. map, the table gives the fixed coordinate limits for each projection and suggests height and width dimensions of the microfilm output. Finally, for the enlarged map, the table gives the coordinate limits for each projection, but the height and width dimensions of the microfilm output are not fixed because of the varying size of the maps. The user can obtain an estimate of the height and width by using the algorithm given in Figure 12. This algorithm is valid for all of the projections except the mercator projection which spaces the latitude lines further apart as one approaches the poles. One way to obtain an estimate of the output dimensions of the mercator projection is to measure the dimensions of the enlarged map on the mercator world map of Figure 2 and then scale it up as close as possible to the maximum dimensions of 6.0 X 9.0 or 9.0 X 6.0 inches. The two projections most frequently used in the FOOTPRINTS program are the mercator and the orthographic projections.

2.3 Antenna Models

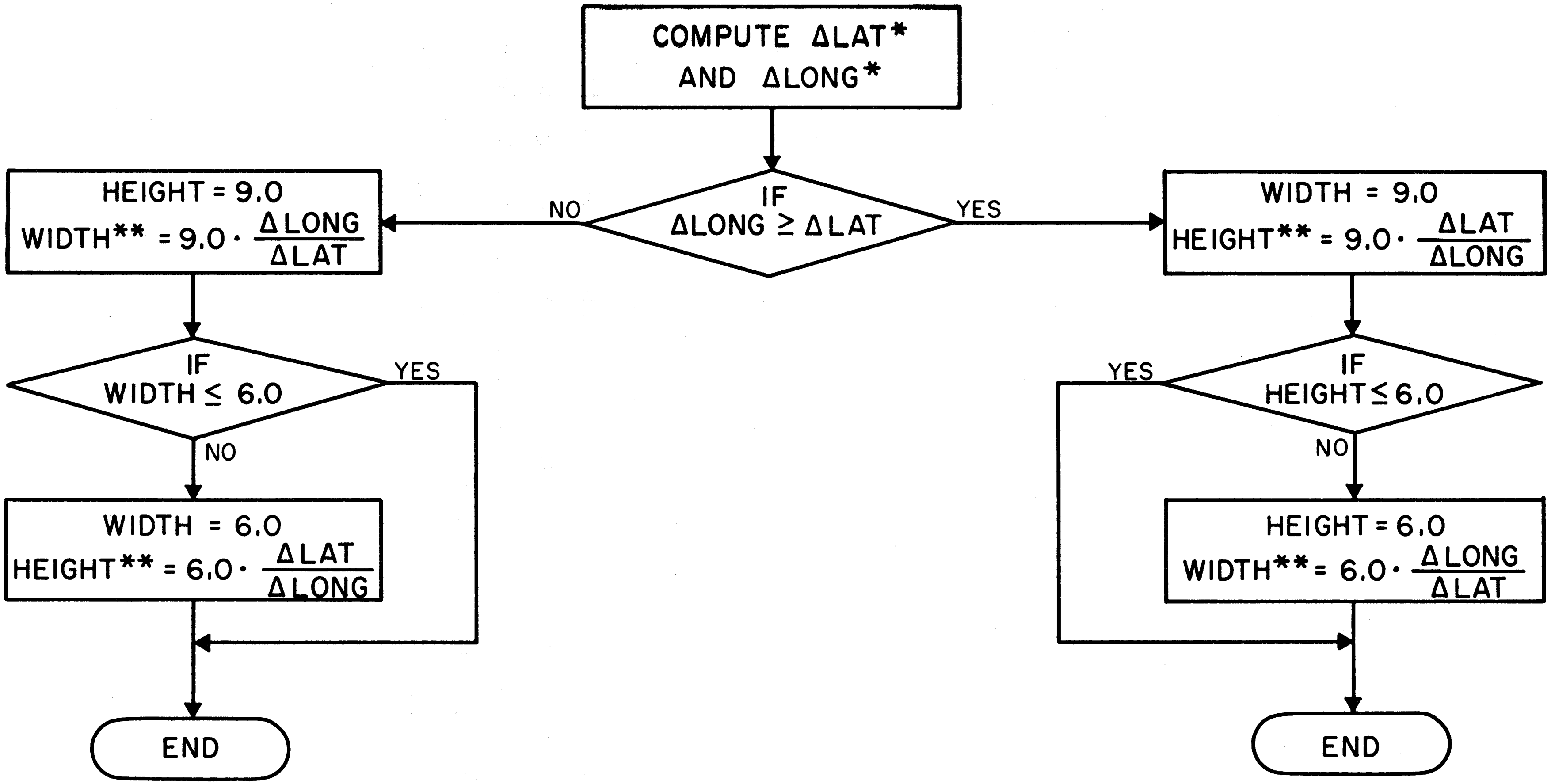
A satellite antenna's primary function is to provide a means of launching the radio frequency (rf) energy from the satellite's transmitter into space. The antenna's second most important function is to focus the rf power toward

Table 1. Map Projection and Parameter Value Guidelines

PROJECTION	WORLD MAP: Projection Reference Point Limits — Latitude (degrees)	WORLD MAP: Projection Reference Point Limits — Longitude (degrees)	WORLD MAP: Suggested Height by Width Dimensions (inches)	U.S. MAP: Projection Limits (fixed) — Latitude (degrees)	U.S. MAP: Projection Limits (fixed) — Longitude (degrees)	U.S. MAP: Suggested Height by Width Dimensions (inches)	ENLARGED MAP: Projection Limits — Latitude[1] (degrees)	ENLARGED MAP: Projection Limits — Longitude[2] (degrees)	ENLARGED MAP: Suggested Height by Width Dimensions (inches)
Mercator	0	-180.0 to 180.0	6.0 by 8.0	20.0 to 55.0	-130.0 to -60.0	5.5 by 9.0	-80.0 to 80.0	-360.0 to 360.0	See Text
Cylindrical Equidistant	0	-180.0 to 180.0	4.5 by 9.0	20.0 to 55.0	-130.0 to -60.0	4.5 by 9.0	-90.0 to 90.0	-360.0 to 360.0	See Fig. 12
Mollweide	0	-180.0 to 180.0	4.5 by 9.0	20.0 to 55.0	-130.0 to -60.0	5.0 by 9.0	-90.0 to 90.0	-360.0 to 360.0	See Fig. 12
Alber's Equal Area Conic	-45.0 or 45.0	-180.0 to 180.0	6.0 by 9.0	20.0 to 55.0	-130.0 to -60.0	5.0 by 9.0	-90.0 to -0.1 or 0.1 to 90.0	-360.0 to 360.0	See Fig. 12
Bi-Parallel Conformal Conic	-45.0 or 45.0	-180.0 to 180.0	6.0 by 9.0	20.0 to 55.0	-130.0 to -60.0	5.0 by 9.0	-90.0 to -0.1 or 0.1 to 90.0	-360.0 to 360.0	See Fig. 12
Stereographic	-90.0 to 90.0	-180.0 to 180.0	6.0 by 6.0	20.0 to 55.0	-130.0 to -60.0	5.0 by 9.0	-180.0 to 180.0	-360.0 to 360.0	See Fig. 12
Orthographic	-90.0 to 90.0	-180.0 to 180.0	6.0 by 6.0	20.0 to 55.0	-130.0 to -60.0	5.0 by 9.0	-180.0 to 180.0	-360.0 to 360.0	See Fig. 12
Lambert Equal Area	-90.0 to 90.0	-180.0 to 180.0	6.0 by 6.0	20.0 to 55.0	-130.0 to -60.0	5.0 by 9.0	-180.0 to 180.0	-360.0 to 360.0	See Fig. 12
Azimuthal Equidistant	-90.0 to 90.0	-180.0 to 180.0	6.0 by 6.0	20.0 to 55.0	-130.0 to -60.0	5.0 by 9.0	-180.0 to 180.0	-360.0 to 360.0	See Fig. 12
Gnomonic	-90.0 to 90.0	-180.0 to 180.0	6.0 by 6.0	20.0 to 55.0	-130.0 to -60.0	5.0 by 9.0	-180.0 to 180.0	-360.0 to 360.0	See Fig. 12

[1] Maximum latitude span is equal to 180.0 degrees except the Gnomonic projection, which is limited to 160.0 degrees, and where the projection limits restrict it.

[2] Maximum longitude span is equal to 360.0 degrees except the Stereographic, Orthographic, Lambert Equal Area, and Azimuthal Equidistant projections which are limited to 180.0 degrees and the Gnomonic projection which is limited to 160.0 degrees.



* ΔLAT = |Upper Latitude Boundary − Lower Latitude Boundary|
ΔLONG = |Left Longitude Boundary − Right Longitude Boundary|

** The height or width dimension should be increased to a multiple of 0.5 inches.

Figure 12. Microfilm height and width estimation algorithm.

desired portions of the visible earth and to block the energy in the direction of other parts of the earth.

For example, it may be desirable to have an antenna pattern which uniformly illuminates the entire visible earth. For this case, an antenna whose pattern has circular symmetry and an 18 degree half-power beamwidth might be used. As another example, it might be desired to communicate with sites within the U. S. only. For this case, the antenna pattern might have an elliptical shape which concentrates the power toward the U. S. and reduces the energy (thereby decreasing possible interference) toward the surrounding areas of Mexico, Canada, and the oceans.

A large variety of antenna types are used on satellites in order to best accommodate the various operating requirements such as frequency of operation, physical size limitations, polarization, and required pattern shape, or even the ability to change the pattern shape while in orbit. The FOOTPRINTS program has models of four common types of satellite antennas:

Parabolic Reflector
Elliptical Reflector
Rectangular Aperture or Horn
Helix.

and models of two specialized types of satellite antennas:

WARC 1977 Elliptical Reflector
Fast Roll-Off Elliptical Reflector.

For the four common antenna types, the user of the program supplies electrical or physical characteristics of the antenna, and the program computes the mainbeam pattern from the model. For the two specialized antenna types, the program requires the electrical characteristics of the antenna, from which the program computes the mainbeam pattern from the model.

In addition to using one of the above antenna types, the user has the option of submitting detailed pattern data to the program. With this method, the user can describe the antenna pattern exactly for the main lobe and side lobes and thus obtain a more refined footprint plot. This input mode is called the "point pattern mode" and is discussed in the Appendix.

A good introductory text on antennas, which describes the common types of antennas modeled by the FOOTPRINTS program, is by Blake (1966). The specialized antennas were developed at World Administrative Radio Conference (WARC) meetings. The WARC 1977 elliptical reflector antenna is described in Appendix 30 of the 1982 Edition of the Radio Regulations of the International Telecommunication Union (ITU). The fast roll-off elliptical reflector antenna resulted from a proposal submitted by the United States to the Panel of Experts preparing for the 1983 RARC-BS (Regional Administrative Radio Conference for Broadcasting Satellites). The following subsections briefly describe the use of the FOOTPRINT antenna models.

PARABOLIC REFLECTOR ANTENNA

The parabolic antenna is composed of a parabolic reflector with a "feed" at the reflector's focal point. The feed is a horn, dipole, or some other form of antenna which beams the power from the satellite's transmitter toward the reflector. The resultant feed-reflector pattern is dependent on several things: the shape of the feed's pattern, the frequency at which the antenna operates, the physical size of the reflector, etc. The parabolic antenna is able to concentrate its input rf power into a pencil-like beam which, in the case of the FOOTPRINT program model, has circular symmetry about the main-beam axis.

The parabolic reflector pattern most easily described is produced when the primary feed uniformly illuminates the reflector. Uniform illumination produces the narrowest possible beamwidth for any given set of antenna frequency and reflector diameter values. For this case, the program computes the main-beam pattern by using the reflector diameter expressed in wavelengths. If the user does not know the diameter in wavelengths, the FOOTPRINTS program accepts other information about the antenna and applies some well-known "rules of thumb" (Kraus, 1950, page 345) to determine reflector diameter. For an idea of the size of areas covered on the earth's surface by antennas of various beamwidths, see Figure 13.

Although a uniform primary illumination gives the narrowest beamwidth, it cannot be physically obtained. Usually the primary feed is an antenna such as a horn whose power gain pattern monotonically decreases from a peak at the beam's center. This tapering has been modeled within the FOOTPRINTS program as a raised cosine. The user specifies the raised cosine's illumination of the parabolic reflector as a ratio of the illumination at the edge of the reflector to the illumination at the reflector's center. Figure 14 illustrates three examples of the raised cosine illumination taper for edge-to-center illumination ratios of 1.0, 0.5, and 0.0. The tapered illumination results in a wider beamwidth, but has lower sidelobes, which is a desirable

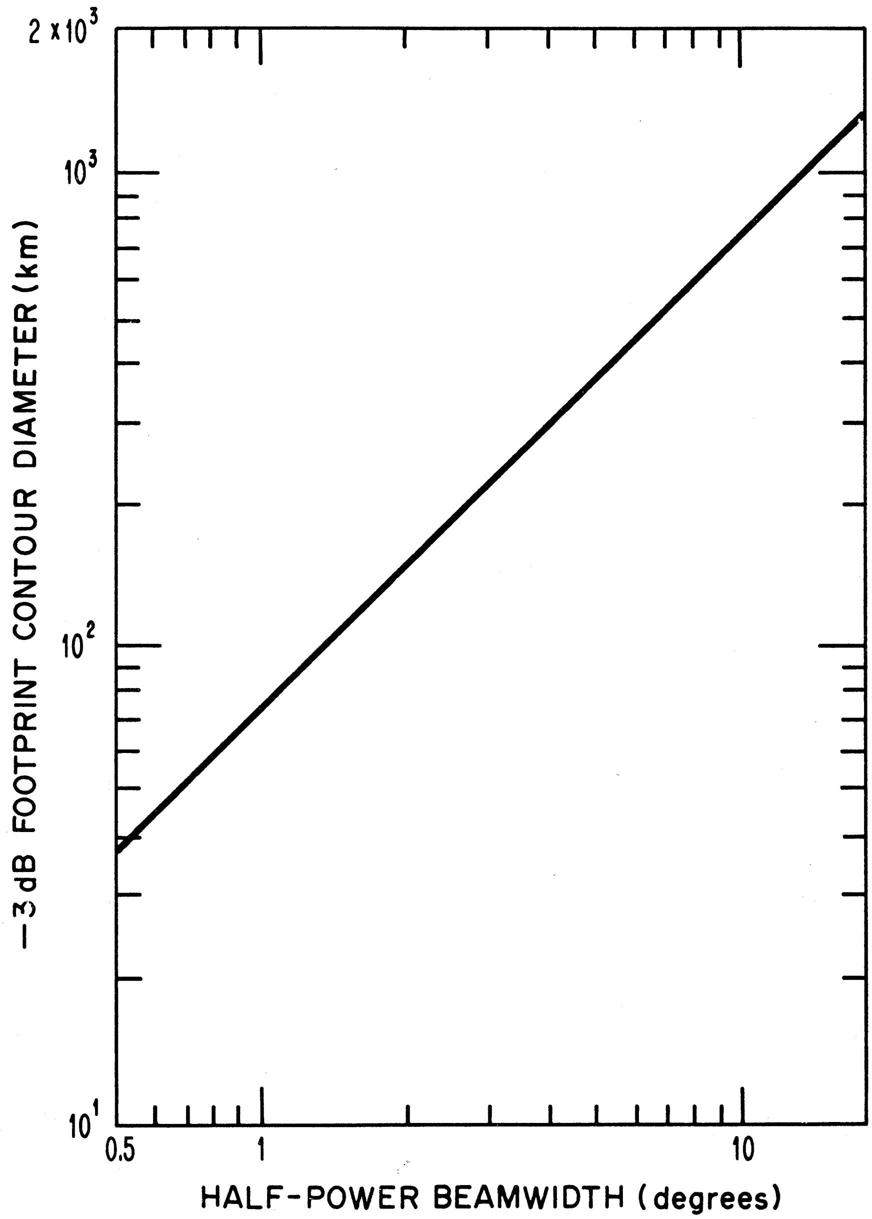
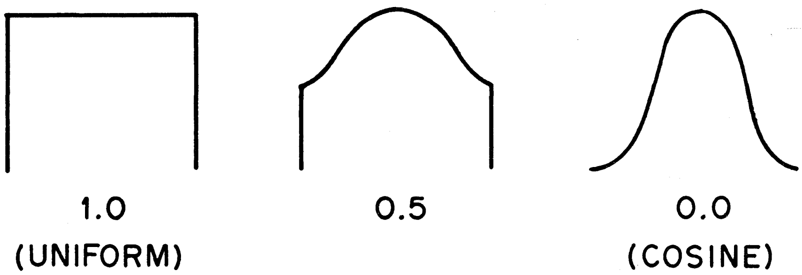


Figure 13. Minimum footprint diameter on the earth's surface as a function of antenna bandwidth (Haakinson, Skinner, Spies, and Bridgewater, 1977).



$$\text{ILLUMINATION RATIO} = \frac{\text{EDGE ILLUMINATION}}{\text{CENTER ILLUMINATION}}$$

Figure 14. Three examples of the raised cosine illumination taper (Haakinson, Skinner, Spies, and Bridgewater, 1977).

property when the effects of interference are to be considered.

If a tapered illumination is desired, the user must know the reflector's diameter. The program cannot derive the diameter from peak gain or beamwidth alone as in the case of uniform illumination.

ELLIPTICAL REFLECTOR ANTENNA

The elliptical reflector antenna is a parabolic reflector whose mouth (reflector opening) has been changed from a circle to an ellipse. An elliptical aperture results in a pattern whose smallest beamwidth is associated with the ellipse's major axis and whose widest beamwidth is associated with the ellipse's minor axis.

To use the elliptical reflector model, the major and minor axis dimensions must be specified. Since this antenna has elliptical symmetry, the FOOTPRINTS program needs to know the clockwise rotation angle of the ellipse's major axis with respect to the antenna's north-south axis. The antenna's north-south axis is defined as a line passing through the antenna 1) perpendicular to the antenna main beam and 2) parallel to the earth's north-south axis when the antenna main beam is aimed toward the earth's center. The primary feed's illumination of the elliptical reflector can be specified along the major and minor axes. The same raised cosine as defined in the parabolic reflector antenna's discussion is used; however, the illumination ratio along the major axis can be different from the ratio along the minor axis.

HORN ANTENNA

Another common type of satellite antenna is the horn having a rectangular aperture. Like the elliptical reflector antenna, the FOOTPRINTS program requires the aperture's height and width dimensions, the clockwise rotation of the antenna's longer (height) dimension with respect to the antenna's north-south axis, and the illumination ratios along the aperture's long and short dimensions. Note that for a rectangular aperture antenna supporting the TE_{10} mode, the H-plane field goes to zero at the edge of the aperture (an illumination ratio of zero) whereas the E-plane field remains nearly uniform (an illumination ratio of one). For more discussion see Kraus (1950) pages 375-381.

HELICAL ANTENNA

As the name implies, this antenna looks like a helix. The helix can radiate in many modes, but the most common one is the axial mode. In this mode, the power gain is a maximum in the direction of the helix axis and is circularly polarized either right or left.

To radiate in the axial mode, the circumference of the helix must be on the order of one wavelength (Kraus, 1950, page 176). The far field pattern then is determined from the spacing between each turn of the helix and the total number of turns. The FOOTPRINTS helical antenna model assumes that the circumference is one wavelength. The model then requires only the turn spacing and number of turns information in order to approximate the pattern.

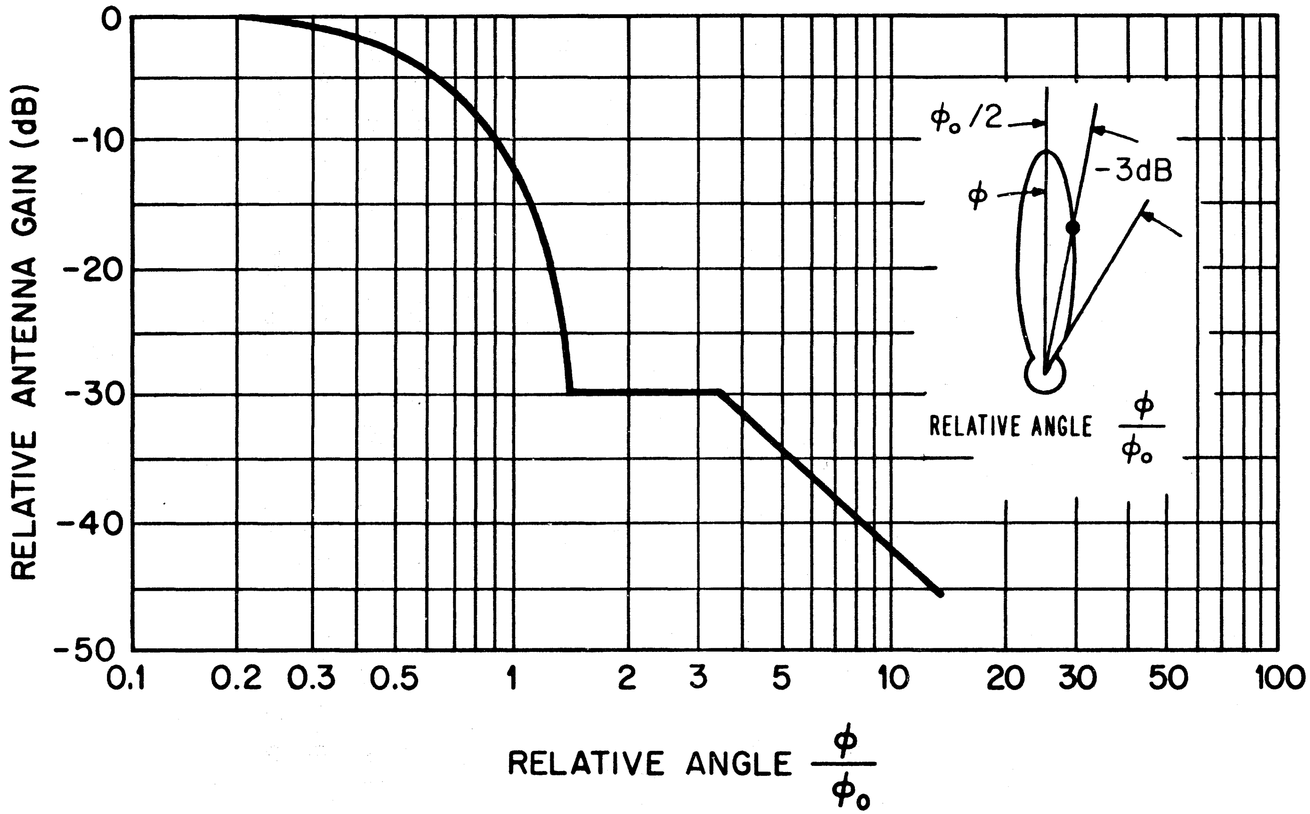
WARC 1977 ELLIPTICAL REFLECTOR ANTENNA

The WARC 1977 elliptical reflector antenna is a parabolic reflector which is similar to the common elliptical antenna, but has a steeper roll-off of the main-beam rf power between -3dB and -30dB. This antenna is from the Final Acts of the 1977 WARC. It was designed to decrease the interference outside the primary service area. Figure 15 shows the reference pattern for this antenna along with the equations describing it.

The WARC 1977 elliptical antenna model is defined by specifying its major and minor axes beamwidths and, since it has elliptical symmetry, its inclination or rotation angle. The axes beamwidths are defined as the half-power (-3dB) beamwidth of the antenna's main beam, expressed in degrees. The inclination angle of the antenna is defined as the counterclockwise rotation angle of the ellipse's major axis with respect to the antenna's east-west axis. The antenna's east-west axis is defined as a line passing through the antenna 1) perpendicular to the antenna's main beam and 2) parallel to the earth's east-west axis when the antenna's main beam is aimed toward the earth's center. (Note that the major and minor axes definitions and the definition of the inclination angle for this antenna are different from the comparable specifications of the elliptical antenna described above.) It is assumed that the WARC 1977 elliptical antenna uniformly illuminates the reflector.

FAST ROLL-OFF ELLIPTICAL REFLECTOR ANTENNA

The fast roll-off elliptical reflector antenna is a parabolic reflector which is similar to the WARC 1977 elliptical antenna, but has an even steeper



Relative Antenna Gain (dB) Formulas:

$-12\left(\frac{\phi}{\phi_o}\right)^2$	for $0 \leq \phi \leq 1.58114\,\phi_o$
-30	for $1.58114\,\phi_o < \phi \leq 3.16228\,\phi_o$
$-\left[17.5 + 25\log_{10}\left(\frac{\phi}{\phi_o}\right)\right]$	for $3.16228\,\phi_o < \phi$

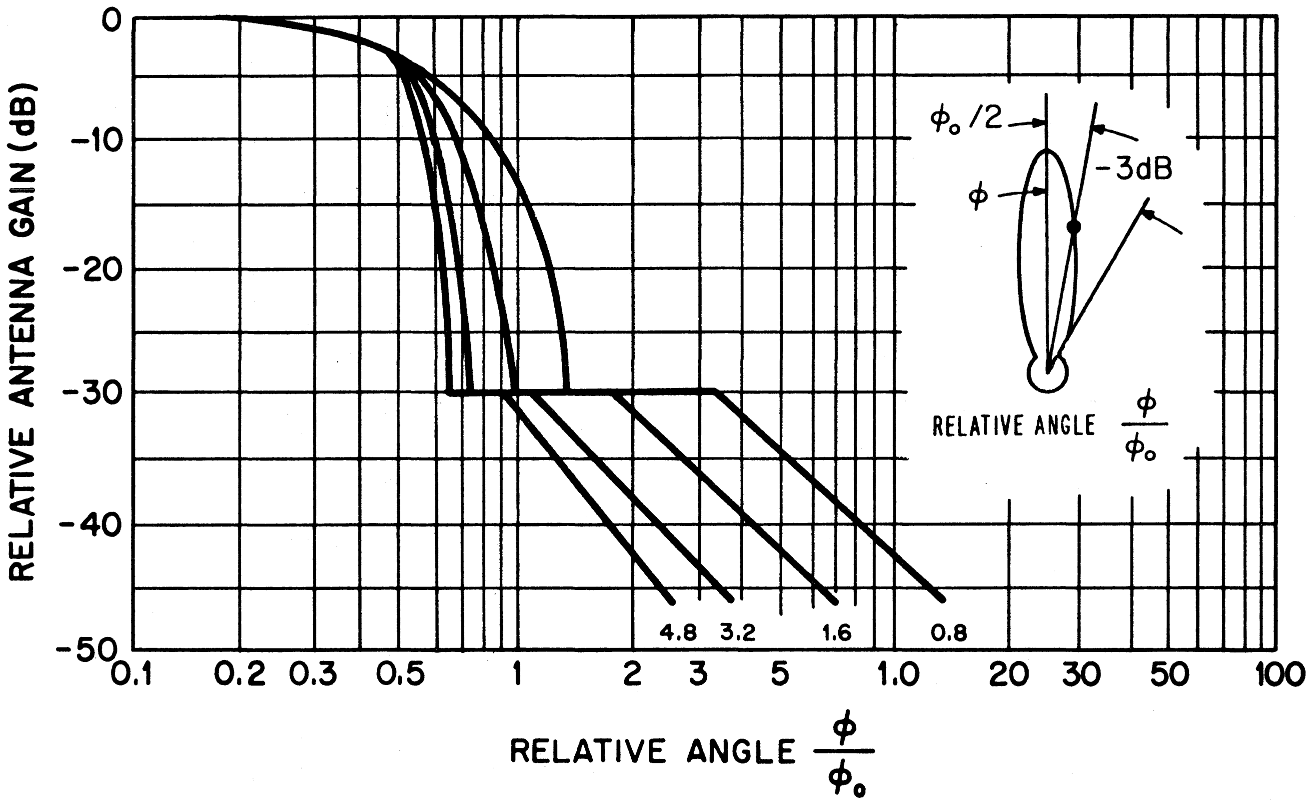
Figure 15. WARC 1977 elliptical antenna reference pattern and equations.

roll-off of the main-beam rf power between -3dB and -30dB. It was designed to further decrease the interference outside the primary service area. Figure 16 shows the reference pattern for this antenna, along with the equations describing it, for beamwidths of 0.8, 1.6, 3.2, and 4.8 degrees. (Note that the reference pattern for this antenna with a beamwidth of 0.8 degrees is the same as the reference pattern for the WARC 1977 elliptical antenna regardless of the beamwidth.) The fast roll-off elliptical antenna is defined the same as the WARC 1977 elliptical antenna discussed above.

2.4 User Supplied Service Area Polygons

A service area is a bounded geographic area to which common broadcasting satellite service is provided. A broadcasting satellite service is a radio-communication service in which signals transmitted or retransmitted by space stations (satellites) are intended for direct reception by the general public. The FOOTPRINTS program can be a useful tool in determining if a broadcasting satellite's service coverage area corresponds to the appropriate service area. To help in a study of this kind, the FOOTPRINTS program has the capability to plot service area polygons along with the earth footprints on the map projections of the earth. A service area polygon is a figure that completely encloses a service area. A service area polygon may range from enclosing a service area with the minimum number of points, to the tracing of the contours of a service area exactly.

The first step in order to utilize the service area polygon option of the FOOTPRINTS program is to set up a service area polygon library file. This file contains all of the service area polygons that the user may wish to plot in a given program execution. An example of this file, called "DTPLGN", is given in Figure 17. Each line in the file is a data record. The first record is a comment that is used to identify the service area polygon file. It is not used by the program, but it must be present in the file. After the first record in the file, each of the service area polygons are defined using three or more records. The first record contains a one to eight character service area identifier, followed by a three digit integer that specifies the number of longitude and latitude data pairs that define the polygon. The rest of the record is a comment, which is not used by the program. The format for this record is "A8,5X,I3". The following record contains the longitude data of the polygon using a format of "10F8.2". If more than ten longitude data points



Relative Antenna Gain (dB) Formulas:

$$-12\left(\frac{\phi}{\phi_o}\right)^2 \qquad \text{for } 0 \le \phi \le 0.5\,\phi_o$$

$$-12\left(\frac{\phi}{0.8}\right)^2\left[\frac{\phi}{\phi_o} - 0.5\left(1 - \frac{0.8}{\phi_o}\right)\right]^2 \qquad \text{for } 0.5\,\phi_o < \phi \le 0.5\,\phi_o + 0.86491$$

$$-30 \qquad \text{for } 0.5\,\phi_o + 0.86491 < \phi \le 0.5\,\phi_o + 2.12982$$

$$-\left\{17.5 + 25\log_{10}\left[\frac{\phi_o}{0.8}\left(\frac{\phi}{\phi_o} - 0.5\left(1 - \frac{0.8}{\phi_o}\right)\right)\right]\right\} \qquad \text{for } 0.5\,\phi_o + 2.12982 < \phi$$

Figure 16. Fast roll-off elliptical antenna reference pattern and equations.

```
"Service Area Polygon Library File Identification"
CCCCCCCC  NP=nnn     "Service Area Polygon Comment"
 -ddd.dd -ddd.dd -ddd.dd  -dd.dd  ...    (up to 10 numbers)
   dd.dd   dd.dd   dd.dd   dd.dd  ...    (up to 10 numbers)
CCC       NP=nnn     "Service Area Polygon Comment"
  ddd.dd  ddd.dd  ddd.dd  ...                                      dd.dd
   dd.dd   dd.dd  ddd.dd  ...    (up to 10 numbers)
   dd.dd   dd.dd   dd.dd  ...                                     -dd.dd
  -dd.dd  -dd.dd   dd.dd  ...    (up to 10 numbers)
CCCCC     NP=nnn     "Service Area Polygon Comment"
  -dd.dd   -d.dd    d.dd  ...    (up to 10 numbers)
   dd.dd   dd.dd   dd.dd  ...    (up to 10 numbers)
.
.
.
CCCCC     NP=nnn     "Service Area Polygon Comment"
 -ddd.dd -ddd.dd  -dd.dd  ...    (up to 10 numbers)
  -dd.dd  -dd.dd   -d.dd  ...    (up to 10 numbers)
CCCCCCCC  NP= -1
               (END OF FILE internally generated by the CDC 170/750)
```

Figure 17. Example of service area polygon library data file structure (DTPLGN).

are needed, another record is used. This continues until all of the longitude data are listed. Following the last longitude record, a new record is started for the corresponding latitude data that make up the data pairs. The latitude records have the same format as the longitude records. This procedure is repeated for each service area polygon. The program assumes North latitude and East longitude are positive and South latitude and West longitude are negative. The last record of the file contains a one to eight character file identifier, followed by a three digit integer set equal to -1. This tells the FOOTPRINTS program that it is at the end of the file. The format for this record is "A8,5X,I3".

The next step in utilizing the service area polygon option of the program is to set up the selection data file that tells the FOOTPRINTS program which service area polygons to plot on each map projection. An example of this file, called "REGNSL", is given in Figure 18. The file specifies a number of data sets, each containing the number of service area polygons to be plotted, followed by the corresponding number of one to eight character service area identifiers, for each anticipated map projection. These data sets are placed in the file in the order that they are to be read by the program. Each time the FOOTPRINTS program does a map projection, it reads one set of these data and does the desired plotting. The format for the number of service area polygons to be plotted is "I3". The format for the service area identifiers is "A8". The range of values for the number of service area polygons to be plotted for a map projection is from -99 to 999. If this number is equal to 999, the program plots all of the polygons in the library file. If this number is equal to 0, the program doesn't plot any polygons. If this number is negative, the program plots all of the polygons in the library except for the polygons which are specified, which total the absolute value of the negative number. Finally, if this number is positive, but less than 999, the program plots only the polygons that are specified which total the value of the positive number. If, during the execution of the program, an end of file is read in REGNSL, the program assumes that no polygons are to be plotted and simply skips the service area polygon plotting section of the program.

3. PROGRAM UTILIZATION

3.1 Program Access

The program FOOTPRINTS is operational on the CDC 170/750 computer at the Department of Commerce Laboratories in Boulder, Colorado. In order to execute

```
nnn
CCC
CCC
CCCCCCCC
CCC
.
.
CCC
nnn
CCCCC
C
CC
.
.
CCCC
.
.
.
nnn
CCCCC
CCC
.
.
CCCCC
     (END OF FILE internally generated by the CDC 170/750)
```

Figure 18. Example of service area polygon selection data file structure (REGNSL).

the program, the user must have a valid account on the computer. An account can be established on the computer by contacting User Services at the Boulder Labs Computer Center. Access to the program can be obtained by contacting the author.

A user logs onto the computer by making contact with the computer (by either a hard line or a telephone modem) and entering a carriage return. If the computer is operational, the user will get the following response:

```
 yy/mm/dd. hh.mm.ss.
N O A A / E R L    170/750    82/05/16.    NOS 1.4 531/528.20
FAMILY:
```

The user responds by entering his/her User Name and Password immediately following the "FAMILY:" prompt in the following manner:

```
        ,username,password
```

If the above response is correct, the computer responds with:

```
        TERMINAL:    nnn, TTY
RECOVER/ CHARGE:
```

The user then enters his/her Charge Number immediately following the "RECOVER/ CHARGE:" prompt in the following manner:

```
                 CHARGE,chargenumber,Z
```

If the above Charge Number is correct, the computer responds with the following:

```
$CHARGE,chargenumber,Z.
/
```

The "/" is the prompt for the CDC 170/750 NOS Operating System. At this point, the user has successfully logged onto the computer and is ready to begin the initialization of the program FOOTPRINTS.

3.2 Program Initialization

The user must now set up the data files to be used by the program FOOTPRINTS. These data files are created and modified by using one of the file editors available on the CDC 170/750 computer. The user should obtain a user's manual to one of these editors and become familiar with it. Additional help can be obtained from User Services.

There are six data files to consider. All of the data files must exist, even though the data contained in them may not be used by FOOTPRINTS for a particular run. A brief description of each of the data files is given below, including a reference to where its internal structure is described in this manual. Once a particular data file is created, it should be stored under the file name given below. If a data file is not needed for a particular run, an empty or old data file should be stored under that data file name.

"ANTENn" - These data files contain detailed point pattern antenna data.
n=0,1,2 The internal structure of these files is given in the Appendix along with a general discussion of the User-Supplied Antenna Pattern. FOOTPRINTS automatically assigns data file ANTENO to Logical Unit Number 10, ANTEN1 to Logical Unit Number 11, and ANTEN2 to Logical Unit Number 12. Additional point pattern antenna data files can be added with only minor modifications to the program.

"DATFIL" - This data file contains the input data for FOOTPRINTS if the user decides to use an input file instead of the interactive mode to enter data. The internal structure of this file is the same as the structure of the input data in the interactive mode, which is given in Section 3.5. The user simply answers the questions in the same order as he/she would in the interactive mode and places these answers in the data file DATFIL.

"REGNSL" - This data file contains the number of service area polygons, and the associated symbols, for each polygon to be plotted. The internal structure of this file is given in Section 2.4.

"DTPLGN" - This data file contains the service area polygon data points. The internal structure of this file is given in Section 2.4.

3.3 Program Command Mode

Before the user executes program FOOTPRINTS, he/she should clear all temporary files from his/her account. This can be done by entering the following command after the computer's "/" prompt.

CLEAR

The user is now ready to load the procedure file that will execute the program. This is accomplished by entering the following:

GET,FOOTPMF

To execute the program FOOTPRINTS, the user enters:

FOOTPMF

After a short wait while program loading takes place, the user will receive the following message indicating that the user has been placed under program control:

```
U.S. DEPARTMENT OF COMMERCE
INSTITUTE FOR TELECOMMUNICATION SCIENCES
PROGRAM 'FOOTPRINTS'              VERSION 2.8              3/03/82
(TYPE "HELP" & CARRIAGE RETURN, IF NEEDED)
```

The program execution is controlled by the user through a set of program commands. In order to obtain plotted footprints, only three of the commands are actually required: the data input command "RUN", the computation command "SUBMIT", and the termination command "QUIT". The remaining commands are not required, but are available to assist the user in data input and program execution.

The user may enter program commands whenever the system is in the program command mode. The program command mode is evident when the program prompt ">" is followed by the computer system input prompt "?". When a program command has completed executing, the program is returned to the program command mode. The program commands and their uses are described below.

1. HELP: Describes Program Commands

   (User information, not required)

   Any time the user needs to recall the program command names, he/she may enter the command "HELP" in order to obtain a brief printed explanation of the various program commands. The execution of the program command "HELP" results in the response given below:

   ```
   COMMAND:          FUNCTION:

   QUIT     -  TERMINATES THE PROGRAM & PLOTS DATA ON MICROFILM
   HELP     -  THIS LISTING
   CHANGE   -  TO CHANGE THE VALUE OF AN INPUT QUANTITY
   RUN      -  BEGINS DATA INPUT MODE
   SUBMIT   -  GENERATES FOOTPRINT & MAP DATA FOR PLOTTING
   SUMMARY  -  PRINTS A SUMMARY OF THE CURRENT FOOTPRINT DATA
   DMS      -  SETS DEGREES/MINUTES/SECONDS MODE FOR LAT/LON INPUT
   DECIMAL  -  SETS DECIMAL DEGREES MODE FOR LAT/LON INPUT
   ```

   After the final line is printed, the program will return to the program command mode.

2. RUN: Initiates Data Input Mode

   (Input data collection, required)

   After the "RUN" command is given, the program begins to question the user for information describing the satellite system, the desired maps and projections, the contours to be plotted, etc. Details about the questions, their meanings, and acceptable responses are contained in Section 3.5. Following each response to the program questions, the user types a carriage return; the program then comes back with the next query. The input prompt in the RUN mode is the symbol "?". To save time, the user may respond to upcoming queries by entering the additional answers, separated by commas, and entering a carriage return after the last answer. The answers must be entered in the order in which the queries would have been asked. The upcoming questions can be determined with the aid of the flow diagram in Section 3.5. The program has mechanisms for recognizing "bad" input data (i.e., alphabetic input where numeric is expected, out of range input values, or misspelled projection names or antenna types). In the case of bad input data, the program will ask the user to reenter the input.

After all of the required information has been given, the program responds with:

'END INPUT MODE'

and returns to the program command mode. The dialogue may be initiated as many times as desired without computation of results. When the user is satisfied with the input data, he/she then submits the data for computation after the dialogue is completed.

Each repetition of the dialogue writes over input data from the previous dialogue. Suppose, for example, a user would like to rerun the program; however, the user is satisfied with all the input data from the previous run up to Question 33. By entering the following:

RUN,33

all of the previous input is preserved up to Question 33 and the program will repeat its queries starting with Question 33.

If the user has set up a data file (DATFIL) to enter the input data automatically, the user would initiate the entering of the data by typing in the following:

RUN,0

If the file has been set up correctly, the program will return to the program command mode. If there was a problem with the input data, the program will generally abort and return to the CDC Operating System. The user can locate where the input data were in error by examining the temporary question file "TAPE30". The user is encouraged to examine the input data for correctness after using the automatic input data feature of the program by executing the program command "SUMMARY", which summarizes the current input data of the program. The automatic input data feature of the program can be repeated as many times as the user wishes, as long as there are sufficient data in the input data file "DATFIL" to answer all of the required questions.

3. SUBMIT: Starts Footprint Computation
(Output data computed for plotting, required)
All of the plotter instructions and footprint computations are initiated by the "SUBMIT" command. When the "SUBMIT" command is executed, the program prints the following:

```
ENTER USER MICROFILM IDENTIFICATION (<=30 CHARS)
(USUALLY CONTAINS NAME & PHONE EXTENSION).
```

The user then enters his/her name and telephone extension in order to identify the microfilm output of the program. An example of this is:

```
KEN GAMAUF    X3677
```

The program then continues with the footprint computation. During the computation, the program will print brief summary statements to the user as the program passes through various sections of the computation. An example of these statements are below:

```
MAP TYPE = WORLD                (*MAP                              *)
  FOOTPRINT # 1 CONTOURS:
      -3.00
      -6.00
     -10.00
ALL CONTOURS PLOTTED
MAP PLOTTED
```

Upon completion of the computation, the program will print the message:

```
'SUBMIT COMPLETED'
```

signifying that the results have been computed and stored for plotting on the microfilm plotter upon termination of the program. The program then returns to the program command mode.

4. QUIT: Terminates Program

(Microfilm plotting initiated, required)

This is the last program command to be given as it will terminate the program and send the plotting data to the microfilm plotter. The user will receive the following message when the "QUIT" command is executed:

```
END OF DISSPLA 8.2 --     nnnn VECTORS GENERATED IN     n PLOT FRAMES.
-ISSCO-  4186 SORRENTO VALLEY BLVD.,SAN DIEGO CALIF. 92121
DISSPLA IS A CONFIDENTIAL PROPRIETARY PRODUCT OF ISSCO AND ITS USE
   IS SUBJECT TO A NONDISSEMINATION AND NONDISCLOSURE AGREEMENT.
 'PROGRAM TERMINATED'
REVERT.
```

Upon completion of the command, the user is put back under the control of the CDC Operating System.

5. SUMMARY: Summarizes Input Data

(User assistance, not required)

Following the execution of this command, the user will get a summary listing of the current input data of the program. This command can be executed either before or after a "SUBMIT" command. At least one execution of the "RUN" command should be made prior to executing this command, however, or the results will not produce useful information. An example of the output of the "SUMMARY" command is given below:

```
FOOTPRINTS SUMMARY
 yy/mm/dd. hh.mm.ss.
WORLD MAP:
  PROJECTION        = MERCATOR
  GRID LINE SPACING =   45.00 DEGREES
  TITLE             = *MAP
  HEIGHT            =    6.00 INCHES
  WIDTH             =    8.00  "   "
  PRP LATITUDE      =    0.00 DEGREES
  PRP LONGITUDE     =  -90.00  "   "
FOOTPRINT # 1
  AIM POINT LATITUDE              =   23.00 DEGREES
  AIM POINT LONGITUDE             =  -76.00  "    "
  SUB-SATELLITE LONGITUDE         =  -90.00  "    "
  ANTENNA TYPE                    = FAST ROLL OFF ELLIPSE ANTENNA
  MAJOR AXIS DIAMETER             =    2.50 DEGREES
  MINOR AXIS DIAMETER             =    1.50  "    "
  INCLINATION ANGLE               =    0.00 DEG. NORTH OF TRUE EAST
  CONTOURS (DB BELOW MAIN BEAM)   =   -3.0   -6.0  -10.0
```

Upon completion of this command, the user is returned to the program command mode.

6. CHANGE: Allows Alteration of Input Data

   (User assistance, not required)

   The user can make line-by-line changes to the input data, rather than repeat the whole dialogue. After the user enters the command "CHANGE", the program responds with:

   QUESTION NUMBER:

   The user enters the question number (no decimal point) followed by a carriage return for Questions 1 through 33, or question number, colon, and footprint number (Q#:F#) followed by a carriage return for all other questions. (If the footprint number is not given, the program will ask for it.) The program responds by printing the question and waits for the user's response. After a satisfactory answer is entered, the user is returned to the program command mode. This command may be repeated as many times as desired and may be used between computation phases to produce modified output plots.

7. DMS: Sets Degrees, Minutes, Seconds Mode

   (Input mode selection, not required)

This command instructs the program to accept latitude/longitude input in the form DEG, MIN, SEC. The user uses commas to separate the quantities as shown; no decimal points are required. North latitude and East longitude are positive; South latitude and West longitude are negative. If this command is not executed, the program will assume latitude/longitude input data to be in decimal degrees. After executing the "DMS" command, the user is returned to the program command mode.

8. DECIMAL: Sets Decimal Degrees Mode
(Input mode selection, not required)
This command returns the program to the decimal degrees mode for latitude/longitude input. North latitude and East longitude are positive; South latitude and West longitude are negative. The decimal degrees mode is the default mode of the program. After executing the "DECIMAL" command, the user is returned to the program command mode.

The above program commands can be used in almost any sequence that the user desires. For example, the user may want to enter the input data (RUN), alter one input answer (CHANGE), obtain a summary of the current input data (SUMMARY), compute the footprint plots (SUBMIT), enter another set of input data (RUN), compute another set of footprint plots (SUBMIT), obtain a summary of the current input data (SUMMARY), and finally terminate the program (QUIT).

3.4 Program Termination

Upon executing the "QUIT" program command, the program FOOTPRINTS is terminated and the user is returned to the CDC Operating System. If the user wishes to log off the computer, he/she enters the following command:

```
BYE
```

The user will get the following response from the computer:

```
ABC       LOG OFF    hh.mm.ss.
ABC       SRU    abc.def UNTS.
```

The total cost of the FOOTPRINTS execution is given as SRU units in the above log off message. One SRU is equal to $.10 for a regular class job. Therefore in the example above, the total cost of the FOOTPRINTS execution was $ab.cdef. If the user wishes to execute the FOOTPRINTS program again, he/she would return to Sections 3.2 or 3.3, depending if re-initialization is necessary.

3.5 Program FOOTPRINTS Dialogue, Questions, Descriptions, and Acceptable Responses

Section 3.3 described how to execute the program FOOTPRINTS through the use of program commands. One of those commands, "RUN", will initiate a dialogue with the user to extract information about the satellite system, desired map characteristics, etc. Although the proper responses to most dialogue questions are self-evident, the user may in some cases require guidance regarding acceptable responses or ranges of parameter values. If the user wishes to use the automatic input data feature of the program, this section will also be very helpful in setting up the input data file. This section presents all of the dialogue questions, discusses their meanings, and lists acceptable responses.

Prior to giving the RUN command, the user has a choice of the input mode for latitude and longitude data. If the user enters the program command "DMS", then the program assumes all latitude and longitude data will be entered in degrees, minutes, and seconds; otherwise, the program assumes all latitude and longitude data will be given in decimal degrees. The program assumes North latitude and East longitude are positive and South latitude and West longitude are negative. For example, if the latitude ordinate is 27 degrees, 20 minutes, 25 seconds North and the longitude ordinate is 75 degrees, 0 minutes, 35 seconds West, the user would enter the data in the DMS mode as:

```
latitude:   27,20,25
longitude: -75,,35            (note both commas)
```

and in the DECIMAL mode as:

```
latitude:   27.3403
longitude: -75.0097
```

Note that due to program restrictions, the user is limited to one point pattern data set per RUN. Other footprints using the built-in antenna models may be specified in a RUN which also has a point pattern footprint; however, they must be specified before the point pattern footprint (see the Appendix for more explicit information on the user-supplied point pattern mode).

All of the footprint questions are discussed in Table 2, which also includes a range of acceptable values for each question. For any execution of the FOOTPRINTS program, the user will not encounter all of the questions in the order listed in Table 2. Therefore, Figure 19, a flow diagram of the user-program information exchange, is provided following Table 2 to show how the order of the questions is affected by various user responses.

Table 2. Program FOOTPRINTS Dialogue, Questions, Descriptions, and Acceptable Responses

PROGRAM QUESTION NUMBER, QUESTION STATEMENT AND INFORMATION	QUESTION DISCUSSION	ACCEPTABLE RANGE OF VALUES
1. IS THE SATELLITE GEOSTATIONARY?	Only geostationary satellite footprints are computed and plotted. If the user answers "NO" to the question, the input mode will terminate.	YES or NO
'NOTE' - THE PROGRAM WILL PLOT THE ANTENNA FOOTPRINTS ON A WORLD MAP, A U.S. MAP, AND/OR AN ENLARGED-AREA MAP. THE FOLLOWING PROJECTIONS ARE AVAILABLE FOR EACH MAP: STEREOGRAPHIC 'ORTHOGRAPHIC LAMBERT EQUAL-AREA GNOMONIC AZIMUTHAL EQUIDISTANT CYLINDRICAL EQUIDISTANT 'MERCATOR MOLLWEIDE ALBERS EQUAL AREA CONIC BI PARALLEL CONFORMAL CONIC ("'" INDICATES A COMMONLY SPECIFIED PROJECTION) THE USER MAY OPTIONALLY SPECIFY GRID LINES AND THE PLOT SIZE (DEFAULT IS 6.0 x 6.0 INCHES FOR THE WORLD AND ENLARGED MAPS, 5.0 x 9.0 INCHES FOR THE U.S. MAP).	This note informs the user what maps and projection options are available. For more details see Section 2.2. Note: For world maps, the Cylindrical Equidistant projection is more commonly specified than the Mercator.	
2. DO YOU WANT A WORLD MAP WITH FOOTPRINTS?	If the user does not want a world map, then a "NO" response will cause the program to jump to Question 12.	YES or NO
'NOTE' - "PROJECTION REFERENCE POINT" (OR "PRP") IS THE CENTER POINT OF THE SPECIFIED MAP. THE WORLD MAP PRP IS USER SPECIFIED, THE U.S. MAP PRP IS FIXED AT 36N, 98W, AND THE ENLARGED MAP PRP IS COMPUTED FROM THE USER-SPECIFIED MAP BOUNDARIES.		

Table 2. (Continued)

3.	PROJECTION REFERENCE POINT LATITUDE=	Latitude data must be entered either in decimal degrees or degrees, minutes, and seconds. This option was selected before entering the RUN mode (see Section 3.3, commands 7 and 8).	Decimal: -90.000000 to +90.000000 degs* DMS: -90 to +90 degs* 0 to 59 mins 0 to 59 secs *(+ = North, - = South)
4.	PROJECTION REFERENCE POINT LONGITUDE =	Longitude data must be entered either in decimal degrees or degrees, minutes, and seconds.	Decimal:-180.000000 to +180.000000 degs** DMS: -180 to +180 degs** 0 to 59 mins 0 to 59 secs **(+ = East, - = West)
5.	WORLD MAP PROJECTION:	Choose from list following Question 1.	Type one name from the available projections.
6.	DO YOU WANT GRID LINES DRAWN ON THE WORLD MAP?	If the user does not want grid lines, then a "NO" response will cause the program to jump to Question 8.	YES or NO
7.	GRID LINE SPACING (DEGREES) =		1 to 180
8.	WORLD MAP TITLE:	The title to be printed on the plot. Note that blanks are ignored so the user should separate words by hyphens.	1 through 40 characters.
9.	DO YOU WISH TO SPECIFY A NON-STANDARD WORLD MAP SIZE?	A "NO" response causes the program to jump to Question 12. The default size is 6.0 inches by 6.0 inches. See Section 2.2 on Map Projections for guidance.	YES or NO
10.	WORLD MAP HEIGHT (INCHES) =	Height corresponds to North-South direction.	1.0 to 9.0 (See Table 1)
11.	WORLD MAP WIDTH (INCHES) =	Width corresponds to East-West direction.	1.0 to 9.0 (See Table 1)
12.	DO YOU WANT A U.S. MAP WITH FOOTPRINTS?	A "NO" response directs program to Question 20.	YES or NO
13.	U.S. MAP PROJECTION:	Choose from list following Question 1.	Type one name from the available projections.

Table 2. (Continued)

14.	DO YOU WANT GRID LINES DRAWN ON THE U.S. MAP?	If the user does not want grid lines, then a "NO" response will cause the program to jump to Question 16.	YES or NO
15.	U.S. MAP GRID LINE SPACING (DEGREES) =		1 to 180
16.	U.S. MAP TITLE:	The title to be printed on the plot. Note that blanks are ignored so the user should separate words by hyphens.	1 through 40 characters.
17.	DO YOU WISH TO SPECIFY A NON-STANDARD U.S. MAP SIZE?	A "NO" response causes the program to jump to Question 20. The default size is 5.0 inches by 9.0 inches. See Section 2.2 on Map Projections for guidance.	YES or NO
18.	U.S. MAP HEIGHT (INCHES) =	Height corresponds to North-South direction.	1.0 to 9.0 (See Table 1)
19.	U.S. MAP WIDTH (INCHES) =	Width corresponds to East-West direction.	1.0 to 9.0 (See Table 1)
20.	DO YOU WANT AN ENLARGED MAP WITH FOOTPRINTS? 'NOTE' - THE ENLARGED MAP MAY BE PLOTTED USING EITHER U.S. OR WORLD MAP DATA. IF THE DESIRED ENLARGED AREA FALLS ENTIRELY WITHIN THE CONTINENTAL U.S., A SIGNIFICANT IMPROVEMENT IN ACCURACY WILL RESULT IF THE U.S. MAP DATA IS USED.	A "NO" response causes the program to jump to Question 33. The enlarged maps are useful for obtaining greater detail about the footprint coverage.	YES or NO
21.	WILL THE DESIRED ENLARGED AREA FALL ENTIRELY WITHIN THE CONTINENTAL U.S.? 'NOTE' - IT IS NECESSARY TO SPECIFY THE BORDERS OF THE DESIRED ENLARGED AREA. INPUT THE BOUNDARY VALUES AS LOWER/UPPER LATITUDE AND LEFT/RIGHT LONGITUDE PAIRS.	See explanatory note above Question 21.	YES or NO
22.	ENLARGED MAP LOWER LATITUDE =	See explanatory note above Question 22.	Decimal: -180.000000 to +180.000000 degs* DMS: -180 to +180 degs* 0 to 59 mins 0 to 59 secs *(+ = North, - = South)
23.	ENLARGED MAP UPPER LATITUDE =		See Question 22.

Table 2. (Continued)

24.	ENLARGED MAP LEFT LONGITUDE =		Decimal: -360.000000 to +360.000000 degs** DMS: -360 to +360 degs** 0 to 59 mins 0 to 59 secs **(+ = East, - = West)
25.	ENLARGED MAP RIGHT LONGITUDE =		See Question 24.
26.	ENLARGED MAP PROJECTION:	Choose from list following Question 1.	Type one name from the available projections.
27.	DO YOU WANT GRID LINES DRAWN ON THE ENLARGED MAP?	"NO" response directs program to Question 29.	YES or NO
28.	ENLARGED MAP GRID SPACING (DEGREES) =		1 to 180
29.	ENLARGED MAP TITLE:	The title to be printed on the plot. Note that blanks are ignored so the user should separate words by hyphens.	1 through 40 characters.
30.	DO YOU WISH TO SPECIFY A NON-STANDARD ENLARGED MAP SIZE?	A "NO" response causes the program to jump to Question 33. The default size is 6.0 inches by 6.0 inches. See Section 2.2 on Map Projections for guidance.	YES or NO
31.	ENLARGED MAP HEIGHT (INCHES) =	Height corresponds to North-South direction.	1.0 to 9.0 (See Table 1)
32.	ENLARGED MAP WIDTH (INCHES) =	Width corresponds to East-West direction.	1.0 to 9.0 (See Table 1)
33.	HOW MANY SETS OF FOOTPRINTS DO YOU WISH TO HAVE PLOTTED?	A maximum of 15 sets of footprints can be plotted on the same map using any combination of the following to obtain the 15 sets: 1) one or more satellites 2) one or more aim points 3) one or more antenna types The user could choose, for example, 15 different satellite locations (each having a different aim point and different antenna type), or two satellite locations (with 6 different aim points for one and 9 different	1 to 15

Table 2. (Continued)

aim points for the other), or 15 aim points from 1 satellite, or 3 satellites with one aim point and 5 different antenna types each, etc.

---------------------------NOTE-------------------------

From here on, all question numbers end with a colon and a numeral from 1 to 15, where the numeral identifies one of 15 footprint sets. (For the case of footprints numbered 10 to 15, an ASCII symbol will be printed corresponding to the following footprint numbers, + = 10, - = 11, * = 12, 1 - 13, (= 14,) = 15.) For example, if the user has asked for 3 sets of footprints to be plotted, the program will ask questions starting with 34:1 until all pertinent questions have been asked. The program will then cycle back to Question 34:2 to ask for information about the second set of footprints, and finally back to Question 34:3 to gather information about the third set. In this table, an n is used for a numeral, 1 through 15.

	'NOTE' - "AIM POINT" IS THE GROUND POSITION TO WHICH THE SATELLITE MAIN BEAM IS POINTED.	This note defines aim point. The user has to supply aim point coordinates in Questions 34 and 35. The aim point latitude and longitude may be outside the specified map boundaries but must be within view of the satellite.	
34:n	AIM POINT LATITUDE #n =		See Question 22.
35:n	AIM POINT LONGITUDE #n =		See Question 24.
36:n	SUB-SATELLITE LONGITUDE #n =	This defines the longitudinal position of the satellite above the equator.	See Question 24.
	'NOTE' - THE FOLLOWING ANTENNA TYPES ARE AVAILABLE: PARABOLA - PARABOLIC DISH (CIRCULAR SYMMETRY) ELLIPSE - PARABOLIC DISH (ELLIPTICAL SYMMETRY) HORN - PLANAR APERTURE HELIX - HELIX	This note informs the user what antenna type options are provided. If the point pattern is not chosen, the program will compute the antenna's main beam pattern from characteristics supplied by the user. However, the user can also supply his antenna pattern by selecting	

Table 2. (Continued)

POINT PATTERN - USER SUPPLIED PATTERN FAST ROLL OFF - ELLIPTICAL SYMMETRY WARC 1977 - ELLIPTICAL SYMMETRY	POINT PATTERN. See Section 2.3 for a description of the antenna models and the Appendix for the point pattern description.	
37:n IS SATELLITE ANTENNA #n IN THE ABOVE LIST?	A "NO" response causes the program to jump to Question 39.	YES or NO
38:n SATELLITE ANTENNA TYPE =	Choose from the list following Question 36. After the user selects a particular antenna type, the program will go to the questions asking for more information about the antenna's physical or electrical characteristics, as follows:	Type one name from the available antennas.

User Response	Program Goes to Question #
PARABOLA	50
ELLIPSE	65
HORN	80
HELIX	95
POINT PATTERN	105
FAST ROLL OFF	115
WARC 1977	120

39:n IS SATELLITE ANTENNA n's POWER GAIN PATTERN KNOWN?	If the antenna pattern is available, then the POINT PATTERN portion of the program should be used as it will produce footprint plots which more accurately reflect the expected footprints than the footprint plots produced by the built-in antenna models. A "YES" response will cause the program to jump to Question 105.	YES or NO

----------------------------NOTE----------------------------

At this point in the dialogue, the user has notified the program that the satellite's antenna is not identified with any of the built-in antenna models or characterized by a specific antenna pattern. The program can still produce footprint plots, however, if the user knows some of the antenna's electrical characteristics (peak power gain or -3 dB beamwidth). If either parameter is known, the pro-

Table 2. (Continued)

gram will assume that the antenna is a uniformly-illuminated parabolic reflector with a circular aperture and footprint plots can be produced.

40:n	IS SATELLITE ANTENNA n's PEAK POWER GAIN KNOWN?	If the gain is known, the program jumps to Question 43.	YES or NO
41:n	IS SATELLITE ANTENNA n's -3 dB (HALF POWER) BEAMWIDTH KNOWN?	See the following note if the response is "NO".	YES or NO

--------------------------NOTE--------------------------

If neither the peak power gain nor the half power beamwidth are known, the user will have a message printed to his terminal that there is insufficient information, the dialogue will terminate, and the program will return to the Program Command Mode.

42:n	ANTENNA n's -3 dB (HALF POWER) BEAMWIDTH (DEGREES) =	The total angle between the two half power points on the antenna's mainbeam. Following the beamwidth response the program jumps to Question 44.	0.1 to 18.0
43:n	ANTENNA n's PEAK POWER GAIN (DBI) =	The peak power gain relative to an isotropic radiator.	15.0 to 60.0
	'NOTE' - THE PROGRAM WILL ASSUME THAT SATELLITE ANTENNA #n IS A UNIFORMLY-ILLUMINATED PARABOLIC DISH HAVING CIRCULAR SYMMETRY, PEAK POWER GAIN OF XX.XX DBI, A -3 dB BEAMWIDTH OF XX.XX DEGREES, AND AN EFFECTIVE DIAMETER OF XXX.XXX WAVELENGTHS.	This message is printed after the user supplies one of the two antenna parameters requested in Questions 42 and 43. To plot the footprints, the program uses several well known "rules-of-thumb" about the assumed antenna and its pattern (see Section 2.3 for additional details).	
	'NOTE' - THE PROGRAM WILL PLOT CONSTANT POWER-DENSITY CONTOURS ON THE EARTH'S SURFACE AND AS INSCRIBED BY THE SPECIFIED MAP(S). THE FOLLOWING CONTOUR LEVELS (RELATIVE TO THE MAIN BEAM POWER DENSITY) ARE ALREADY SUPPLIED: -2, -4, -6, -10, -20, -30, & -40 dB. ALTERNATIVE OR ADDITIONAL CONTOURS MAY ALSO BE SPECIFIED.	This message is printed at the user's terminal whenever the program has a sufficient amount of input information about any of the selected antenna models (Parabolic, Elliptic, Horn, Helix, Fast-Roll Off, Warc 1977) or the assumed antenna (based on the user-supplied antenna electrical characteristics).	

Table 2. (Continued)

44:n	DO YOU WISH TO USE THE SUPPLIED CONTOUR LEVELS FOR FOOTPRINT #n?	The levels are listed in the note above Question 44. If "NO", the program jumps to Question 47.	YES or NO
45:n	DO YOU WISH TO SPECIFY ANY ADDITIONAL CONTOURS LEVELS FOR FOOTPRINT #n?	If "NO", the program goes to Question 34 for information about the next footprint (#n+1). If all footprint data have been gathered, the program prints 'END INPUT MODE' at the user's terminal and the program returns to the Program Command Mode.	YES or NO
46:n	NUMBER OF ADDITIONAL CONTOURS =	Up to three additional contours may be specified in addition to the seven already supplied. The program jumps next to Question 48.	1 to 3
47:n	NUMBER OF USER-SPECIFIED CONTOURS =	The user specifies the number of desired contours.	1 to 10
48:n	CONTOUR #1 (DB) = CONTOUR #2 (DB) = CONTOUR #3 (DB) = . . .	Contour levels are specified in units of dB relative to the mainbeam gain; e.g., -3. After the user completes this question, the program will proceed in the same manner as discussed in Question 45.	-80.0 to 0.0
	'PARABOLIC' - PARABOLIC DISH WITH CIRCULAR SYMMETRY	The dialogue will start here if the user selects PARABOLA as the response for Question 38.	
50:n	DO YOU WISH TO USE THE SAME ANTENNA DATA AS IN FOOTPRINT #m?	The program asks this question only if a parabolic antenna has been selected for any of the preceding footprint sets. A "YES" response directs the user to Question 44. This question is repeated for each previous set in which a parabolic antenna was selected.	YES or NO
51:n	DO YOU KNOW THE PARABOLIC REFLECTOR'S DIAMETER?	The program ordinarily computes the antenna's pattern by using the reflector diameter and the illumination ratio. A "YES" response to this question directs the program to Questions 52 through 58 which elicit the reflector diameter data and the illumination ratio. A "NO" response directs the program to Questions 59 through 62 which ask for antenna peak power gain and beamwidth.	YES or NO

Table 2. (Continued)

52:n IS THE REFLECTOR DIAMETER IN METERS OR WAVELENGTHS?	Diameter in wavelengths is preferred but the program will compute it if the diameter is in meters and the antenna's operating frequency is known. A "WAVELENGTHS" response will send the program to Question 56.	METERS OR WAVELENGTHS
53:n REFLECTOR DIAMETER (METERS) =	Physical diameter of the antenna's aperture.	0.1 to 30.0
54:n DO YOU KNOW THE OPERATING FREQUENCY?	If the user does not know the operating frequency, the program jumps to Question 59.	YES or NO
55:n OPERATING FREQUENCY (MHZ) =	Center frequency which will be used by the antenna to transmit from the satellite to the earth. Program skips to Question 57.	100.0 to 100000.0
56:n REFLECTOR DIAMETER (WAVELENGTHS) =	Electrical diameter of the antenna's aperture.	3.2 to 580.0
57:n IS THE EDGE/CENTER ILLUMINATION RATIO KNOWN?	The user has an option to define the primary pattern on the parabolic reflector. The pattern is a raised cosine pattern with the maximum power density at the reflector's center. If the user chooses an edge/center ratio of 1, the illumination of the reflector is uniform. If the user chooses an edge/center ratio of 0, the illumination is a cosine pattern which is 1 (maximum) at the reflector's centers and goes to 0 (minimum) at the reflector's edges. Any ratio between 1 and 0 flattens out the pattern.	YES or NO
'NOTE' - THE PROGRAM WILL ASSUME AN EDGE/CENTER ILLUMINATION RATIO OF 1.0 (UNIFORM ILLUMINATION).	If the user responds with a "NO" answer to Question 57, this message is printed and the program goes to Question 44.	
58:n ILLUMINATION RATIO =	Ratio of illumination at the reflector's edge to reflector's center. After this question, the program has sufficient antenna data and directs the user to Qustion 44.	0.0 to 1.0
59:n IS THE EFFECTIVE PEAK POWER GAIN KNOWN?	This question is asked only if the user doesn't know the antenna's diameter. If the user knows either the peak power gain or -3 dB beamwidth, the program assumes a uniform illumina-	YES or NO

Table 2. (Continued)

	tion ratio and computes an approximate diameter. If neither of these parameters are known, the user will be issued a message that there is insufficient information to plot footprints using this antenna model. A "NO" response causes the program to jump to Question 61.	
60:n EFFECTIVE PEAK POWER GAIN (DBI) =	In order to approximate the antenna's diameter, the program requires the antenna's peak power gain relative to an isotropic radiator. The program then jumps to Question 44.	15.0 to 60.0
61:n IS THE -3 DB (HALF POWER) BEAMWIDTH KNOWN?	See Question 59 for description.	YES or NO
62:n -3 dB BEAMWIDTH (DEGREES) =	If Question 59 was answered "NO", the program asks for the beamwidth, in degrees, between the two half power points of the main beam pattern. Note that a half power beam width of 18 degrees covers the visible earth from the geostationary orbit. The program then jumps to Question 44.	0.1 to 18.0
'ERROR' - INSUFFICIENT ANTENNA INFORMATION IS AVAILABLE TO PLOT FOOTPRINTS.	This message is printed if the user has provided an insufficient amount of information. The program will return to the Program Command mode after this message.	
'NOTE' - FOOTPRINT #n WILL BE GENERATED USING A PARABOLIC DISH HAVING CIRCULAR SYMMETRY, AN EFFECTIVE DIAMETER OF XXX.XX WAVELENGTHS, AND AN EDGE/CENTER ILLUMINATION RATIO OF X.XX.	The user gets this message when sufficient data has been provided. The program returns to Question 44.	
'ELLIPSE' - PARABOLIC DISH WITH ELLIPTICAL SYMMETRY	The dialogue will start at this point if the user selects ELLIPSE as the response to Question 38.	

Table 2. (Continued)

65:n	DO YOU WISH TO USE THE SAME ANTENNA DATA AS IN FOOTPRINT #m?	If an elliptical antenna has been selected for any of the preceding footprints sets, the program will ask whether the user wants to use any of the previous elliptical antenna data sets. A "YES" response directs the program to Question 44.	YES or NO
66:n	DO YOU WISH TO SPECIFY THE ANTENNA'S DIMENSIONS IN METERS OR WAVELENGTHS?	The program computes the elliptical reflector antenna's pattern by using the antenna's major and minor axis dish diameter in wavelengths or meters. A "WAVELENGTHS" response will send the program to Question 70.	METERS or WAVELENGTHS
67:n	OPERATING FREQUENCY (MHZ) =	Frequency which will be used by the antenna to transmit from the satellite to the earth.	100.0 to 100000.0
68:n	LENGTH OF PARABOLIC DISH ALONG ITS MAJOR AXIS (METERS) =	Physical size of the antenna measured along its major (vertical) axis. Along this axis, the antenna pattern will be at its narrowest.	0.1 to 30.0
69:n	LENGTH OF PARABOLIC DISH ALONG ITS MINOR AXIS (METERS) =	Physical size of the antenna measured along its minor (horizontal) axis. Along this axis, the radiation pattern will be its widest. The program jumps to Question 72 after this response.	0.1 to 30.0
70:n	LENGTH OF PARABOLIC DISH ALONG ITS MAJOR AXIS (WAVELENGTHS) =	Electrical size of the antenna measured along its major (vertical) axis.	3.2 to 580.0
71:n	LENGTH OF PARABOLIC DISH ALONG ITS MINOR AXIS (WAVELENGTHS) =	Electrical size of the antenna measured along its minor (horizontal) axis.	3.2 to 580.0
72:n	ARE THE EDGE/CENTER ILLUMINATION RATIOS KNOWN?	The user has an option to define the primary pattern on the parabolic reflector. The pattern is a raised cosine pattern with the maximum power density at the reflector's center. If the user chooses an edge/center ratio of 1, the illumination on the reflector is uniform. If the user chooses a ratio of 0, the illumination is a cosine pattern which is 1 (maximum) at the reflector's center and goes to 0 (mini-	YES or NO

Table 2. (Continued)

		mum) at the reflector's edges. Any ratio between 1 and 0 flattens out the pattern.	
	'NOTE' - THE PROGRAM WILL ASSUME THAT BOTH EDGE/CENTER ILLUMINATION RATIOS ARE 1.0 (UNIFORM ILLUMINATION).	If the user responds with a "NO" answer to Question 72, this message is printed and Questions 73 and 74 are skipped.	
73:n	MAJOR AXIS ILLUMINATION RATIO =	Ratio of illumination at the edge of reflector along the major axis to the reflector's center.	0.0 to 1.0
74:n	MINOR AXIS ILLUMINATION RATIO =	Ratio of illumination at the edge of reflector along the minor axis to the reflector's center.	0.0 to 1.0
	'NOTE' - "INCLINATION ANGLE" IS THE ANGLE BETWEEN THE ANTENNA'S MAJOR AXIS AND TRUE NORTH.	Because of the elliptical antenna's shape, it can be tilted on the satellite to change its coverage pattern on the earth. Thus, the user has to define the orientation of the antenna's axes with respect to the earth's axes. Looking from behind the satellite towards the earth, the inclination angle is defined as the angle between the antenna's long axis and the north-south axis of the earth. It is defined in degrees "east" of north. Again, remember the antenna's radiation pattern is narrowest along the major axis of the antenna.	
75:n	IS THE INCLINATION ANGLE KNOWN?		YES or NO
	'NOTE' - THE PROGRAM WILL ASSUME AN INCLINATION ANGLE OF 0.0 DEGREES.	This note is printed if the user responds with a "NO" to Question 75 and Question 76 is skipped.	
76:n	INCLINATION ANGLE (DEGREES) =		0.0 to 359.9
	'NOTE' - FOOTPRINT #n WILL BE GENERATED USING A PARABOLIC DISH HAVING ELLIPTICAL SYMMETRY, MAJOR & MINOR DIAMETERS OF XXX.XX & XXX.XX WAVELENGTHS, MAJOR & MINOR ILLUMINATION RATIOS OF X.XX & X.XX, AND AN INCLINATION ANGLE OF XXX.XX DEGREES.	The user gets this message when sufficient data has been provided. The program returns to Question 44.	

Table 2. (Continued)

	'HORN' - PLANAR APERTURE	The dialogue will start here if the user selects HORN as the response to Question 38.	
80:n	DO YOU WISH TO USE THE SAME ANTENNA DATA AS IN FOOTPRINT #m?	The program asks this question only if a horn antenna has been selected for any of the preceding footprints sets. A "YES" response starts the dialogue at Question 44.	YES or NO
81:n	DO YOU WISH TO SPECIFY THE ANTENNA'S DIMENSIONS IN METERS OR WAVELENGTHS?	The program computes the horn antenna pattern based on the electrical dimensions of the aperture. Dimensions in wavelengths are preferred, but the program will compute it if the dimensions in meters and the antenna's operating frequency are known. A "WAVELENGTHS" response will send the program to Question 85.	WAVELENGTHS or METERS
82:n	OPERATING FREQUENCY (MHZ) =	Frequency which will be used by the antenna to transmit from the satellite to the earth.	100.0 to 100000.
	'NOTE' = "HEIGHT" AND "WIDTH" REFER TO THE LONGEST AND SHORTEST DIMENSIONS OF THE APERTURE.		
83:n	APERTURE HEIGHT (METERS) =	Physical size of the antenna measured along the aperture's longest (vertical) dimension. Remember, along this dimension the antenna pattern will be at its narrowest.	0.1 to 30.0
84:n	APERTURE WIDTH (METERS) =	Physical size of the antenna measured along the aperture's shortest (horizontal) dimension; along this dimension, the pattern will be its widest. The program jumps to Question 87 after this response.	0.1 to 30.0
85:n	APERTURE HEIGHT (WAVELENGTHS) =	Electrical size of the antenna measured along its longest (vertical) dimension.	3.2 to 580.0
86:n	APERTURE WIDTH (WAVELENGTHS) =	Electrical size of the antenna measured along its shortest (horizontal) dimension.	3.2 to 580.0
87:n	ARE THE EDGE/CENTER ILLUMINATION RATIOS KNOWN?	The user has an option to define the current distribution pattern on the horn's aperture.	YES or NO

Table 2. (Continued)

	The pattern is a raised cosine pattern with the maximum energy at the reflector's center. If the user chooses an edge/center ratio of 1, the illumination on the reflector is uniform. If the user chooses a ratio of 0, the illumination is a cosine pattern which is 1 (maximum) at the reflector's edges. Any ratio between 1 and 0 flattens out the pattern.	
'NOTE' - THE PROGRAM WILL ASSUME THAT BOTH EDGE/CENTER ILLUMINATION RATIOS ARE 1.0 (UNIFORM ILLUMINATION).	If the user responds with a "NO" answer to Question 87, this message is printed and the program jumps to Question 90.	
88:n LONG-AXIS ILLUMINATION RATIO =	Ratio of illumination at the edge of the aperture along the longest dimension to the aperture's center.	0.0 to 1.0
89:n SHORT-AXIS ILLUMINATION RATIO =	Ratio of illumination at the edge of the aperture along the shortest dimension to the aperture's center.	0.0 to 1.0
'NOTE' - "INCLINATION ANGLE" IS THE ANGLE BETWEEN THE ANTENNA'S LONG-AXIS AND TRUE NORTH.	Because of the horn antenna's shape, it can be tilted on the satellite to change its coverage pattern on the earth. Thus, the user has to define the orientation of the antenna's axes with respect to the earth's axes. Looking from behind the satellite towards the earth, the inclination angle is defined as the angle between the antenna's long axis and the north-south axis of the earth. It is defined in degrees "east" of north. Again, remember the antenna's radiation pattern is narrowest along the long axis of the antenna.	
90:n IS THE INCLINATION ANGLE KNOWN?		YES or NO
'NOTE' - THE PROGRAM WILL ASSUME AN INCLINATION ANGLE OF 0.0 DEGREES.	This note is printed if the user responds with a "NO" to Question 90 and Question 91 is skipped.	
91:n INCLINATION ANGLE (DEGREES) =		0.0 to 359.9

Table 2. (Continued)

	'NOTE' - FOOTPRINT #n WILL BE GENERATED USING A HORN ANTENNA HAVING DIMENSIONS OF XXX.XX BY XXX.XX WAVELENGTHS, ILLUMINATION RATIOS OF X.XX & X.XX, AND AN INCLINATION ANGLE OF XXX.XX DEGREES.	The user gets this message when sufficient data have been provided. The program returns to Question 44.	
	'HELIX' - HELICAL ANTENNA	The dialogue will start here if the user selects HELIX as the response for Question 38.	
95:n	DO YOU WISH TO USE THE SAME ANTENNA DATA AS IN FOOTPRINT #m?	The program asks this question only if a helix antenna has been selected for any of the preceding footprint sets. A "YES" response directs the program to Question 44.	YES or NO

------------------------------NOTE------------------------------

The helix antenna model assumes the helix's diameter to be 1 $\pm$ 0.25 wavelengths. This results in a main beam directed along the helix's axis. The model needs only the number of turns and their spacing to plot footprints.

96:n	DO YOU WISH TO SPECIFY THE TURNS SPACING IN METERS OR WAVELENGTHS?	The helix model prefers the spacing between turns to be given in wavelengths; however, the program will compute the spacing in wavelengths if the user supplies the physical spacing and the antenna's operating frequency. A "WAVELENGTHS" response causes the program to jump to Question 99.	WAVELENGTHS or METERS
97:n	OPERATING FREQUENCY (MHZ) =	Center frequency which will be used by the antenna to transmit from the satellite to the earth.	100.0 to 100000.0
98:n	TURNS SPACING (METERS) =	Physical length from one turn to the next measured parallel to the helix's axis. After the user's response, the program jumps to Question 100.	0.005 to 5.0
99:n	TURNS SPACING (WAVELENGTHS) =	Electrical length from one turn to the next measured parallel to the helix's axis.	0.01 to 500.0

Table 2. (Continued)

100:n NUMBER OF TURNS =	Number of complete loops of the helix.	1.0 to 1000.0
'NOTE' - FOOTPRINT #n WILL BE GENERATED USING A XXX TURN HELIX ANTENNA HAVING A SPACING OF XXX.XX WAVELENGTHS BETWEEN TURNS.	The user gets this message when sufficient data have been provided. The program now returns to Question 44.	
'POINT PATTERN' - ASYMMETRIC PATTERN DATA	The dialogue will start here if the user selects POINT PATTERN as the response to Question 38 or a "YES" response is given to Question 39.	
105:n LOGICAL UNIT NO. OF PATTERN DATA FILE =	See Appendix A for details.	10 to 28
106:n DO YOU WISH TO SPECIFY AN INCLINATION ANGLE?	The AZIMUTH = 0 axis (see Figure A.1 and the OMEGA = 0 axis (see Figure A.2) are assumed to be parallel with the north-south axis of the earth. The user can rotate the point pattern about its (0,0) point by specifying an inclination or rotation angle. If "NO" is the response, the program goes to Question 108.	YES or NO
'NOTE' - THE PROGRAM WILL ASSUME AN INCLINATION ANGLE OF 0.0 DEGREES.	This message is printed to the user's terminal if the user does not specify a rotation angle and Question 107 is skipped.	
107:n INCLINATION ANGLE (DEGREES) =	The inclination angle is specified as a clock-rotation of the AZIMUTH = 0 axis or the OMEGA = 0 axis about the (0,0) point.	0.0 to 359.9
108:n DO YOU WISH TO SPECIFY AIM POINT OFFSETS?	The (0,0) point of either the AZEL (Figure A.1) or the POLAR (Figure A.2) coordinate system is assumed to be pointed at the user-specified aim point. The user can translate the point pattern by specifying aim point offsets.	YES or NO
'NOTE' - THE PROGRAM WILL ASSUME NO AIM POINT OFFSETS.	This message is printed to the user's terminal if a "NO" response is given to Question 108 and Questions 109 and 110 are skipped.	
109:n AIM POINT LATITUDE OFFSET =	A positive offset moves the pattern's (0,0), point north and a negative offset, south.	-90.0 to +90.0

Table 2. (Continued)

110:n AIM POINT LONGITUDE OFFSET =	A positive offset moves the pattern's (0,0) point east and a negative offset, west.	-180.0 to 180.0
'NOTE' - FOOTPRINT #n WILL BE PLOTTED FROM DATA CONTAINED IN FILE #XX, WITH AN INCLINATION ANGLE OF XXX.XX DEGREES, AND LATITUDE/LONGITUDE OFFSETS OF XXX.XX AND XXX.XX DEGREES.	The user gets this message when sufficient point pattern data set specifications have been provided. Since the program assumes the point pattern footprint will be the last data set to be defined, the dialogue mode terminates and program returns to the Program Command mode.	
'FAST ROLL OFF' - ELLIPTICAL SYMMETRY ANTENNA	The dialogue will start at this point if the user selects FAST ROLL OFF as the response to Question 38.	
115:n DO YOU WISH TO USE THE SAME ANTENNA DATA AS IN FOOTPRINT #m?	If a fast roll-off antenna has been selected for any of the preceding footprints sets, the program will ask whether the user wants to use any of the previous fast roll-off antenna data sets. A "YES" response directs the program to Question 44.	YES or NO
116:n BRAMWIDTH OF ANTENNA ALONG ITS MAJOR AXIS (DEGREES) =	Antenna's half power (-3 dB) beamwidth along its major (horizontal) axis.	0.1 to 18.0
117:n BEAMWIDTH OF ANTENNA ALONG ITS MINOR AXIS (DEGREES) =	Antenna's half power (-3 dB) beamwidth along its minor (vertical) axis.	0.1 to 18.0
'NOTE' - "INCLINATION ANGLE" IS MEASURED COUNTERCLOCKWISE FROM TRUE EAST.	Because of the fast roll-off antenna's shape, it can be tilted on the satellite to change its coverage pattern on the earth. Thus, the user has to define the orientation of the antenna's axis with respect to the earth's axis. Looking from behind the satellite towards the earth, the inclination angle is defined as the angle between the antenna's major axis and the east-west axis of the earth. It is defined as degrees "north" of east. The antenna's radiation pattern is widest along its major axis beamwidth.	

Table 2. (Continued)

118:n IS THE INCLINATION ANGLE KNOWN?		YES or NO
'NOTE' - THE PROGRAM WILL ASSUME AN INCLINATION ANGLE OF 0.0 DEGREES.	This note is printed if the user responds with a "NO" to Question 118 and Question 119 is skipped.	
119:n INCLINATION ANGLE (DEGREES) =		0.0 to 359.9
'NOTE' - FOOTPRINT #n WILL BE GENERATED USING THE FAST ROLL OFF ANTENNA HAVING ELLIPTICAL SYMMETRY, MAJOR & MINOR DIAMETERS OF XXX.XX & XXX.XX DEGREES, AND AN INCLINATION ANGLE OF XXX.XX DEGREES.	The user gets this message when sufficient data has been provided. The program returns to Question 44.	
'WARC 1977' - ELLIPTICAL SYMMETRY ANTENNA	The dialogue will start at this point if the user selects WARC 1977 as the response to Question 38.	
120:n DO YOU WISH TO USE THE SAME ANTENNA DATA AS IN FOOTPRINT #m?	If a Warc 1977 antenna has been selected for any of the preceding footprints sets, the program will ask whether the user wants to use any of the previous Warc 1977 antenna data sets. A "YES" response directs the program to Question 44.	YES or NO
121:n BEAMWIDTH OF ANTENNA ALONG ITS MAJOR AXIS (DEGREES) =	Antenna's half power (-3 dB) beamwidth along its major (horizontal) axis.	0.1 to 18.0
122:n BEAMWIDTH OF ANTENNA ALONG ITS MINOR AXIS (DEGREES) =	Antenna's half power (-3 dB) beamwidth along its minor (vertical) axis.	0.1 to 18.0
'NOTE' = "INCLINATION ANGLE" IS MEASURED COUNTERCLOCKWISE FROM TRUE EAST.	Because of the Warc 1977 antenna's shape, it can be tilted on the satellite to change its coverage pattern on the earth. Thus, the user has to define the orientation of the antenna's axis with respect to the earth's axis. Looking from behind the satellite towards the earth, the inclination angle is defined as the angle between the antenna's major axis and the east-west axis of the earth. It is defined as degrees "north" of east. The antenna's radiation pattern is widest along its major axis beamwidth.	

Table 2. (Continued)

123:n IS THE INCLINATION ANGLE KNOWN?		YES or NO
'NOTE' - THE PROGRAM WILL ASSUME AN INCLINATION ANGLE OF 0.0 DEGREES.	This note is printed if the user responds with a "NO" to Question 123 and Question 124 is skipped.	
124:n INCLINATION ANGLE (DEGREES) =		0.0 to 359.9
'NOTE' - FOOTPRINT #n WILL BE GENERATED USING THE WARC 1977 ANTENNA HAVING ELLIPTICAL SYMMETRY, MAJOR & MINOR DIAMETERS OF XXX.XX & XXX.XX DEGREES, AND AN INCLINATION ANGLE OF XXX.XX DEGREES.	The user gets this message when sufficient data has been provided. The program returns to Question 44.	

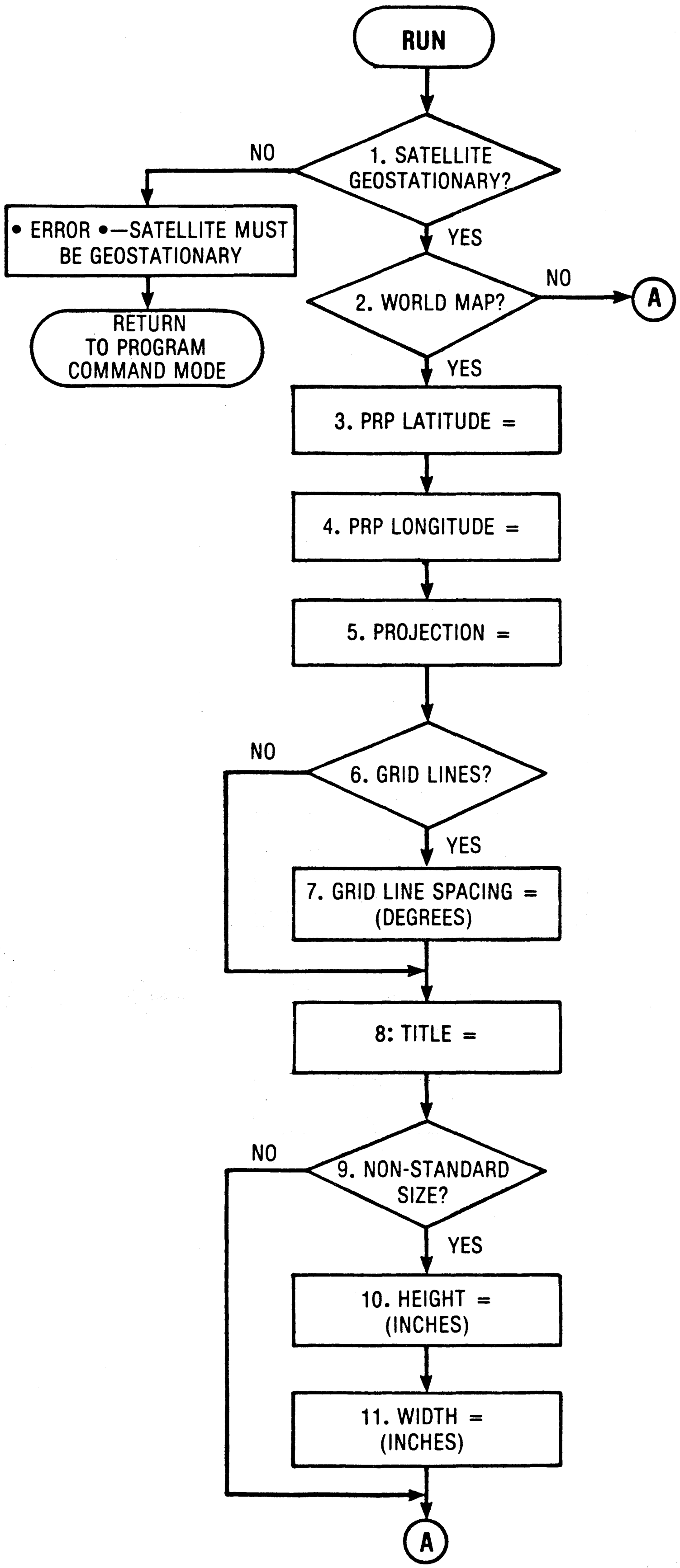


Figure 19. Flow diagram of the dialogue mode.

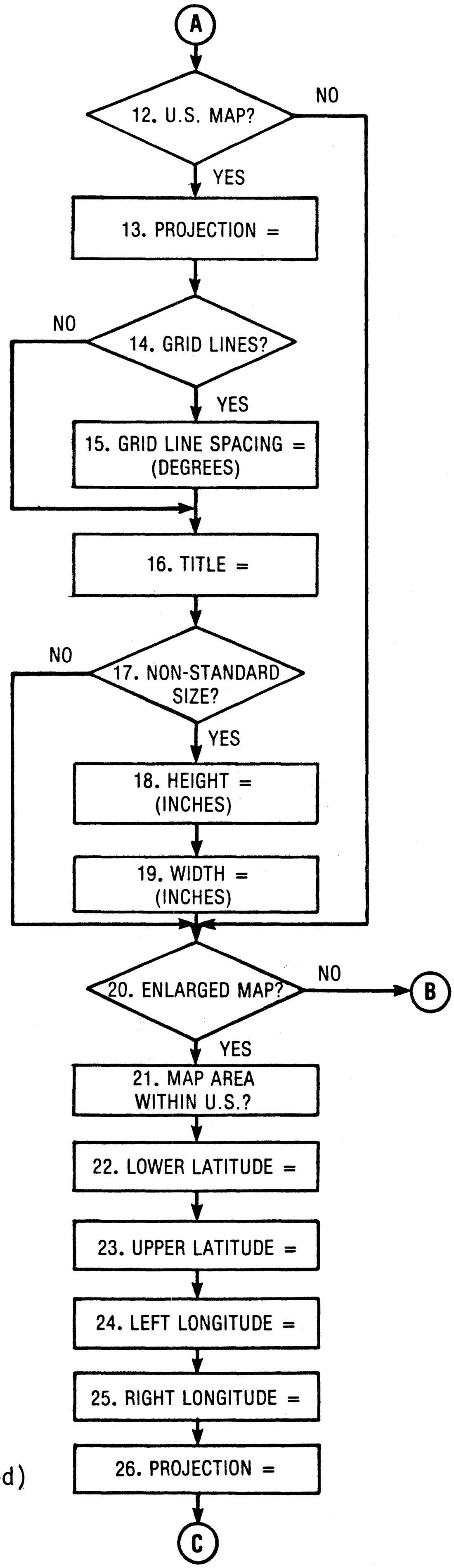


Figure 19. (Continued)

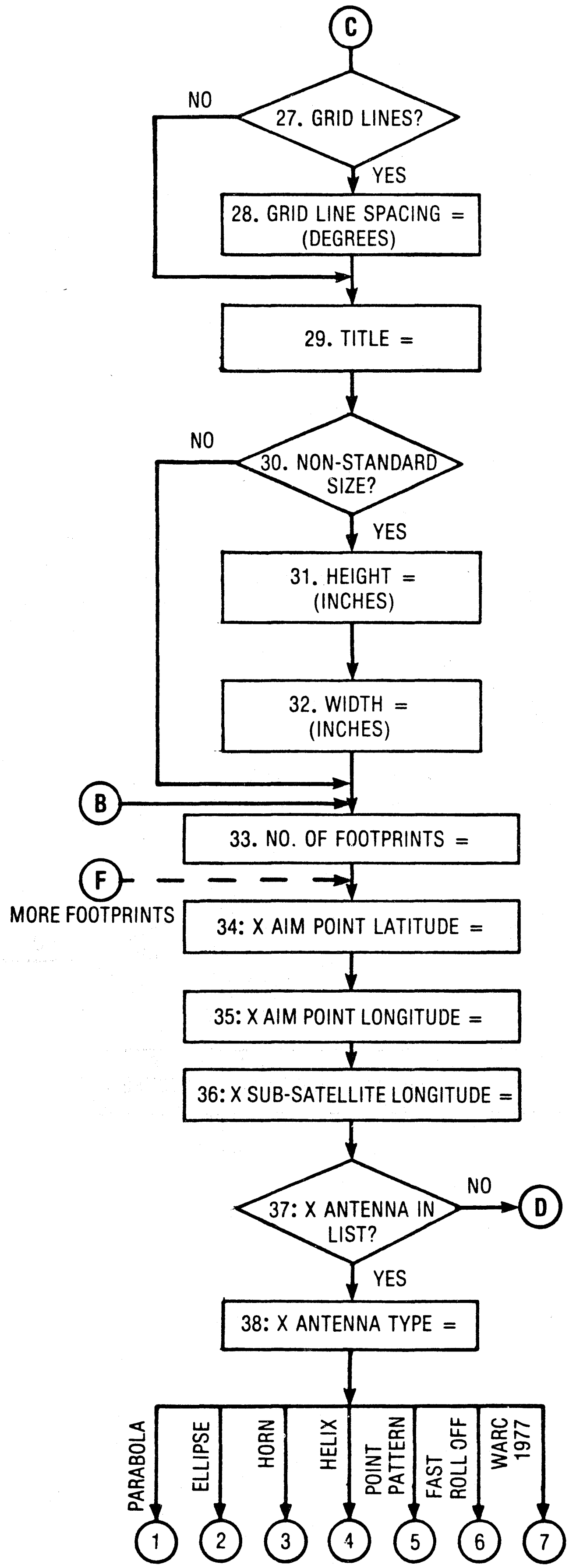


Figure 19. (Continued)

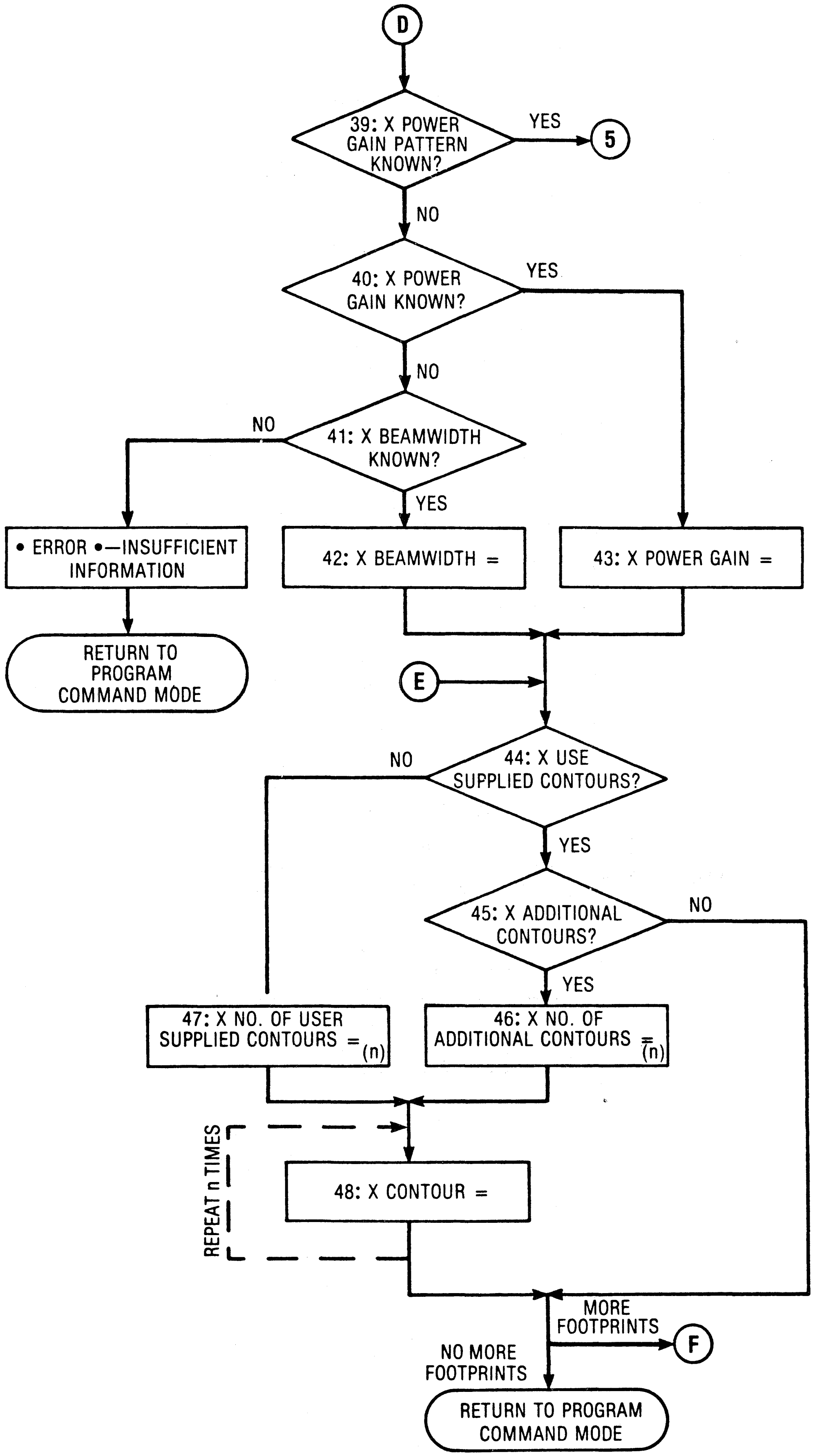


Figure 19. (Continued)

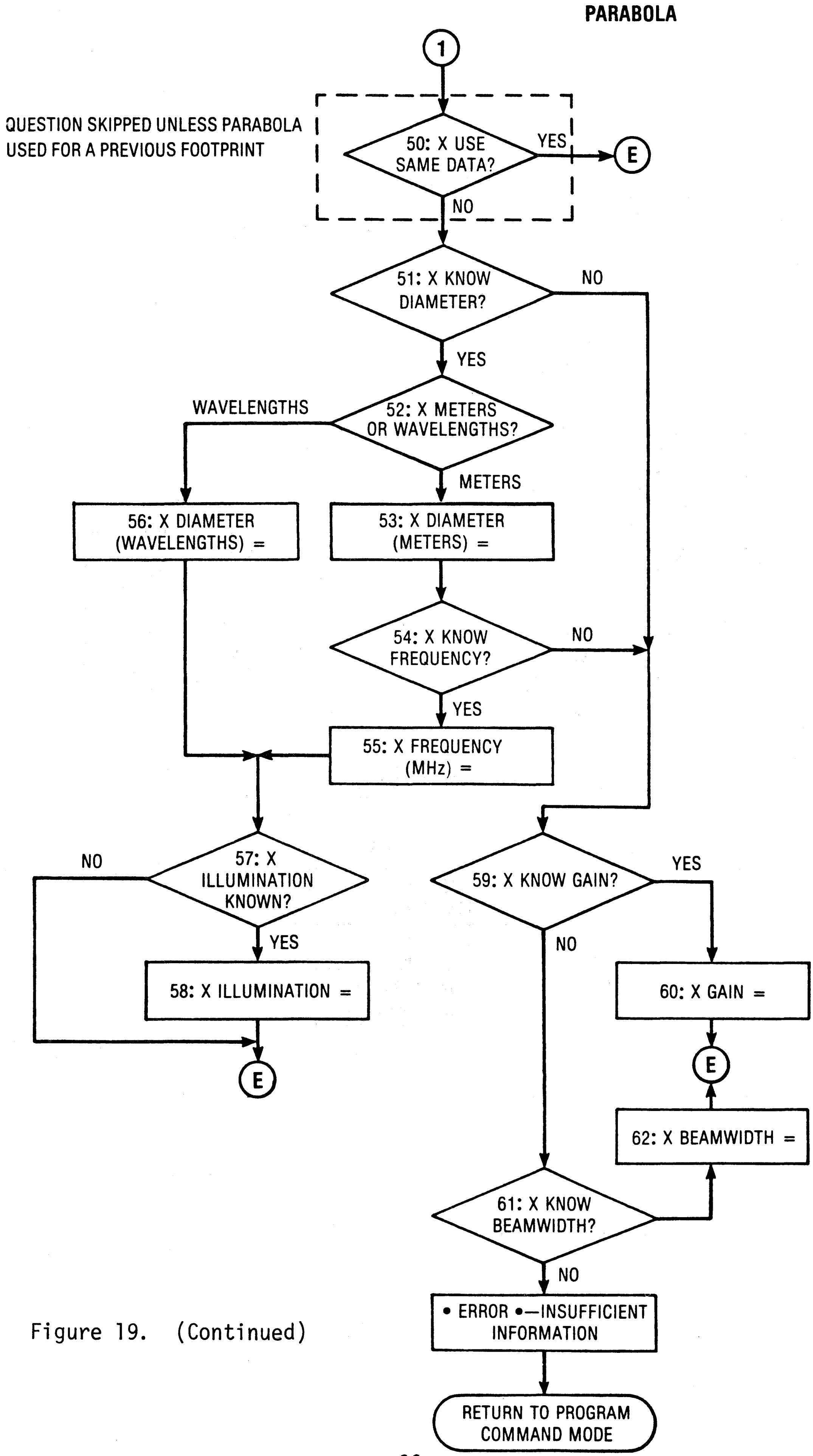


Figure 19. (Continued)

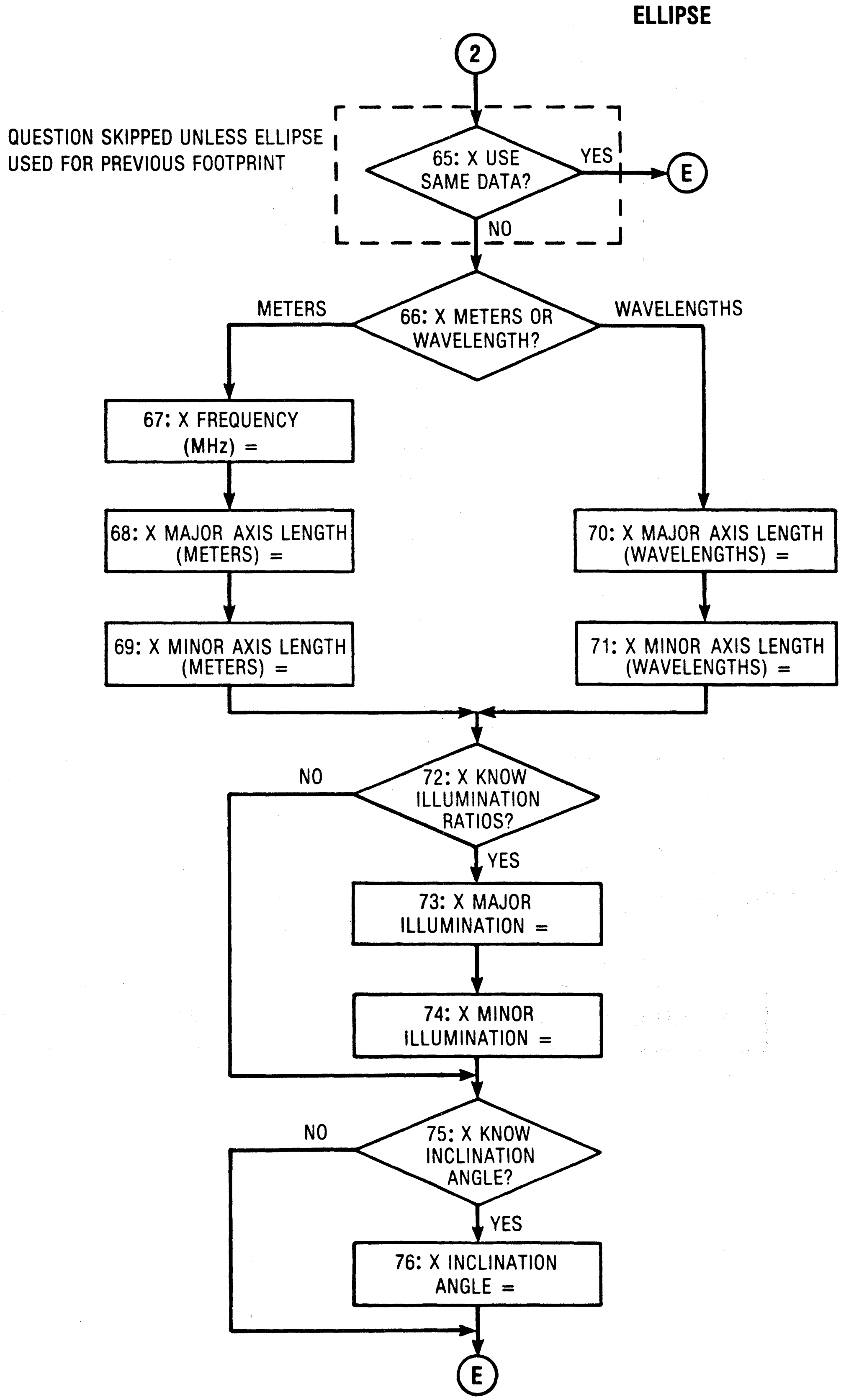


Figure 19. (Continued)

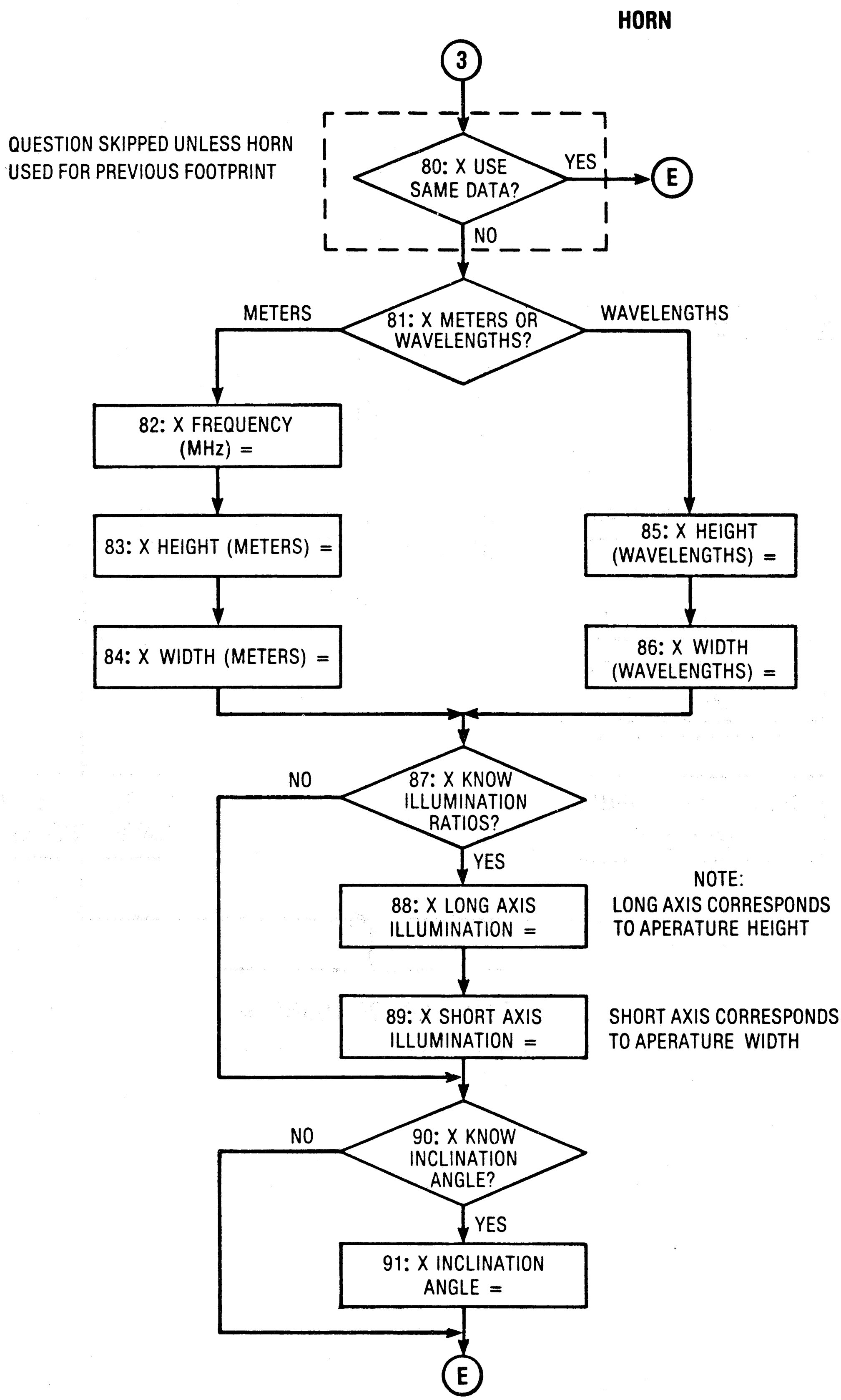


Figure 19. (Continued)

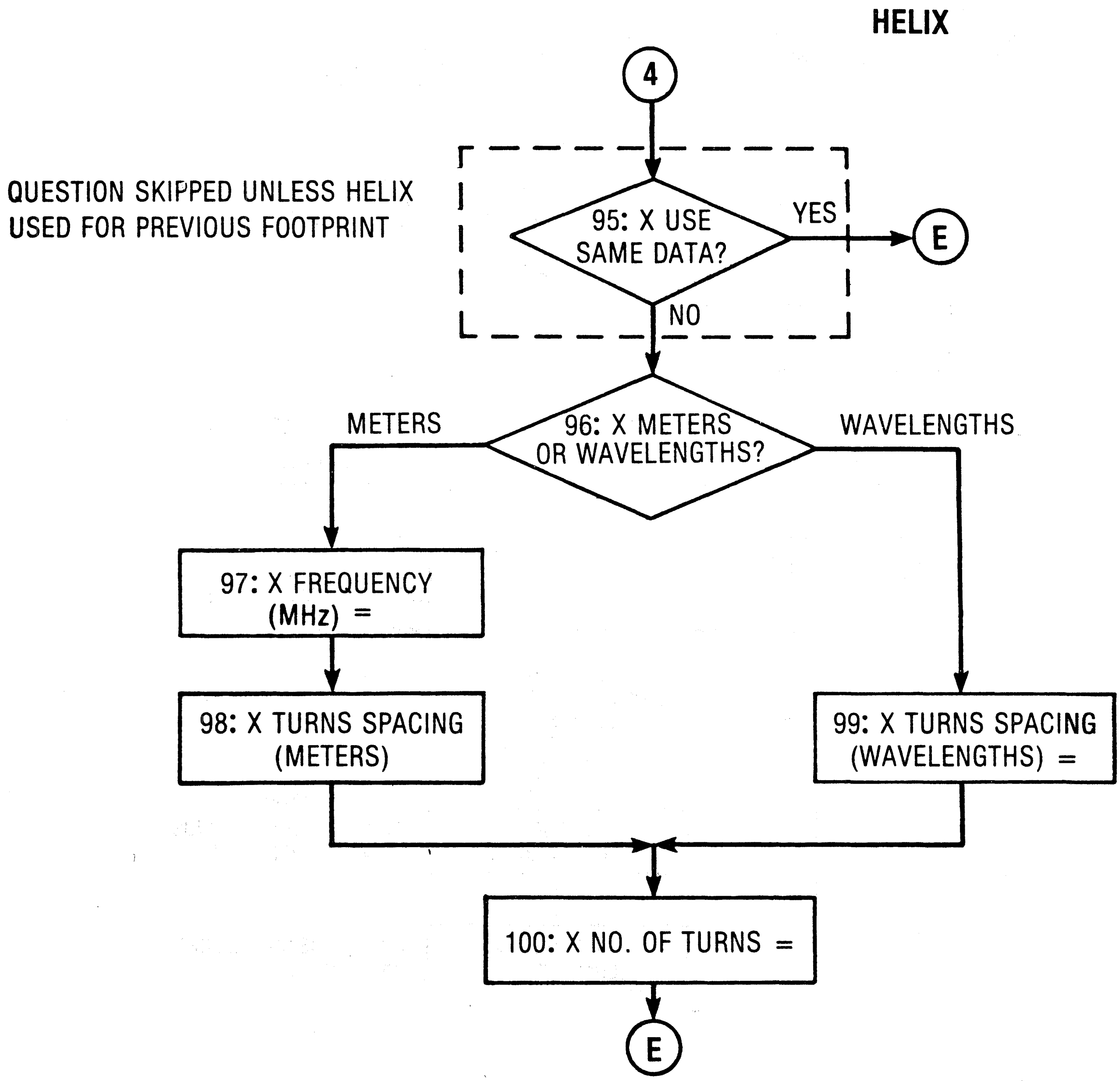


Figure 19. (Continued)

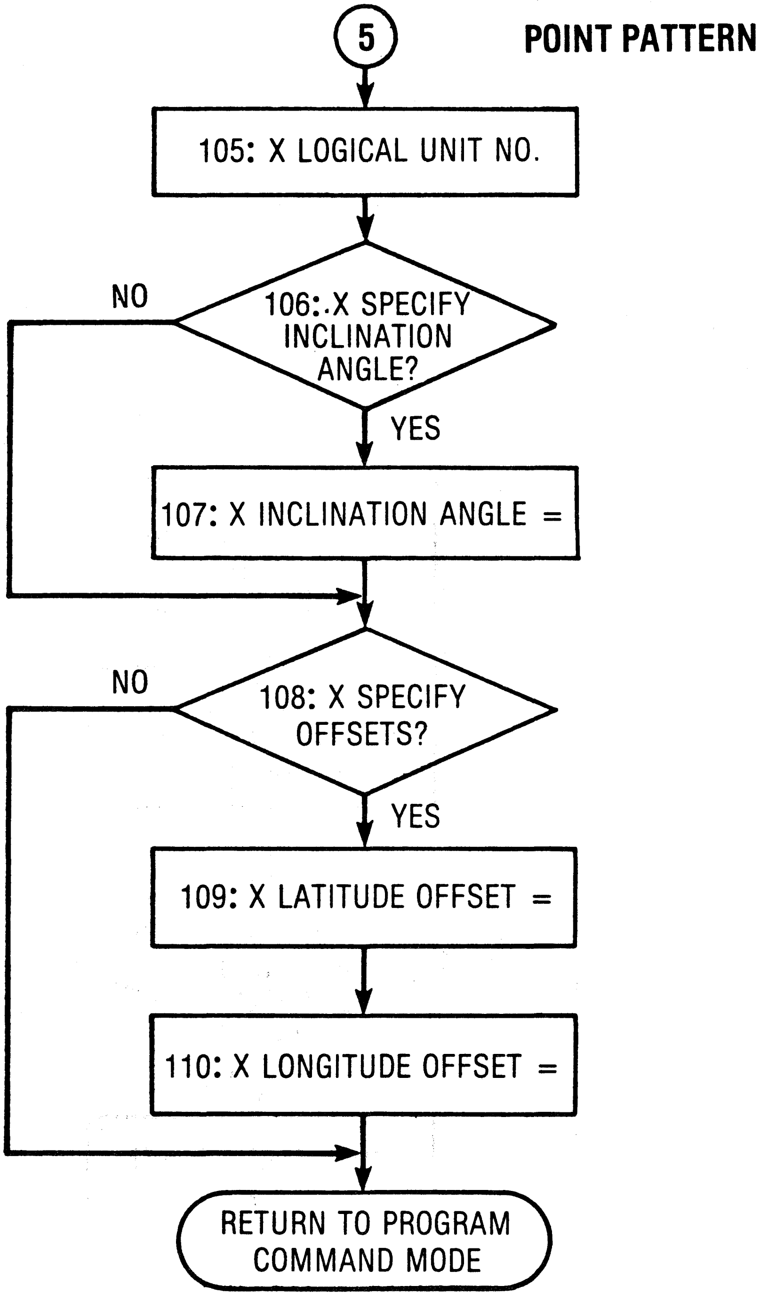


Figure 19. (Continued)

FAST ROLL OFF

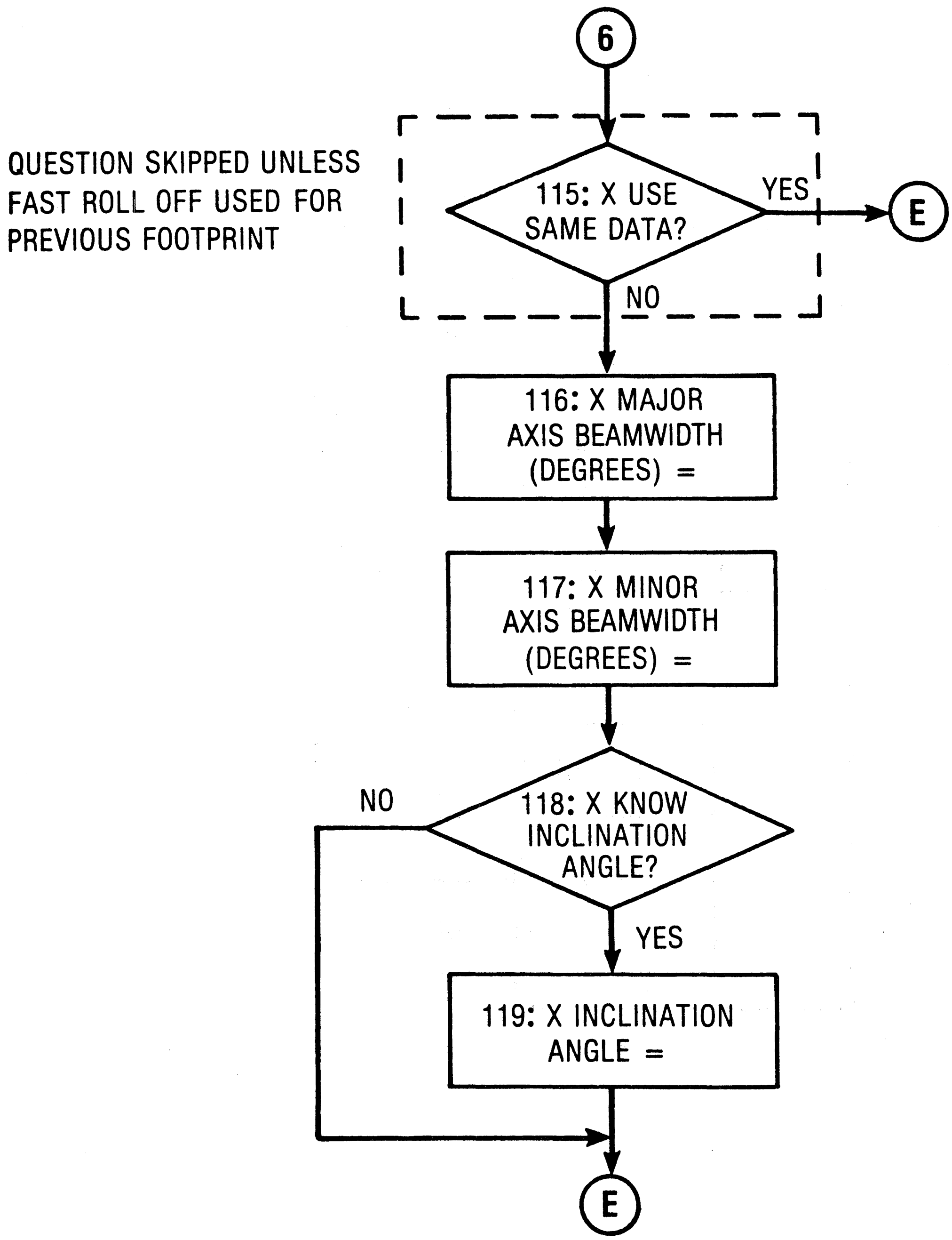


Figure 19. (Continued)

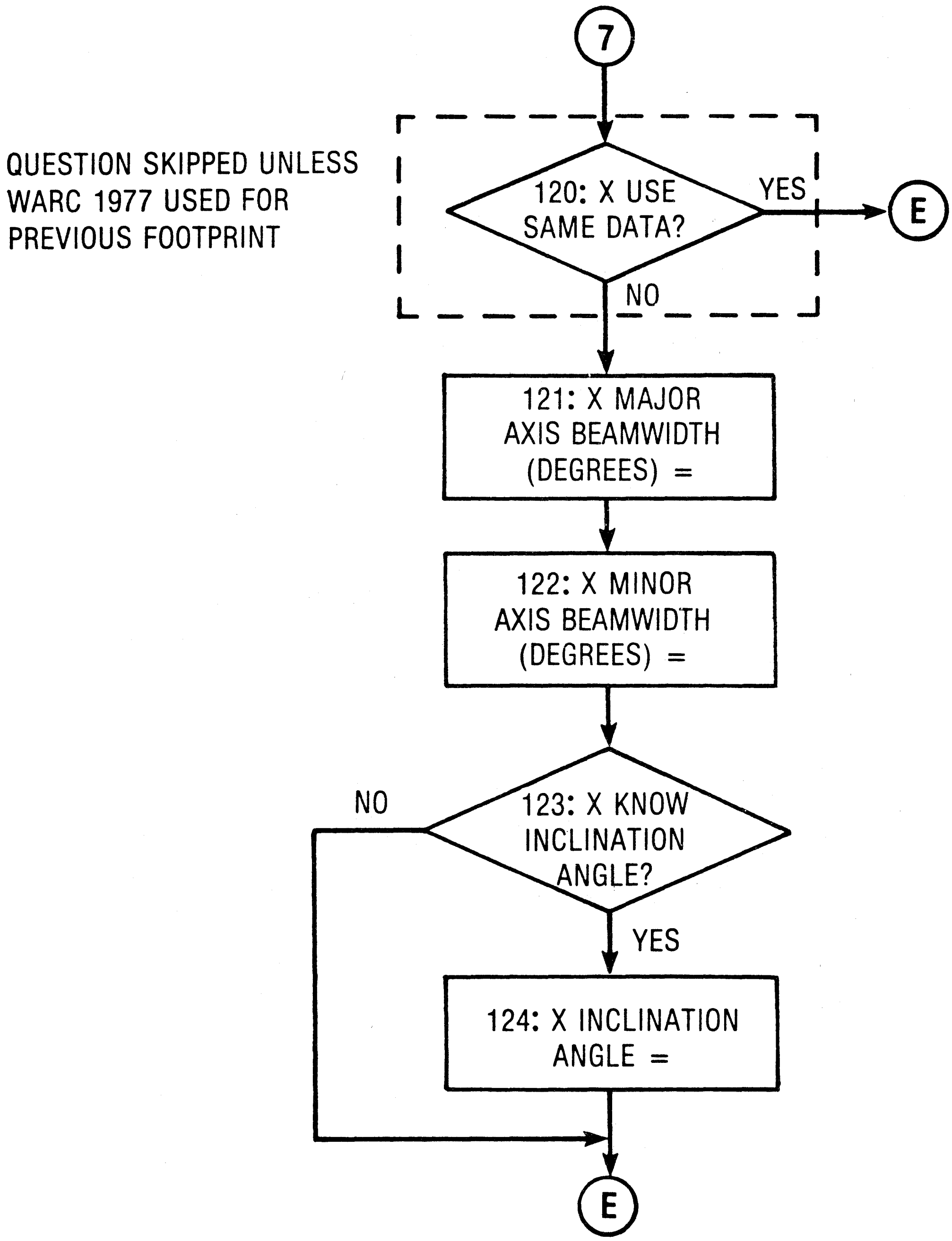


Figure 19. (Continued)

3.6 Description of the Output Data

The primary outputs of the FOOTPRINTS program are the footprint plots, illustrating contours of constant antenna gain on the earth's surface from a satellite at synchronous altitude, and the antenna coverage area polygons. An example of a typical FOOTPRINTS program output is given in Figure 20. This output consists of an orthographic world projection containing one footprint with six contour levels, and one service area polygon. The maximum gain on the earth's surface is at the aim point of the satellite's antenna, denoted by the ◊ symbol inside of the contours. The satellite position is denoted by the X symbol on the equator.

The contours plotted on Figure 20 indicate -3, -6, -10, -20, -30, and -60dB levels of antenna gain from the antenna aim point. The innermost contour, which surrounds the antenna aim point, is the -3dB contour. Along this contour, the satellite's antenna gain is one-half of that available at the aim point. The area enclosed by the -3dB contour is called the 3dB coverage area since at any point within the contour, the gain will be within 3dB (one-half) of the maximum available signal level. The second innermost contour is the -6dB contour, along which the gain is one-fourth of that at the aim point. The area inside of the -6dB contour is called the 6dB coverage area.

Along the -10dB and -20dB contours, the antenna gain is one-tenth and one-hundredth of that at the aim point, respectively. Similar comments could be made for the -30dB and -60dB contours or any other contours requested by the user. Note that the -3, -6, and -10dB contours are closed contours whereas the -20, -30, and -60dB contours are open. An open contour indicates that the particular level does not continuously intersect the earth's surface. A limb line could be drawn to close these contours which would show where the earth's surface blocks regions of the earth that are beyond the line-of-sight of the satellite. It is also possible to have contour levels that do not intersect with the earth at any location.

By adding to the footprint plot the service area polygon that encloses the desired area of signal coverage, the user can determine if the satellite's antenna gain pattern on the earth's surface meets his/her design criterion. The service area polygon of Figure 20 encloses the Central Time Zone of the continental United States. Note that if the user required that the antenna's 3dB coverage area enclose the signal coverage area, this requirement would not be met; but if the user required that the antenna's 6dB coverage area

FOOTPRINTS

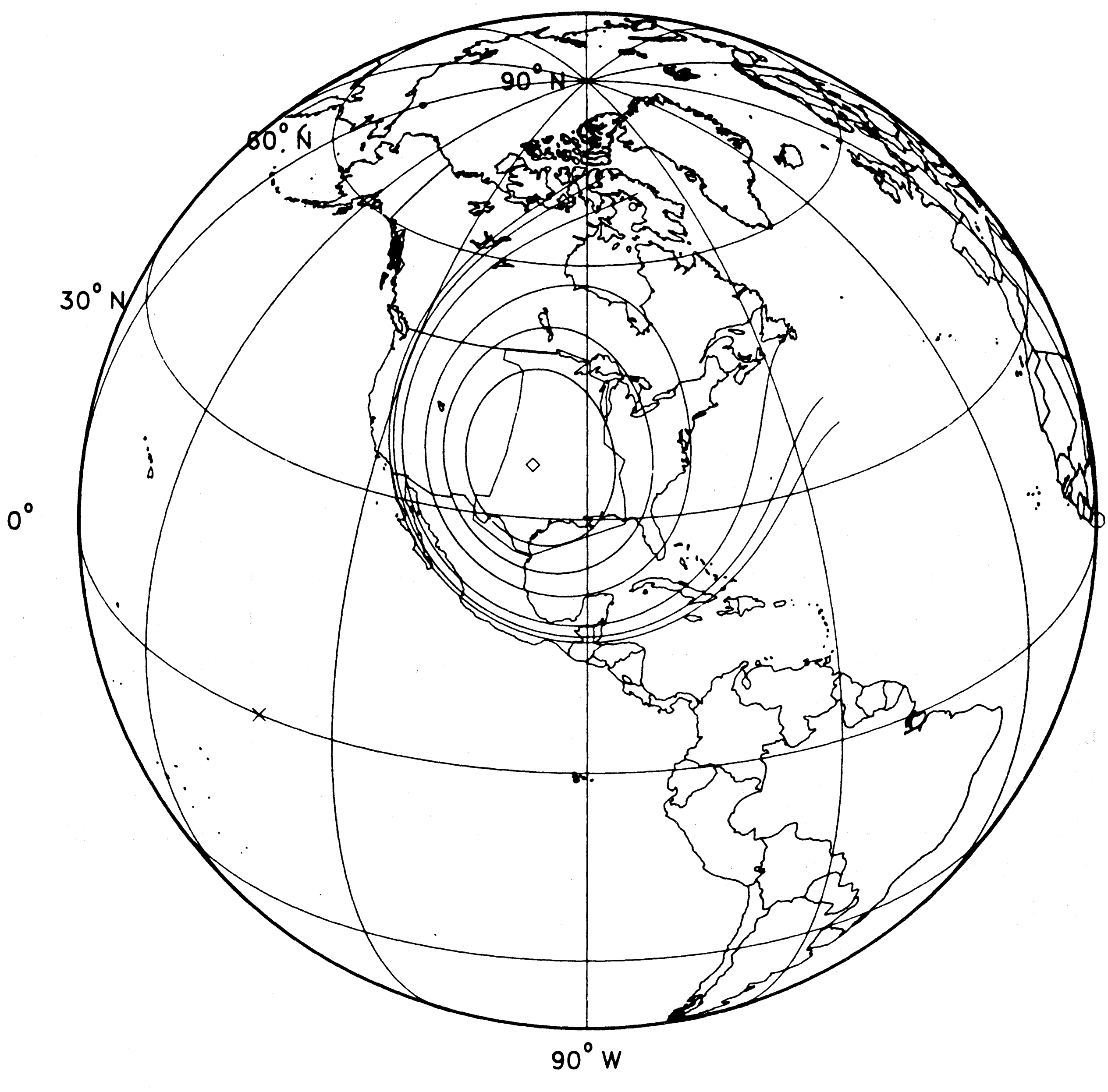


Figure 20. Typical program FOOTPRINTS output.

enclose the signal coverage area, this requirment would be met. Also, by plotting service area polygons where potential interference may occur, the user can determine if unwanted signals are present.

By using the footprint plots and the service area polygons, the user is able to determine if the desired area of signal coverage is obtained, along with the detection of any potential areas of interference.

4. SAMPLE PROGRAM EXECUTIONS

The following examples are sample executions of the FOOTPRINTS program.

Sample Number 1.

The interaction between the user and the program FOOTPRINTS for this example is shown in Figure 21. The user has successfully accessed the program FOOTPRINTS when the header is printed on the user's terminal. The user initiates the dialogue or input mode by typing in the command RUN. As noted in the terminal text in Figure 21, three different maps were requested (i.e., world, U.S., and enlarged world) all of which were plotted using the orthographic map projection. A single footprint with three contour levels was requested using a satellite antenna with a parabolic reflector and circular symmetry. At the end of the input mode, the user typed in the SUMMARY command to obtain a summary of the input parameters. The user then entered the SUBMIT command which initiated the footprint calculations and generated the data to be plotted. Finally, the QUIT command was entered which terminated the FOOTPRINTS program and sent the output data to the microfilm plotter. Figures 22, 23, and 24 are the U.S., enlarged world, and world output plots respectively, from this sample execution.

Sample Number 2.

The interaction between the user and the program FOOTPRINTS for this example is shown in Figure 25. This sample execution uses an Alber's equal area conic world map projection with two satellite antenna footprints. The first antenna is a parabolic reflector with elliptical symmetry and the second antenna is the WARC 1977 reflector with elliptical symmetry. The first footprint has seven contour levels, while the second footprint has three contour levels. Figure 26 is the output plot produced by this sample.

```
U.S. DEPARTMENT OF COMMERCE
INSTITUTE FOR TELECOMMUNICATION SCIENCES

PROGRAM 'FOOTPRINTS'                    VERSION 2.8                  3/03/82

(TYPE "HELP" & CARRIAGE RETURN, IF NEEDED)


>
? RUN


  1.  IS THE SATELLITE GEOSTATIONARY?
? YES

     'NOTE' - THE PROGRAM WILL PLOT THE ANTENNA FOOTPRINTS ON A
              WORLD MAP, A U.S. MAP, AND/OR AN ENLARGED-AREA MAP.
              THE FOLLOWING PROJECTIONS ARE AVAILABLE FOR EACH MAP:

                  STEREOGRAPHIC
                ' ORTHOGRAPHIC
                  LAMBERT EQUAL AREA
                  GNOMONIC
                  AZIMUTHAL EQUIDISTANT
                  CYLINDRICAL EQUIDISTANT
                ' MERCATOR
                  MOLLWEIDE
                  ALBERS EQUAL AREA CONIC
                  BI PARALLEL CONFORMAL CONIC

              ("'" INDICATES A COMMONLY SPECIFIED PROJECTION)
              THE USER MAY OPTIONALLY SPECIFY GRID LINES AND THE
              PLOT SIZE (DEFAULT IS 6.0 X 6.0 INCHES FOR THE WORLD
              AND ENLARGED MAPS, 5.0 X 9.0 INCHES FOR THE U.S. MAP).

  2.  DO YOU WANT A WORLD MAP WITH FOOTPRINTS?
? YES

     'NOTE' - "PROJECTION REFERENCE POINT" (OR "PRP") IS THE CENTER
              POINT OF THE SPECIFIED MAP.  THE WORLD MAP PRP IS
              USER SPECIFIED, THE U.S. MAP PRP IS FIXED AT 36N,
              98W, AND THE ENLARGED MAP PRP IS COMPUTED FROM THE
              USER-SPECIFIED MAP BOUNDARIES.

  3.  PROJECTION REFERENCE POINT LATITUDE =
? 40
  4.  PROJECTION REFERENCE POINT LONGITUDE =
? -105
  5.  WORLD MAP PROJECTION:
? ORTHOGRAPHIC
  6.  DO YOU WANT GRID LINES DRAWN ON THE WORLD MAP?
? YES
  7.  GRID LINE SPACING (DEGREES) =
? 30
  8.  WORLD MAP TITLE:
? WORLD-PARABOLA
  9.  DO YOU WISH TO SPECIFY A NON-STANDARD WORLD MAP SIZE?
? NO
```

Figure 21. Sample number 1.

```
 12.  DO YOU WANT A U.S. MAP WITH FOOTPRINTS?
? YES
 13.  U.S. MAP PROJECTION:
? ORTHOGRAPHIC
 14.  DO YOU WANT GRID LINES DRAWN ON THE U.S. MAP?
? YES
 15.  U.S. MAP GRID LINE SPACING (DEGREES) =
? 10
 16.  U.S. MAP TITLE:
? U.S.-PARABOLA
 17.  DO YOU WISH TO SPECIFY A NON-STANDARD U.S. MAP SIZE?
? NO


 20.  DO YOU WANT AN ENLARGED MAP WITH FOOTPRINTS?
? YES

      'NOTE' - THE ENLARGED MAP MAY BE PLOTTED USING EITHER U S. OR
               WORLD MAP DATA.  IF THE DESIRED ENLARGED AREA FALLS
               ENTIRELY WITHIN THE CONTINENTAL U.S., A SIGNIFICANT
               IMPROVEMENT IN ACCURACY WILL RESULT IF THE U.S. MAP
               DATA IS USED.

 21.  WILL THE DESIRED ENLARGED AREA FALL ENTIRELY WITHIN THE
      CONTINENTAL U.S.?
? NO

      'NOTE' - IT IS NECESSARY TO SPECIFY THE BORDERS OF THE DESIRED
               ENLARGED AREA.  INPUT THE BOUNDARY VALUES AS
               LOWER/UPPER LATITUDE AND LEFT/RIGHT LONGITUDE PAIRS.

 22.  ENLARGED MAP LOWER LATITUDE =
? 20
 23.  ENLARGED MAP UPPER LATITUDE =
? 60
 24.  ENLARGED MAP LEFT LONGITUDE =
? -125
 25.  ENLARGED MAP RIGHT LONGITUDE =
? -65
 26.  ENLARGED MAP PROJECTION:
? ORTHOGRAPHIC
 27.  DO YOU WANT GRID LINES DRAWN ON THE ENLARGED MAP?
? YES
 28.  ENLARGED MAP GRID SPACING (DEGREES) =
? 20
 29.  ENLARGED MAP TITLE:
? ENLARGED-PARABOLA
 30.  DO YOU WISH TO SPECIFY A NON-STANDARD ENLARGED MAP SIZE?
? YES
 31.  ENLARGED MAP HEIGHT (INCHES) =
? 6.0
 32.  ENLARGED MAP WIDTH (INCHES) =
? 9.0


 33.  HOW MANY SETS OF FOOTPRINTS DO YOU WISH TO HAVE PLOTTED?
? 1
```

Figure 21. (Continued)

```
      'NOTE' - "AIM POINT" IS THE GROUND POSITION TO WHICH THE
               SATELLITE MAIN BEAM IS POINTED.

 34:1  AIM POINT LATITUDE #1 =
? 40
 35:1  AIM POINT LONGITUDE #1 =
? -105
 36:1  SUB-SATELLITE LONGITUDE #1 =
? -120

      'NOTE' - THE FOLLOWING SATELLITE ANTENNA TYPES ARE AVAILABLE:

                 PARABOLA         - PARABOLIC DISH (CIRCULAR SYMMETRY)
                 ELLIPSE          - PARABOLIC DISH (ELLIPTICAL SYMMETRY)
                 HORN             - PLANAR APERATURE
                 HELIX            - HELIX
                 POINT PATTERN    - ASYMMETRIC PATTERN DATA
                 FAST ROLL OFF    - ELLIPTICAL SYMMETRY
                 WARC 1977        - ELLIPTICAL SYMMETRY

 37:1  IS SATELLITE ANTENNA #1 IN THE ABOVE LIST?
? YES
 38:1  SATELLITE ANTENNA TYPE =
? PARABOLA

      'PARABOLA' - PARABOLIC DISH WITH CIRCULAR SYMMETRY

 51:1  DO YOU KNOW THE PARABOLIC REFLECTOR'S DIAMETER?
? YES
 52:1  IS THE REFLECTOR DIAMETER IN METERS OR WAVELENGTHS?
? WAVELENGTHS
 56:1  REFLECTOR DIAMETER (WAVELENGTHS) =
? 20
 57:1  IS THE EDGE/CENTER ILLUMINATION RATIO KNOWN?
? NO

      'NOTE' - THE PROGRAM WILL ASSUME AN EDGE/CENTER ILLUMINATION
               RATIO OF 1.0 (UNIFORM ILLUMINATION).

      'NOTE' - FOOTPRINT # 1 WILL BE GENERATED USING A PARABOLIC DISH
               HAVING CIRCULAR SYMMETRY, AN EFFECTIVE DIAMETER OF
                20.00 WAVELENGTHS, AND AN EDGE/CENTER ILLUMINATION
               RATIO OF 1.00 .

      'NOTE' - THE PROGRAM WILL PLOT CONSTANT POWER-DENSITY CONTOURS
               ON THE EARTH'S SURFACE AND AS INSCRIBED BY THE SPECIFIED
               MAP(S).  THE FOLLOWING CONTOUR LEVELS (RELATIVE TO THE
               MAIN BEAM POWER DENSITY) ARE ALREADY SUPPLIED:  -2, -4,
               -6, -10, -20, -30, & -40 DB.  ALTERNATIVE OR ADDITIONAL
               CONTOURS MAY ALSO BE SPECIFIED.

 44:1  DO YOU WISH TO USE THE SUPPLIED CONTOUR LEVELS FOR
       FOOTPRINT #1?
? NO
```

Figure 21. (Continued)

```
 47:1   NUMBER OF USER-SPECIFIED CONTOURS =
? 3
 48:1   CONTOUR #1 (DB) =
? -3
        CONTOUR #2 (DB) =
? -6
        CONTOUR #3 (DB) =
? -10

   'END INPUT MODE'


>
? SUMMARY


 FOOTPRINTS SUMMARY
  82/07/15. 10.33.36.

 WORLD MAP:
   PROJECTION          = ORTHOGRAPHIC
   GRID LINE SPACING =    30.00 DEGREES
   TITLE               = *WORLD-PARABOLA                                    *
   HEIGHT              =     6.00 INCHES
   WIDTH               =     6.00  "   "
   PRP LATITUDE        =    40.00 DEGREES
   PRP LONGITUDE       = -105.00   "     "

 U.S. MAP:
   PROJECTION          = ORTHOGRAPHIC
   GRID LINE SPACING =    10.00 DEGREES
   TITLE               = *U.S.-PARABOLA                                     *
   HEIGHT              =     5.00 INCHES
   WIDTH               =     9.00  "   "
   PRP LATITUDE        =    36.00 DEGREES
   PRP LONGITUDE       =   -98.00   "     "

 WORLD ENLARGED MAP:
   LOWER LATITUDE      =    20.00 DEGREES
   UPPER LATITUDE      =    60.00   "     "
   LEFT LONGITUDE      = -125.00   "     "
   RIGHT LONGITUDE     =   -65.00   "     "
   PROJECTION          = ORTHOGRAPHIC
   GRID LINE SPACING =    20.00 DEGREES
   TITLE               = *ENLARGED-PARABOLA                                 *
   HEIGHT              =     6.00 INCHES
   WIDTH               =     9.00  "   "
   PRP LATITUDE        =    40.00 DEGREES
   PRP LONGITUDE       =   -95.00   "     "

 FOOTPRINT # 1
   AIM POINT LATITUDE              =    40.00 DEGREES
   AIM POINT LONGITUDE             = -105.00   "     "
   SUB-SATELLITE LONGITUDE         = -120.00   "     "
   ANTENNA TYPE                    = PARABOLIC DISH (CIRCULAR SYMMETRY)
   DIAMETER                        =    20.00 WAVELENGTHS
   ILLUMINATION RATIO              =     1.00
   CONTOURS (DB BELOW MAIN BEAM) =    -3.0    -6.0   -10.0
```

Figure 21. (Continued)

```
>
? SUBMIT

 ENTER USER MICROFILM IDENTIFICATION (<=30 CHARS)
 (USUALLY CONTAINS NAME & PHONE EXTENSION).

? KEN GAMAUF   X3677


 MAP TYPE = U.S.               (*U.S.-PARABOLA                              *)

   FOOTPRINT # 1 CONTOURS:

        -3.00
        -6.00
       -10.00

  ALL CONTOURS PLOTTED

  MAP PLOTTED


 MAP TYPE = WORLD ENLARGED     (*ENLARGED-PARABOLA                          *)

   FOOTPRINT # 1 CONTOURS:

        -3.00
        -6.00
       -10.00

  ALL CONTOURS PLOTTED

  MAP PLOTTED


 MAP TYPE = WORLD              (*WORLD-PARABOLA                             *)

   FOOTPRINT # 1 CONTOURS:

        -3.00
        -6.00
       -10.00

  ALL CONTOURS PLOTTED

  MAP PLOTTED


 'SUBMIT COMPLETED'


>
? QUIT
```

Figure 21. (Continued)

```
*** END OF DISSPLA PLOTTING ***

END OF DISSPLA 8.2 --     79265 VECTORS GENERATED IN     3 PLOT FRAMES.
-ISSCO-  4186 SORRENTO VALLEY BLVD.,SAN DIEGO CALIF. 92121

DISSPLA IS A CONFIDENTIAL PROPRIETARY PRODUCT OF ISSCO AND ITS USE
   IS SUBJECT TO A NONDISSEMINATION AND NONDISCLOSURE AGREEMENT.


 'PROGRAM TERMINATED'
```

Figure 21. (Continued)

U.S.-PARABOLA

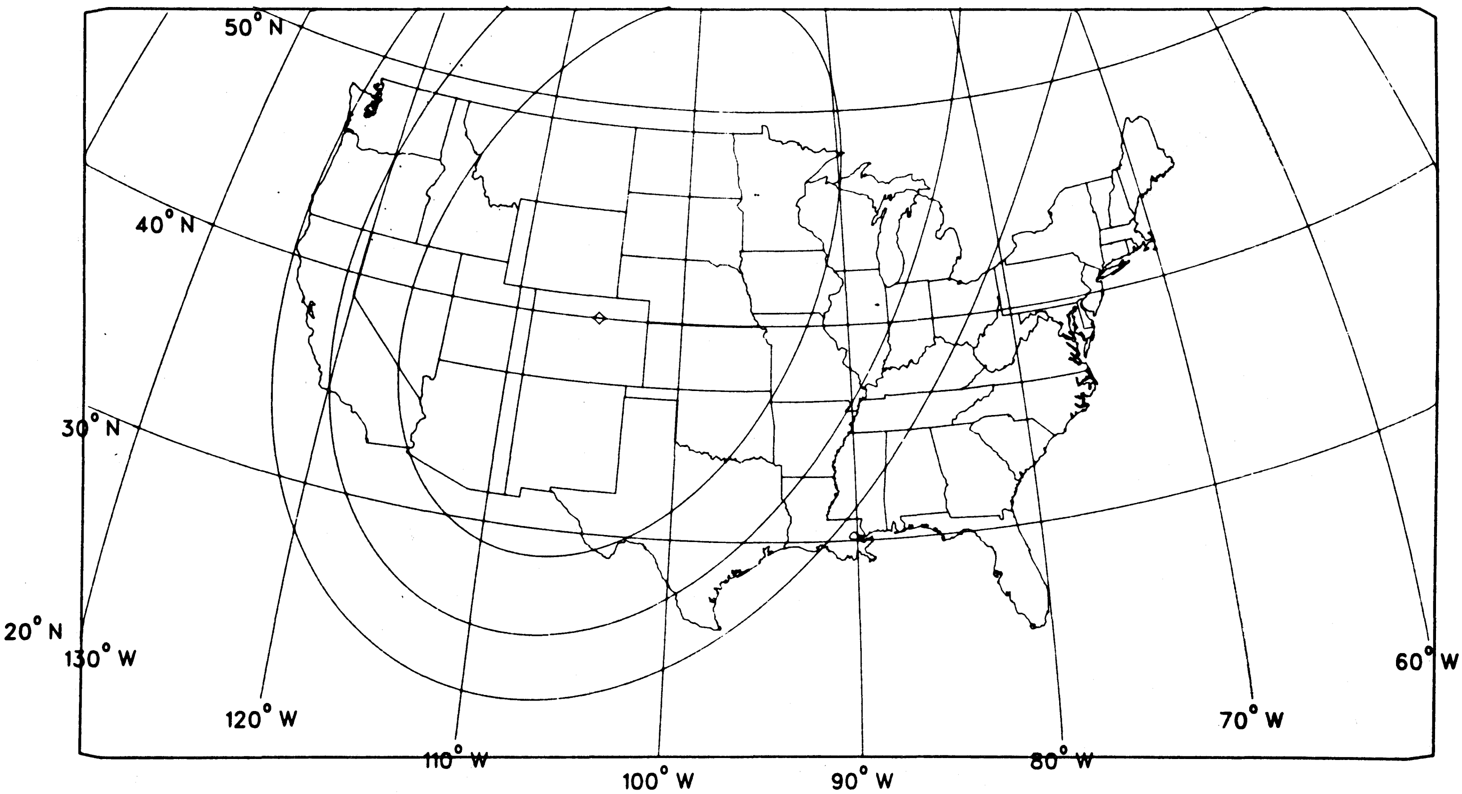


Figure 22. U.S. map footprint plot from sample execution number 1.

ENLARGED-PARABOLA

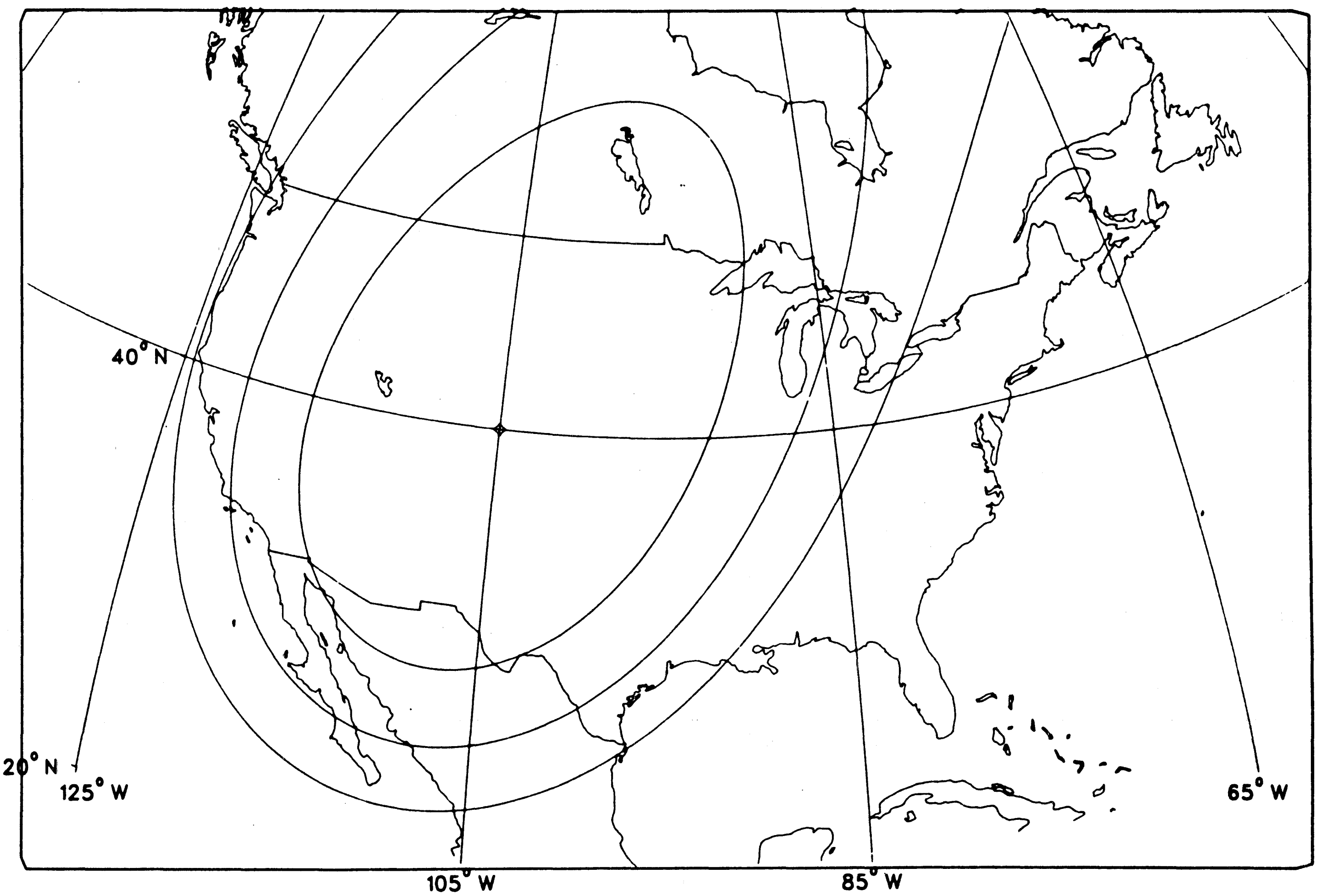


Figure 23. Enlarged map footprint plot from sample execution number 1.

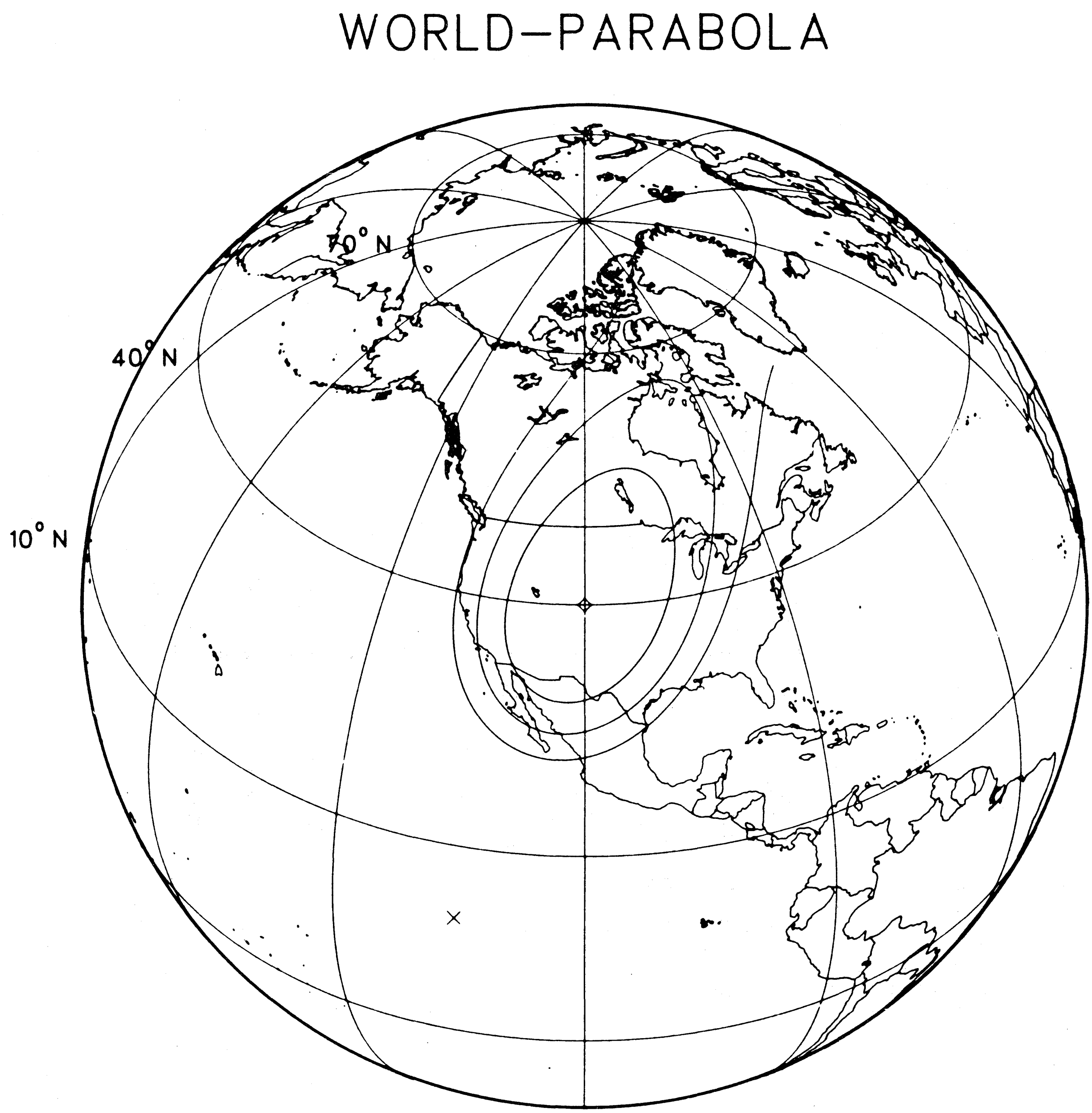


Figure 24. World map footprint plot from sample execution number 1.

```
U.S. DEPARTMENT OF COMMERCE
INSTITUTE FOR TELECOMMUNICATION SCIENCES

PROGRAM 'FOOTPRINTS'                VERSION 2.8                3/03/82

(TYPE "HELP" & CARRIAGE RETURN, IF NEEDED)


>
? RUN


  1.  IS THE SATELLITE GEOSTATIONARY?
? YES

     'NOTE' - THE PROGRAM WILL PLOT THE ANTENNA FOOTPRINTS ON A
              WORLD MAP, A U.S. MAP, AND/OR AN ENLARGED-AREA MAP.
              THE FOLLOWING PROJECTIONS ARE AVAILABLE FOR EACH MAP:

                  STEREOGRAPHIC
                ' ORTHOGRAPHIC
                  LAMBERT EQUAL AREA
                  GNOMONIC
                  AZIMUTHAL EQUIDISTANT
                  CYLINDRICAL EQUIDISTANT
                ' MERCATOR
                  MOLLWEIDE
                  ALBERS EQUAL AREA CONIC
                  BI PARALLEL CONFORMAL CONIC

              ("'" INDICATES A COMMONLY SPECIFIED PROJECTION)
              THE USER MAY OPTIONALLY SPECIFY GRID LINES AND THE
              PLOT SIZE (DEFAULT IS 6.0 X 6.0 INCHES FOR THE WORLD
              AND ENLARGED MAPS, 5.0 X 9.0 INCHES FOR THE U.S. MAP).

  2.  DO YOU WANT A WORLD MAP WITH FOOTPRINTS?
? YES

     'NOTE' - "PROJECTION REFERENCE POINT" (OR "PRP") IS THE CENTER
              POINT OF THE SPECIFIED MAP.  THE WORLD MAP PRP IS
              USER SPECIFIED, THE U.S. MAP PRP IS FIXED AT 36N,
              98W, AND THE ENLARGED MAP PRP IS COMPUTED FROM THE
              USER-SPECIFIED MAP BOUNDARIES.

  3.  PROJECTION REFERENCE POINT LATITUDE =
? 45
  4.  PROJECTION REFERENCE POINT LONGITUDE =
? -90
  5.  WORLD MAP PROJECTION:
? ALBERS EQUAL AREA CONIC
  6.  DO YOU WANT GRID LINES DRAWN ON THE WORLD MAP?
? YES
  7.  GRID LINE SPACING (DEGREES) =
? 30
  8.  WORLD MAP TITLE:
? MULTIPLE-FOOTPRINTS
  9.  DO YOU WISH TO SPECIFY A NON-STANDARD WORLD MAP SIZE?
? YES
 10.  WORLD MAP HEIGHT (INCHES) =
? 6.0
```

Figure 25. Sample number 2.

```
 11.  WORLD MAP WIDTH (INCHES) =
? 9.0


 12.  DO YOU WANT A U.S. MAP WITH FOOTPRINTS?
? NO


 20.  DO YOU WANT AN ENLARGED MAP WITH FOOTPRINTS?
? NO


 33.  HOW MANY SETS OF FOOTPRINTS DO YOU WISH TO HAVE PLOTTED?
? 2

      'NOTE' - "AIM POINT" IS THE GROUND POSITION TO WHICH THE
               SATELLITE MAIN BEAM IS POINTED.


 34:1  AIM POINT LATITUDE #1 =
? 38
 35:1  AIM POINT LONGITUDE #1 =
? -122
 36:1  SUB-SATELLITE LONGITUDE #1 =
? -135

      'NOTE' - THE FOLLOWING SATELLITE ANTENNA TYPES ARE AVAILABLE:

                PARABOLA        - PARABOLIC DISH (CIRCULAR SYMMETRY)
                ELLIPSE         - PARABOLIC DISH (ELLIPTICAL SYMMETRY)
                HORN            - PLANAR APERATURE
                HELIX           - HELIX
                POINT PATTERN   - ASYMMETRIC PATTERN DATA
                FAST ROLL OFF   - ELLIPTICAL SYMMETRY
                WARC 1977       - ELLIPTICAL SYMMETRY


 37:1  IS SATELLITE ANTENNA #1 IN THE ABOVE LIST?
? YES
 38:1  SATELLITE ANTENNA TYPE =
? ELLIPSE


      'ELLIPSE' - PARABOLIC DISH WITH ELLIPTICAL SYMMETRY

 66:1  DO YOU WISH TO SPECIFY THE ANTENNA'S DIMENSIONS IN METERS
       OR WAVELENGTHS?
? WAVELENGTHS
 70:1  LENGTH OF PARABOLIC DISH ALONG ITS MAJOR AXIS
       (WAVELENGTHS) =
? 30
 71:1  LENGTH OF PARABOLIC DISH ALONG ITS MINOR AXIS
       (WAVELENGTHS) =
? 20
 72:1  ARE THE EDGE/CENTER ILLUMINATION RATIOS KNOWN?
? NO

      'NOTE' - THE PROGRAM WILL ASSUME THAT BOTH EDGE/CENTER
               ILLUMINATION RATIOS ARE 1.0 (UNIFORM ILLUMINATION).
```

Figure 25. (Continued)

```
 75:1   IS THE INCLINATION ANGLE KNOWN?
? YES
 76:1   INCLINATION ANGLE (DEGREES) =
? 100

       'NOTE' - FOOTPRINT # 1 WILL BE GENERATED USING A PARABOLIC DISH
                HAVING ELLIPTICAL SYMMETRY, MAJOR & MINOR DIAMETERS
                OF  30.00 &  20.00 WAVELENGTHS, MAJOR & MINOR
                ILLUMINATION RATIOS OF 1.00 & 1.00, AND AN INCLINATION
                ANGLE OF 100.00 DEGREES.

       'NOTE' - THE PROGRAM WILL PLOT CONSTANT POWER-DENSITY CONTOURS
                ON THE EARTH'S SURFACE AND AS INSCRIBED BY THE SPECIFIED
                MAP(S).  THE FOLLOWING CONTOUR LEVELS (RELATIVE TO THE
                MAIN BEAM POWER DENSITY) ARE ALREADY SUPPLIED:  -2, -4,
                -6, -10, -20, -30, & -40 DB.  ALTERNATIVE OR ADDITIONAL
                CONTOURS MAY ALSO BE SPECIFIED.

 44:1   DO YOU WISH TO USE THE SUPPLIED CONTOUR LEVELS FOR
        FOOTPRINT #1?
? YES
 45:1   DO YOU WISH TO SPECIFY ANY ADDITIONAL CONTOUR LEVELS FOR
        FOOTPRINT #1?
? NO


 34:2   AIM POINT LATITUDE #2 =
? 18
 35:2   AIM POINT LONGITUDE #2 =
? -66
 36:2   SUB-SATELLITE LONGITUDE #2 =
? -90


 37:2   IS SATELLITE ANTENNA #2 IN THE ABOVE LIST?
? YES
 38:2   SATELLITE ANTENNA TYPE =
? WARC 1977


       'WARC 1977' - ELLIPTICAL SYMMETRY ANTENNA

121:2   BEAMWIDTH OF ANTENNA ALONG ITS MAJOR AXIS
        (DEGREES) =
? 1.08
122:2   BEAMWIDTH OF ANTENNA ALONG ITS MINOR AXIS
        (DEGREES) =
? 0.65

       'NOTE' - "INCLINATION ANGLE" IS MEASURED COUNTERCLOCKWISE FROM
                TRUE EAST.

123:2   IS THE INCLINATION ANGLE KNOWN?
? YES
124:2   INCLINATION ANGLE (DEGREES) =
? 136
```

Figure 25. (Continued)

```
   'NOTE' - FOOTPRINT # 2 WILL BE GENERATED USING THE WARC 1977
            ANTENNA HAVING ELLIPTICAL SYMMETRY, MAJOR & MINOR DIAMETERS
            OF   1.08 &    .65 DEGREES, AND AN INCLINATION ANGLE
            OF 136.00 DEGREES.

 44:2  DO YOU WISH TO USE THE SUPPLIED CONTOUR LEVELS FOR
       FOOTPRINT #2?
? NO
 47:2  NUMBER OF USER-SPECIFIED CONTOURS =
? 3
 48:2  CONTOUR #1 (DB) =
? -3
       CONTOUR #2 (DB) =
? -6
       CONTOUR #3 (DB) =
? -10

  'END INPUT MODE'


>
? SUMMARY


 FOOTPRINTS SUMMARY
  82/07/16. 08.17.38.

 WORLD MAP:
   PROJECTION         = ALBERS EQUAL AREA CONIC
   GRID LINE SPACING =   30.00 DEGREES
   TITLE              = *MULTIPLE-FOOTPRINTS                        *
   HEIGHT             =    6.00 INCHES
   WIDTH              =    9.00  "  "
   PRP LATITUDE       =   45.00 DEGREES
   PRP LONGITUDE      =  -90.00  "    "

 FOOTPRINT # 1
   AIM POINT LATITUDE              =   38.00 DEGREES
   AIM POINT LONGITUDE             = -122.00  "    "
   SUB-SATELLITE LONGITUDE         = -135.00  "    "
   ANTENNA TYPE                    = PARABOLIC DISH (ELLIPTICAL SYMMETRY)
   MAJOR AXIS DIAMETER             =   30.00 WAVELENGTHS
   MINOR AXIS DIAMETER             =   20.00 "     "     "
   INCLINATION ANGLE               =  100.00 DEG. EAST OF TRUE NORTH
   MAJOR AXIS ILLUMINATION RATIO =     1.00
   MINOR AXIS ILLUMINATION RATIO =     1.00
   CONTOURS (DB BELOW MAIN BEAM) =    -2.0   -4.0   -6.0  -10.0  -20.0
                                     -30.0  -40.0

 FOOTPRINT # 2
   AIM POINT LATITUDE              =   18.00 DEGREES
   AIM POINT LONGITUDE             =  -66.00  "    "
   SUB-SATELLITE LONGITUDE         =  -90.00  "    "
   ANTENNA TYPE                    = WARC 1977 ELLIPSE ANTENNA
   MAJOR AXIS BEAMWIDTH            =    1.08 DEGREES
   MINOR AXIS BEAMWIDTH            =     .65  "    "
   INCLINATION ANGLE               =  136.00 DEG. NORTH OF TRUE EAST
   CONTOURS (DB BELOW MAIN BEAM) =    -3.0   -6.0  -10.0
```

Figure 25. (Continued)

```
>
? SUBMIT

 ENTER USER MICROFILM IDENTIFICATION (<=30 CHARS)
 (USUALLY CONTAINS NAME & PHONE EXTENSION).

? KEN GAMAUF    X3677


 MAP TYPE = WORLD               (*MULTIPLE-FOOTPRINTS                             *)

   FOOTPRINT # 1 CONTOURS:

       -2.00
       -4.00
       -6.00
      -10.00
      -20.00
      -30.00
      -40.00

  ALL CONTOURS PLOTTED

   FOOTPRINT # 2 CONTOURS:

       -3.00
       -6.00
      -10.00

  ALL CONTOURS PLOTTED

  MAP PLOTTED


 'SUBMIT COMPLETED'


>
? QUIT



 *** END OF DISSPLA PLOTTING ***


 END OF DISSPLA 8.2 --     41328 VECTORS GENERATED IN     1 PLOT FRAMES.
 -ISSCO-  4186 SORRENTO VALLEY BLVD.,SAN DIEGO CALIF. 92121

 DISSPLA IS A CONFIDENTIAL PROPRIETARY PRODUCT OF ISSCO AND ITS USE
    IS SUBJECT TO A NONDISSEMINATION AND NONDISCLOSURE AGREEMENT.


  'PROGRAM TERMINATED'
```

Figure 25. (Continued)

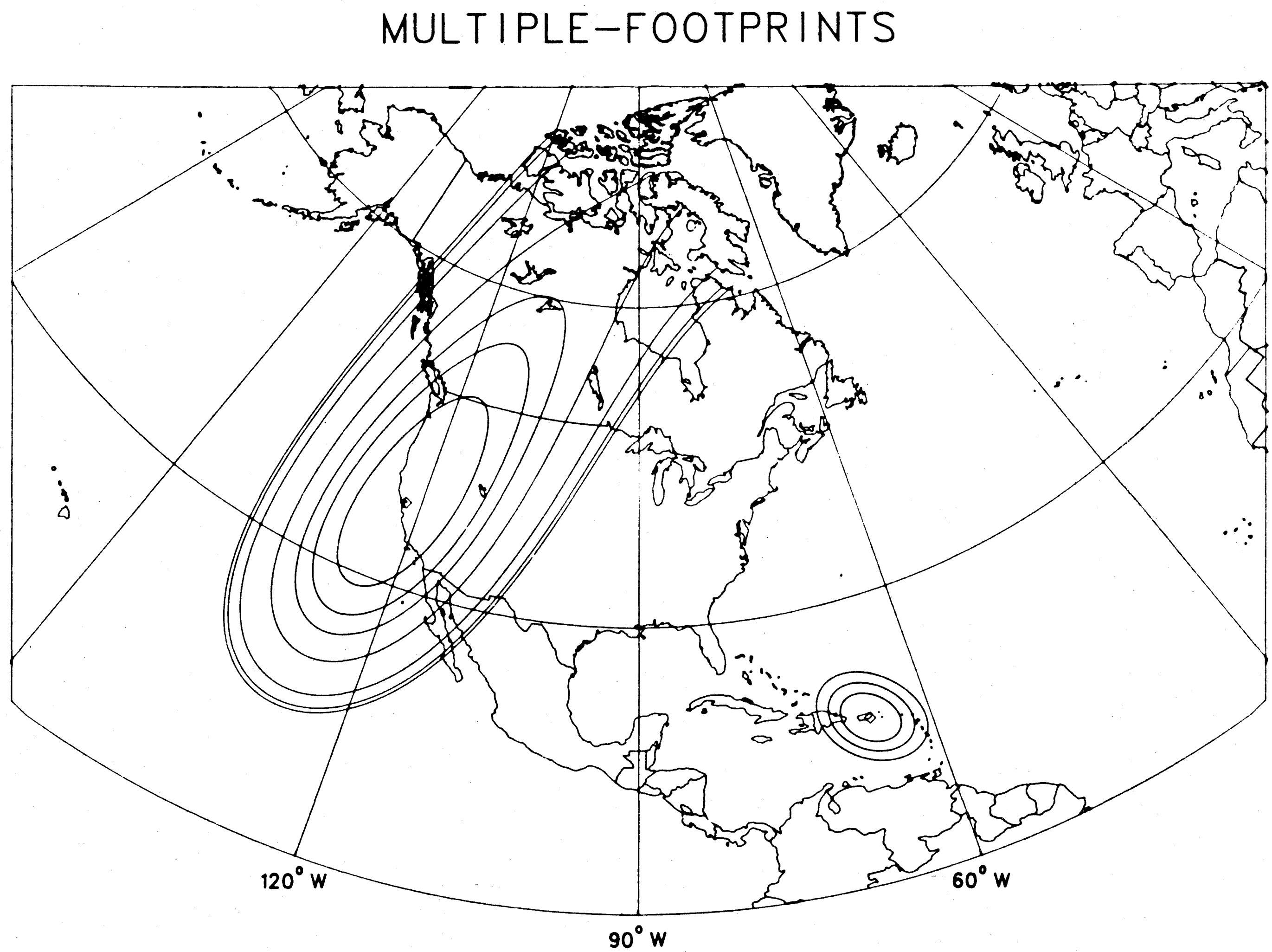


Figure 26. Multiple footprint plots from sample execution number 2.

Sample Number 3.

The last sample execution shows only the output plots of several 3dB coverage areas in the Americas. Figure 27 shows the -3dB contours for seven different footprints, while Figure 28 shows the -3dB contours of the seven different footprints along with the service area polygons that define the signal coverage areas.

5. ACKNOWLEDGMENTS

The author would like to thank all of the people at the Institute for Telecommunication Sciences who were of help in preparing this report and the work described within. In particular, the author wishes to thank E. Haakinson and K. Spies for their discussions and explanations concerning the original FOOTPRINTS computer program, R. Jennings for his supervision of the entire project, and C. Cunningham for her care and patience when typing the manuscript.

6. REFERENCES

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Robinson, A., R. Sale, and J. Morrison (1978), Elements of Cartography, (John Wiley and Sons, New York, N.Y.).

Spies, K.P., and E.J. Haakinson (1980), Calculation of geostationary satellite footprints for certain idealized antennas, National Telecommunications and Information Administration Report 80-51 (NTIS Access No. PB 81-168379).

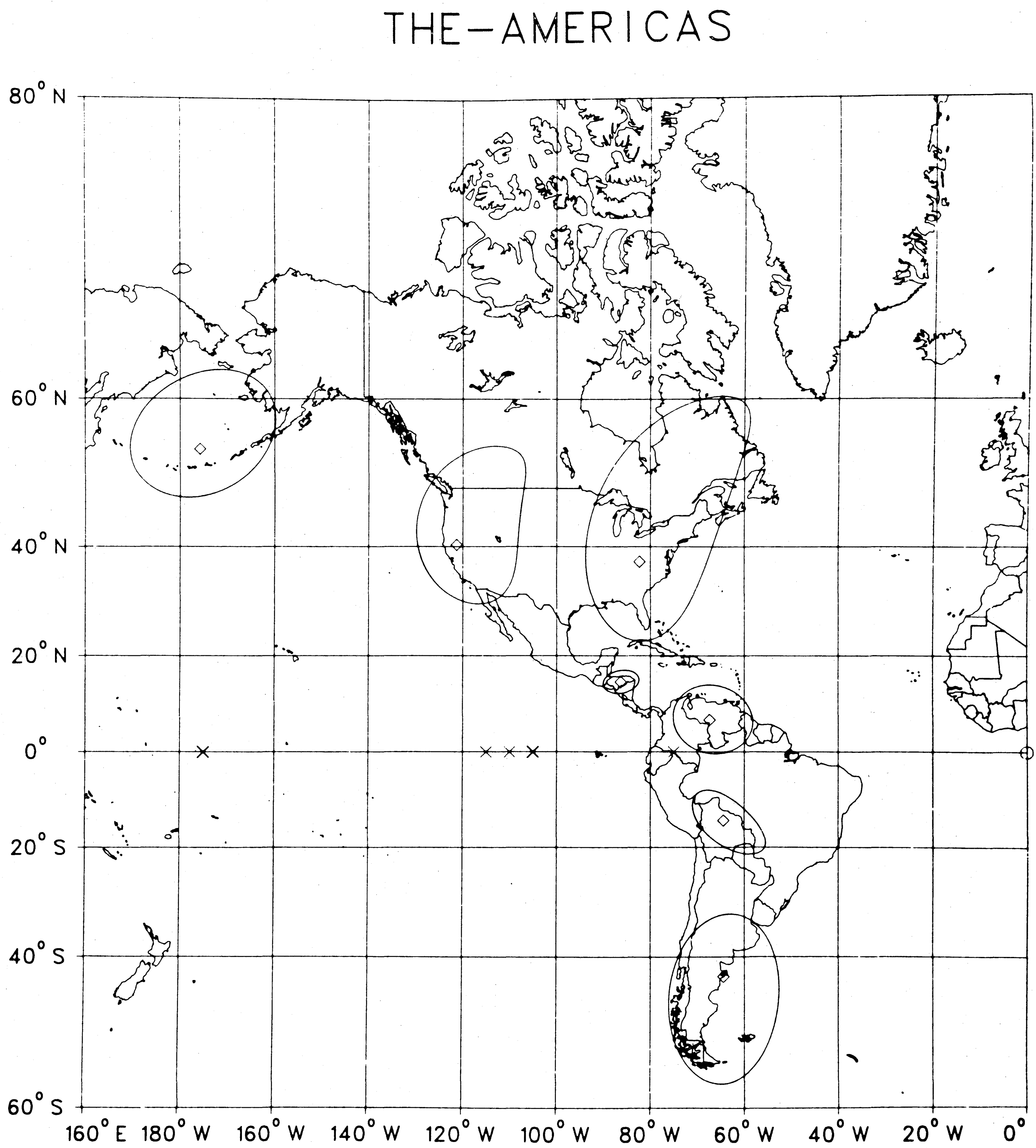

Figure 27. -3dB contours for seven different footprint plots from sample execution number 3.

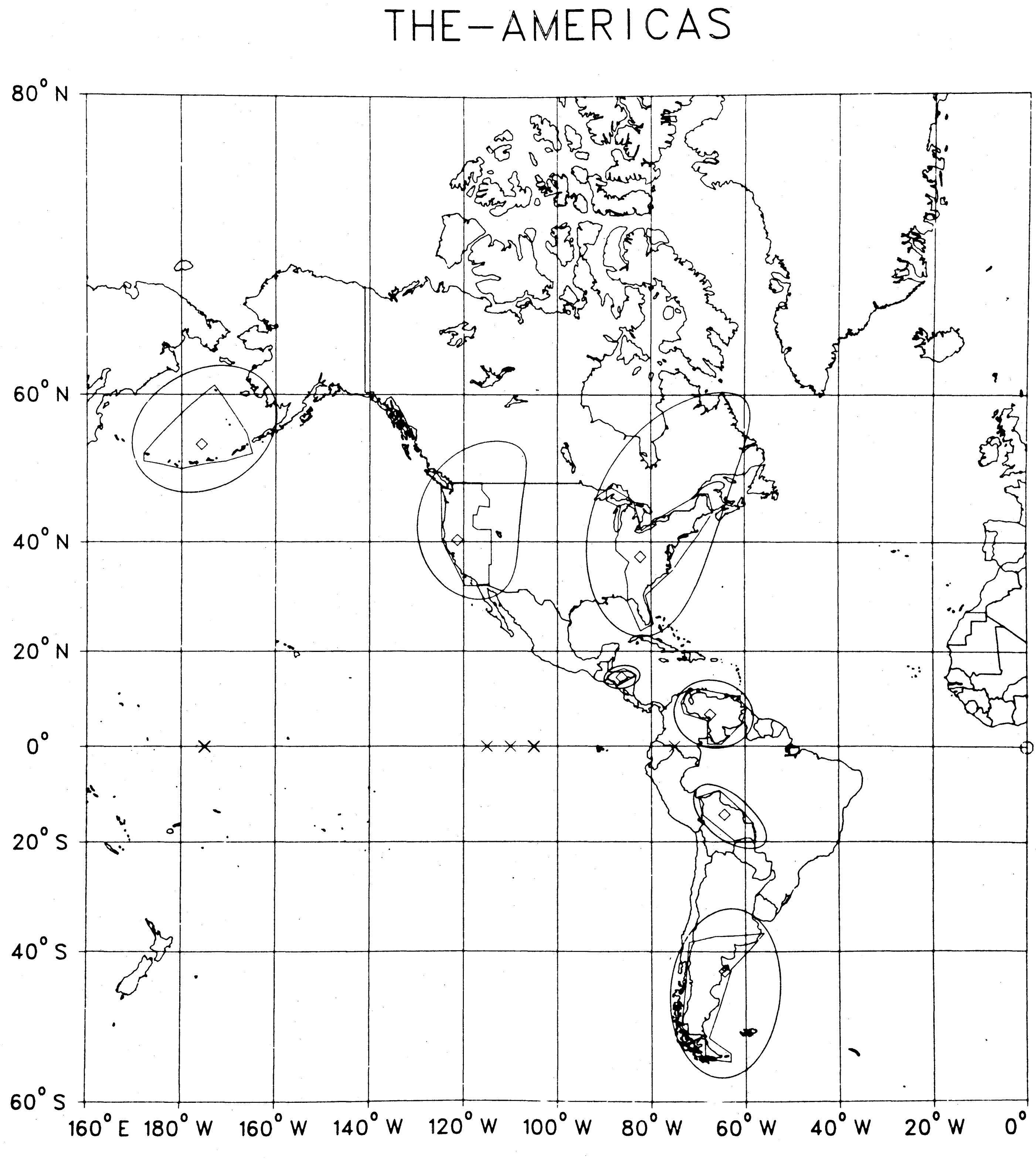

Figure 28. Service area polygons and -3dB contours for seven different footprint plots from sample execution number 3.

APPENDIX: USER-SUPPLIED ANTENNA PATTERN (POINT PATTERN)

A.1 General Description

In addition to the antenna models previously discussed, FOOTPRINTS also has the capability of projecting complex antenna patterns onto a map of the earth's surface using sets of user-supplied data. For example, the user may have a power gain pattern as measured from an actual antenna or computed by an antenna simulation model. The user describes the pattern by tabulating the coordinates of points located along each contour, expressing the coordinates of each point in terms of the angular displacement (in degrees) from the main beam. A separate set of points is tabulated for each contour. The FOOTPRINTS program projects the points in the data set towards the earth's surface from the given satellite position and connects the points to form the footprint of the contour. Since the program connects the points using straight lines, the resolution of the footprint plot depends on the spacing of the points selected by the user.

The user can specify the contour data in either of two commonly used antenna coordinate systems: azimuth-elevation and polar. The first, the azimuth-elevation (AZEL) system, resembles an X-Y system and consists of data pairs in the form

AZIMUTH, ELEVATION

where "azimuth" is the horizontal component of offset (in degrees) between the contour point and the main-beam axis, and "elevation" is the vertical component of offset (in degrees) between the contour point and the main-beam axis (see Figure A-1 for a pictorial description). Antenna pattern measurements often are collected in this form due to the ease of resolving positions into AZEL coordinates. Note the following coordinate restrictions:

$$-180.0 \leq \text{AZIMUTH} \leq +180.0$$

$$-90.0 \leq \text{ELEVATION} \leq +90.0 \; .$$

The second, the polar coodinate (POLAR) system, consists of data pairs in the form

ALPHA, OMEGA

where "alpha" is the angle (in degrees) between the main-beam axis and the contour point projection vector as measured in the plane containing the two vectors, and "omega" is the angle (in degrees) between the antenna's vertical reference plane and the plane containing the main-beam axis and the contour

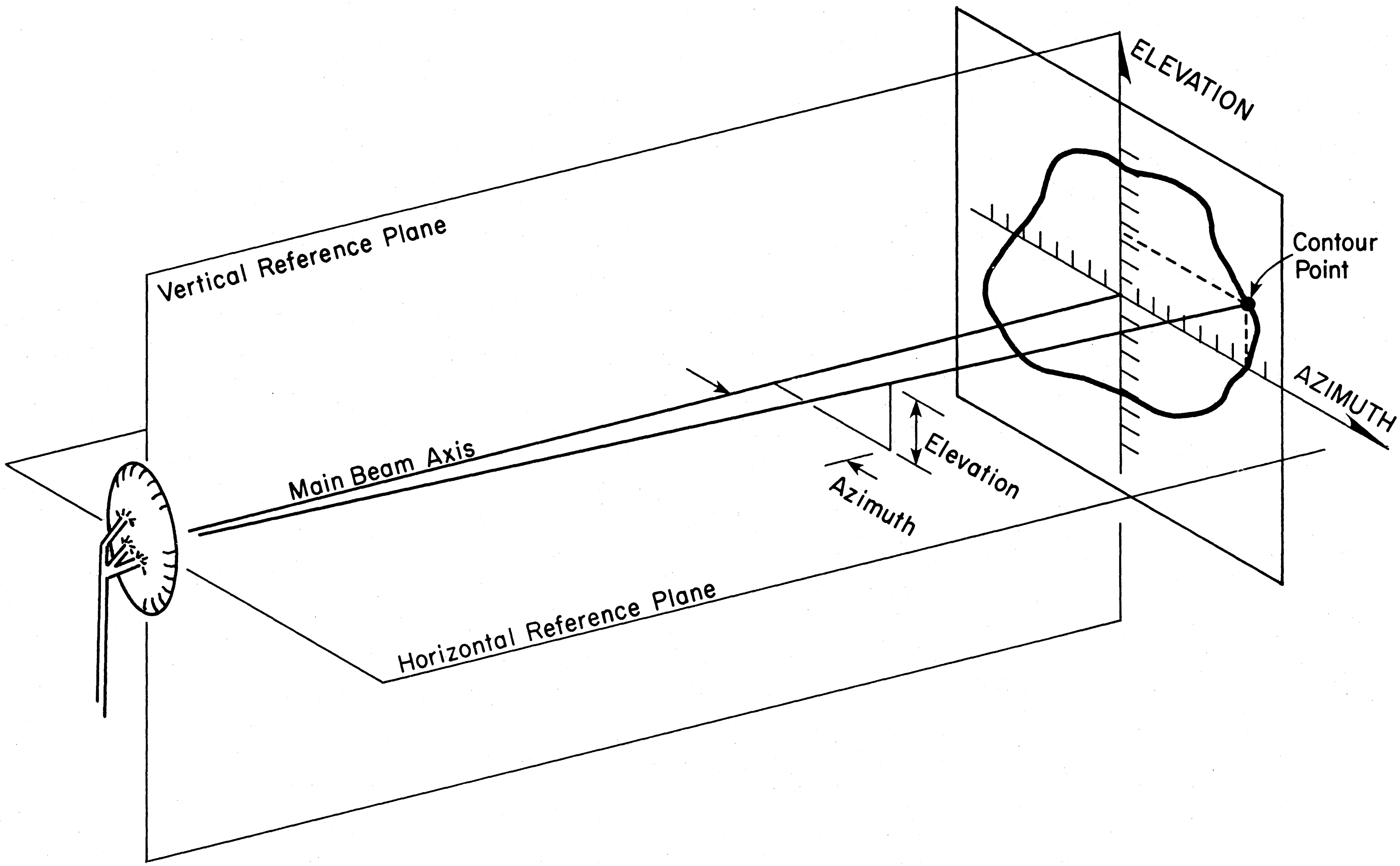

Figure A-1. The azimuth-elevation coordinate system, AZEL (Haakinson, Skinner, Spies and Bridgewater, 1977).

point projection vector (see Figure A-2). Antenna pattern data generated using a theoretical model are usually expressed in this system. Note the following coordinate restrictions:

$$0.0 \leq \text{ALPHA} \leq 180.0$$
$$0.0 \leq \text{OMEGA} \leq 360.0.$$

As an example, Figure A-3 shows a contrived pattern consisting of three contours, where the reference system is AZEL. Figure A-4 shows the results after the FOOTPRINTS program projects these contours onto the earth's surface. The contours projected without map and grid background are useful for making transparent overlays to assist in identifying and analyzing contours from a complex pattern. Figures A-5 and A-6 are examples of such overlays.

The pattern can be rotated or translated on the earth's surface by the program user without altering the original data sets. The values for inclination and aim point offset are supplied by the user during the RUN mode of FOOTPRINTS. Figure A-7 shows an example of rotating the pattern; Figure A-8 shows the original pattern with a different map projection, a new orientation, aim point, and sub-satellite longitude.

A.2 Input Procedures

The user tabulates and stores the antenna pattern input data in a computer file prior to exectuion of the FOOTPRINTS program (see Section A.3 for details on how to set up a data file). During the RUN mode of program execution, in Questions 105 through 110, the user is asked to supply additional parameters related to the antenna pattern. All of the input parameters requested are optional except for Question 105, the logical unit number of the point pattern data file.

Questions 106 and 107 allow the user to specify an inclination (clockwise rotation) angle for the entire pattern. If the user does not wish to specify a value, the program will set the inclination angle to 0 degrees. Questions 108 through 110 request aim point offset data. The values specified will be added to the current aim point latitude and longitude, which, in effect, shifts the centering of the pattern by the amount of the offset. If the user does not wish to specify offsets, the program will set these values to zero.

Due to plotting restrictions, the user is limited to <u>one</u> set of point patterns per SUBMIT or RUN. Other footprints using the built-in antenna models

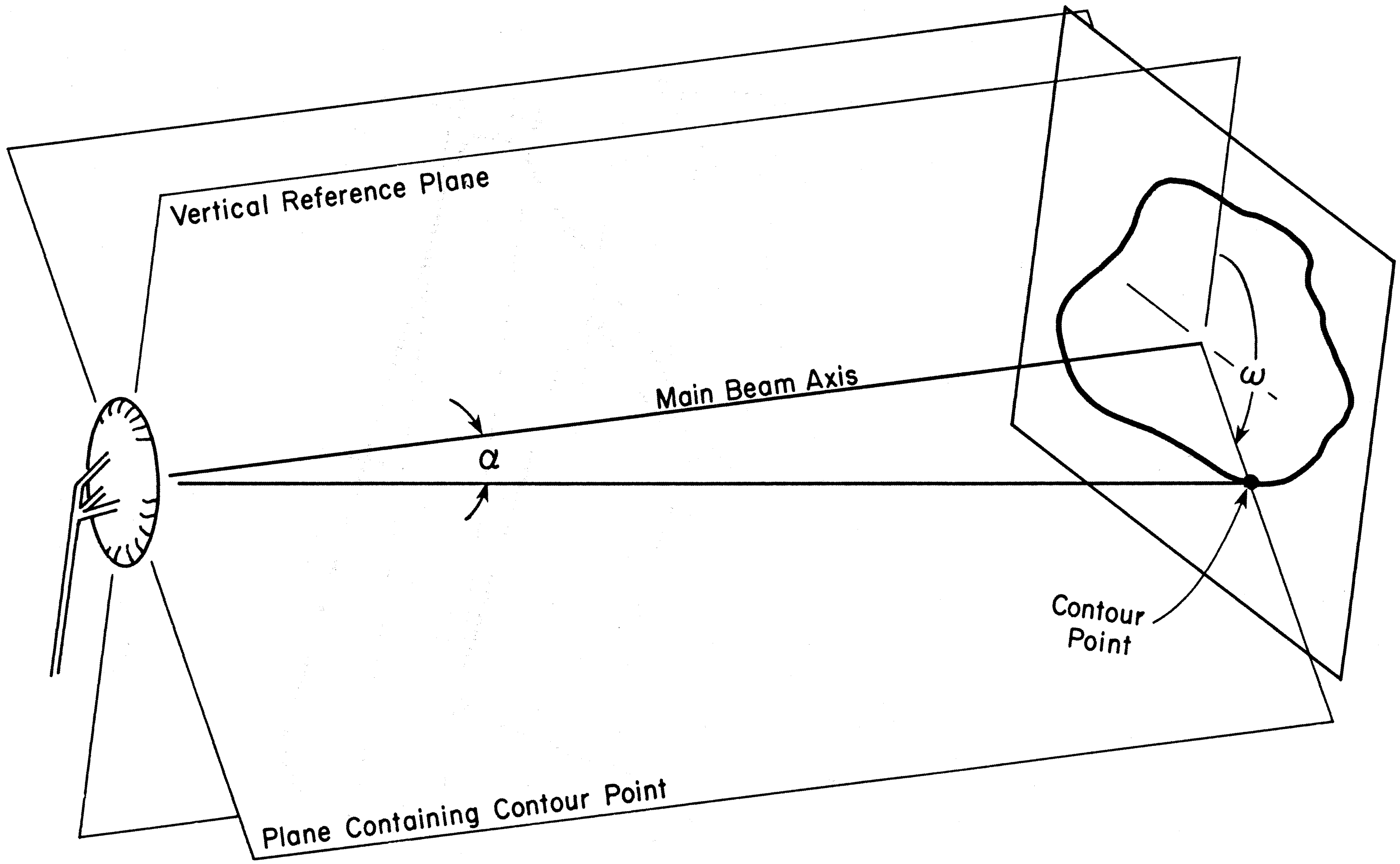

Figure A-2. The polar coordinate system, POLAR (Haakinson, Skinner, Spies, and Bridgewater, 1977).

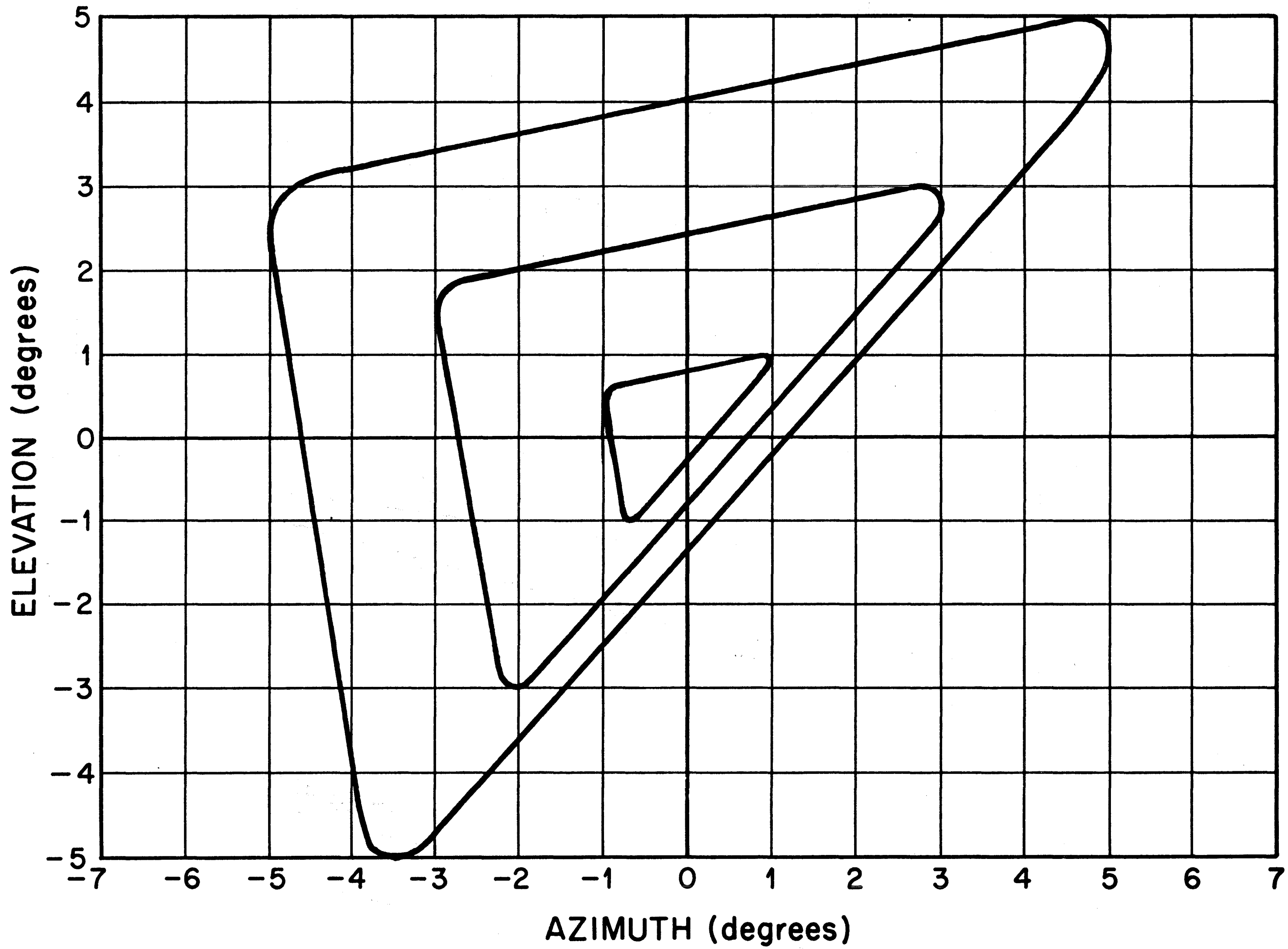

Figure A-3. Fabricated antenna pattern showing user specified contours.

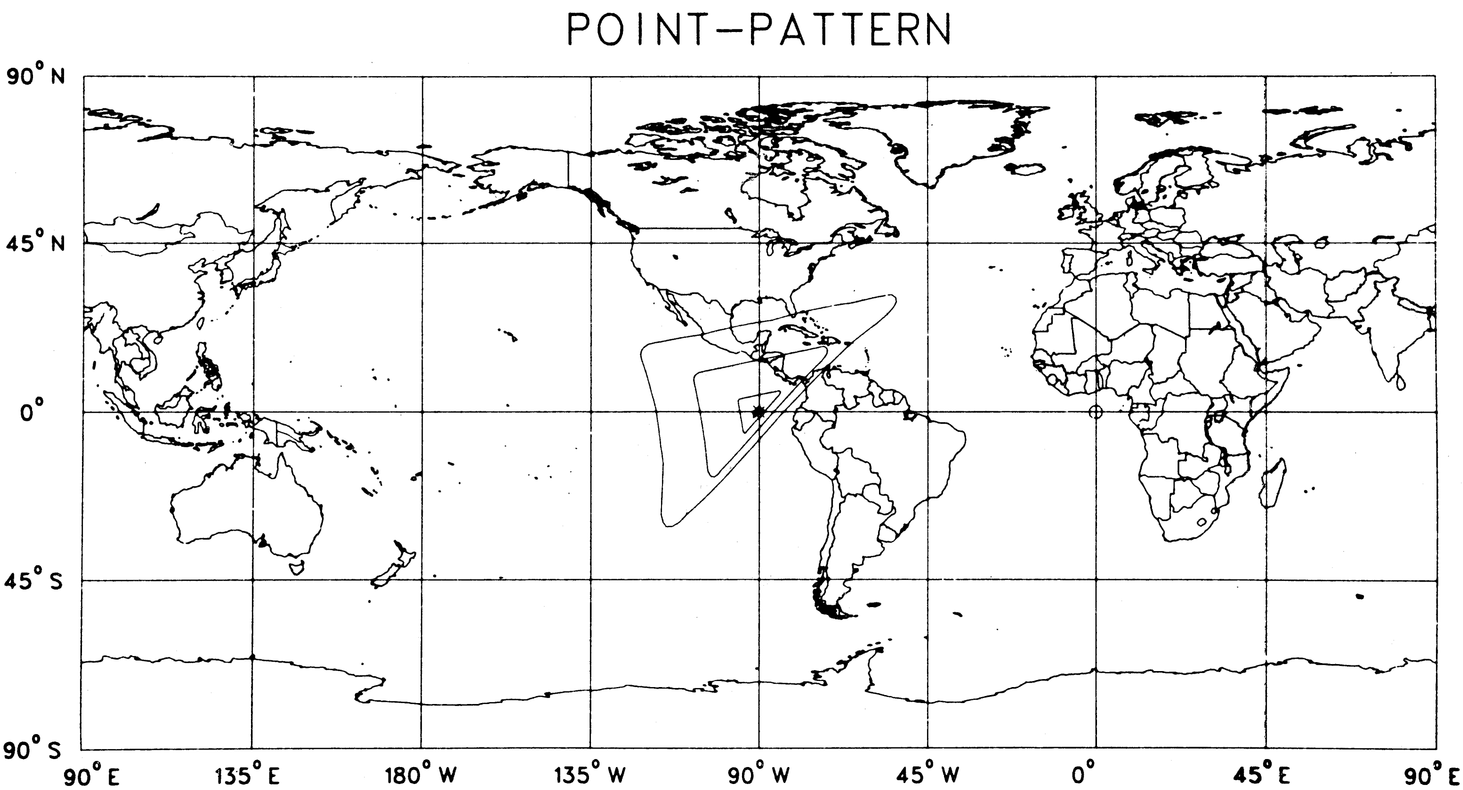

Figure A-4. Footprint plot from the point pattern of Figure A-3.

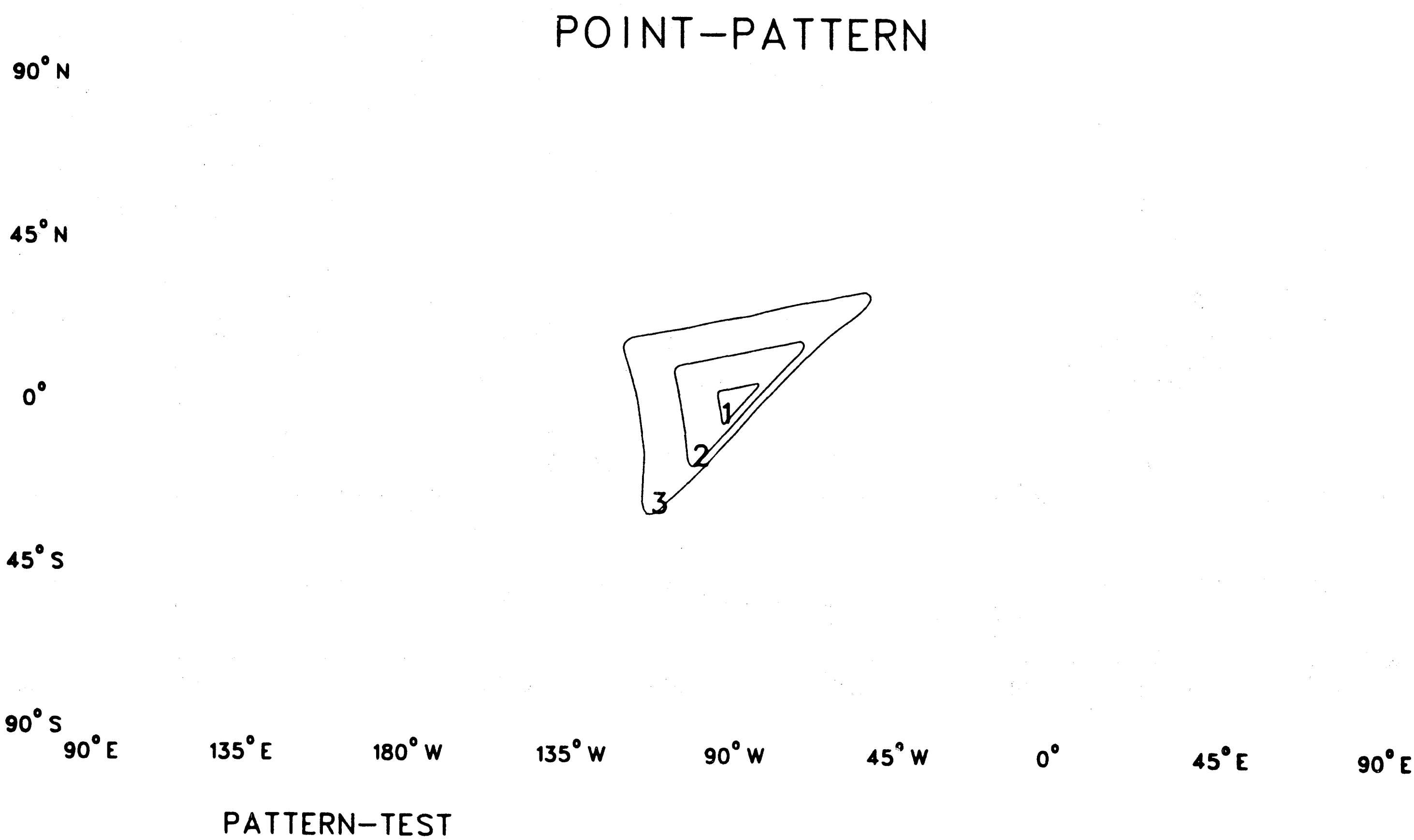

Figure A-5. Overlay of all three point pattern contours.

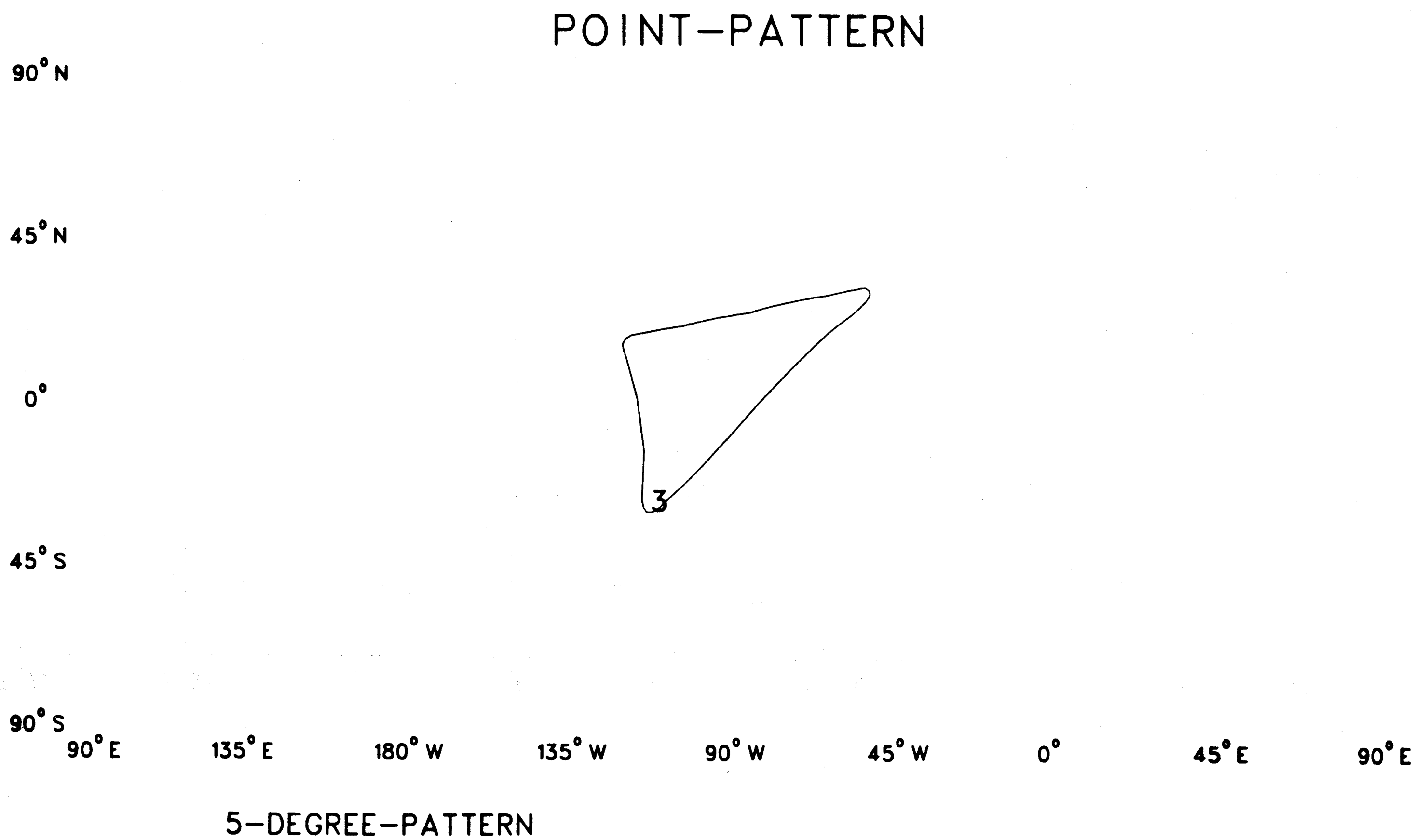

Figure A-6. Overlay of outer point pattern contour.

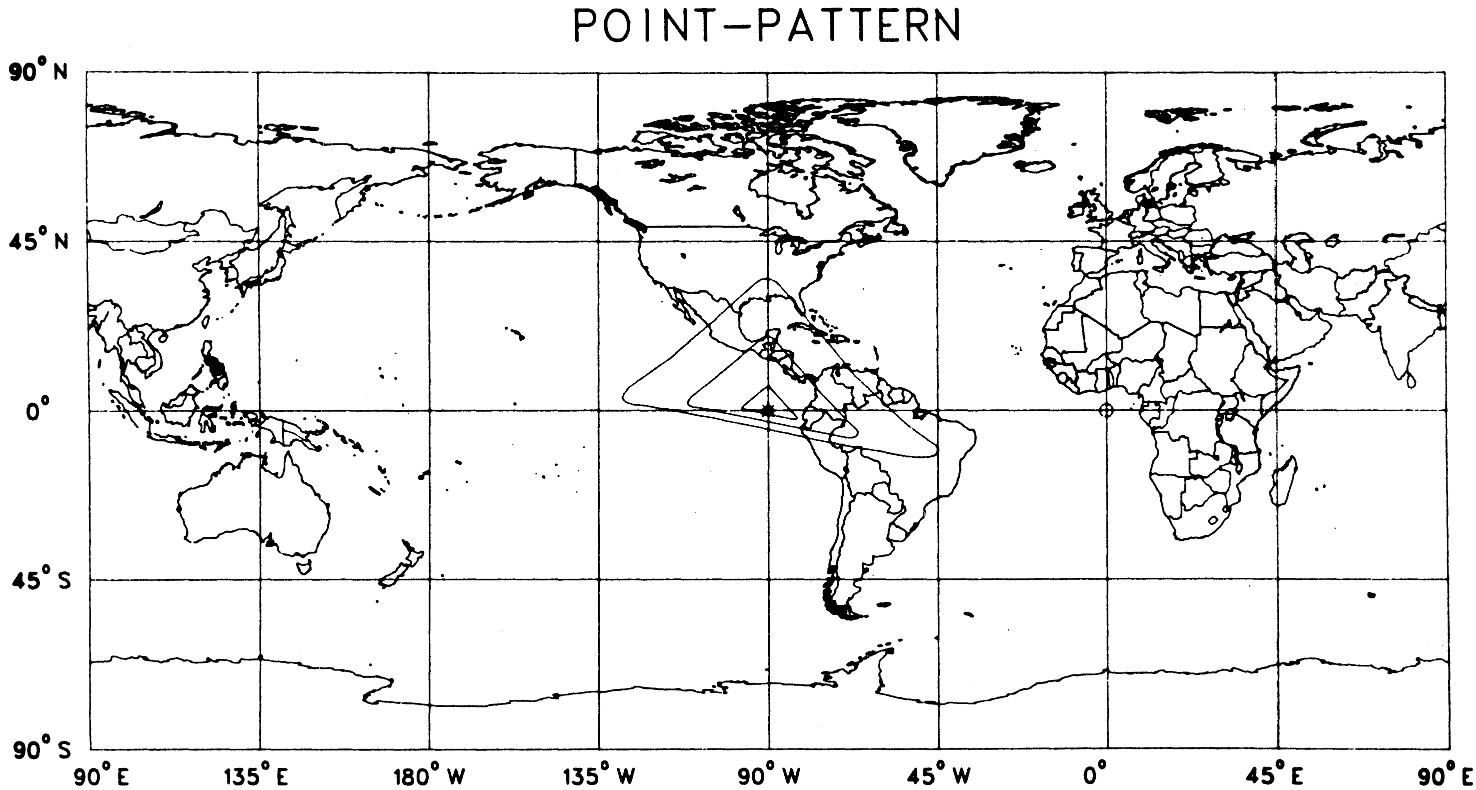

Figure A-7. Footprint plot with a 60 degree rotation of the point pattern of Figure A-3.

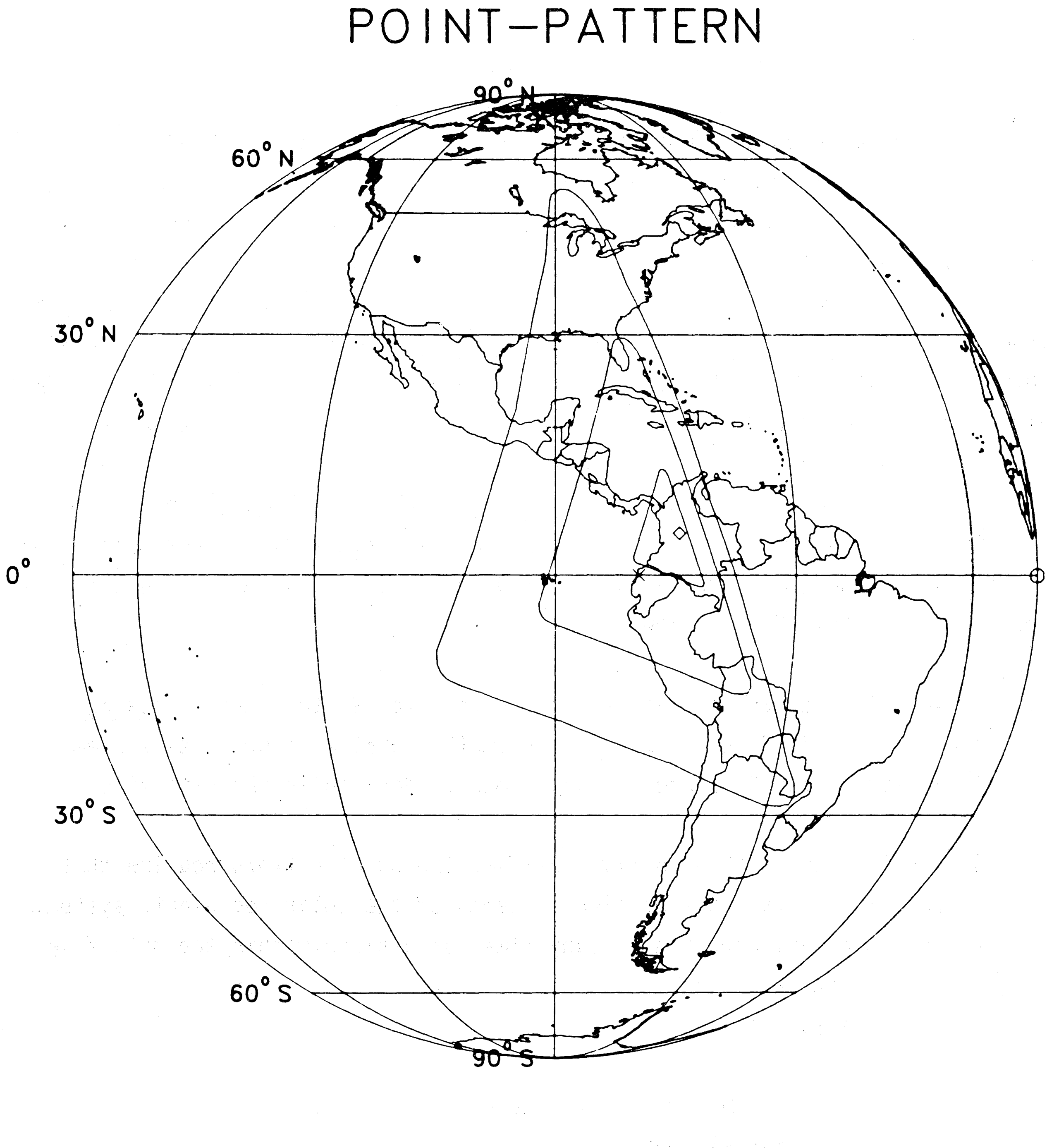

Figure A-8. Another footprint plot from the point pattern of Figure A-3.

may be specified ahead of the point pattern. If, for example, the user indicates that four footprints are to be plotted and requests a point pattern for footprint number 2, the program will not solicit information for footprints 3 and 4.

A.3 The Data File Structure

For an example of the data file in which the user stores the desired pattern data, see Figure A-9. The format of the data file is free format with commas separating the elements in each data record or line. The file is partitioned into blocks, each block containing data pairs (in AZEL or POLAR form) corresponding to points along a single contour or contour segment. The program connects all points within a given block with straight lines; thus, separate contours or contour segments must reside in separate data blocks. The last data pair in the block should be equal to the first data pair if connection of the antenna pattern is desired.

The capitalized words such as "AZEL", "OVERLAY", and "BLOCK" are called "directives" or "statements" that are used to delimit the data blocks and direct the plotting. The use of these and other directives available for the data file structure is described as follows:

AZEL

(Optional) The AZEL directive informs the program that the <u>following</u> data are specified in terms of the azimuth-elevation coordinate system. It may appear anywhere and as many times as desired in the data file.

POLAR

(Optional) The POLAR directive notifies the point pattern routine that the <u>following</u> data are specified in terms of the polar coordinate system. It may appear anywhere and as many times as desired within the data file. <u>Note</u>: If neither the AZEL nor the POLAR directives are present, the program will assume the AZEL mode by default.

OVERLAY,m,b_1,b_2,...

(Optional) Use of this directive causes the program to generate, in addition to the normal footprints plot, an additional plot consisting of a box outline, a title (specified by a separate TITLE directive), and the footprints of data blocks b_1,b_2,... . This plot will have the same dimensions and projection as the normal plot, but will not contain any map information. "Overlays" provide the user with separate displays of

```
AZEL

OVERLAY, i, b_j, b_k, .....

TITLE, i, title for overlay i

OVERLAY, m, b_n, b_p, .....

TITLE, m, title for overlay m
      .
      .
      .
      .
      .
BLOCK, n, blockname
     X,X
     X,X
      .
      .
      .
      .
      .
BLOCK, p, blockname
     X,X
     X,X
      .
      .
      .
      .
      .
                              END OF FILE (internally
                              generated by the CDC 170/750)
```

Figure A-9. Example of point pattern data file structure (ANTENn).

various combinations of contours comprising complex footprints patterns. Each overlay is identified by an overlay number "m", $0 \leq m \leq 9$; as such, up to ten different overlay plots may be generated from a single data file. Only one OVERLAY statement with a given overlay number may appear in the data file. Block numbers ($b_1, b_2, \ldots$) appearing in one overlay statement may appear in other overlay statements. OVERLAY directives must appear before the first BLOCK directive.

BLOCK,n,blockname

("blockname" optional) This directive is used to identify the beginning of a section of pattern data and to associate the data with the block number "n" ($0 \leq n \leq 99$). For every BLOCK directive encountered during program execution, the program will print the BLOCK statement along with the first 40 characters of "blockname" on the user's terminal to inform the user of the progress of computations.

SKIP,$b_1, b_2, b_3, \ldots$

(Optional) The SKIP declarative informs the point pattern routine that it is to skip the specified data blocks (identified by block number b_1, b_2, b_3, etc.). Data in the designated blocks will not be plotted on any maps or overlays. SKIP may appear anywhere in the data file as long as it precedes the block(s) to be skipped. There is no limit on the number of SKIP declaratives that may appear in a data file.

END

(Optional) This directive may be used to signal the end of a block of data. If not used, the next BLOCK directive or the end-of-file will be interpreted as the END statement for the previous set of data. If the END directive appears outside of a data block, it will be ignored.

TITLE,m,overlay-title

(Used when an OVERLAY directive is used.) This statement directs the program to print a title beneath the plot of overlay "m". Only the first 40 nonblank characters in the "overlay-title" subfield will be used; the remainder will be ignored. TITLE may appear anywhere in the data file.

The rules that apply to user input during the RUN mode also apply to each line of the data file (blanks may be used anywhere, subfields delimited) by a slash, semicolon, colon, or comma, etc.). Additionally, the user may insert comment lines into the data file by beginning each comment line with an asterisk (*). The comments will be completely ignored when the data file is being processed, and they may be placed anywhere as desired.

To minimize execution time, the user is urged to specify block numbers in OVERLAY statements in the same order as they appear in the file. For example, if the file consists of ten blocks that appear in the sequence 0 through 9, and if blocks 2, 4, 6, and 7 are to be plotted on an overlay, then the optimal OVERLAY statement should be

```
OVERLAY,n,2,4,6,7              (n = overlay number)
```

This would require one pass through the data file to plot the entire overlay. If, however, the user gives

```
OVERLAY,n,6,2,7,4
```

the program will have to sift through the entire data file three times before it finishes the overlay. This represents a very significant increase in execution time, particularly if the data file is lengthy (> 500 lines) or if several overlays are to be plotted.

FORM **NTIA-29**
(4-80)

U.S. DEPARTMENT OF COMMERCE
NAT'L. TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

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7. AUTHOR(S) K. Gamauf	9. Project/Task/Work Unit No. 910 4140
8. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Department of Commerce National Telecomm. and Information Administration Institute for Telecommunication Sciences 325 Broadway, Boulder, CO 80303	10. Contract/Grant No.
11. Sponsoring Organization Name and Address U.S. Department of Commerce National Telecommun. and Information Administration Institute for Telecommunication Sciences 325 Broadway, Boulder, CO 80303	12. Type of Report and Period Covered NTIA Report 13.

14. SUPPLEMENTARY NOTES

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 use of the revised computer program FOOTPRINTS. The Program automatically computes and plots earth footprints and service area polygons on a map projection of the earth's surface. The program can be used as a design tool to maximize geostationary satellite antenna coverage over a particular portion of the earth's surface and to limit potential interference in adjacent areas.

This program is a revised version of a program written several years ago at the Institute for Telecommunication Sciences. The program can accommodate a broad range of user-supplied input details ranging from minimal information to very specific antenna pattern data. The program is written in the FORTRAN IV computer language for use in an interactive (time-sharing) mode on a CDC 170/750 computer.

This manual provides a general description of the FOOTPRINTS program, explains the execution of the program, including the input of the required information, and interprets the program output. Sample executions of the program also are provided.

Key Words: Broadcasting Satellite Service; computer program; footprints; geostationary satellite; service area

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