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AN AUTOMOBILE ANTENNA EVALUATION SYSTEM

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EXECUTIVE SUMMARY

Normally the performance evaluation of an automobile antenna requires that the automobile be placed on a rotating platform and received signal be recorded as the automobile is rotated. Obviously, this restricts the performance to a laboratory environment.

The present report describes a portable automobile antenna system which is capable of providing the antenna response at any desired location. The antenna response is obtained by driving the test car at any desired location around a chosen circle of small radius. The azimuth information is obtained from an electronic compass mounted on the roof of the car. The (commercial) air signal received by the test antenna mounted on the automobile, the signal received by a standard antenna developed for the system and the azimuth information are fed to a data acquisition system which is controlled by a small computer. All data are stored and processed digitally and results are plotted in standard polar plot format. Enough information is provided so that the absolute or the relative (to a standard antenna developed for the purpose) gain of the test antenna can be obtained. The system is portable and, hence, antenna performance can be evaluated in urban or any other desired environment.

This is a first prototype system. Improvements can still be made in data storage and signal processing capability of the system. The speed of the printing system is slow at the present and can be improved if so desired.

TABLE OF CONTENTS

I. INTRODUCTION

This report describes the development of a portable system capable of evaluating the performance of an automobile antenna. The objective of the program has been to design and develop a standard antenna and associated electronics system so that the performance of a variety of entertainment antennas mounted on automobiles may be evaluated by receiving commercially available signals. The frequency bands of interest are AM, FM, CB, VHF and UHF. Basically, the system compares the response of the antenna under test to a desired signal with that of the standard antenna.

II. THE STANDARD ANTENNA

2.1 Design of the Antenna

The design of the standard antenna was obtained by using the well-known broadband properties of biconical and discone antennas [1] [2]. Figure 2.1 shows a sketch of the standard antenna system which essentially consists of a coaxial fed monopole using a 5-ft diameter circular ground plane. The monopole element is an inverted cone of angle 2α, base $2b$, height h and slant-height L as shown in the figure. For convenience we have chosen a cone angle $2\alpha = 60°$ so that the geometry then indicates

$$\begin{aligned} b &= L/2 \\ L &= 1.15\ h. \end{aligned} \tag{1}$$

Satisfactory broadband performance from such an antenna can be obtained over a 3 to 1 band of frequencies provided the parameter L is chosen as [1,2]

$$L = 0.38\,\lambda \tag{2}$$

where λ is the wavelength at the lowest frequency of the band.

It is evident that the same antenna cannot be used satisfactorily for the AM to UHF bands of frequencies. We have designed the antenna for the following two bands of frequencies: 90-300 MHz - Band 1; 300-1000 MHz - Band 2. The required parameters L and h, as obtained from Eqs. (1) and (2) are:

$L \simeq 15''$, $h \simeq 13''$ for Band II.

$L \simeq 50''$, $h \simeq 43''$ for Band I.

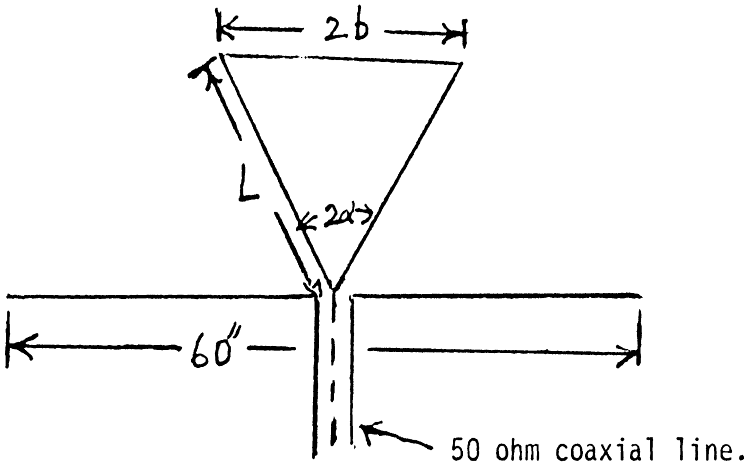


Figure 2.1 A sketch of the standard antenna.

Both antennas use 60" diameter circular ground plane. It is assumed that the Band I antenna will be suitable for the AM-band also.

For transportability, the Band 2 antenna and a part of its ground plane is designed as one compact unit; the full ground plane and the Band 1 antenna configuration can then be obtained as simple extension of the Band 2 antenna.

The monopole element for Band 2 is fabricated as an inverted cone from a solid block of aluminum; the Band 1 cone configuration is obtained as an extension of the cone height to the required value. The extension is obtained by introducing a number of inclined metal rods along the rim of the solid cone base.

The ground plane in the compact unit consists of a 15" - diameter aluminum sheet. It is extended to its full size (60" diameter) by introducing a number of radially oriented metal rods along its rod.

Thus, the compact unit occupies a space of approximately 15" x 15" x 15"; the design was such that the standard whip antennas (length 32") used in automobiles can be used as the required extension rods.

2.2 Construction of the Antenna

Based on the design discussed in Section 2.1, the standard antenna was constructed using twenty four (24) 32"-long standard whip antennas for ground plane and cone extensions. A photograph of the Band 1 antenna configuration is shown in Fig. 2.2. The antenna has a 15-inch diameter aluminum ground plane which is

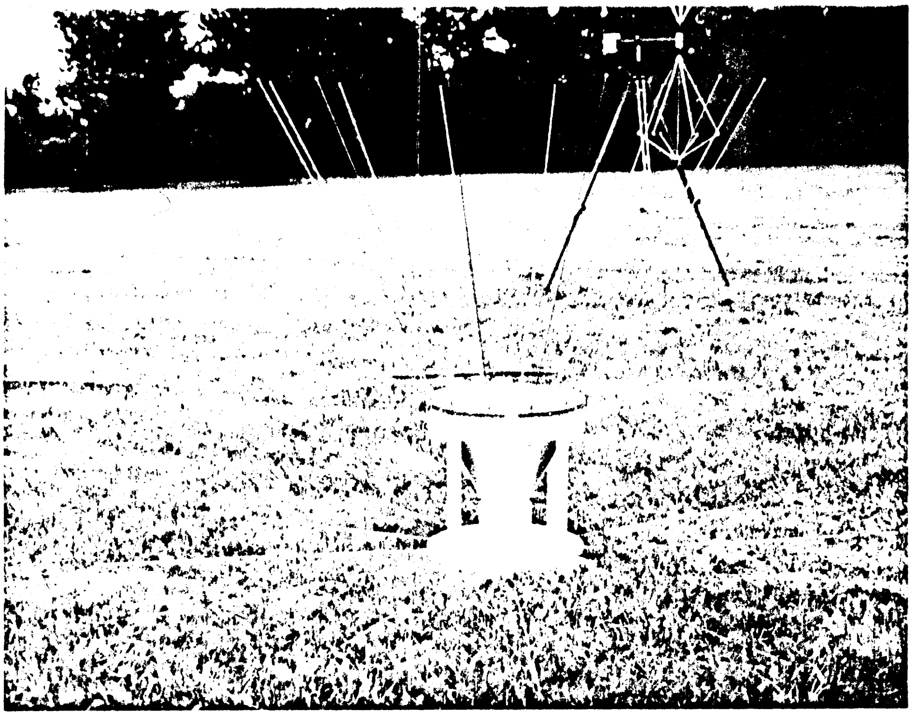


Figure 2.2 A photograph of the standard antenna.

extended to the full size with the help of 12 equally spaced and radially oriented whips attached to the edge of the aluminum ground plane. A BNC antenna connector is also attached on the outer edge of the ground plane. A 0.141 semi-rigid (50Ω) coaxial cable goes from the connector to the tip of the cone which rises from the center of the ground plane. The cone is made of aluminum and is 13 inches high having a total angle of 60 degrees. The cone is then extended in size by adding 12 standard whips equally spaced around edge of its base. For ruggedness, a plexiglass cylinder is used at the base of the cone as well as three nylon pillars to support the cone.

The antenna is also mechanically designed for conversion to a simple monopole. In such case the cone is removed and is replaced by a single whip antenna at the center of the ground plane.

2.3 Measured Impedance Characteristics

Impedance characteristics of the standard antenna were measured using a Hewlett Packard 3510A network analyzer and a capacitance meter. Since the network analyzer covers the range of frequencies 45 MHz to 18 GHz, the measurements were carried out over 45 MHz to 1000 MHz. Figures 2.3 and 2.4 show the VSWR characteristics of the antenna with and without extensions, respectively. As expected, the performance of the antenna without extensions is better (VSWR $<$ 1.5) but over a limited frequency range. With addition of extensions the low frequency (45-100 MHz) performance is drastically improved (Fig. 2.4),

Figure 2.3 Measured VSWR characteristics of the standard antenna (Band 1: with extensions)

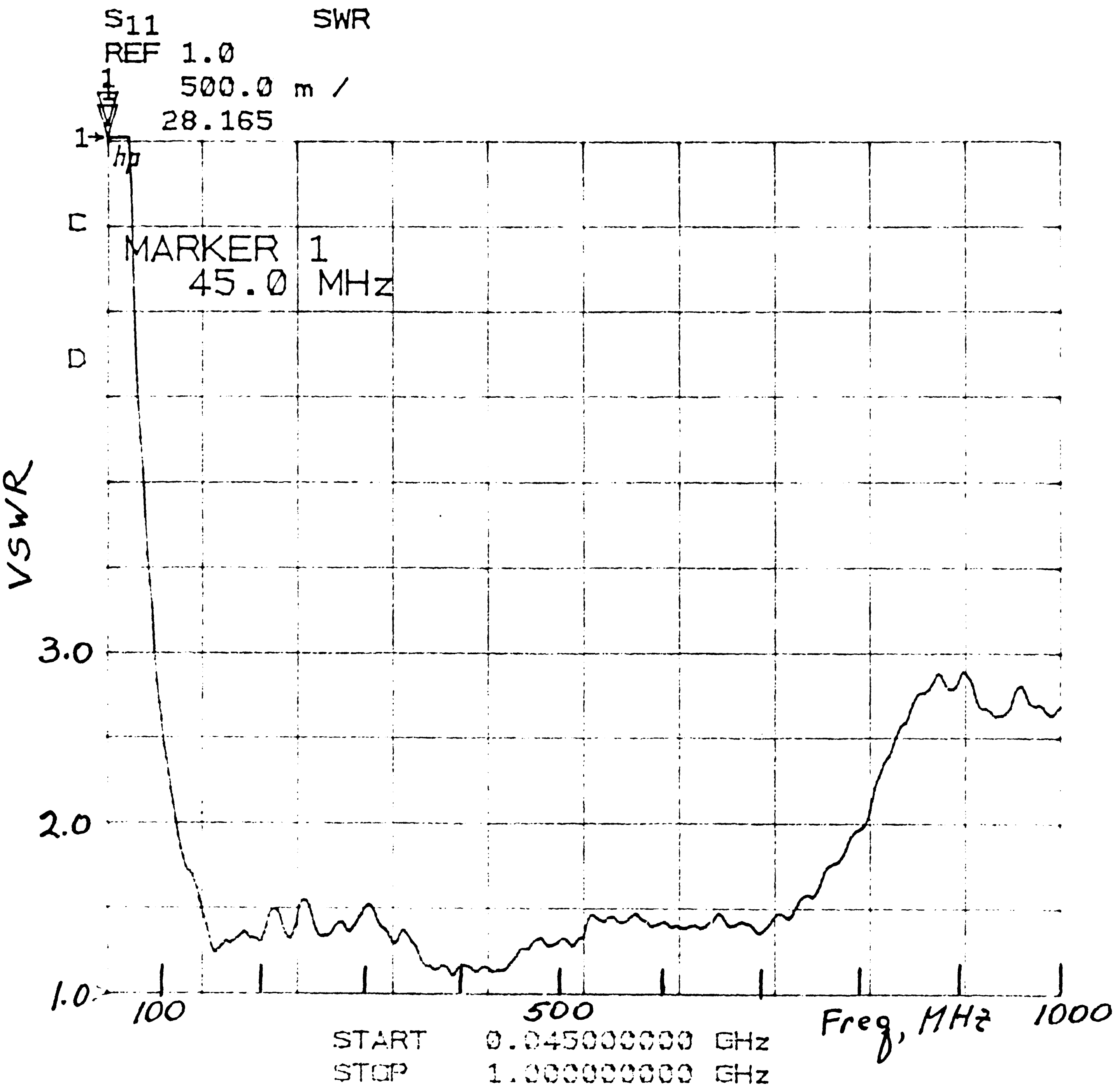
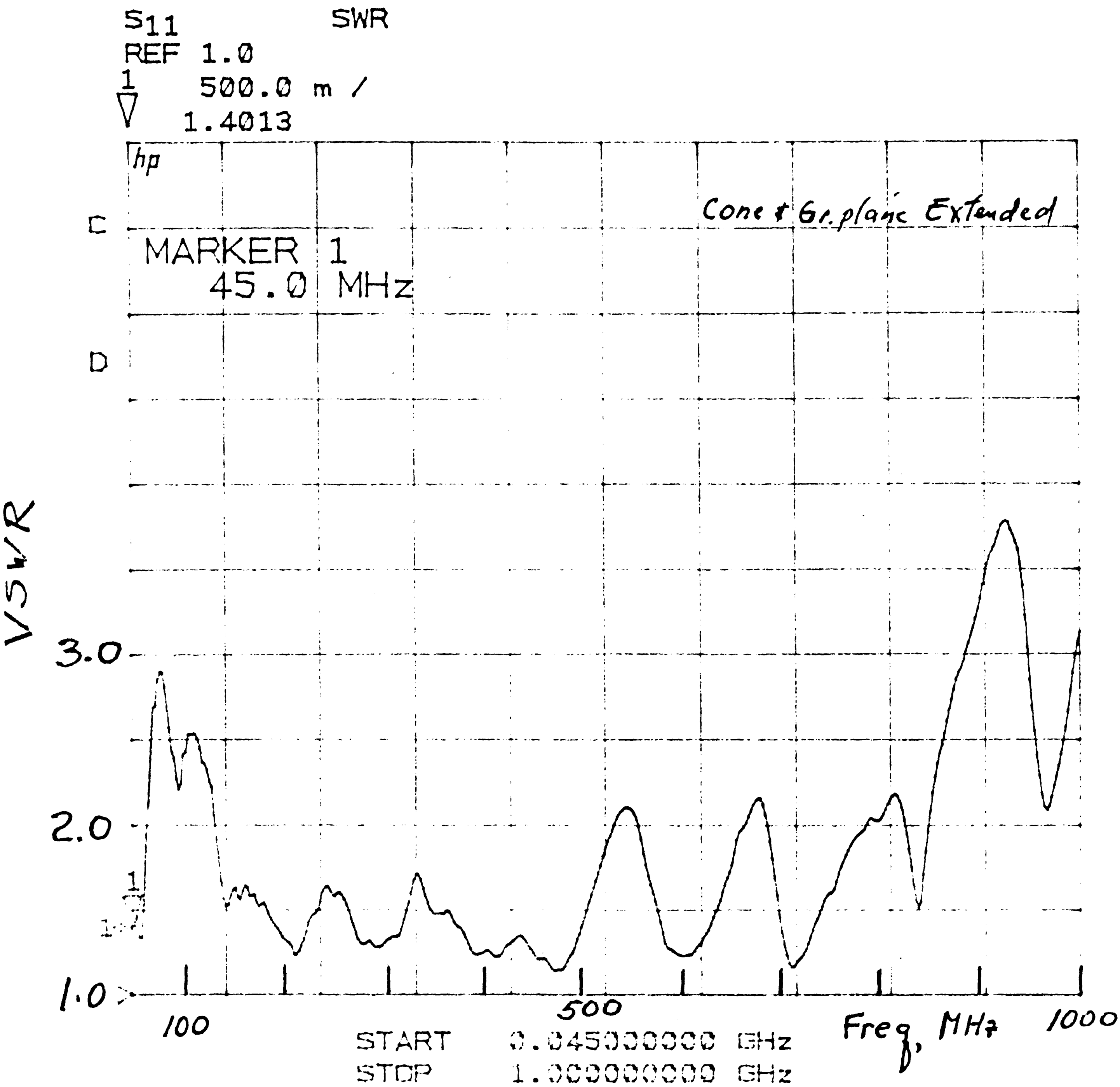


Figure 2.4 Measured VSWR characteristics of the standard antenna (Band 2: without extensions).



although there is a slight increase in VSWR (VSWR < 2) in the midrange (140-800 MHz). Overall, it is therefore suggested that the extensions be always used.

2.4 Gain Characteristics

The gain vs frequency for the standard antenna was obtained by comparing the measured response of the standard antenna with that of three different reference antennas when they were illuminated by a signal of desired frequency. The following three different reference antennas of known gain were used:

(i) Monopole. The monopole element consisted of a metallic rod of length 108" and diameter 0.75". A FET amplifier with C_m 5 pF and G_v = -2.6 dB was used to couple the antenna to a 50 ohm receiver. The gain of the antenna can be obtained by using "short antenna theory" and is given by

$$G_{AM}(dB) = 20 \log \left[\frac{4\pi}{\lambda^2} \; \frac{\sqrt{\Gamma o/\varepsilon o}}{50} \left(\frac{L}{2}\right)^2\right] - 2.6dB \qquad (3)$$

where,

$L = 2.8$ m (108"),

λ = wavelength in meters,

$\sqrt{\frac{\mu_o}{\varepsilon_o}}$ = impedance of free space

$= 120\pi$ ohms.

The operation of the monopole is limited to frequencies below 30 MHz.

(ii) Biconical Antenna. This was a standard EMI antenna designed per MIL-STO-461A and operates in the range 30-200 MHz. Similar antennas are also available from EMI antenna manufacturers.

(iii) Dipole Antennas. These were tuned dipoles and (three of them) were used for measurements in the range 100-1000 MHz. The dipoles were made by Ailtech.

Fig. 2.5 shows photographs the various antennas. The gain vs frequency for the standard antenna is shown in Fig. 2.6 where the values obtained from the individual reference antennas are also indicated. The gain of the standard antenna is found to be low at low frequencies because it feeds a 50 ohm load. With increase of frequency the gain increases and approaches 0 dB (isotropic) at higher frequencies. The oscillations in the results are probably due to resonances of the (whip) extensions and are also evident in the VSWR results (Fig. 2.4) around 100 MHz.

Figure 2.5 Photographs of standard and reference antennas (used for gain calibration)

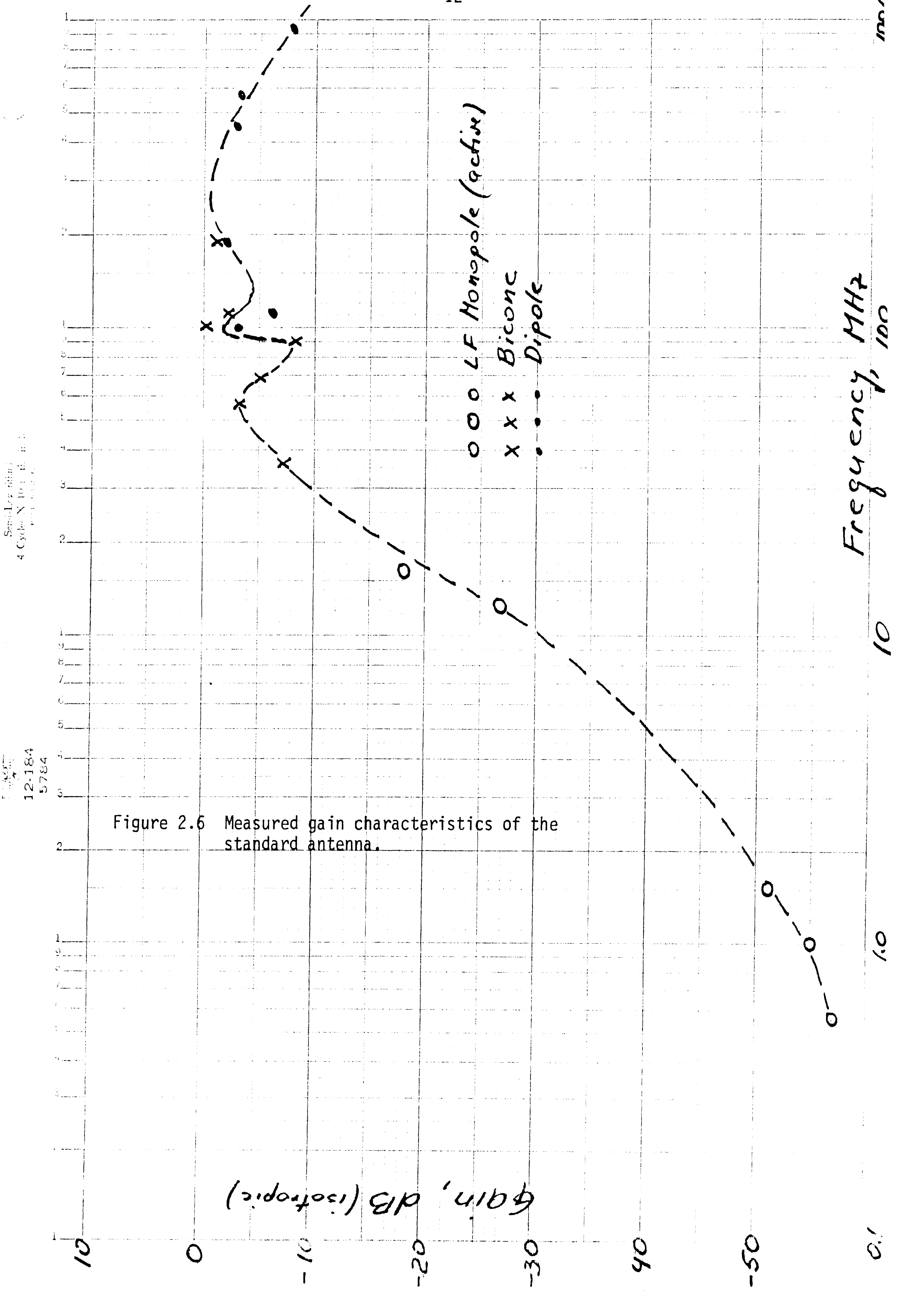


Figure 2.6 Measured gain characteristics of the standard antenna.

III. THE SYSTEM DESCRIPTION

The complete antenna evaluation system consists of (a) an electronic package, (b) the vehicle test antenna and the standard or reference antenna and (c) an electronic compass that can be mounted on the roof of the test vehicle. The standard antenna characteristics have been discussed in Section II. In the following sections we describe the other components of the system and give some results obtained from sample measurements.

3.1 Hardware

A block diagram showing the hardware configuration of the complete system is given in Fig. 3.1. For the sake of discussion the system is divided into section as shown in Fig. 3.1. The first section encompasses the analog signal path of the system. This includes the reference and test antennas, the receiver and the electronic compass. The reference and test antennas are connected to a receiver which in turn is connected to the HP 3421 A/D converter or the Data Acquisition System. At the present time the receiver is a spectrum analyzer powered by a 12 VDC to 110 V AC inverter. The electronic compass (mounted on the roof of the test vehicle) produces a continuous analog x-y pair of signals depending on the orientation of the vehicle in the earth's magnetic field contaminated by the test vehicle. These directional signals are then also fed into the HP 3421 A/D converter. In the analog section of Fig. 3.1, all of the cables are marked according to their respective function. Since the

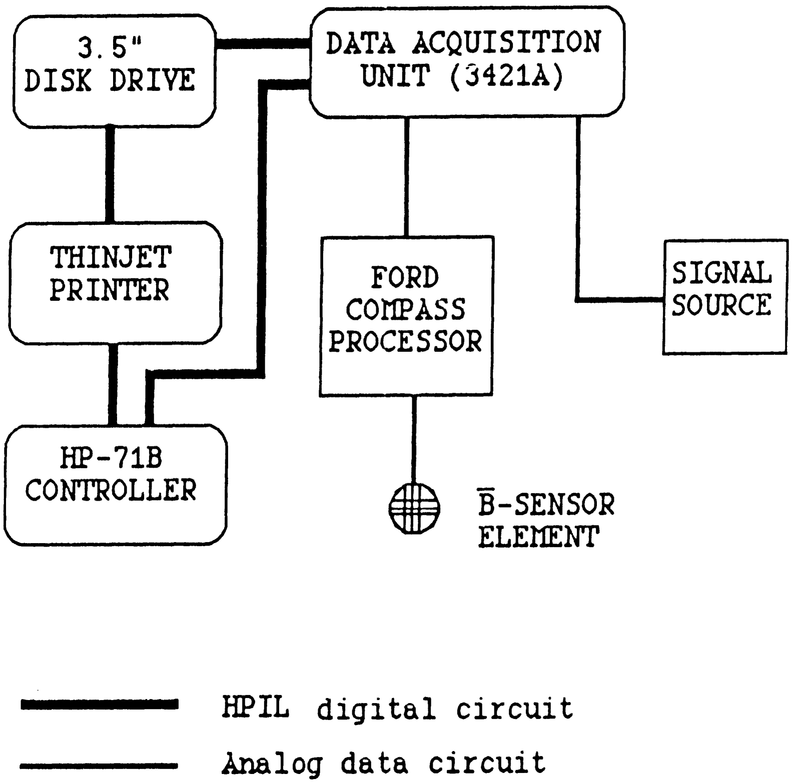


Figure 3.1 Hardware configuration.

HPIL is a serial poll bus, the order in which the various devices are interconnected is important for proper operation of the system. Currently, the printer is the first device connected to the HP-71B followed by the disk drive and finally the HP 3421 data acquisition unit.

The second section comprises of the digital processing storage and the output part of the system. It consists of an HP-71B controller/computer, the HP 3421 A/D converter, an HP 9114 3.5" floppy drive and a Think-Jet printer, all connected to an HPIL bus structure for interdevice communication. The floppy drive serves to store programs, calibration and test data. The Think-Jet printer has a 640 x 640 pixel graphics capability and prints the final polar plot. The HP-71B does all the necessary data processing operations.

3.2 Software

There are numerous subroutines in the software package, but there are only three main divisions on the operator level. The general layout can be followed from Fig. 3.2 showing the software configuration. We shall now look at each subroutine as it fits in the general scheme of operation (for detailed instructions on operation see Section 3.3).

The first main system operation consists in collecting a compass calibration reading. As can be seen by viewing Fig. 3.3, the MAIN module (Fig. 3.3) calls the GETCAL (Fig. 3.4) subroutine which runs through the compass calibration procedure. After answering a few housekeeping questions, the routine starts to

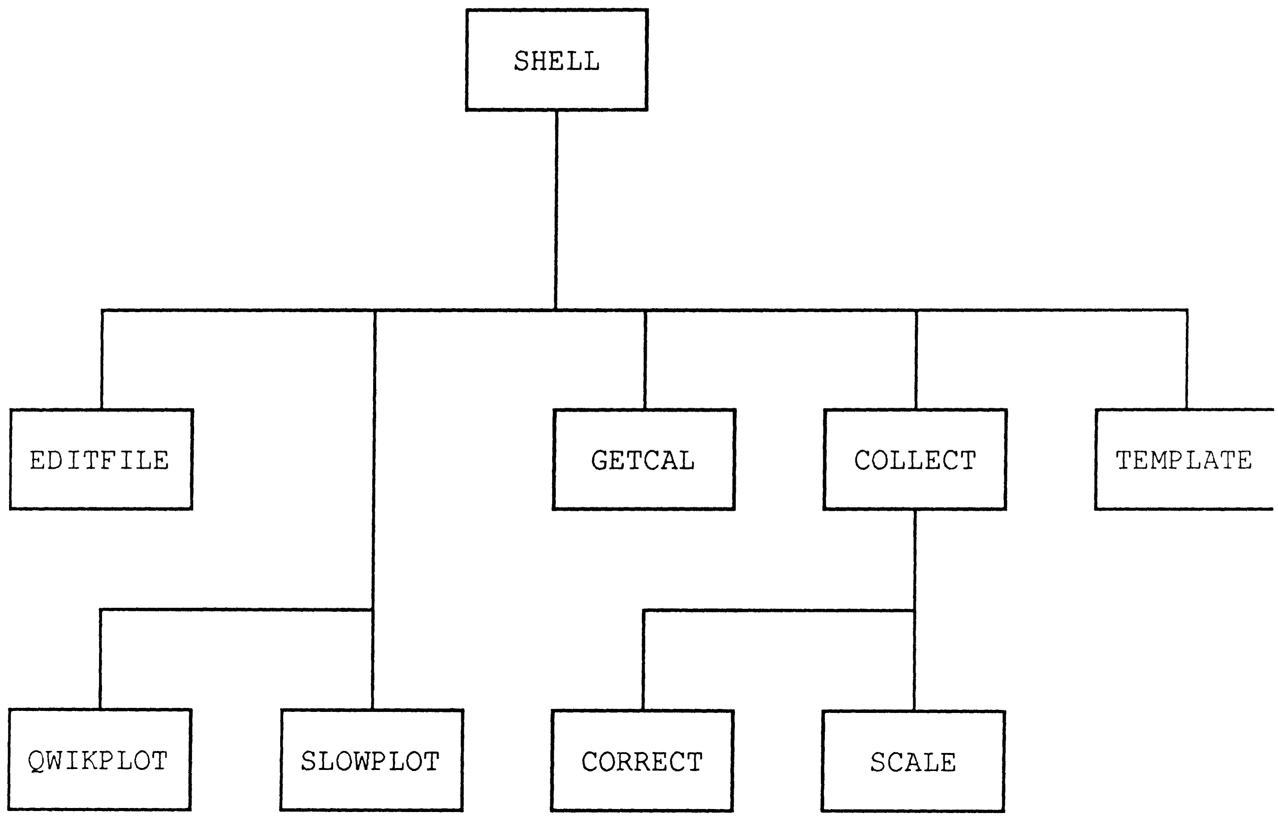


Figure 3.2 Software configuration.

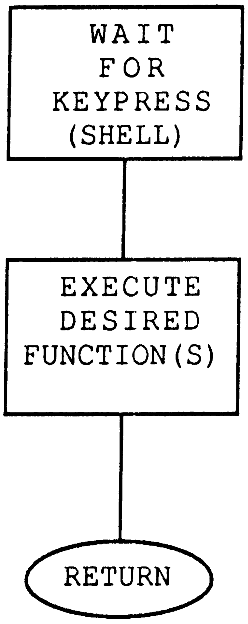


Figure 3.3 SHELL logical flow.

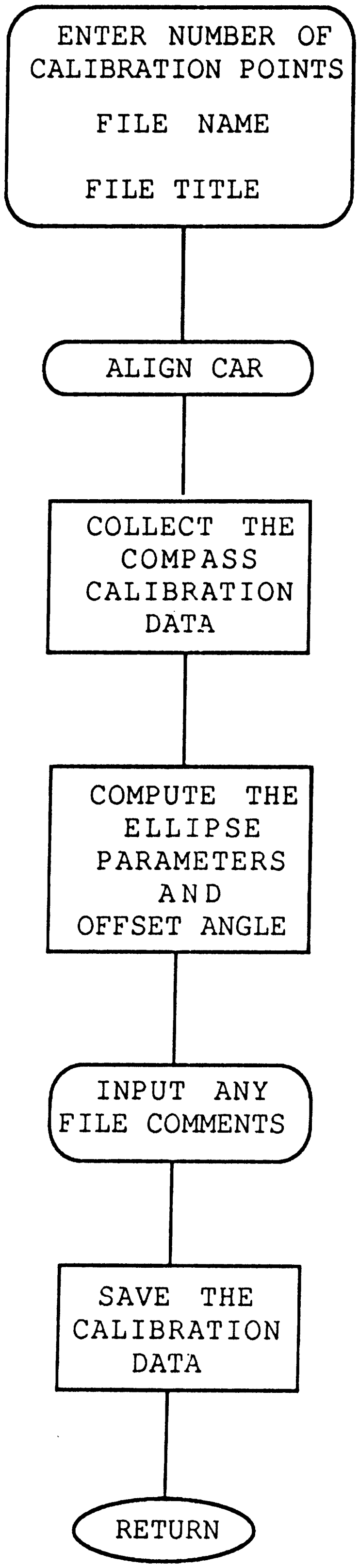


Figure 3.4 GETCAL logical flow.

collect data from the compass as the car drives counterclockwise in a circle. This produces a calibration file which is used to correct the angular data for the antenna measurements. The response of the compass in the most general circumstances is expected to be a rotated-and-translated ellipse. After the raw data are read in, they are processed to extract general parameters of this ellipse; its tilt with respect to the X-axis, major and minor axes, and its center are obtained. Since the car's starting position is known, any later measurements can be mapped onto this calibration ellipse.

The second main system operation is the collection of the radiation pattern of an antenna. The subroutine invoked is called COLLECT (Fig. 3.5) and it performs several tasks. In the first measurement it collects a reading of the reference antenna. It then waits for the operator to switch to the test antenna and position the car before collecting radiation pattern data. After the collection run, it calculates the minimum and maximum signal levels and calls the SCALE subroutine (Fig. 3.6), which rescales the raw signal levels into dBm (SCALE must be modified if the receiver is changed in order to preserve any sense in the rescaled amplitude levels). The next subroutine called is CORRECT (Fig. 3.7) which takes the angular data and corrects them using a previous compass calibration result, storing the result. It then returns to the MAIN module.

The third main system operation is (Fig. 3.7) plotting the data. Two subroutines are currently resident for this. The

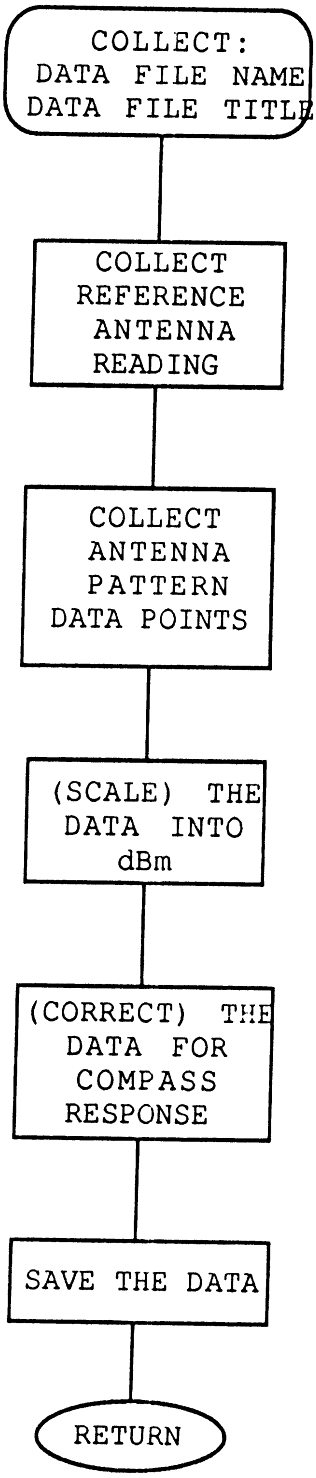


Figure 3.5 COLLECT logical flow.

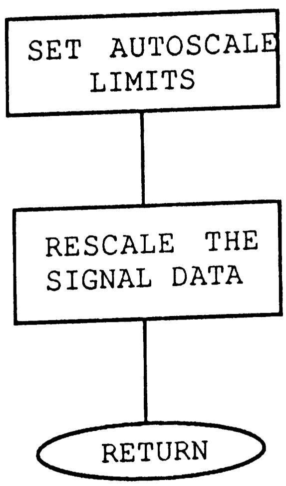


Figure 3.6 SCALE logical flow.

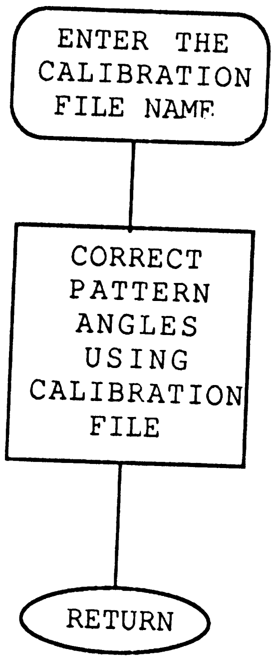


Figure 3.7 CORRECT logical flow.

first is called QWIKPLOT and it plots a rough character-oriented picture of the antenna radiation pattern; the results do not have a high level of detail and are most often used as quick checks on the validity of the data collected. The second subroutine is called SLOWPLOT and it produces a pixel-oriented picture of very high resolution. Its main disadvantage is that it is rather slow (on the order of about 15-20 minutes). The user can specify a reference value for a particular plot so that two different plots can be compared.

3.3 Operations

The first program that has to be run is the MAIN module. This sets up the user-defined keys on the HP-71B and primes the system to response to the user. Note that if any of the subroutines mentioned in the SOFTWARE section are not in RAM then eventually there will be an error and loss of data could result; error handling is minimal due to the lack of memory on the HP-71B. Make sure that all subroutines are loaded on the disk as well is SLOWPLOT is invoked; virtually all other subroutines are cleared to get enough memory to produce the image.

In order to collect meaningful data, the first thing to run is the GETCAL routine by pressing the appropriately labelled key. The first question it asks is how many points are to be taken for the calibration. Although it's better to take as many data points as possible memory constraints give an upper limit of about 100. The second question it asks is what to name the calibration file - usually this is in the form of: FCxxxx where xxxx is a four digit value. The second question it asks is for a title to the calibration file; it is also a good place for comments. The program then waits until the car is pointing in the starting position. A good technique is to slowly drive the car in a circle and when the start position is reached press ENDLINE (this prevents bunching of points as would happen if the car has to accelerate otherwise). Practice is a good idea to get the feel of how long the system takes to acquire the necessary number of points. After a few seconds of crunching, the program will save the calibration file and return to the MAIN module.

At this point the system is ready to take data for an antenna. Press the key labelled COLLECT to start. The first question is how many data points you wish to take - usually just the same number as the calibration routine. The program then asks for the data file name (usually FDxxxx) and the file title, which will be displayed on the polar plots. The next question is whether the reference antenna is connected to the receiver. If not, connect it and then press "Y" followed by the ENDLINE key. The system will then take the reference antenna reading. After this, connect the test antenna to the receiver and press ENDLINE to start taking the test antenna pattern data. When the measurement is finished, the unit will beep and process the raw data just taken. It then asks for the transmitter frequency and location, followed by asking for any comments. When the data is corrected the system will ask for the appropriate calibration file to use.

The corrected data is then saved. This procedure can be repeated a number of times, but memory constraints will cause an OUT OF MEMORY error to occur; if this happens, flush the memory by purging all the current data files -- do not purge the calibration file.

The other main activity is to plot the data out and see the results. There are two programs for doing this; QWIKPLOT and SLOWPLOT. Press the appropriate key to run either one. QWIKPLOT is faster, but the resolution is rather bad, especially if the antenna has a deep null pattern. SLOWPLOT is much better in detail, but takes about 15-20 minutes for a 100 point data file.

When some changes are wanted in the acquired data EDITFILE can be called (Fig. 3.8). This program allows changing file names, comments, reference signal levels, etc., that otherwise may require repeating measurements.

3.4 Data Collection Procedure

As mentioned in the Introduction the purpose of the Antenna Evaluation System is to obtain the performance characteristics of an automobile antenna receiving a desired signal. The system developed is capable of producing the complete horizontal plane response of the antenna to commercial signals available at a place, i.e., in effect it produces the horizontal plane pattern of the antenna mounted on the car at the desired frequency. The system requires the following data to be collected systematically at a place where the antenna response is desired.

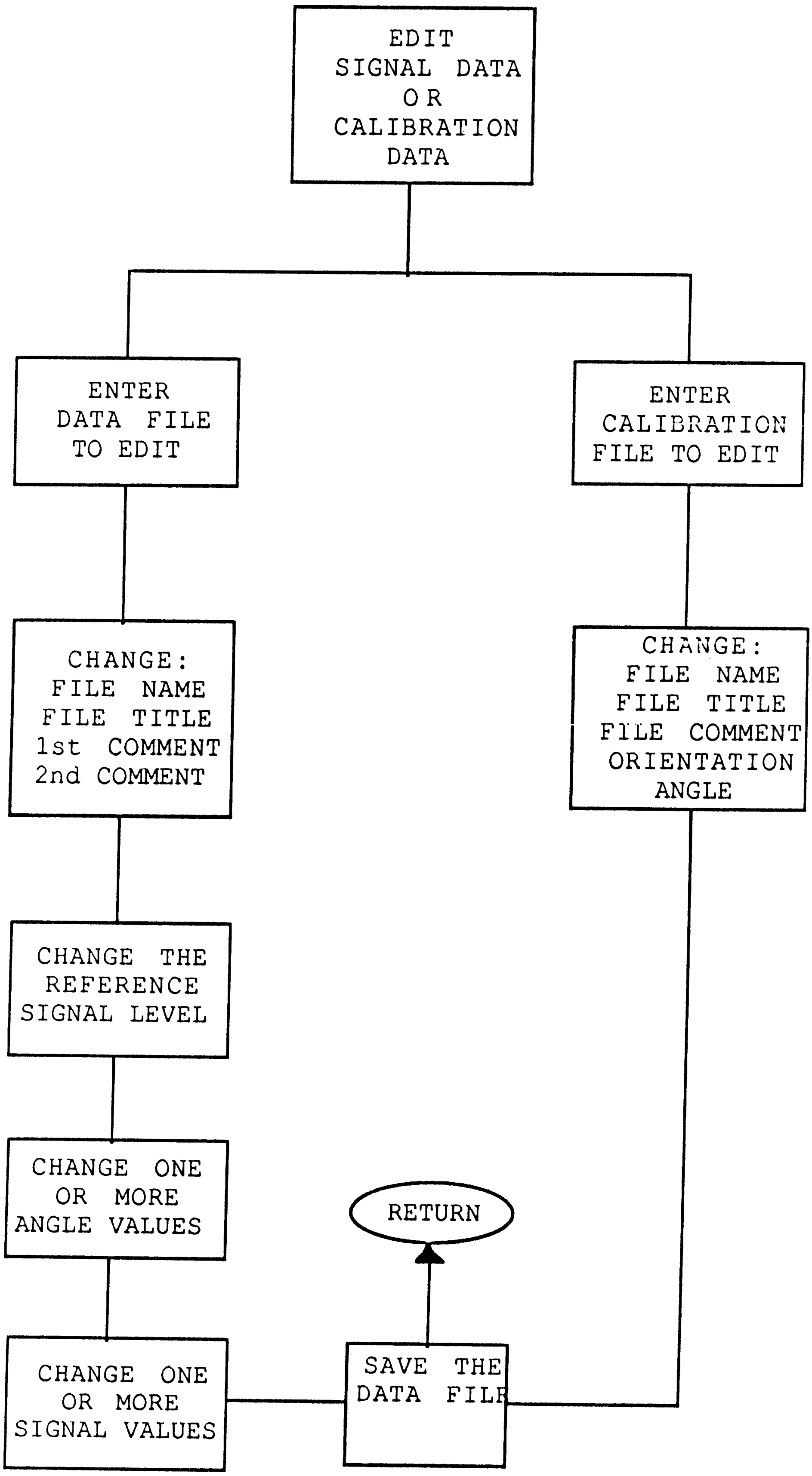


Figure 3.8 EDITFILE logical flow.

(a) Compass Data: With the compass placed at the roof of the antenna and connected to the system as described in section 3.2, data are collected as the car is driven slowly around a circle of convenient radius, the center of the circle being approximately the desired place. Remove the compass.

(b) Reference Antenna Data: Place the standard or reference antenna at a convenient place near the circle mentioned above and connect it appropriately to the system. Then collect the data appropriate for the desired signal. Remove the standard antenna.

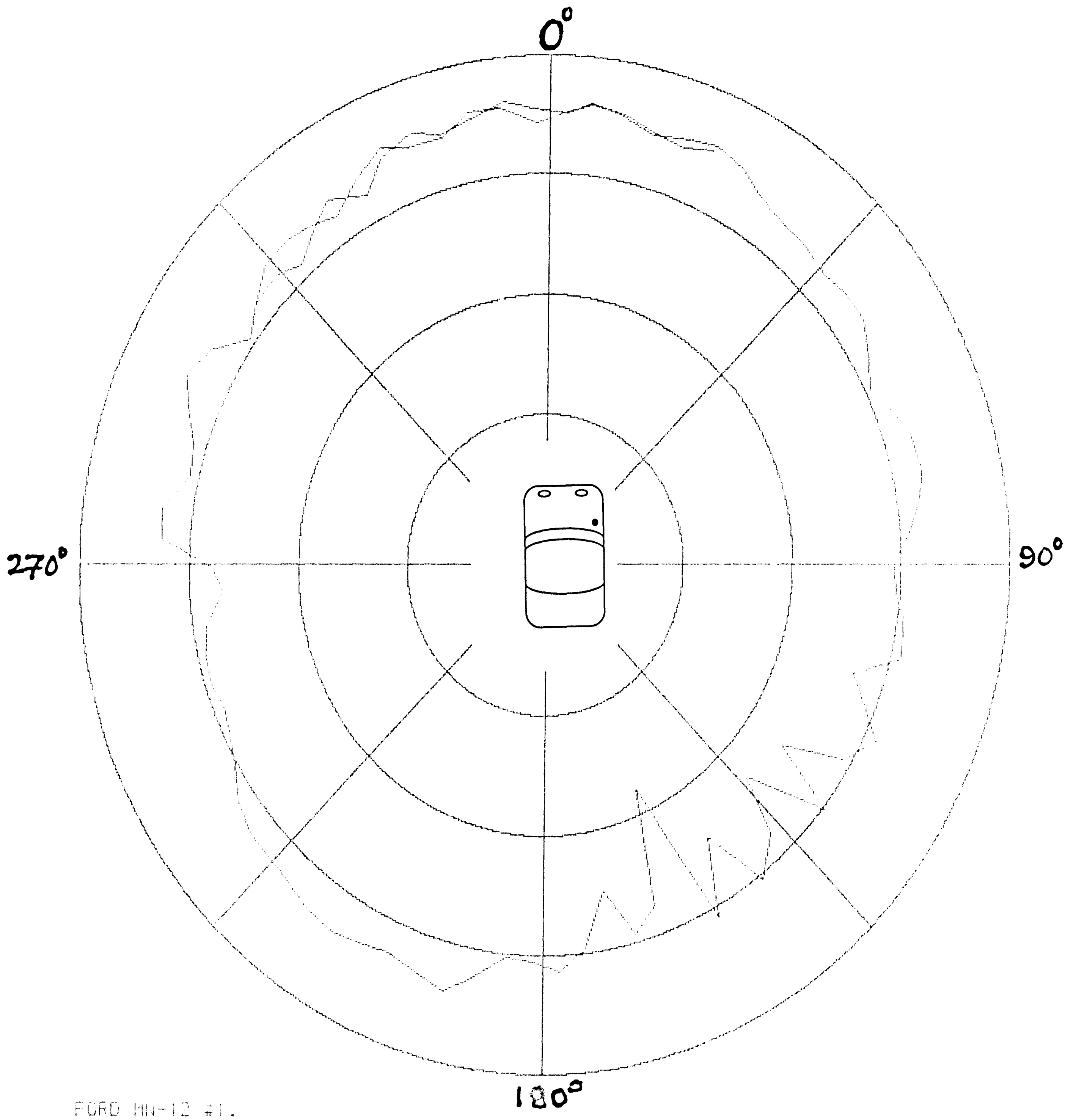
(c) Automobile Antenna Data: Connect the antenna appropriately to the system. Collect data appropriate for the desired signal as the car is driven around the circle described earlier. Remove the antenna connection.

At every place where the antenna response is desired, procedures (b) and (c) be repeated for available signals of every frequency and the data be stored for later processing.

The system then processes the data and produces as output the polar plots (in dB) of the antenna response for each frequency with the response from the standard antenna and other significant levels indicated in each plot. The absolute gain and/or the gain relative to the standard antenna for the test antenna can then be obtained directly from the plots.

3.5 Sample Results

Using a variety of Ford automobiles a series of antenna response measurements were carried out with the system and at a number of locations. Here we present a few selected sample results for the Ford NM-12 automobile obtained from the data collected at a location near the University of Michigan Willow Run Laboratory. Test antenna used were the standard whip and a bent whip (bent approximately 12 inches from the pillar). Data were collected with commercial FM signals at 91.7, 95.0, 101.1 and 105.3 MHz available at the test location. The resultant antenna response plots are shown in Figs. 3.9 - 3.16. Each plot represents the signal received (in dB) by the NM-12 antenna (whip or the bent whip) as a function of direction or azimuth angle. In each plot the 0° reference is in the forward direction of the test automobile (as shown by the inset) and, for convenience, the direction of the source (i.e., station originating the signal) is also indicated. From these results it is observed that the standard whip outperforms the bent version at all of the frequencies except at 105.3 MHz where both versions perform about equally.



FORD MN-12 #1.

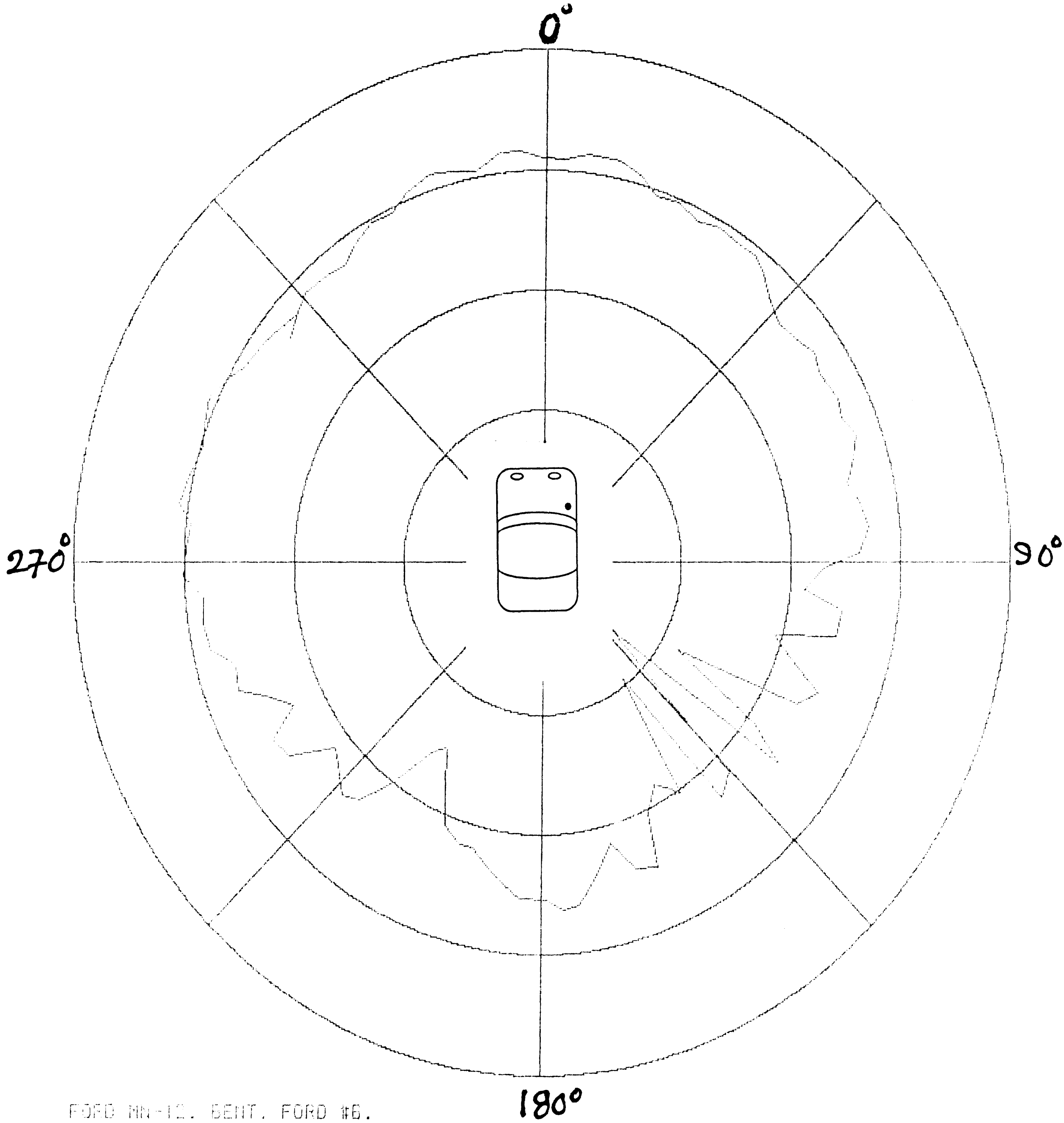
FD070
CORRECTED BY FD070 87/03/07

Station frequency: 91.7 MHz
Station angle: -56 DEG

REFERENCE ANTENNA LEVEL: -46.2 dBm.
TEST ANTENNA MAX LEVEL: -43.7 dBm.
TEST ANTENNA MIN LEVEL: -62.2 dBm.

[illegible] 10 dB/div
[illegible] [illegible] dBm.

Figure 3.9 Measured horizontal plane radiation pattern Ford MN-12 whip antenna at 91.7 MHz.



FORD MN-12. BENT. FORD #6.

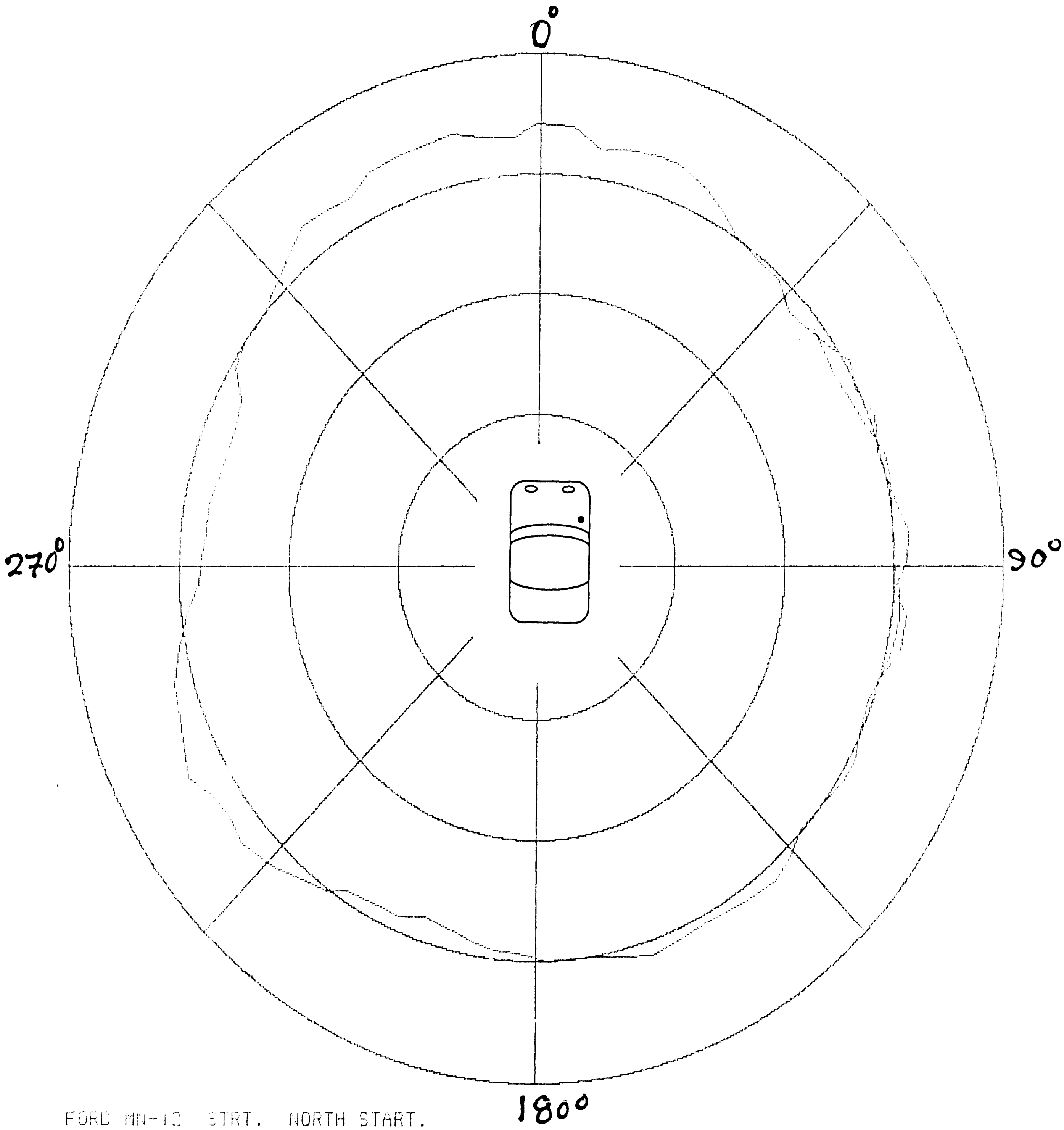
FD075
CORRECTED BY FC070 87/03/07

Station frequency: 91.7 MHz
Station angle: -56 DEG

REFERENCE ANTENNA LEVEL: -46.2 dBm.
TEST ANTENNA MAX LEVEL: -48.3 dBm.
TEST ANTENNA [illegible]: -74.4 dBm.

[illegible] 10 dB/div
Outer [illegible] dBm.

Figure 3.10 Measured horizontal plane radiation pattern of Ford MN-12 bent whip antenna at 91.7 MHz.



FORD MN-12 STRT. NORTH START.

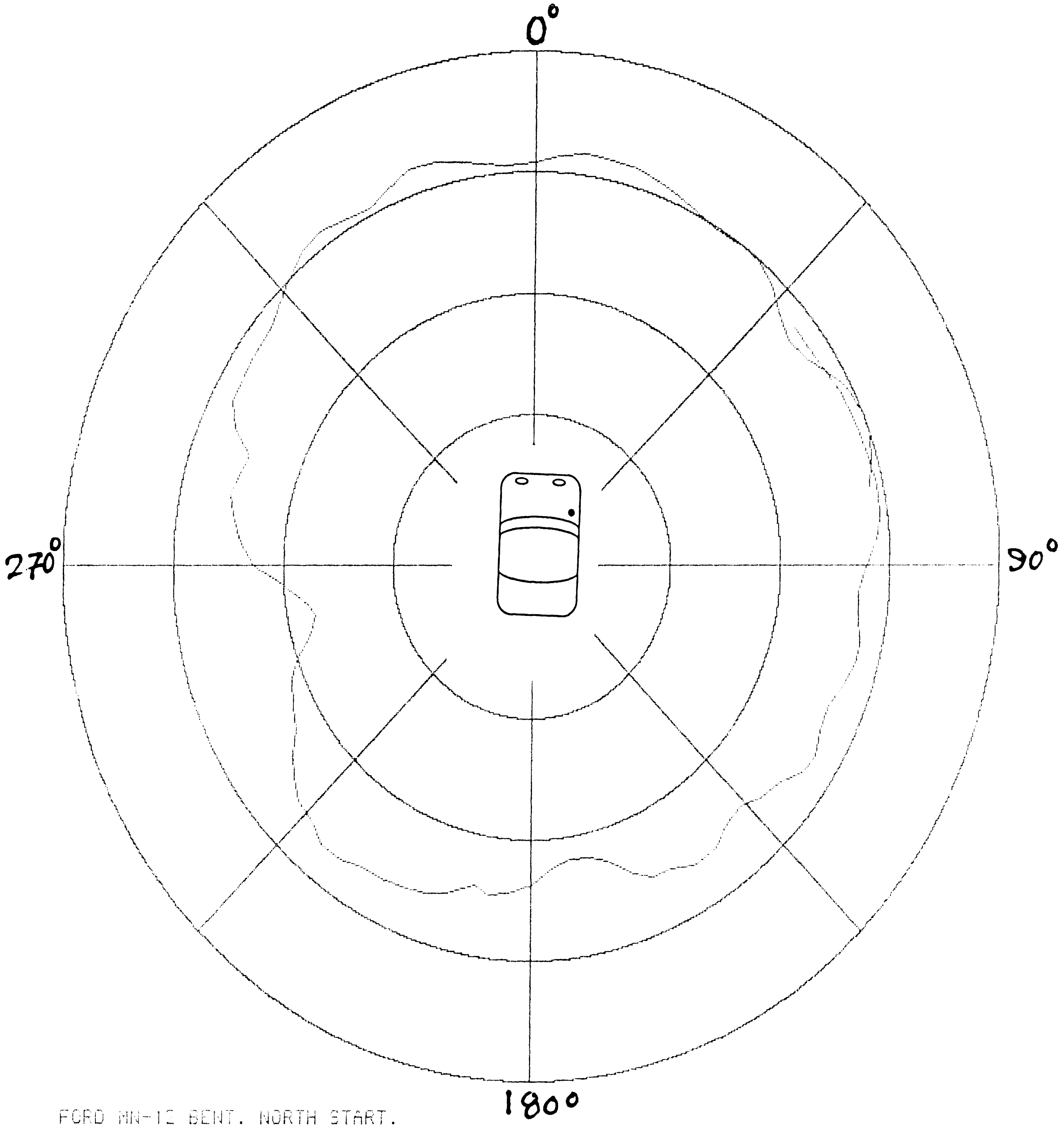
FD082
CORRECTED BY FC071 87/03/07

Station frequency: 95.5 MHz
Station angle: +46 DEG

REFERENCE ANTENNA LEVEL: -50.5 dBm.
TEST ANTENNA MAX LEVEL: -45.7 dBm.
TEST ANTENNA MIN LEVEL: -52.6 dBm.

Scale: 10 dB/div
Outer ring: -40 dBm.

Figure 3.11 Measured horizontal plane radiation pattern of Ford MN-12 whip antenna at 95.5 MHz.



FORD MN-12 BENT. NORTH START.

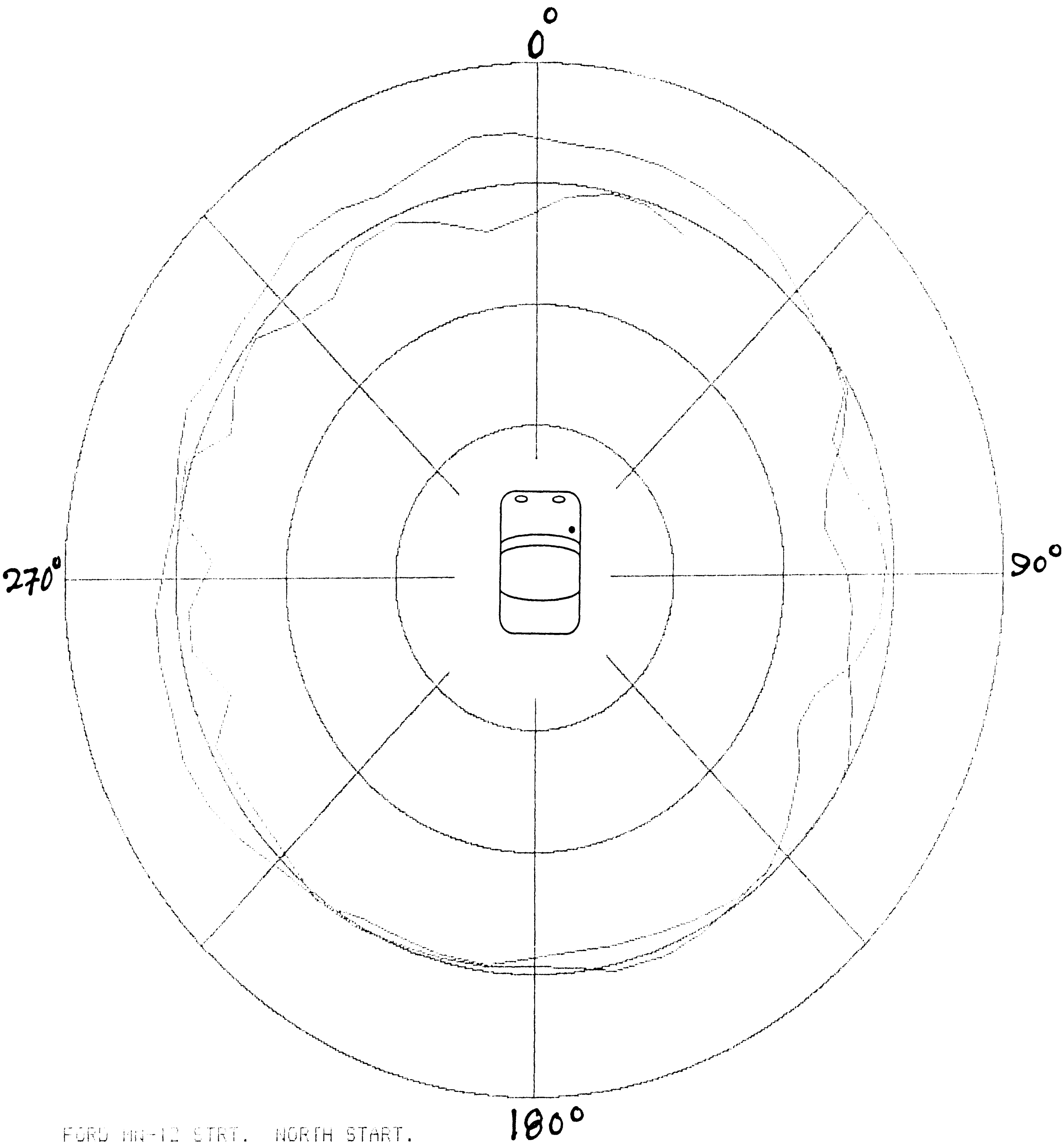
FD033
CORRECTED BY FC071 87/03/07

Station frequency: 95.5 MHz
Station angle: +46 DEG

REFERENCE ANTENNA LEVEL: -50.5 dBm.
TEST ANTENNA MAX LEVEL: -47.8 dBm.
TEST ANTENNA MIN LEVEL: -62.5 dBm.

Scale: 10 dB/div
Outer ring: -40 dBm.

Figure 3.12 Measured horizontal plane radiation pattern of Ford MN-12 bent whip antenna at 95.5 MHz.



FORD MN-12 STRT. NORTH START.

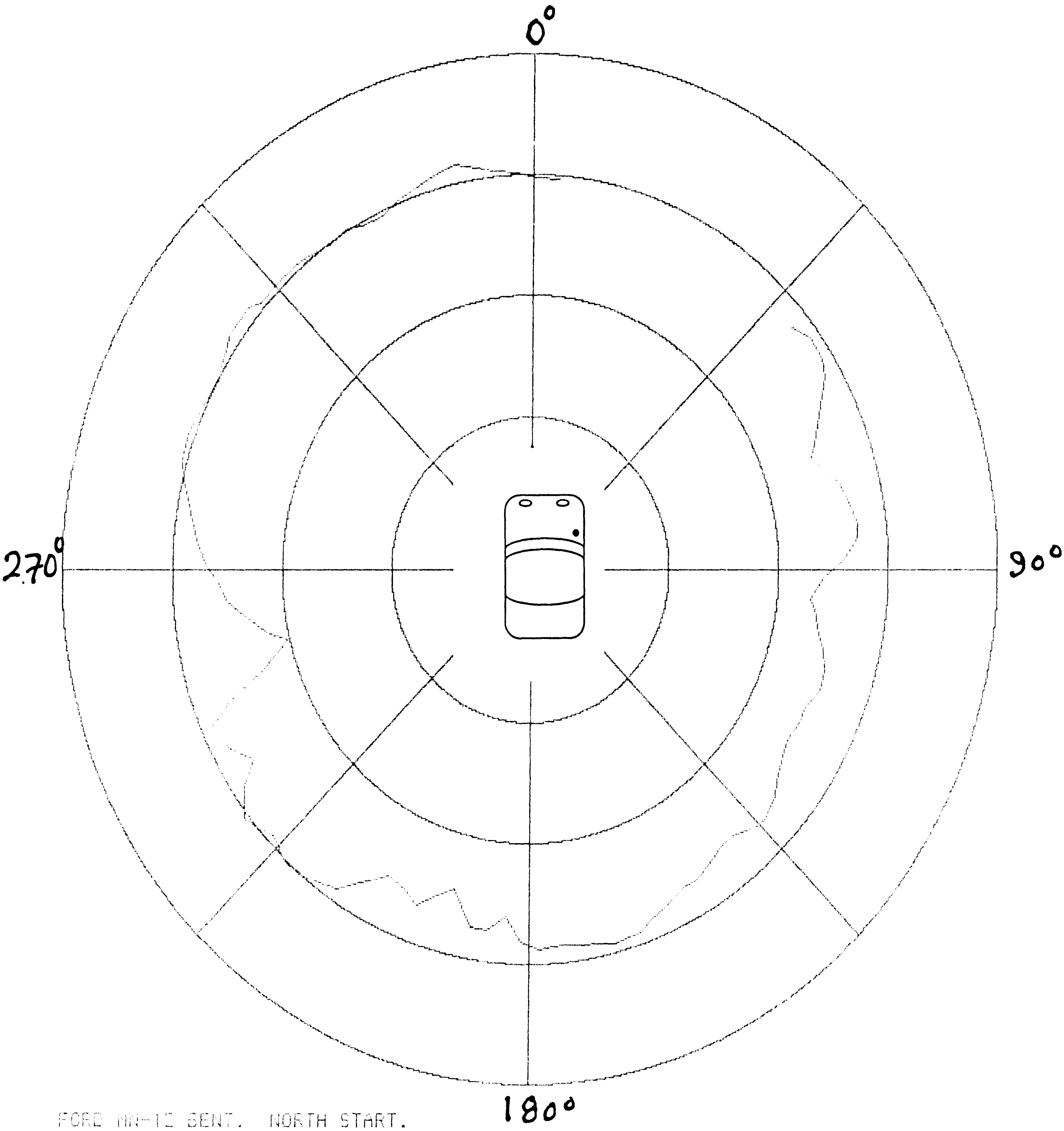
FD021
CORRECTED BY FC071 87/03/07

Station frequency: 101.1 MHz
Station angle: +46 DEG

REFERENCE ANTENNA LEVEL: -50.0 dBm.
TEST ANTENNA MAX LEVEL: -45.7 dBm.
TEST ANTENNA MIN LEVEL: -56.2 dBm.

Scale: 10 dB/div
Outer ring: -40 dBm.

Figure 3.13 Measured horizontal plane radiation pattern of Ford MN-12 whip antenna at 101.1 MHz.



FORD MN-12 BENT. NORTH START.

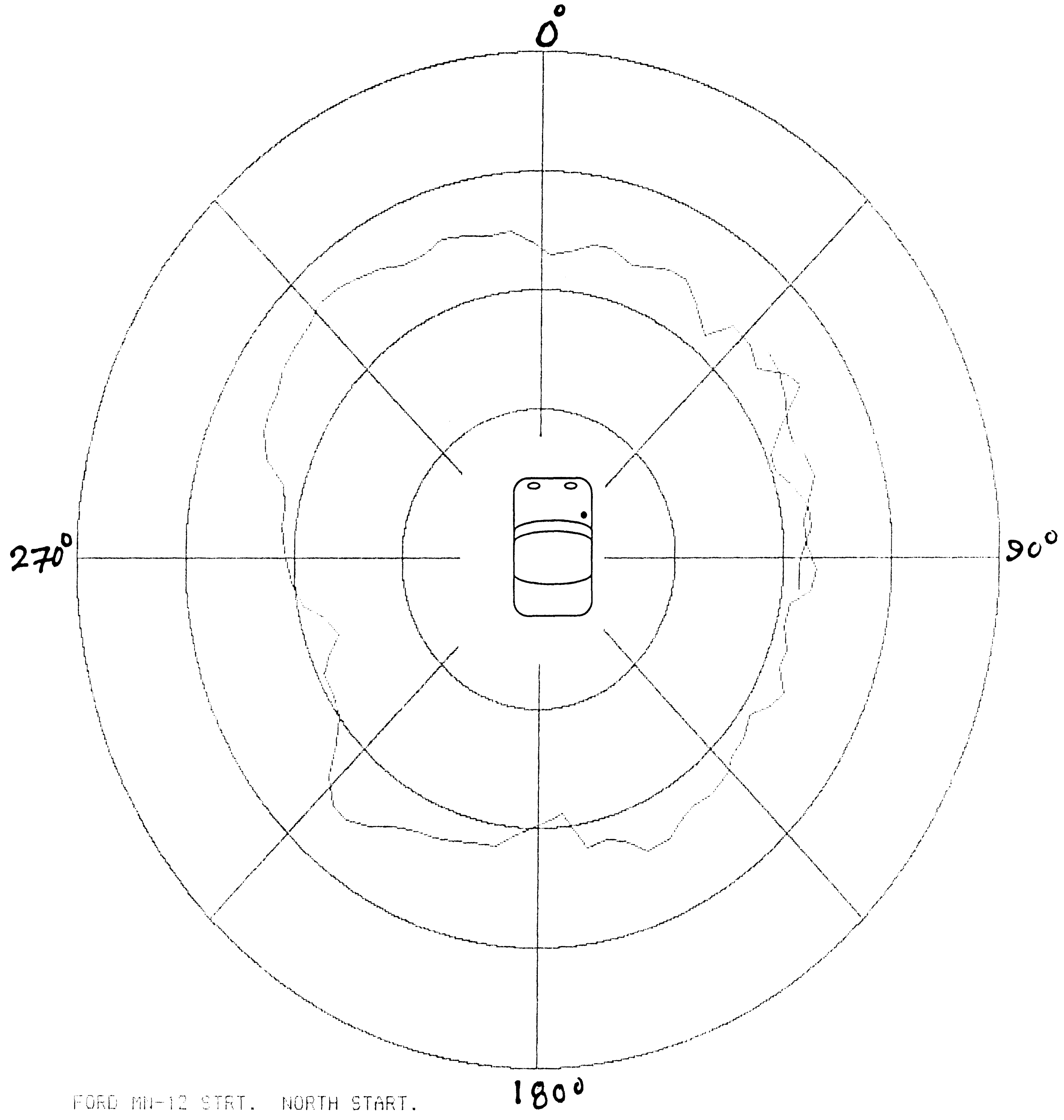
FD010
CORRECTED BY FD071 87/03/07

Station frequency: 101.1 MHz
Station angle: +46 DEG

REFERENCE ANTENNA LEVEL: -50.0 dBm.
TEST ANTENNA MAX LEVEL: -48.4 dBm.
TEST ANTENNA MIN LEVEL: -59.8 dBm.

Scale: 10 dB/div
Outer ring: -40 dBm.

Figure 3.14 Measured horizontal plane radiation pattern of Ford MN-12 bent whip antenna at 101.1 MHz.



FORD MN-12 STRT. NORTH START.

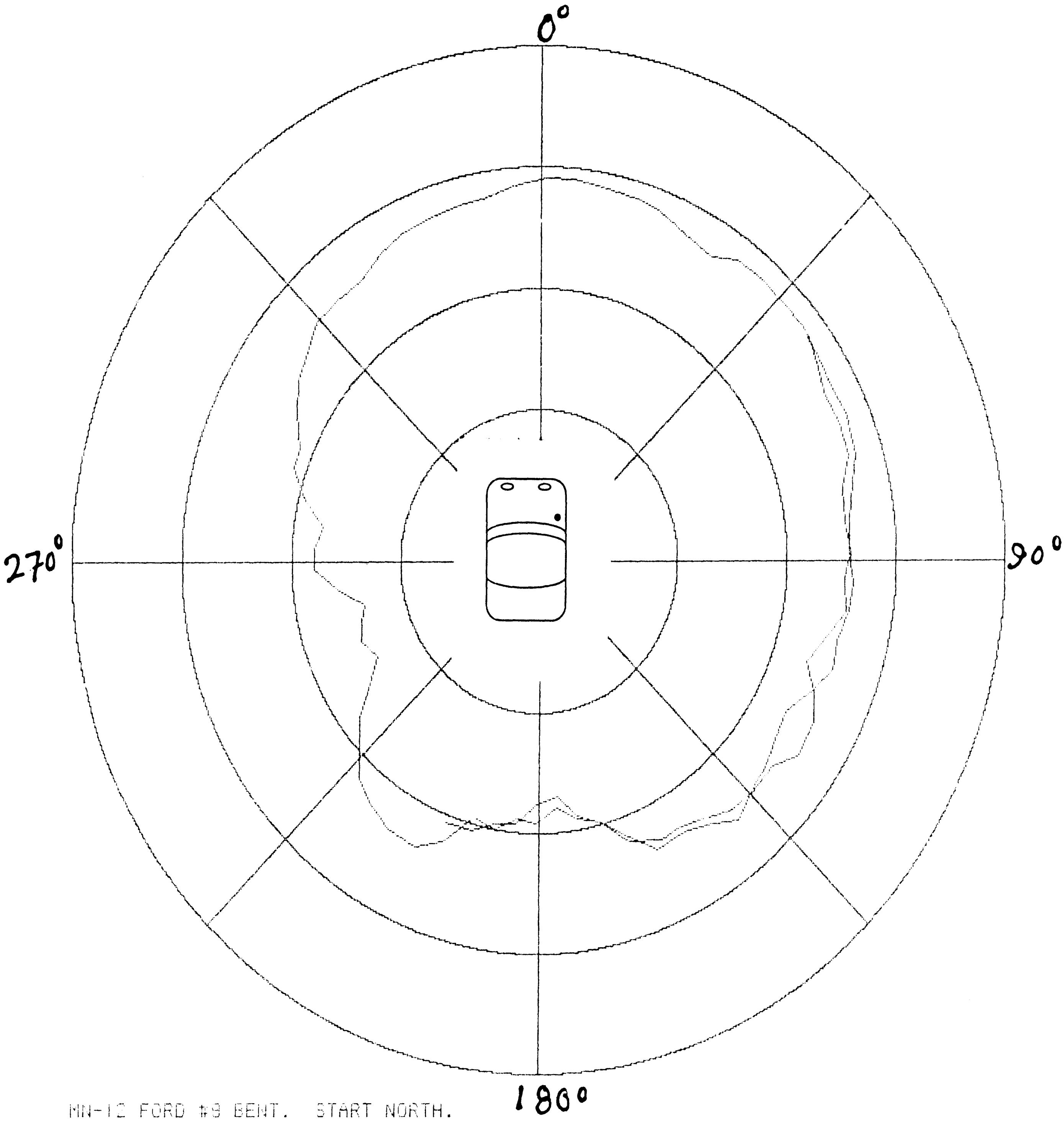
FD379
CORRECTED BY FC071 87/03/07

Station frequency: 105.3 MHz
Station angle: +46 DEG

REFERENCE ANTENNA LEVEL: -54.0 dBm.
TEST ANTENNA MAX LEVEL: -53.0 dBm.
TEST ANTENNA MIN LEVEL: -63.0 dBm.

Scale: 10 dB/div
Outer ring: -40 dBm.

Figure 3.15 Measured horizontal plane radiation pattern of Ford MN-12 whip antenna at 105.3 MHz.



MN-12 FORD #9 BENT. START NORTH.

FD078
CORRECTED BY FC071 87/03/07

Station frequency: 105.3 MHz
Station angle: +46 DEG

REFERENCE ANTENNA LEVEL: -54.0 dBm.
TEST ANTENNA MAX LEVEL: -50.9 dBm.
TEST ANTENNA MIN LEVEL: -66.3 dBm.

Scale: 10 dB/div
Outer ring: -40 dBm.

Figure 3.16 Measured horizontal plane radiation pattern of Ford MN-12 bent whip antenna at 105.3 MHz.

IV. CONCLUSIONS

A portable automobile antenna evaluation system has been developed. It consists of a standard antenna of known gain and associated computer and other electronic systems. The system can be used to determine the response of an automobile antenna to available commercial signals at any desired location where the car can be driven around a circle of convenient radius. Although we have used a spectrum analyzer as the receiver, the system can also operate with the automobile receiver instead and this should be investigated further. The present system is slow due to limitations of the computer used. The speed of the system can be improved by using better computing and printing equipment.

V. ACKNOWLEDGEMENT

We are pleased to acknowledge the benefit of several discussions with and active participation from Mr. Robert Schuessler of the Ford Motor Company.

VI. REFERENCES

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VII. APPENDIX

COMPUTER PROGRAMS

```
10 ! ******************************************************************************
20 !
30 ! SHELL is the global environment under which all data acquisition
40 !        operations run.  In effect, it is the user interface.
50 !
60 !        It includes all the necessary functions that deal with the
70 !        calibration, collection, correction, and
80 !        subsequent saving of field data onto the disk.
90 !
100 ! A          : Major axis of ellipse.
110 ! B          : Minor axis of ellipse.
120 ! A1         : Test antenna maximum
130 ! A2         : Test antenna minimum
140 ! A3         : Reference antenna signal
150 ! T1         : Correction angle for the data (derived in the CORRECT subroutine
160 ! E1         : 0=do not have a loaded calibration correction file.
170 ! N1         : Number of antenna data points.
180 ! N2         : Number of calibration data points.
190 ! X0         : Abcissa of calibration ellipse center (derived in the CORRECT su
200 ! Y0         : Ordinate of correction ellipse center (derived in the CORRECT su
210 ! F1,D1      : Tone and period of error notification beep.
220 ! F2,D2      : Waiting for operator input tone and period.
230 ! F1$        : Data filename
240 ! F2$        : Calibration filename.
250 ! T1$        : Data file title.
260 ! T2$        : Calibration file title.
270 ! C1$        : Operator comments on antenna data.
280 ! C2$        : Machine comments on antenna data.
290 ! C3$        : Operator comments on calibration data.
300 ! C4$        : Machine comments on calibration data.
310 ! C$()       : Command array used in the autoanswer mode.
320 ! X(),Y()    : Compass response which has been compensated by the CORRECT subro
330 ! T()        : Angles of antenna data points.
340 ! R()        : Magnitude of antenna data points.
350 ! F(,)       : Uncompensated (raw) compass input
360 !            : (defines tilted, off-centered ellipse.
370 ! D$         : Operator decision input.
380 !
390 ! ******************************************************************************
400 !
410 DESTROY ALL @ CFLAG 20 @ CFLAG 30 @ CFLAG 40 @ CFLAG 41 ! Reinitialize syste
420 DIM A$[12],T1$[80],T2$[80],F1$[6],F2$[6],C1$[80],C2$[80],C3$[80],C4$[80]
425 SHORT L1,L2,U1,U2,H,B,R1,F1,B1
430 USER ON
440 INPUT 'Waiting for command...';A$ @ A$=A$[1,8]
450 USER OFF
460 GOSUB A$
```

```
470 GOTO 430
480 'AUTO': SFLAG 20 ! User is using a macro file.
490 INPUT 'Command file name? ';A$
500 'READ': ASSIGN #2 TO A$ @ READ #2;N @ DIM C$(N)[80] @ READ #2;C$() @ ASSIGN
510 FOR L=1 TO N
520 GOSUB C$(L)
530 NEXT L
540 'LOOPBACK': PURGE A$ @ ASSIGN #2 TO A$
550 PRINT #2;L @ PRINT #2;C$() @ ASSIGN #2 TO *
560 POP @ GOTO 'READ' ! Restart using the updated macro file.
570 RETURN
580 !
590 'CALIBRAT': ! Get a calibration.
600 CALL GETCAL(T1,X0,Y0,A,B,P(,),N2,F2$,C3$,C4$,T2$,L,C$())
610 SFLAG 30
620 RETURN
630 !
640 'COLLECT': ! Collect an antenna data set.
650 CALL COLLECT(X(),Y(),R(),T(),C1$,C2$,T1$,F2$,A1,A2,A3,N1,L,C$())
660 RETURN
670 !
680 'QWIKPLOT': ! Do a quick plot of a file.
690 INPUT '(C)al. or (D)ata? ';D$
700 IF D$[1,1]<>'C' AND D$[1,1]<>'D' THEN 'QWIKPLOT'
710 IF D$[1,1]<>'D' THEN 'CALPLOT'
720 SFLAG 33 @ CFLAG 31
730 CALL QWIKPLOT(R(),T(),F1$,C1$,C2$,T1$,F2$,C3$,C4$,T2$,A1,A2,A3,N1)
740 CFLAG 33
750 RETURN
760 !
770 'CALPLOT': SFLAG 31 @ CFLAG 33
780 CALL QWIKPLOT(R1(),T(),F2$,C1$,C2$,T1$,F2$,C3$,C4$,T2$,A1,A2,A3,N2)
790 CFLAG 31 @ RETURN
800 !
810 'SLOWPLOT': ! Do a slow plot of a file.
820 INPUT '(C)al. or (D)ata? ';D$
830 IF D$[1,1]<>'C' AND D$[1,1]<>'D' THEN 'SLOWPLOT'
840 IF D$[1,1]<>'D' THEN 'CALPLOT1'
870 PURGE QWIKPLOT @ PURGE COLLECT @ PURGE GETCAL @ PURGE CORRECT @ PURGE SCALE
880 SFLAG 33 @ CFLAG 31
890 CALL SLOWPLOT(R(),T(),F1$,C1$,C2$,T1$,F2$,C3$,C4$,T2$,A1,A2,A3,N1)
900 CFLAG 33
910 COPY QWIKPLOT:2 TO QWIKPLOT @ COPY COLLECT:2 TO COLLECT @ COPY EDITFILE:2 TO
930 COPY GETCAL:2 TO GETCAL @ COPY CORRECT:2 TO CORRECT @ COPY SCALE:2 TO SCALE
950 RETURN
960 !
970 'CALPLOT1': SFLAG 31 @ CFLAG 33
980 CALL SLOWPLOT(R1(),T1(),F2$,C1$,C2$,T1$,F2$,C3$,C4$,T2$,A1,A2,A3,N2)
990 CFLAG 31
1000 COPY QWIKPLOT:2 TO QWIKPLOT @ COPY COLLECT:2 TO COLLECT @ COPY EDITFILE:2 T
1020 COPY GETCAL:2 TO GETCAL @ COPY CORRECT:2 TO CORRECT @ COPY SCALE:2 TO SCALE
1040 RETURN
1050 !
```

```
1060 'TEMPLATE': COPY TEMPLATE:2 TO TEMPLATE @ CALL TEMPLATE
1070 PURGE TEMPLATE @ RETURN
1080 !
1090 'SAVEFILE': ! Store a file on disk.
1100 INPUT 'File name? ';F$ @ IF F$='' THEN RETURN
1110 INPUT 'New filename? ';N$ @ IF N$='' THEN N$=F$
1120 COPY F$ TO N$&":2"
1130 RETURN
1140 !
1150 'GETFILE': ! Transfer a file from disk to memory.
1160 INPUT 'File name? ';F$ @ IF F$='' THEN RETURN
1170 INPUT 'New filename? ';N$ @ IF N$='' THEN N$=F$
1180 COPY F$&":2" TO N$
1190 RETURN
1200 !
1210 !
1220 'PLOTPARS': ! Redefine the default SLOWPLOT plotting parameters.
1230 INPUT '(R)edefine (C)reate';D$
1240 IF D$<>'C' AND D$<>'R' THEN 1230
1250 INPUT 'Grid name? ';G1$ @ INPUT 'Amplitude ref. (dBm)? ';F
1260 INPUT 'Dot reference? ';G @ INPUT 'Dots per dBm? ';E
1270 INPUT 'Number of lines?';N @ INPUT 'Spacing of lines? ';S
1280 IF D$='C' THEN CREATE DATA PLOTPARS @ ASSIGN #1 TO 'PLOTPARS'
1290 ASSIGN #1 TO 'PLOTPARS'
1300 PRINT #1;G$,F,G,E,S,N
1310 ASSIGN #1 TO * @ RETURN
1320 !
1330 'QUIT': POP ! Get out of the loop (it's MILLER time...)
1340 USER OFF
1350 END
```

```
10 SUB GETCAL(T1,X0,Y0,A,B,P(,),N2,F2$,C3$,C4$,T2$,L,C$())
20 !
30 ! ***********************************************************************
40 !
50 ! P(,)   : X',Y' elliptic calibration curve.
60 ! X0 Y0  : Center of X',Y' plane and of ellipse.
70 ! Px     : Summation variables used in the calculation of X0 and Y0.
80 ! L1     : Length vector variable used in the major axis calculation
90 ! FNA1,2: Center of ellipse determination function.
100 !
110 ! FLAGS:
120 !        20 : 1=Auto command file is active.
130 !        21 : 1=Calibration file comment is active.
140 !        22 : 1=Calibration file title is active.
150 !
160 ! MACRO FORMAT:
170 !                 Number of calibration points.
180 !                 Calibration file name (format is FC###).
190 !                 Calibration file title flag.  (1=active request)
200 !                 Calibration file comments.  (1=active request)
210 !
220 ! ***********************************************************************
230 !
240 GOTO 450
250 'FNA1': X0=0 @ Y0=0
260 FOR I=1 TO N2
270 X0=X0+P(I,1)
280 Y0=Y0+P(I,2)
290 NEXT I
300 X0=X0/N2 @ Y0=Y0/N2
310 RETURN
320 !
330 ! ***********************************************************************
340 !
350 'FNA2': P2=-9999 @ P1=9999 @ P3=P1 @ P4=P2
360 FOR I=1 TO N2
370 P1=MIN(P1,P(I,1)) @ P2=MAX(P2,P(I,1)) @ P3=MIN(P3,P(I,2)) @ P4=MAX(P4,P(I,2))
380 X0=(P1+P2)/2
390 Y0=(P3+P4)/2
400 NEXT I
410 RETURN
420 !
```

```
430 ! ***********************************************************************
440 !
450 IF FLAG(20) THEN GOTO 'AUTOANS' ! Get stuff from command file.
460 INPUT '# OF CAL. POINTS?';N2
470 INPUT 'CALIBRATION FILE NAME?';F2$
480 IF F2$<>'' THEN 'ALLOCATE'
490 BEEP F2,D2
500 DISP 'CAL. FILE MUST BE NAMED'
510 GOTO 470
520 !
530 'ALLOCATE': DESTROY P,X0,X1,X2,Y0,Y2,L1,T1,T2,T2$
540 SHORT P(N2,2),X0,X1,X2,Y0,Y2,L1,T1,T2
550 DIM T2$[80]
560 IF FLAG(22) THEN INPUT 'CAL. FILE TITLE?';T2$
570 DISP 'POINT CAR NORTH' @ WAIT 1.5
580 INPUT 'PRESS ENDLINE TO START CAL';D$
590 !
600 ! ***********************************************************************
610 !
620 ! Take compass readings.
630 ! ***********************************************************************
640 !
650 !
660 FOR I=1 TO N2
670 OUTPUT :3 ;'F1RA1Z1N4LS2-3;T3'
680 ENTER :3 ;P(I,1),P(I,2)
690 NEXT I
700 !
710 ! ***********************************************************************
720 !
730 ! Find the major and minor axes.
740 !
750 ! ***********************************************************************
760 !
770 GOSUB 'FNA1'
780 A=-9999 @ B=9999
790 FOR I=1 TO N2
800 L1=SQRT((P(I,1)-X0)^2+(P(I,2)-Y0)^2)
810 IF L1>A THEN M1=I @ A=L1
820 IF L1<B THEN M2=I @ B=L1
830 NEXT I
840 !
850 ! Construct the X',Y' coordinate plane.
860 !
870 ! Find the X-intercept.
880 !
890 X1=Y0*(X0-P(M1,1))/(P(M1,2)-Y0)+X0
900 !
910 ! Calculate the rotation angle.
920 !
925 I=1
930 T1=ANGLE(X0-X1,Y0)
940 X2=(P1(I,1)-X0)*COS(T1)+(P1(I,2)-Y0)*SIN(T1)-X0
950 Y2=(P1(I,2)-Y0)*COS(T1)-(P1(I,1)-X0)*SIN(T1)-Y0
960 T2=ANGLE(X2,Y2)
```

```
970 C4$='CAL. FILE '&DATE$&' '&TIME$
980 IF FLAG(21) THEN INPUT 'CAL. FILE COMMENTS?';C3$
990 DISP 'SAVING CAL. FILE ';F2$
1000 ASSIGN #1 TO F2$
1010 PRINT #1;F2$,T2$,C4$,T1,T2,X0,Y0,A,B,N2,P(,)
1020 ASSIGN #1 TO *
1030 COPY F2$ TO F2$&":2"
1040 GOTO 'FINISH'
1050 !
1060 'AUTOANS': ! If we are in the auto answer mode,
1070 !              plug in the values from the command array, and update the file
1080 !
1090 L=L+1 @ N2=VAL(C$(L))
1100 L=L+1 @ F2$=C$(L)
1110 F2=VAL(F2$)+1 @ IF F2<10 THEN C$(L)=C$(L)[1,4]&STR$(F2) @ GOTO 'ACTIVE'
1120 IF F2>9 AND F2<100 THEN C$(L)=C$(L)[1,3]&STR$(F2) @ GOTO 'ACTIVE'
1130 C$(L)=C$(L)[1,2]&STR$(F2)
1140 'ACTIVE': L=L+1 @ D=FLAG(21,VAL(C$(L))) @ L=L+1 @ D=FLAG(22,VAL(C$(L)))
1150 GOTO 'ALLOCATE'
1160 'FINISH': SUB END
```

```
10 SUB COLLECT(X(),Y(),R(),T(),C1$,C2$,T1$,F2$,A1,A2,A3,N1,L,C$())
20 !
30 ! ****************************************************************************
40 !
50 ! FLAGS:
60 !           20 : 1=Auto command file is active.
70 !           23 : 1=Data file comment is active.
80 !           24 : 1=Data file title is active.
90 !
100 ! MACRO FORMAT:
110 !                 Number of data points.
120 !                 Data file name.  (format is FD###)
130 !                 Data file title flag. (1=active request)
140 !                 Data file comments flag.  (1=active request)
150 !
160 ! ****************************************************************************
170 IF FLAG(20) THEN 'AUTOANS'
180 INPUT 'NUMBER OF DATA POINTS?';N1
190 DESTROY X,Y,Z,R,T,C1$,C2$,T1$
200 SHORT X(N1),Y(N1),Z(N1),R(N1),T(N1)
210 DIM C1$[80],C2$[80],T1$[80],F1$[30]
220 INPUT 'DATA FILE NAME?';F1$
230 INPUT 'DATA FILE TITLE?';T1$
240 !
250 !  Get the reference antenna reading.
260 !
270 INPUT 'REF. ANT. READY?';D$
280 IF D$[1,1]<>'Y' THEN 270
290 OUTPUT :3 ;'F1RA1Z1N4LS4;T3'
300 ENTER :3 ;A3
310 [illegible]
```

```
320 !
330 !  Prime operator for collecting the field pattern data.
340 !
350 INPUT 'Press any key to start';D$
360 FOR I=1 TO N1
370 OUTPUT :3 ;'F1RA1Z1N4LS2-4;T3'
380 ENTER :3 ;X(I),Y(I),Z(I)
390 NEXT I
400 BEEP 2500,.15
410 DISP 'DONE...CRUNCHING NOW'
420 A1=-9999
430 A2=9999
440 !
450 !  Find the endpoint boundaries of the test antenna.
460 !
470 FOR I=1 TO N1
480 A1=MAX(A1,Z(I))
490 A2=MIN(A2,Z(I))
500 NEXT I
510 !
520 !  Convert from voltage to actual dBm values.
530 !
540 CALL SCALE(Z(),R(),A1,A2,A3,N1)
550 INPUT 'Station frequency?';P1$
560 IF C1$<>'' THEN C1$=C1$&' MHz'&CHR$(31) ELSE C1$='        MHz'&CHR$(31)
570 P1$='.' @ INPUT 'Transmitter =?',P1$;P1$ @ C1$=C1$&P1$
580 GOTO 'CORRECT'
590 !
600 'AUTANS': ! If we are in the auto answer mode,
610 !           plug in the values from the command array and update the file.
620 L=L+1 @ N1=VAL(C$(L))
630 L=L+1 @ F1$=C$(L)
640 F1=VAL(F1$)+1 @ IF F1<10 THEN C$(L)=C$(L)[1,4]&STR$(F1) @ GOTO 'ACTIVE'
650 IF F1>9 AND F1<100 THEN C$(L)=C$(L)[1,3]&STR$(F1)
660 C$(L)=C$(L)[1,2]&STR$(F1)
670 'ACTIVE': L=L+1 @ D=FLAG(23,VAL(C$(L))) @ L=L+1 @ D=FLAG(24,VAL(C$(L)))
680 GOTO 'ALLOCATE'
690 !
700 'FINISH': IF FLAG(23) THEN INPUT 'DATA FILE COMMENTS?';C1$
710 !
720 'CORRECT': CALL CORRECT(X(),Y(),T(),T1,T2,A,B,X0,Y0,N1,C2$,F2$)
730 DISP 'SAVING DATA...'
740 ASSIGN #1 TO F1$
750 PRINT #1;F1$,T1$,C1$,C2$,A1,A2,A3,N1
760 FOR I=1 TO N1
770 PRINT #1;T(I),R(I)
780 NEXT I
790 ASSIGN #1 TO *
800 COPY F1$ TO F1$&":2"
810 PURGE F1$
820 SUB END
```

```
10 SUB CORRECT(X(),Y(),T(),T1,T2,A,B,X0,Y0,N1,C2$,F2$)
20 !
30 ! Compensate for a tilted elliptical compass response.
40 !
50 DIM C4$[80]
60 'CALOAD': IF NOT FLAG(30) THEN INPUT 'CAL. FILE NAME? ';F2$ ELSE GOTO 'GOTCAL
70 IF F2$='' AND NOT FLAG(30) THEN BEEP @ DISP 'NEED ACTIVE CAL. FILE'
80 IF F2$='' AND NOT FLAG(30) THEN GOTO 'CALOAD'
90 'GOTCAL': ASSIGN #1 TO F2$ @ READ #1;F2$,T2$,C4$,T1,T2,X0,Y0,A,B,N2
100 ASSIGN #1 TO *
110 'OK': SHORT S,C
120 S=SIN(T1)
130 C=COS(T1)
140 FOR I=1 TO N1
150 T(I)=ANGLE((X(I)-X0)*C+(Y(I)-Y0)*S,(Y(I)-Y0)*C-(X(I)-X0)*S)-T2
160 NEXT I
170 C2$=C2$&'CORRECTED BY '&F2$&' '&DATE$
180 SUB END
```

```
10 SUB SCALE(Z(),R(),A1,A2,A3,N1)
20 SHORT A,S1,S2,S3,R1,O
30 INPUT 'Attenuator setting=?';A
40 S2=0 ! Minimum voltage expected from the S-A. Set to 0V initially.
50 S3=.8 ! WAS .8 FOR SAMaximum voltage expected from the S-A. Set to 0.8V initi
60 R1=80 ! Maximum dynamic range of the S-A (in dBm). (Baseline to top of screen
70 'SCLSTRT': S1=R1/(S3-S2) ! Dynamic range of S-A screen.  Set for 100 dBm/V in
80 IF A1>S3 OR A2>S3 OR A3>S3 THEN 'OVERFLOW'
90 IF A1<S2 OR A2<S2 OR A3<S2 THEN 'UNDRFLOW'
100 FOR I=1 TO N1
110 R(I)=S1*Z(I)+A-R1
120 NEXT I
130 A1=A1*S1+A-R1
140 A2=A2*S1+A-R1
150 A3=A3*S1+A-R1
160 GOTO 'SUBEND'
170 !
180 'OVERFLOW': BEEP !   The maximum voltage reading exceeded the initially
190 !                    specified top-of-screen voltage.  Operator is presented
200 !                    with a choice:  ABORT or CONTINUE with modified boundaries.
210 !
220 O=MAX(A1,A2) @ O=MAX(O,A3)
230 DISP 'VOLTAGE OVERFLOW' @ DISP O
240 WAIT 3 @ INPUT 'ABORT or CONTINUE?';D$
250 IF D$[1,1]='A' THEN 'HALT' ELSE S2=O
260 GOTO 'SCLSTRT' !     Rescale the Z() vector using the new scaling factor.
270 !
280 'UNDRFLOW': BEEP !   The maximum voltage reading exceeded the initially
290 !                    specified top-of-screen voltage.  Operator is presented
300 !                    with a choice:  ABORT or CONTINUE with modified boundaries.
```

```
310 !
320 O=MIN(A1,A2) @ O=MIN(O,A3)
330 DISP 'VOLTAGE UNDERFLOW' @ DISP O
340 WAIT 3 @ INPUT 'ABORT or CONTINUE?';D$
350 IF D$[1,1]='A' THEN 'HALT' ELSE S3=0
360 GOTO 'SCLSTRT'
370 'HALT': RUN SHELL
380 'SUBEND': SUB END
```

```
10 SUB QWIKPLOT(R(),T(),F1$,C1$,C2$,T1$,F2$,C3$,C4$,T2$,A1,A2,A3,N1)
20 !      F$  :  FILE NAME.
30 !      L$  :  HORIZONTAL GRID LINE
40 !      F1$ :  FILE TITLE
50 !      T1$ :  TITLE OF PLOT.
60 !      P$():  CHARACTER GRID ARRAY.
70 !      C1$ :  FIRST COMMENT.
80 !      C2$ :  SECOND COMMENT.
90 !      I   :  LOOP INDEX
100 !
110 ! FLAGS:
120 !          31 : Calibration file plot. (1=active)
130 !          33 : Antenna file plot. (1=active)
140 !
150 ! **********************************************************************
160 !
170 OPTION BASE 1
180 DIM P$(40)[80],L$[80]
190 SHORT X1,Y1,X0,Y0,A,B1,H,B,P,S,C
200 H=40
210 B=40
220 ! Generate the horizontal grid line.
230 FOR I=1 TO 80
240 L$[I,I]=CHR$(95)
250 NEXT I
260 !
270 ! Get the file to be plotted.
280 !
290 IF NOT FLAG(31) THEN GOTO 'ANTENNA'
300 !
310 'NEEDCAL': INPUT 'DESIRED CAL. FILE? ';F2$ @ ASSIGN #1 TO F2$
320 READ #1;F2$,T2$,T1,X0,Y0,A,B1,N1
330 DESTROY X,Y,P,R,T @ SHORT X(N1),Y(N1),R(N1),T(N1),P(N1,2)
340 READ #1;P(,) @ ASSIGN #1 TO *
350 FOR I=1 TO N1 @ X(I)=P(I,1)-X0 @ Y(I)=P(I,2)-Y0 @ NEXT I
360 A1=-9999 @ A2=9999 @ A3=0
370 FOR I=1 TO N1 @ R(I)=SQRT(X(I)^2+Y(I)^2) @ A1=MAX(A1,R(I))
380 T(I)=ANGLE(X(I),Y(I)) @ NEXT I
390 PRINT 'A=';A,'B=';B1,'X0=';X0,'Y0=';Y0
400 GOTO 'HAVEFILE'
```

```
410 !
420 'ANTENNA': INPUT 'DESIRED ANT. FILE? ';F$
430 ASSIGN #1 TO F$
440 READ #1;F1$,T1$,C1$,C2$,A1,A2,A3,N1
450 DESTROY R,T @ SHORT R(N1),T(N1)
460 FOR I=1 TO N1
470 READ #1,T(I),R(I)
480 ! PRINT T(I),R(I)
490 NEXT I
500 ASSIGN #1 TO *
510 !
520 ! ***********************************************************************
530 !
540 !     Build up the vertical grid line.
550 !     Then we map the polar coordinates onto the Cartesian C$ matrix.
560 !     A1 is the test antenna max, A3 is the reference antenna max.
570 !     Then we map the polar coordinates onto the Cartesian C$ matrix.
580 !
590 ! ***********************************************************************
600 !
610 'HAVEFILE':
620 IF NOT FLAG(31) THEN S1=ABS(MAX(A1,A3)) ELSE S1=ABS(A1)
630 IF NOT FLAG(31) THEN S2=MIN(A2,A3) ELSE S2=A2
640 IF FLAG(33) THEN GOSUB 'SCALEIT'
650 IF FLAG(33) THEN 'TRIGS'
660 R1=40*.9/ABS(S1)
670 FOR I=1 TO N1
680 R(I)=.9*40/(ABS(S2)-ABS(S1))*(ABS(S2)-ABS(R(I)))
690 NEXT I
700 A4=.9*40/(ABS(S2)-ABS(S1))*(ABS(S2)-ABS(A3))
710 'TRIGS': GOSUB 'GETGRID'
720 P=VAL(C1$[POS(C1$,CHR$(31))+1,LEN(C1$)]) ! Extract phi.
730 FOR I=1 TO N1 @ T(I)=T(I)+ANGLE(COS(P),SIN(P)) @ NEXT I
740 FOR I=2 TO N1-1 @ IF I=N1 THEN J=1 ELSE J=I+1
750 X1=INT(R(I)*SIN(T(I))+B)+1
760 X2=INT(R(J)*SIN(T(J))+B)+1
770 Y1=INT(H-R(I)*COS(T(I)))/2+1
780 Y2=INT(H-R(J)*COS(T(J)))/2+1
790 IF INT(X1-X2)=0 AND INT(Y1-Y2)=0 THEN 830
800 IF INT(X1-X2)=0 THEN Q=1 ELSE Q=(X2-X1)/ABS(X2-X1)
810 FOR M=X1 TO X2 STEP Q @ Y=INT((Y2-Y1)/(X2-X1+.000001)*(M-X1)+Y1) @ IF Y<=0 T
820 P$(Y)[M,M]='.' @ NEXT M
830 P$(Y1)[X1,X1]='*'
840 NEXT I
850 IF NOT FLAG(31) THEN GOSUB 'REFCIRC'
860 !
870 ! Print out the grid with the data mapped onto it.
880 !
890 GOSUB 'DUMP'
900 !
910 !  Print out the file comments ( if any ).
920 !  After this we are done with the plot.
930 !
940 GOSUB 'COMMENTS'
950 GOTO 'END'
960 !
970 ! ***********************************************************************
```

```
980 !
990 'GETGRID':
1000 FOR I=1 TO 40
1010 P$(I)[40]=CHR$(124)
1020 NEXT I
1030 P$(21)[1,80]=L$
1040 RETURN
1050 !
1060 ! ************************************************************************
1070 !
1080 'DUMP': FOR I=1 TO 40
1090 PRINT P$(I)[1,80]
1100 NEXT I
1110 RETURN
1120 !
1130 ! ************************************************************************
1140 !
1150 'REFCIRC': ! Generate the reference antenna level circle.
1160 FOR I=0 TO 355 STEP 5
1170 X1=INT(A4*SIN(I)+B)+1
1180 Y1=INT(A4*COS(I)+H)/2+1
1190 P$(Y1)[X1,X1]='+'
1200 NEXT I
1210 RETURN
1220 !
1230 ! ************************************************************************
1240 !
1250 'COMMENTS': IF NOT FLAG(33) THEN 'CALPRINT' @ PRINT 'ANTENNA FILE DATA'
1260 PRINT T1$ @ PRINT @ PRINT F1$
1270 PRINT C2$ @ PRINT @ PRINT 'Station frequency: ';C1$[1,POS(C1$,CHR$(31))]
1280 PRINT @ PRINT 'Station angle: ';C1$[POS(C1$,CHR$(31))+1,LEN(C1$)]
1290 PRINT @ PRINT @ PRINT 'REFERENCE ANTENNA LEVEL=';A3;'dBm'
1300 PRINT 'TEST ANTENNA MAX LEVEL=';A1;'dBm'
1310 PRINT 'TEST ANTENNA MIN LEVEL=';A2;'dBm'
1320 PRINT USING '@' @ RETURN
1330 'CALPRINT': PRINT @ PRINT 'CALIBRATION FILE DATA' @ PRINT T2$ @ PRINT @ PRI
1340 PRINT C3$ @ PRINT C4$ @ PRINT USING '@' @ RETURN
1350 !
1360 'SCALEIT': F3=10*INT(A1/10) @ E=1.0 @ G=30
1370 FOR I=1 TO N1 @ R(I)=MAX(G+(R(I)-F3)*E,0) @ NEXT I @ RETURN
1380 'END': SUB END
```

```
10 SUB SLOWPLOT(R(),T(),F1$,C1$,C2$,T1$,F2$,C3$,C4$,T2$,A1,A2,A3,N1)
20 !  This routine plots out the antenna pattern.
30 !      A(,):  ARRAY CONTAINING BITMAP FOR SIX PRINTER LINES.
40 !      R() :  ARRAY CONTAINING RADIAL COMPONENT OF DATA POINT.
50 !      T() :  ARRAY CONTAINING ANGULAR COMPONENT OF DATA POINT.
60 !      X() :  ARRAY CONTAINING THE X COMPONENT.
70 !      Y() :  ARRAY CONTAINING THE Y COMPONENT.
80 !      B3():  BOTTOM INDEX OF A() ARRAY FOR EACH QUADRANT.
90 !      T3():  TOP INDEX OF A() ARRAY FOR EACH QUADRANT.
100 !      M(,):  MATRIX CONTAINING THE REORDERED X & Y ARRAYS,
110 !              and the indices to the original X & Y arrays
120 !             (n,3) points to the post points, (n,4) points to the pre points
130 !      A1   :  MINIMUM AMPLITUDE IN DATA SET.
140 !      A2   :  MAXIMUM AMPLITUDE IN DATA SET.
150 !      R1   :  MAXIMUM RADIUS OF GRID.
160 !      R2   :  MINIMUM RADIUS OF GRID.
170 !      R3   :  DIFFERENCE IN RADIUS FOR CONCENTRIC CIRCLES.
180 !      R4   :  RADICAL TERM IN EVALUATION OF FUNCTION VALIDITY.
190 !      R5   :  ROOT OF Y1 EXPRESSION.
200 !      B1   :  BYTE VALUE OF X IN LEFT HEMISPHERE.
210 !      B2   :  BIT POSITION IN BYTE.
220 !      N1   :  NUMBER OF DATA POINTS IN FILE.
230 !      Y2   :  BITMAP ARRAY INDEX VARIABLE.
240 !      F$   :  FILE NAME.
250 !      L$   :  GRID EQUICIRCLE LABELING STRING
260 !      F1$ :  FILE TITLE
270 !      T1$ :  TITLE OF PLOT.
280 !      C1$ :  FIRST COMMENT.
290 !      C2$ :  SECOND COMMENT.
300 !      I    :  LOOP INDEX
310 !      J    :  LOOP INDEX
320 !      K    :  LOOP INDEX
330 OPTION BASE 1
340 SHORT B0(4),T0(4),B3(4),T3(4),S,S1,S2,S3,S4,Z1,Z2
350 DIM I$(4)[10],G$[80]
360 H=320
370 B=320
380 R1=320
390 F1=0
400 M1=0
410 INPUT 'What file to plot';F$
420 IF F$='' THEN GOTO 'HAVEFILE'
430 !  File is in external RAM or on the disc drive.
440 ASSIGN #1 TO F$
450 READ #1;F1$,T1$,C1$,C2$,A1,A2,A3,N1
460 DESTROY R,T,X,Y,M,F2
470 SHORT R(N1),T(N1),F2(N1)
480 INTEGER X(N1),Y(N1),M(N1,2),X1,Y1,L1,L2,U1,U2,B1,B2,B5
490 FOR I=1 TO N1
500 READ #1;T(I),R(I)
510 NEXT I
520 ASSIGN #1 TO *
```

```
530 !
540 DEF FNQ(D) ! This is the min-max Y-value determination.
550 ! For D=1 the calculation is for X,Y(n+1).
560 ! For D=2 the calculation is for X,Y(n-1).
570 ON ERROR GOSUB 'BOOBOO' @ GOTO 600
580 'BOOBOO': IF ERRN=7 THEN RETURN ELSE STOP
590 !
600 L1=MIN(Y(I),Y(M(I,D))) @ L1=MAX(L1,B0(L))
610 U1=MAX(Y(I),Y(M(I,D))) @ U1=MIN(U1,T0(L))
620 IF L1=Y(I) THEN L2=X(I) @ U2=X(M(I,D)) ELSE L2=X(M(I,D)) @ U2=X(I)
630 U1=INT(U1+.5) @ L1=INT(L1+.5)
640 IF D=2 THEN 'REVERS'
650 L2=(L1-Y(I))*(X(M(I,D))-X(I))/(Y(M(I,D))-Y(I))+X(I)
660 U2=(U1-Y(I))*(X(M(I,D))-X(I))/(Y(M(I,D))-Y(I))+X(I)
670 U2=INT(U2+.5) @ L2=INT(L2+.5)
680 GOTO 'ENDDEF'
690 'REVERS': L2=(L1-Y(M(I,D)))*(X(I)-X(M(I,D)))/(Y(I)-Y(M(I,D)))+X(M(I,D))
700 U2=(U1-Y(M(I,D)))*(X(I)-X(M(I,D)))/(Y(I)-Y(M(I,D)))+X(M(I,D))
710 'ENDDEF': U2=INT(U2+.5) @ L2=INT(L2+.5) @ OFF ERROR @ END DEF
720 !
730 !    Scale the data to fit the plotting window.
740 !    Convert from polar to cartesian system.
750 !    Build a data point pointer table.
760 !
770 GOSUB 'GRIDPARS'
780 F3=10*INT(A1/10)+10 @ E=7.5 @ G=245 @ INPUT 'OUTER RING VALUE',STR$(F3);F3$
785 F3=VAL(F3$)-10 ! Set level down to next highest ring for computation.
790 P=VAL(C1$[POS(C1$,CHR$(31))+1,LEN(C1$)]) ! Extract phi.
800 FOR I=1 TO N1
810 T(I)=T(I)+ANGLE(COS(P),SIN(P))
820 R(I)=MAX(G+(R(I)-F3)*E,0)
830 NEXT I
840 FOR I=1 TO N1
850 X(I)=INT(R(I)*SIN(T(I))+H+.5)
860 Y(I)=INT(R(I)*-COS(T(I))+B+.5)
870 M(I,1)=I+1
880 M(I,2)=I-1
890 NEXT I
900 M(N1,1)=1
910 M(1,2)=N1
920 'INTERP': !
930 !  we can now build the pattern up into the bitmap array.
940 !  Due to limited memory, the data mapping is done
950 !  in four sections.  Each section is encoded and hardcopied.
960 !
970 B0(1)=0
980 T0(1)=160
990 FOR I=2 TO 4 @ B0(I)=T0(I-1)+1 @ T0(I)=T0(I-1)+160 @ NEXT I
1000 !
1010 GOSUB 'SLOPE'
1020 !
1030 FOR L=1 TO 4
1040 DISP 'QUADRANT';L
1050 DESTROY A$ ! Reinitialize the bitmap array.
1060 DIM A$(161)[30]
1070 GOSUB 'GETGRID' ! Load a quadrant of the background grid.
```

```
1080 GOSUB 'DATALINK'
1090 GOSUB 'DUMP'
1100 NEXT L
1110 !
1120 !  Print out the file comments ( if any ).
1130 !  After this we are done with the plot.
1140 !
1150 GOSUB 'COMMENTS'
1160 GOTO 'END'
1170 !
1180 !  Map the data onto the grid pattern.
1190 !
1200 'DATALINK': OFF ERROR
1210 FOR I=2 TO N1-1
1220 IF Y(I)<B0(L) AND Y(M(I,1))<B0(L) OR Y(I)>T0(L) AND Y(M(I,1))>T0(L) THEN 'P
1230 D=FNQ(1)
1240 GOSUB 'LINEPLOT'
1250 'PRE': IF Y(I)<B0(L) AND Y(M(I,2))<B0(L) OR Y(I)>T0(L) AND Y(M(I,2))>T0(L)
1260 D=FNQ(2)
1270 GOSUB 'LINEPLOT'
1280 ! IF U3=1 OR L3=1 THEN GOSUB 'INTRCEPT'
1290 ! IF O0=0 THEN GOSUB 'LINEPLOT' ! Plot line unless it's outside plotting wi
1300 ! O0=0
1310 IF B0(L)<Y(I) AND Y(I)<T0(L) AND B0(L)<Y(M(I,1)) AND Y(M(I,1))<T0(L) THEN 1
1320 'NXTPNT': NEXT I
1330 'NXTQUAD': RETURN
1340 !
1350 'LINEPLOT': X1=L2 @ Y1=L1 ! Initialize  the line's start points.
1360 D1=U2-L2 @ D2=U1-L1 ! DeltaX and DeltaY.
1370 X9=1 ! X increment.
1380 IF D1<0 THEN D1=-D1 @ X9=-1 @ X1=L2
1390 Y9=1 ! Y increment.
1400 IF D2<0 THEN D2=-D2 @ Y9=-1
1410 IF D1>D2 THEN E1=D2+D2-D1 @ D2=D2-D2 ELSE 'MOVEY'
1420 D1=D2-(D1+D1)
1430 'NEXTX': ! IF X1=U2 THEN 'DONELINE'
1440 B1=INT(X1/8)+1 ! Byte position.
1450 B2=7-INT(MOD(X1,8)) ! Bit position.
1460 B5=INT(Y1)-B0(L)+1
1470 A$(B5)[B1,B1]=CHR$(BINIOR(NUM(A$(INT(Y1)-B0(L)+1)[B1,B1]),2^B2))
1480 IF E1>0 THEN Y1=Y1+Y9 @ E1=E1+D1 ELSE E1=E1+D2
1490 IF X1=U2 THEN 'DONELINE'
1500 X1=X1+X9
1510 GOTO 'NEXTX'
1520 'MOVEY': E1=D1+D1-D2 @ D1=D1+D1
1530 D2=D1-(D2+D2)
1540 'NEXTY': ! IF Y1=U1 THEN 'DONELINE'
1550 B1=INT(X1/8)+1 ! Byte position.
1560 B2=7-INT(MOD(X1,8)) ! Bit position.
1570 B5=INT(Y1)-B0(L)+1
1580 A$(B5)[B1,B1]=CHR$(BINIOR(NUM(A$(INT(Y1)-B0(L)+1)[B1,B1]),2^B2))
1590 IF E1>0 THEN X1=X1+X9 @ E1=E1+D2 ELSE E1=E1+D1
1600 IF Y1=U1 THEN 'DONELINE'
1610 Y1=Y1+Y9
1620 GOTO 'NEXTY'
1630 'DONELINE': RETURN
1640 !
```

```
1650 'ERRORS': IF ERRN=7 THEN F2(P)=F2(P-1)
1660 IF ERRN=8 THEN F2(P)=640
1670 RETURN
1680 !
1690 ! Precalculate the inverse slope between point pairs.
1700 !
1710 'SLOPE': DEFAULT OFF @ ON ERROR GOSUB 'ERRORS'
1720 FOR P=1 TO N1
1730 F2(P)=(X(M(P,1))-X(P))/(Y(M(P,1))-Y(P))
1740 IF F2(P)<1/640 THEN F2(P)=1/640
1750 NEXT P
1760 DEFAULT ON @ OFF ERROR
1770 RETURN
1780 !
1790 !  Reads in a grid quadrant.
1800 !
1810 'GETGRID': IF F=1 THEN 'PASS'
1820 ASSIGN #2 TO "GRIDDATA:2"
1830 F=1
1840 GOSUB 'INIT'
1850 'PASS': RESTORE #2,M1
1860 FOR N=B3(L) TO T3(L)
1870 READ #2;A$(N)
1880 M1=M1+1
1890 NEXT N
1900 RETURN
1910 !
1920 !  Dump out a quadrant to the printer.
1930 !
1940 'DUMP': IF L=1 THEN PRINT @ PRINT @ PWIDTH INF
1950 PWIDTH INF
1960 PRINT CHR$(27)&"*r640S";
1970 PRINT CHR$(27)&"*rA";
1980 FOR K=B3(L) TO T3(L)
1990 !
2000 !  If we are past the grid center, then label the grid lines.
2010 !
2020 IF L=3 AND K=5 THEN GOSUB 'LABEL'
2030 PRINT CHR$(27)&"*b80W";
2040 PRINT A$(K)[1,80];
2050 NEXT K
2060 PRINT CHR$(27)&"*rB";
2070 RETURN
2080 !
2090 ! Initialize array boundaries for each quadrant.
2100 !
2110 'INIT': FOR K=1 TO 4 @ B3(K)=1 @ T3(K)=160 @ NEXT K
2120 T3(1)=T3(1)+1
2130 RETURN
2140 !
2150 !  Prints out the dBm levels below the grid axis.
2160 !
2170 'LABEL': RETURN @ PRINT CHR$(27)&"*rB";
2180 J=1
2190 FOR I=Z2 TO Z1 STEP INT((Z2-Z1)/3) @ I$(J)=STR$(I) @ J=J+1 @ NEXT I
2200 PRINT USING 2210;I$
```

```
2210 IMAGE #,10A
2220 N=19-2*LEN(I$(4))
2230 FOR I=Z1 TO Z2 STEP INT((Z1-Z2)/3) @ I$(J)=STR$(I) @ J=J+1 @ NEXT I
2240 PRINT USING 2250;I$
2250 IMAGE #,10A
2260 PRINT CHR$(27)&"*r6405";
2270 RETURN
2280 !
2290 !
2300 !
2310 'COMMENTS': PRINT @ PRINT T1$ @ PRINT @ PRINT F1$ @ PRINT C2$
2320 PRINT @ PRINT 'Station frequency: ';C1$[1,POS(C1$,CHR$(31))-1]
2330 PRINT 'Station angle: ';C1$[POS(C1$,CHR$(31))+1,LEN(C1$)]
2340 PRINT @ PRINT
2350 PRINT USING 2360;A3
2360 IMAGE "REFERENCE ANTENNA LEVEL: ",MDD.D," dBm."
2370 PRINT USING 2380;A1
2380 IMAGE "TEST ANTENNA MAX LEVEL:  ",MDD.D," dBm."
2390 PRINT USING 2400;A2
2400 IMAGE "TEST ANTENNA MIN LEVEL:  ",MDD.D," dBm."
2410 PRINT @ PRINT 'Scale:          ';W/E;'dB/div' @ PRINT USING 2420;F3+W/E
2420 IMAGE "Outer ring:  ",MDD," dBm."
2430 PRINT CHR$(12) @ RETURN
2440 !
2450 !
2460 !
2470 'GRIDPARS': ASSIGN #1 TO 'PLOTPARS'
2480 READ #1;O#,E,G,W
2490 ASSIGN #1 TO *
2500 RETURN
2510 !
2520 !
2530 !
2540 'INTRCEPT': ! Find interception of the data line and the plotting window.
2550 PRINT 'INTERCEPT'
2560 M1=1/F2(I) ! Slope of the data line.
2570 ! Calculate the interception point.
2580 D=Y(I)-1/F2(I)*X(I) @ C=(H-1/F2(I)*(D-B))/(1+F2(I)^(-2))
2590 R4=(H-1/F2(I)*(D-B))^2-(1+F2(I)^(-2))*(H^2+(D-B)^2-R1^2) ! Quadratic formul
2600 ! If solution is imaginary, then the line is
2610 ! totally outside of the printing window, so skip it.
2620 IF R4<0 THEN 'WHOA' ELSE R4=SQRT(R4)
2630 ! Find the roots.
2640 S5=C+R4/(1+F2(I)^(-2)) @ S6=C-R4/(1+F2(I)^(-2))
2650 S6=S1-R1/(M1^2+1)
2660 IF (X(I)<=S5)<=X(M(I,1)) AND (X(I)<=S6)<=X(M(I,1)) THEN 'CHORD'
2670 IF NOT ((X(I)<=S5)<=X(M(I,1))) THEN 'TRYS6'
2680 IF U3=1 AND L3=0 THEN U1=(S5-X(I))/F2(I)+Y(I) @ U2=X5 @ U3=0 @ RETURN
2690 IF L3=1 AND U3=0 THEN L1=(S5-X(I))/F2(I)+Y(I) @ L2=X5 @ L3=0 @ RETURN
2700 'TRYS6': X1=S6
2710 IF U3=1 AND L3=0 THEN U1=(S6-X(I))/F2(I)+Y(I) @ U2=X5 @ U3=0 @ RETURN
2720 IF L3=1 AND U3=0 THEN L1=(S6-X(I))/F2(I)+Y(I) @ L2=X5 @ L3=0 @ RETURN
2730 'CHORD': S7=(S5-X(I))/F2(I)+Y(I)
2740 S8=(S6-X(I))/F2(I)+Y(I)
2750 U1=MAX(S7,S8) @ L1=MIN(S7,S8)
```

```
2760 U1=MIN(U1,T0(L)) @ L1=MAX(L1,B0(L))
2770 L2=(L1-Y(I))*(X(M(I,1))-X(I))/(Y(M(I,1))-Y(I))+X(I)
2780 U2=(U1-Y(I))*(X(M(I,1))-X(I))/(Y(M(I,1))-Y(I))+X(I)
2790 U3=0 @ L3=0
2800 RETURN
2810 'WHOA': OO=1 @ RETURN
2820 !
2830 !
2840 !
2850 'END': SUB END
```

```
10 SUB TEMPLATE
20 !
30 ! TEMPLATE is used to redefine the keyboard for personalized
40 !           use by the operator.  It is also used to configure
50 !           the AUTO command parameters.
60 !
70 ! FLAGS:
80 !        31:  1=Fast plot for cal. file.
90 !        32:  1=Slow plot for cal. file.
100 !       33:  1=Fast plot for antenna data file.
110 !       34:  1=Slow plot for antenna data file.
120 !
130 ! ************************************************************************
140 !
150 INTEGER B(4)
160 DIM D$[8],F$[8],F1$[8],F2$[8],F3$[8],F4$[8],C$(50)[80]
170 !
180 ! Define the keyboard.
190 !
200 INPUT 'Save current KEYS?';D$
210 IF D$[1,1]='Y' THEN RENAME KEYS TO 'OLDKEYS'
220 INPUT 'New KEYS file name?';F3$
230 IF F3$<>'' THEN RENAME F3$ TO KEYS
240 DEF KEY 'Q','AUTO'&CHR$(13)
250 DEF KEY 'W','CALIBRATE'&CHR$(13)
260 DEF KEY 'E','COLLECT'&CHR$(13)
270 DEF KEY 'R','QWIKPLOT'&CHR$(13)
280 DEF KEY 'T','SLOWPLOT'&CHR$(13)
290 DEF KEY 'U','TEMPLATE'&CHR$(13)
300 DEF KEY 'O','SAVEFILE'&CHR$(13)
310 DEF KEY 'P','GETFILE'&CHR$(13)
320 DEF KEY 'S','QUIT'&CHR$(13)
330 RENAME F3$ TO KEYS
340 !
350 ! Finished defining the keys, now ask if we want
360 ! change the parameters for the AUTO mode.
370 !
380 INPUT 'Change AUTO defaults?';D$
390 IF D$[1,1]='Y' THEN 'PARMS' ELSE 'ALTRFLGS'
400 !
410 ! ************************************************************************
```

```
420 !
430 ! This section redefines the default conditions under which AUTO runs.
440 !
450 'PARMS': INPUT 'New auto file title';F$
460 !
470 ! Reinitialize the system control flags.
480 FOR I=20 TO 24 @ CFLAG I @ NEXT I
490 FOR I=31 TO 34 @ CFLAG I @ NEXT I
500 !
510 FOR L=1 TO 50
520 INPUT 'Module?';C$(L) ! Ask the user for the module to be exec'd.
530 GOSUB C$(L)
540 NEXT L
550 BEEP @ DISP 'ERROR- CMND OVFL' @ WAIT 1000 @ GOTO 'PARMS'
560 'CALIBRAT': ! Define the calibration auto run parameters.
570 INPUT 'Number of cal. points?';N @ L=L+1 @ C$(L)=STR$(N)
580 INPUT 'Initial cal. filename';D$ @ L=L+1 @ C$(L)=D$
590 INPUT 'Request title input?';D$ @ IF D$[1,1]='Y' THEN L=L+1 @ C$(L)='1'
600 INPUT 'Request comment input?';D$ @ IF D$[1,1]='Y' THEN L=L+1 @ C$(L)='1'
610 RETURN
620 !
630 'COLLECT': ! Define the collect auto run parameters.
640 INPUT 'Number of data points?';N @ L=L+1 @ C$(L)=STR$(N)
650 INPUT 'Initial data filename';D$ @ L=L+1 @ C$(L)=D$
660 INPUT 'Request title input?';D$ @ IF D$[1,1]='Y' THEN L=L+1 @ C$(L)='1'
670 INPUT 'Request comment input?';D$ @ IF D$[1,1]='Y' THEN L=L+1 @ C$(L)='1'
680 RETURN
690 !
700 'QWIKPLOT': ! Define the auto run qwikplot parameters.
710 C$(L)='QWIKPLOT'&CHR$(13)
720 RETURN
730 !
740 'SLOWPLOT': ! Define the auto run parameters for slowplot.
750 C$(L)='SLOWPLOT'&CHR$(13)
760 RETURN
770 !
780 'SAVEFILE': ! Auto run parameters for savefile.
790 C$(L)='SAVEFILE'&CHR$(13)
800 RETURN
810 !
820 'GETFILE': ! Auto run parameters for getfile.
830 C$(L)='GETFILE'&CHR$(13)
840 RETURN
850 !
860 'LOOPBACK': ! Auto run loopback resets the auto run file for another run.
870 C$(L)='LOOPBACK'&CHR$(13)
880 RETURN
890 !
900 'QUIT': ! Auto run mode termination.
910 C$(L)='QUIT'&CHR$(13)
920 POP
930 'END': ! Save the new auto parameters.
940 INPUT 'Auto file name?';F4$ @ IF F4$='' THEN 940
950 ASSIGN #1 TO F4$
960 PRINT #1;C$
970 ASSIGN #1 TO *
```

```
980 'ALTRFLGS': INPUT 'Redefine user input?';D$ @ IF D$[1,1]='N' THEN 'OUT'
990 INPUT 'Data title request?';D$ @ IF D$='Y' THEN SFLAG 24
1000 INPUT 'Data comment request?';D$ @ IF D$='Y' THEN SFLAG 23
1010 INPUT 'Cal. title request?';D$ @ IF D$='Y' THEN SFLAG 22
1020 INPUT 'Cal. comment request?';D$ @ IF D$='Y' THEN SFLAG 21
1030 'SUBEND': SUB END
```