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A FORTRAN PROGRAM FOR RECTANGULAR MICROSTRIP ANTENNAS. (U)
APR 82 W F RICHARDS, Y T LO

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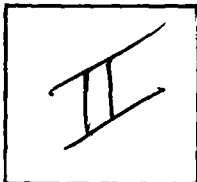
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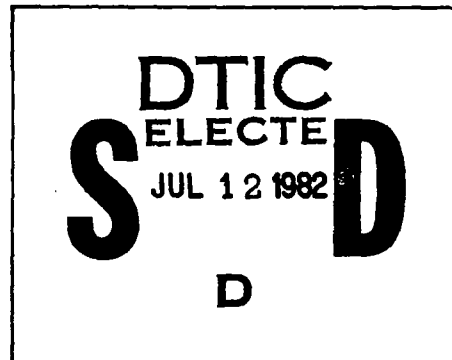
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University of Illinois at Urbana-Champaign

W.F. Richards and Y.T. Lo

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report supplies a program, with examples, for the analysis of rectangular microstrip antennas. The formulas upon which the program is based are also provided. The theory from which these formulas were obtained is based on the "cavity model" of the microstrip antenna developed at the University of Illinois by Lo, Richards, et al. Details of the theory can be found in the references listed in the bibliography at the end of the report.		

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RADC-TR-82-78 has been reviewed and approved for publication.

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INTRODUCTION

This report supplies a program, with examples, for the analysis of rectangular microstrip antennas. The formulas upon which the program is based are also provided. The theory from which these formulas were obtained is based on the "cavity model" of the microstrip antenna developed at the University of Illinois by Lo, Richards, *et al.* Details of the theory can be found in the references listed in the bibliography at the end of the report.

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CHAPTER 1: FORMULAS AND DEFINITIONS

For completeness, the basic formulas and procedures used to compute the pattern and impedance of a microstrip antenna are reviewed. The geometrical parameters used in the formulas that follow are defined in figure 1.

I GENERAL NOTATIONS

The following notations are used in the formulas within this appendix.

- (1) $k_0 = 2\pi f/c$ where f is the frequency and c is the speed of light in free space.
- (2) $\eta_0 = 377\Omega$.
- (3) $\epsilon_{0m} = 1$ for $m = 0$ and 2 otherwise.
- (4) (r, θ, ϕ) is the coordinate of a point in spherical coordinates. The direction perpendicular to the ground plane corresponds to $\theta = 0$. The line $\theta = \pi/2$, $\phi = 0$ is the x axis while $\phi = \pi/2$ is the y axis.
- (5) $p_m = (k^2 - (m\pi/a)^2)^{1/2}$ (the branch is irrelevant).
- (6) $k = k_0\epsilon_r^{1/2}(1-j\delta)^{1/2}$ where the branch is also irrelevant, ϵ_r is the relative dielectric constant of the dielectric substrate, and δ is the loss tangent of the dielectric substrate (later to be replaced by the "effective loss tangent." See V.)
- (7) $\Phi_m^{(1)} = \left(\frac{\epsilon_{0m}}{a}\right)^{1/2} \cos[p_m(b-y)]\cos(m\pi x/a)$, for $y \geq y_1$, and
 $\Phi_m^{(2)} = \left(\frac{\epsilon_{0m}}{a}\right)^{1/2} \cos(p_m y)\cos(m\pi x/a)$, for $y < y_1$.
- (8) $j_0(x) = \sin(x)/x$ (the spherical Bessel function of zero order).
- (9) Δ is the skin depth.

II PATTERN AND RADIATED POWER

Radiated power, P_{rad} , is computed in subroutine VRAD. This routine calls the double integration routine, VDOUBL, which applies 4-point Gaussian quadrature recursively to integrate the power pattern supplied by VPPAT. The function VPPAT calls VPAT which computes the complex polar pattern of the antenna by application of the following formulas:

$$F = -\frac{e^{-jk_0 r}}{r} \frac{jk_0 r \eta_0 b}{2\pi} \sum_{m=0}^{\infty} \frac{\epsilon_{0m} \cos(m\pi x_1/a)}{p_m b \sin(p_m b)} j_0\left(\frac{m\pi d}{2a}\right) \left[(-1)^m e^{jk_0 a \sin\theta \cos\phi} - 1 \right] \\ \cdot \left\{ \hat{x} \left[\cos(p_m y_1) e^{jk_0 b \sin\theta \sin\phi} - \cos[p_m(b-y_1)] \right] \frac{jk_0 a \sin\theta \cos\phi}{(m\pi)^2 - (k_0 a \sin\theta \cos\phi)^2} \right.$$

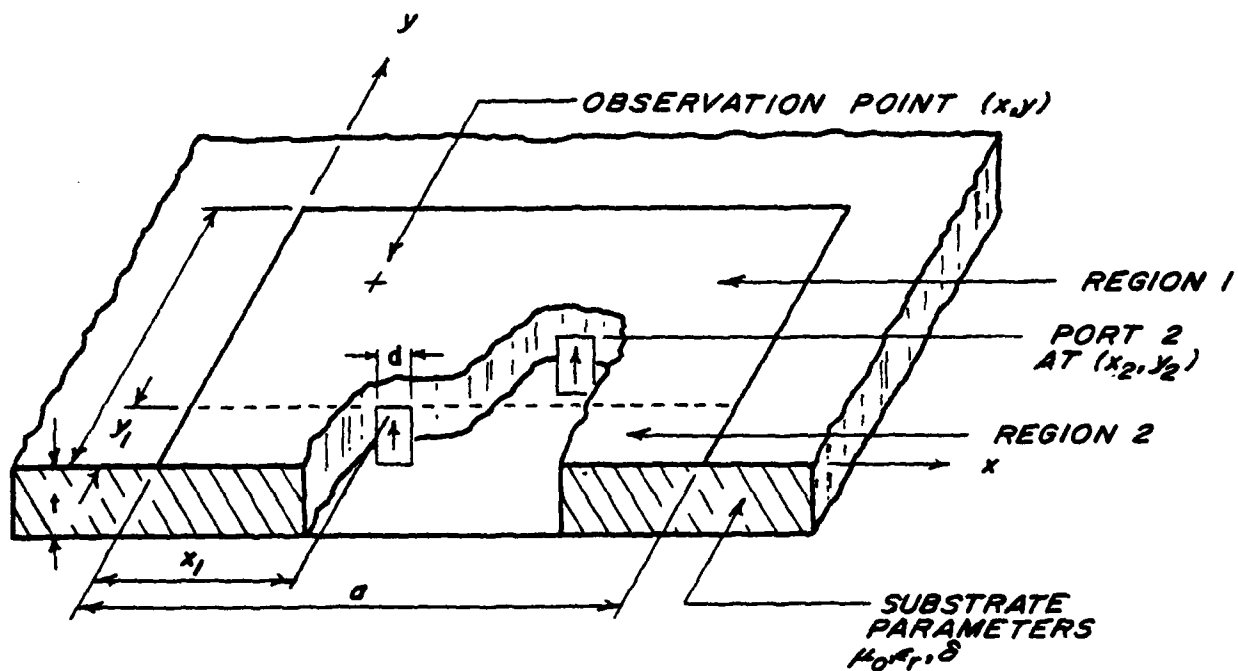


Figure 1. Geometry and Idealized Feeds for the Rectangular Microstrip Antenna

$$\begin{aligned}
& - \hat{y} \frac{b}{a} \left[p_m b \sin(p_m b) e^{jk_0 y_1 \sin \theta \sin \phi} + j k_0 b \sin \theta \sin \phi \right. \\
& \cdot \left. \left[\cos(p_m y_1) e^{jk_0 b \sin \theta \sin \phi} - \cos[p_m (b - y_1)] \right] \right] \\
& \cdot \left[(p_m b)^2 - (k_0 b \sin \theta \sin \phi)^2 \right]^{-1} \Big\}
\end{aligned}$$

$$E_\theta = k_0 (-F_x \sin \phi + F_y \cos \phi)$$

$$E_\phi = -k_0 (F_x \cos \phi + F_y \sin \phi) \cos \theta$$

where E_θ and E_ϕ are the θ and ϕ components of the electric far field, F_x and F_y are the x and y components of $\vec{F}$, and $\hat{x}$ and $\hat{y}$ are the unit vectors in the x and y directions.

III STORED ENERGY AND OHMIC LOSSES

The stored electric energy, W_E , is computed from

$$4\pi f W_E = \epsilon_r k_0 t (k_0 b)^2 \eta_0 \sum_{m=0}^{\infty} \frac{j \delta \left(\frac{m\pi d}{2a} \right)}{\left| p_m b \sin(p_m b) \right|^2}$$

$$\cdot \left\{ y_1 \left| \Phi_m^{(1)}(x_1, y_1) \right|^2 N(p_m y_1) + (b - y_1) \left| \Phi_m^{(2)}(x_1, y_1) \right|^2 N[p_m (b - y_1)] \right\},$$

where

$$N(z) = \frac{1}{2} [j_0(j_2 \text{Im} z) + j_0(2 \text{Re} z)].$$

The dielectric loss is found from

$$P = 4\pi f \delta W_E.$$

The copper loss is determined using

$$\frac{P_{Cu}}{P_d} \approx \frac{\Delta}{\delta t}$$

(at resonance). All these quantities are computed within subroutine VENLS.

IV IMPEDANCE

The impedances are computed in subroutines VZ1 and VZ2. The former is called by VZ2 to compute z_{11} and z_{22} while z_{12} is computed within VZ2 by the following formula for $y_2 > y_1$:

$$z_{12} = -jk_0 t \eta_0 \sum_{m=0}^{\infty} \left\{ \frac{\epsilon_{0m}}{a} \cos(m\pi x_1 / a) \cos(m\pi x_2 / a) j \delta \left(\frac{m\pi d}{2a} \right) \right\}$$

$$\left. \frac{\cos[p_m(b-y_2)]\cos(p_my_1)}{p_m\sin(p_mb)} \right\}.$$

For $y_1 = y_2$, this series is accelerated by writing it as

$$\begin{aligned} z_{12} = & -jk_0\epsilon\eta_0 \left\{ \frac{\cos(ky_1)\cos[k(b-y_1)]}{k\sin(kb)} \right. \\ & + \sum_{m=1}^{\infty} \frac{2}{a} \cos(m\pi x_1/a) \cos(m\pi x_2/a) j_0^2 \left(\frac{m\pi d}{2a} \right) \\ & \cdot \left[\frac{\cos(p_my_1)\cos[p_m(b-y_1)]}{p_m\sin(p_mb)} + \frac{a\tau}{m\pi} \right] \\ & + \frac{jk_0\epsilon\eta_0\tau}{\pi^3} \left(\frac{a}{d} \right)^2 \left[F\left(\frac{\pi(x_1+x_2)}{a} \right) + F\left(\frac{\pi(x_1-x_2)}{a} \right) \right. \\ & \left. \left. - \frac{1}{2} \left[F\left(\frac{\pi(x_1+x_2+d)}{a} \right) + F\left(\frac{\pi(x_1+x_2-d)}{a} \right) + F\left(\frac{\pi(x_1-x_2+d)}{a} \right) + F\left(\frac{\pi(x_1-x_2-d)}{a} \right) \right] \right] \right\} \end{aligned}$$

where $\tau = 1$ for $b > y_1 > 0$ and $\tau = 2$ for $y_1 = 0$ or $y_1 = b$. The driving point impedance, z_{11} , is computed using the accelerated formula for z_{12} with x_2 and y_2 replaced by x_1 and y_1 , respectively. Similarly, z_{22} is computed with x_1 and y_1 replaced by x_2 and y_2 .

The function $F(x)$ is related to Clausen's integral and is given by

$$F(x) = \sum_{m=1}^{\infty} \cos \frac{(mx)}{m^3}.$$

This function is written in terms of $\ln x$ and a rapidly converging series of Chebyshev polynomials. It is evaluated in function VF.

V EFFECTIVE LOSS TANGENT

The "effective" loss tangent is found by first computing the fields within the "cavity" based on k found from the *actual* loss tangent of the substrate. From these fields, computations of the electric stored energy, the radiated power, and the power loss in the dielectric and copper are made. From these quantities, the antenna " Q " is computed from

$$Q = \frac{4\pi f W_E}{P_{\text{rad}} + P_d + P_{\text{Cu}}}.$$

An "effective" loss tangent, δ_{eff} , is defined as

$$\delta_{\text{eff}} = \frac{1}{Q}.$$

This loss tangent is then used to compute an improved k and the whole process is repeated to find new (and more accurate) predictions of the stored energy and losses. A new δ_{eff} is found, and so on. The program as supplied computes a twice iterated δ_{eff} . However, for thin substrates, the procedure converges after a single iteration and the first δ_{eff} computed is adequate. A simple modification of the program will eliminate the second iteration.

CHAPTER 2: PROGRAM LISTING

The FORTRAN program listed in this chapter was implemented on the CYBER 175 computer located at the University of Illinois, Urbana, IL. The program uses CDC's "extended FORTRAN" and the Graphics Compatibility System (GCS) produced by the United States Military Academy. Names of subroutines provided by GCS all begin with the letter "U." These GCS routines are used in certain input/output subroutines including those that plot results. Such routines have been listed below in a section entitled "INPUT/OUTPUT AND PLOTTING." It is this section of the program which is rather strongly installation dependent and would probably require user modification.

The other major sections of the program listed below are the "MAIN PROGRAM" and the "NUMERICAL" sections. The former controls the flow of execution of the program while the latter computes the impedance, pattern, *etc.* Both these sections are fairly transportable, particularly the NUMERICAL section. Only a few non-ANSI FORTRAN statements and routines are used in these sections and these can be easily eliminated or modified.

The overall simplified flow-chart of the program is shown in fig. 2. Other details of specific subroutines can be obtained by referring to their respective documentation in comment cards.

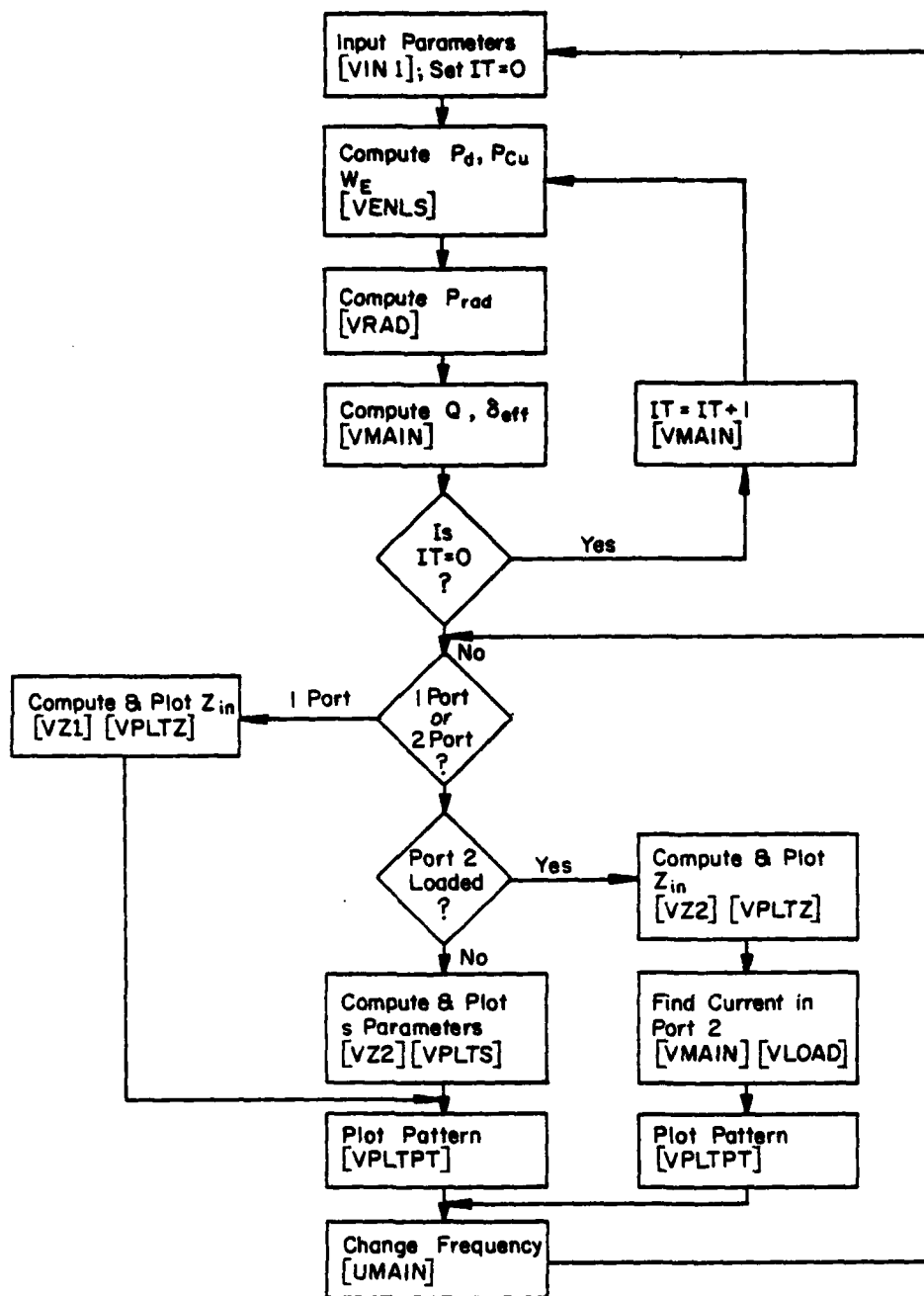


Figure 2. Simplified Flow Chart for the Program

MAIN PROGRAM

```
PROGRAM VMAIN(INPUT,OUTPUT,TAPE1=OUTPUT,TAPE2=INPUT,RESULT, N/S
1      TAPE3=RESULT)
```

```
*****
** This is the main program of a group of routines that computes **
** (1) Input impedance of a **
** (a) Single port rectangular microstrip antenna; **
** (b) Two port rectangular microstrip antenna with one of its **
** ports loaded by a specified impedance (in subroutine **
** "VLOAD"); **
** (2) The "s" parameters of a two port microstrip antenna; **
** (3) The radiation pattern of a **
** (a) Single port rectangular microstrip antenna; **
** (b) Two port rectangular microstrip antenna with one of its **
** ports loaded by a specified impedance. **
*****
```

```
REFERENCES: The method used is described in the following
publications:
```

- [1] Y. T. Lo, D. Solomon, W. F. Richards, "Theory and Experiment on Microstrip Antennas," IEEE TRANS. ANTENNAS PROPAGAT. Vol. AP-27, pp. 137-145, MAR 79.
- [2] Y. T. Lo, W. F. Richards, D. D. Harrison, "An Improved Theory for Microstrip Antennas and Applications," RADC-TR INTERIM REPORT (PART I), DEC 78.
- [3] W. F. Richards, Y. T. Lo, D. D. Harrison, "Improved Theory for Microstrip Antennas," IEE ELECTRONICS LETTERS, Vol. 15, pp. 42-44, JAN 79.

LIMITATIONS:

The current version does not include an estimate of surface wave power as this computation is currently under critical evaluation. This version also requires the specification of the so called "effective feed width." This parameter arises from an attempt to idealize the fields in the vicinity of a coaxial or microstrip feed so that the source can be considered as a uniform current ribbon of width D (the effective width) flowing from the patch to the ground plane. Since the observed shift of impedance loci into inductive half of the Smith Chart depends rather strongly on the field distribution in the vicinity of the feed, this idealization needs some refinements and a more rigorous treatment of this problem is under way. For the present, the user should try some different values of D until he finds one which fits measured results most closely. The representation of the fields for frequencies far away from resonance, say near the mean of two widely spaced adjacent resonant frequencies, is currently not sufficiently accurate for all applications. We will do further research to develop better computations in this regime.

IMPLEMENTATION REQUIREMENTS: Except for the input/output which relies heavily upon the graphics capabilities of the GCS system developed by the United States Military Academy, the program is written in ANSI FORTRAN and should be relatively transportable. All GCS subroutine names begin with a "U" in this program. Some of the input/output utilizes extended features of CDC's FORTRAN as implemented on the University of Illinois's CYBER 175 (NOS V. 4.7) and will have to be modified for use on other systems. Non-ANSI FORTRAN statements are flagged as N/S.

USER INSTRUCTIONS: The parameter descriptions and options are explained through the use of examples provided with this listing.

```

REAL LOSS, KO, LOSSO
INTEGER P, ANS, PO
COMPLEX Z, Z11, Z12, Z22, ZL, ZIN, I2
COMMON /DELTA/ DELTA
COMMON /OPT/ ANS
COMMON /I1/ A, B, T, D, DIELO, LOSS, SIGM, P, XP, YP, XPP, YPP, L,
* FO, NFREQ, KO, TWOPI, PDO2A, PXPOA, BOA, BAND, PI,
* ETAO, K, GAIN, DELTAF
COMMON /I2/ AO, BO, TO, DO, DIELO, LOSSO, SIGMO, PO, XPO, YPO, XPP, YPP,
* LO, FOO, BANDO, DELTAO
DATA AO/0./, BO/0./, TO/0./, DO/0./, DIELO/1./, LOSSO/0./, SIGMO/580./,
* PO/1./, XPO/0./, YPO/0./, XPP/0./, YPP/0./, LO/"N"/, FOO/0./,
* BANDO/0./, DELTAO/0./, C/30000./, PI/3.1415926535898/,
* TWOPI/6.2831853071796/, ETAO/377./
CALL USTART
1 CALL VIN1
IT = 0
DELTA = LOSS

C
C
C Find the nearest resonant frequency to the specified center frequency

CALL VSEARC (M, N)
KO = SQRT(((M*PI/A)**2 + (N*PI/B)**2)/DIEL)
PDO2A = PI * D / (2 * A)
PXPOA = PI * XP / A
BOA = B / A

C
C
C Compute "closed form" sum of asymptotic expression of the summand
for the driving point impedance series

S1 = VS(XP, XP)
IF (P .LT. 2) GO TO 2
S2 = VS(XPP, XPP)
S3 = VS(XP, XPP)

C
C
C Compute stored electric energy, WWE, copper loss, PCU, and dielectric
loss, PD, for "effective loss tangent", DELTA. (Dielectric loss is
always computed using the actual loss tangent, LOSS).

2 CALL VENLS (DELTA, WWE, PCU, PD)

C
C
C Compute radiated power, PRAD, for effective loss tangent, DELTA

CALL VRAD (DELTA, PRAD)
POWER = PRAD + PCU + PD
Q = 2 * WWE / POWER
DELTA = 1/Q
IT = IT + 1

C
C
C Iterate the calculation twice to ensure proper value of DELTA
is obtained.

IF (IT .LT. 2) GO TO 2

C
C
C Compute the pattern along the zenith direction to determine
antenna gain.

CALL VPAT (0., 0., Z11, Z22, DELTA, (1., 0.), XP, YP)
E = Z11*CONJG(Z11)+Z22*CONJG(Z22)
GAIN = 10.*ALOG(2*TWOPI*E/(ETAO*PRAD))
1 /ALOG(10.)
F = FO - (NFREQ/2)*DELTAF
NO2 = NFREQ/2 + 1
WRITE (1,7)
READ (2,8) ANS
CALL EOF(2)
IF (ANS .EQ. 0) ANS = 3
DO 3 K = 1, NFREQ
KO = TWOPI * F / C

```

N/S

```

C      GO TO (10, 20), P
C
C      Find the driving point impedance of the one port
C
10  C      CALL VZ1 (Z, DELTA, XP, YP, S1)
C
C      Input data to the plotting program, VPLTZ
C
C      CALL VPLTZ (Z, F, 0)
C      GO TO 30
C
C      Compute the "z" parameters of the two port
C
20  C      CALL VZ2 (Z11, Z12, Z22, DELTA, S1, S2, S3)
C      IF (L .EQ. "N") GO TO 202
C
C      Compute impedance of load on port two of the microstrip
C
C      CALL VLOAD (F, ZL)
C
C      Compute the input impedance as seen at port one of the loaded
C      microstrip antenna.
C
C       $ZIN = Z11 - Z12^2 / (Z22 + ZL)$ 
C      CALL VPLTZ (ZIN, F, 0)
C
C      Compute the current flowing through the load at port two.
C
C       $I2 = -Z12 / (Z22 + ZL)$ 
C
C      Depending on the options chosen, compute the pattern of the antenna.
C
C      IF (ANS .EQ. 1 .OR. (ANS .EQ. 2 .AND. K .EQ. NO2))
1  C      CALL VPLTPT (I2, F)
C      GO TO 3
C
C      Input the two port parameters to the "s" parameter plotting
C      program for the case of a non-loaded two port antenna.
C
202 C      CALL VPLTS (F, Z11, Z12, Z22, 0)
30  C      IF (ANS .EQ. 1 .OR. (ANS .EQ. 2 .AND. K .EQ. NO2))
1  C      CALL VPLTPT (I2, F)
3  C      F = F + DELTAF
C      IF (P .EQ. 1) GO TO 5
C      IF (L .NE. "N") GO TO 5
C
C      Plot "s" parameters
C
C      CALL VPLTS (F0, Z11, Z12, Z22, 1)
C      GO TO 6
C
C      Plot the input impedance to the microstrip.
C
5  C      CALL VPLTZ (Z, F0, 1)
6  C      WRITE (1,9)
C      READ (2,11) ANS
C      CALL EOF(2)
C      IF (ANS .EQ. 0) ANS = "Y"
C      IF (ANS .EQ. "Y") GO TO 1
C      STOP
7  C      FORMAT ("Choose an option:",/,
1  C      " (1) Plot patterns at",
2  C      " all frequencies.",/,
3  C      " (2) Plot pattern only",
4  C      " at center frequency.",/,
5  C      " (3) Plot no patterns",/,
6  C      "Type option (1, 2, or 3): ",)
8  C      FORMAT(I1)
9  C      FORMAT ("Continue (type Y or N) ",)

```

N/S

11 FORMAT (A1)
END

საქართველოს მთავრობის

```

*****
*
* PURPOSE:  This subroutine performs the integral from 0 to A of the
*           integral from 0 to B of the externally declared function
*           F(X,Y).
*
* PARAMETERS:  The parameters are as stated above and M is the log base
*              two plus one of the number of point Gaussian quadrature
*              formula used in the mechanical quadrature.  INT is the
*              integral.
*
*****

```

12

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```

COMPLEX ZL
INTEGER STRING(4)
COMMON /I1/ A, B, T, D, DIEL, LOSS, SIGM, P, XP, YP, XPP, YPP, L,
*          FO, NFREQ, KO, TWOPI, PDO2A, PXPOA, BOA, BAND, PI,
*          ETAO, K, GAIN, DELTAF
COMMON /LDID/ STRING
IF (K.GT. 1) GO TO 1
PRINT *, "INPUT CAPACITANCE IN PICO FARADS: C = ",
READ *, C
ENCODE (40, 2, STRING) C
C = C * 1.E-6
ZL = CMPLX(0., -1./(F*TWOPI*C))
FORMAT ("CAPACITIVE LOAD: C = ", E8.2, " ")
RETURN
END

```

CCCCCCCC

```
*****  
*  
* PURPOSE: This routine returns a load impedance of zero, (the  
* impedance of a short). It is loaded as the default VLOAD  
* subroutine.  
*  
*****
```

```
SUBROUTINE VLOAD(F, ZL)  
INTEGER STRING(4)  
COMPLEX ZL  
COMMON /LDID/ STRING  
DATA STRING /"short circuit" /  
ZL = (0.,0.)  
RETURN  
END
```

C
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```
*****
*
* PURPOSE: This group of functions compute certain quantities used in the
*           evaluation of electric stored energy computed in subroutine
*           VENLS.
*****
```

```
REAL FUNCTION M (Z)
COMPLEX Z
REAL JO, IO
M = (IO(2*AIMAG(Z)) - JO(2*REAL(Z)))/2
RETURN
END
REAL FUNCTION N (Z)
COMPLEX Z
REAL JO, IO
N = (JO(2*REAL(Z)) + IO(2*AIMAG(Z)))/2
RETURN
END
REAL FUNCTION IO (X)
T = EXP(X)
IO = 1.
IF (X .NE. 0.) IO = (T - 1/T) / (2*X)
RETURN
END
```

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SUBROUTINE VPAT (THETA, PHI, ETHETA, EPHI, DELTA, I, X, Y)

```
*****
*
* PURPOSE:  To evaluate the electric far field at direction
*           (THETA,PHI)
*
* PARAMETERS: ETHETA and EPHI are the THETA and PHI
*             components of electric field. DELTA is the
*             loss tangent used in the computation.
*
*****
```

```
COMPLEX ETHETA, EPHI, FX, FY, PM, KSQ, PMB, PMY, CPY, CPBMY, I, XF,
* F, PMBSPB, EKYSS, EKBSS, XT, YT, XTERM, YTERM, D2, FACTOR
REAL KO, MPI, KASC, KBSS, KYSS, JO
COMMON /I1/ A, B, T, D, DIEL, LOSS, SIGM, P, XP, YP, XPP, YPP, L,
* FO, NFREQ, KO, TWOPI, PDO2A, TPXPOA, BOA, BAND, PI,
* ETAO, K, GAIN, DELTAF
PXOA = PI * X / A
FX = (0.,0.)
FY = (0.,0.)
M = 0
CT = COS(THETA)
ST = SIN(THETA)
CP = COS(PHI)
SP = SIN(PHI)
KYSS = KO * Y * SP * ST
KBSS = KO * B * SP * ST
KASC = KO * A * CP * ST
KSQ = DIEL * KO**2 * CMPLX(1., -DELTA)
1 MPI = M * PI
PM = CSQRT(KSQ - (MPI/A)**2)
PMY = PM * Y
PMB = PM * B
CPY = CCOS(PMY)
CPBMY = CCOS(PMB-PMY)
PMBSPB = CSIN(PMB) * PMB
EKYSS = CEXP(CMPLX(0.,KYSS))
EKBSS = CEXP(CMPLX(0.,KBSS))
D1 = MPI**2 - KASC**2
D2 = PMB**2 - KBSS**2
XF = CPY * EKBSS - CPBMY
F = CEXP(CMPLX(0.,KASC))
IF (M .NE. 2*(M/2)) F = -F
F = F - 1.
IF (ABS(D1) .GT. 1.E-5) GO TO 2
```

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>>>-----> Find limiting value of expression when D1 ----> 0.

```
XT = XF
IF (M .GT. 0) XT = XT / 2.
GO TO 3
2 XT = XF * F * CMPLX(0.,KASC) / D1
3 YT = -BOA * F * (PMBSPB * EKYSS + CMPLX(0.,KBSS)*XF) / D2
FACTOR = COS(M * PXOA) * JO(M * PDO2A) / (PMBSPB)
IF (M .GT. 0) FACTOR = FACTOR * 2.
M = M + 1
IF (MOD(M,2) .EQ. 0) GO TO 30
XTERM = FACTOR * XT
YTERM = FACTOR * YT
GO TO 1
30 XTERM = XTERM + FACTOR * XT
YTERM = YTERM + FACTOR * YT
FX = FX + XTERM
FY = FY + YTERM
IF (SQRT(CABS(XTERM)**2 + CABS(YTERM)**2) .LT. 0.0001 *
* SQRT(CABS(FX)**2 + CABS(FY)**2)) GO TO 4
GO TO 1
```

```

4 FACTOR = KO**2 * T * ETAO * B / TWOPI
  ETHETA = (-FX*SP + FY*CP) * FACTOR * I
  EPHI = -(FX*CP + FY*SP) * CT * FACTOR * I
  RETURN
END

```

```

REAL FUNCTION JO(X)
  JO = 1.
  IF (X .NE. 0.) JO = SIN(X) / X
  RETURN
END

```

FUNCTION VPPAT (THETA, PHI)

CCCCCCCC

```
*****
*
* PURPOSE:  THIS SUBROUTINE COMPUTES THE POWER PATTERN (TIMES THE SIN OF
*           OF THE POLAR ELEVATION ANGLE, THETA) FROM THE COMPLEX PATTERN
*           COMPUTED IN SUBROUTINE VPAT.
*
* PARAMETERS: (THETA, PHI) IS THE DIRECTION OF OBSERVATION IN SPHERICAL
*             COORDINATES.
*
*****
```

```
COMPLEX ETHETA, EPHI
COMMON /DELTA/ DELTA
COMMON /I1/ A, B, T, D, DIEL, LOSS, SIGM, P, XP, YP, XPP, YPP, L,
*          FO, NFREQ, KO, TWOPI, PDO2A, TPXPOA, BOA, BAND, PI,
*          ETAO, K, GAIN, DELTAF
CALL VPAT (THETA, PHI, ETHETA, EPHI, DELTA, (1.,0.), XP, YP)
VPPAT = SIN(THETA) * (ETHETA * CONJG(ETHETA) + EPHI * CONJG(EPHI))
RETURN
END
```

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SUBROUTINE VRAD (DELTA, PRAD)

```
*****
*
* PURPOSE: To evaluate the power radiated by the microstrip antenna
*
* PARAMETERS: DELTA is the effective loss tangent, and PRAD is the
*             radiated power computed using numerical quadrature.
*
*****
```

```
* COMMON /I1/ A, B, T, D, DIEL, LOSS, SIGM, P, XP, YP, XPP, YPP, L,
*             FO, NFREQ, KO, TWOPI, PDO2A, TPXPOA, BOA, BAND, PI,
*             ETAO, K, GAIN, DELTAF
* EXTERNAL VPPAT
* CALL VDOUBL (VPPAT, 3, 0., PI/2., 0., TWOPI, PRAD)
* PRAD = PRAD / ETAO
* RETURN
* END
```

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FUNCTION VS (X1, X2)

```
*****
*
* PURPOSE:  THIS FUNCTION EVALUATES THE CONTRIBUTION DUE TO THE FIRST
*            TERM IN THE ASYMPTOTIC SERIES OF THE SUMMAND IN THE Z-PARAM
*            EXPRESSIONS.  (THIS IS USED TO APPLY KUMMER'S TRANSFORMATION
*            TO ACCELERATE THE CONVERGENCE OF THE SERIES).
*
* PARAMETERS: X1 AND X2 ARE THE ABSCISSA OF THE LOCATIONS OF PORTS 1
*            AND 2, RESPECTIVELY.
*
*****
```

```
* COMMON /I1/ A, B, T, D, DIEL, LOSS, SIGM, P, XP, YP, XPP, YPP, L,
*            F0, NFREQ, KO, TWOPI, PDO2A, TPXPOA, BOA, BAND, PI,
*            ETA0, K, GAIN, DELTAF
F1 = PI * (X1 + X2) / A
F2 = PI * (X1 - X2) / A
F3 = PI * (X1 + X2 + D) / A
F4 = PI * (X1 + X2 - D) / A
F5 = PI * (X1 - X2 + D) / A
F6 = PI * (X1 - X2 - D) / A
VS = VF(F3) + VF(F4) + VF(F5) + VF(F6)
VS = VF(F1) + VF(F2) - 0.5 * VS
VS = - (A/D)**2 * (1/PI)**3 * VS
RETURN
END
```

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SUBROUTINE VSEARC (MO, NO)

```
*****
*
* PURPOSE: This subroutine searches for the combination of mode indices,
* (MO,NO) which yields the resonant wave number closest two the
* wave number of free space at the chosen center frequency
* times the permittivity of the dielectric.
*
*****
```

```
REAL MIN, KG, KMN
INTEGER V
COMMON /I1/ A, B, TT, D, DIEL, LOSS, SIGM, P, XP, YP, XPP, YPP, L,
*          FO, NFREQ, KO, TWOPI, PDO2A, TPXPOA, BOA, BAND, PI,
*          ETAO, K, GAIN, DELTAF
DATA C/30000./
KG = TWOPI * FO * SQRT(DIEL) / C
M = KG * A / PI
N = 0
MIN = (M+1) * PI / A - KG
MO = M + 1
NO = 0
V = 1
1 IF (V .EQ. 1) GO TO 2
M = M - 1
GO TO 3
2 N = N + 1
3 KMN = SQRT((M*PI/A)**2 + (N*PI/B)**2)
IF (KMN .LT. KG) GO TO 4
V = 0
GO TO 5
4 V = 1
5 T = ABS(KMN - KG)
IF (T .GE. MIN) GO TO 6
MIN = T
MO = M
NO = N
6 IF (M .NE. 0) GO TO 1
IF (V .EQ. 1) GO TO 7
N = N - 1
GO TO 8
7 N = N + 1
8 T = ABS(N*PI/B - KG)
IF (T .GE. MIN) RETURN
MO = 0
NO = N
RETURN
END
```

CCCCCCCCCCCC

SUBROUTINE VZ1 (Z, DELTA, X, Y, S)

```
*****
*
* PURPOSE: This subroutine computes the driving point impedance of a
*           rectangular microstrip antenna feed at point (X,Y).
*
* PARAMETERS: Z is the complex driving point impedance. DELTA is the
*             effective loss tangent. (X,Y) is the coordinate of the feed.
*             S is the "closed form" sum of the asymptotic form of the
*             summand for Z. (It is used to accelerate the convergence
*             the series.
*
*****
```

```
COMPLEX Z, TERM, K, KSQ, PM, PMB, PY, PBM, SUBTOT
REAL MPI, KO, LOSS, JO
COMMON /I1/ A, B, T, D, DIEL, LOSS, SIGM, P, XP, YP, XPP, YPP, L,
*          FO, NFREQ, KO, TWOPI, PDO2A, PXPOA, BOA, BAND, PI,
*          ETAO, KK, GAIN, DELTAF
TAU = 1.0
IF (Y .EQ. 0.) TAU = 2.
KSQ = DIEL * KO**2 * CMPLX(1.,-DELTA)
K = CSQRT(KSQ)
Z = A * S + CCOS(K*Y) * CCOS(K*(B-Y)) / (K*CSIN(K*B))
M = 0
SUBTOT = (0., 0.)
PXOA = PI * X / A
1 M = M + 1
MPI = M * PI
PM = CSQRT(KSQ - (MPI/A)**2)
PMB = PM * B
PY = PM * Y
PBM = PMB - PY
TERM = (2*CCOS(PY)*CCOS(PBM)/(PM*CSIN(PMB)) + TAU*A/MPI) *
*      (COS(M*PXOA) * JO(M*PDO2A))**2
SUBTOT = SUBTOT + TERM
IF (3*(M/3) .NE. M) GO TO 1
Z = Z + SUBTOT
IF (CABS(SUBTOT) .LT. 0.001 * CABS(Z)) GO TO 2
SUBTOT = (0.,0.)
GO TO 1
2 Z = -Z * CMPLX(0.,1.) * KO * T * ETAO / A
RETURN
END
```

CCCCCCCCCCCC

SUBROUTINE VZ2 (Z11, Z12, Z22, DELTA, S1, S2, S3)

```
*****
*
* PURPOSE: This subroutine computes the open circuit parameters of the
*           two port with port one at (XP,YP) and port two at (XPP,YPP)
*           (where these parameters are in common block I1).
*
* PARAMETERS: Z11, Z12, and Z22 are the computed open circuit parameters
*             DELTA is the effective loss tangent. S1, S2, and S3 are the
*             "closed form" sums of the asymptotic form of the summands
*             corresponding to Z11, Z12, and Z22 summations, respectively.
*
*****
```

```
COMPLEX Z11, Z12, Z22, TERM, K, KSQ, PM, PMB, PYP, PBMYPP, SUBTOT
REAL MPI, KO, LOSS, JO
COMMON /I1/ A, B, T, D, DIEL, LOSS, SIGM, P, XXP, YYP, XXPP, YPP, L,
FO, NFREQ, KO, TWOPI, PDO2A, PXPOA, BOA, BAND, PI,
ETAO, KK, GAIN, DELTAF
IF (YYP .LT. YPP) GO TO 10
XP = XXPP
YP = YPP
XPP = XXP
YPP = YYP
GO TO 20
10 XP = XXP
YP = YYP
XPP = XXPP
YPP = YPP
20 TAU = 1.0
IF (YP .EQ. 0.) TAU = 2.
KSQ = DIEL * KO**2 * CMPLX(1., -DELTA)
K = CSQRT(KSQ)
CODE = 1
Z12 = CCOS(K*(B-YPP)) * CCOS(K*YP) / (K*CSIN(K*B))
IF (ABS(YP - YPP) .LT. 0.001) CODE = 2
IF (CODE .EQ. 2) Z12 = Z12 + S3 * A
M = 0
SUBTOT = (0., 0.)
PXPOA = PI * XP / A
PXPPOA = PI * XPP / A
1 M = M + 1
MPI = M * PI
PM = CSQRT(KSQ - (MPI/A)**2)
PMB = PM * B
PYP = PM * YP
PBMYPP = PM * (B - YPP)
TERM = 2*CCOS(PBMYPP) * CCOS(PYP) / (PM*CSIN(PMB))
IF (CODE .EQ. 2) TERM = TERM + TAU*A/MPI
TERM = TERM * COS(M*PXPOA) * COS(M*PXPPOA) * JO(M*PDO2A)**2
SUBTOT = SUBTOT + TERM
IF (3*(M/3) .NE. M) GO TO 1
Z12 = Z12 + SUBTOT
IF (CABS(SUBTOT) .LT. 0.000001 * CABS(Z12)) GO TO 2
SUBTOT = (0., 0.)
GO TO 1
2 Z12 = -Z12 * CMPLX(0., 1.) * KO * T * ETAO / A
CALL VZ1 (Z11, DELTA, XXP, YYP, S1)
CALL VZ1 (Z22, DELTA, XXPP, YPP, S2)
RETURN
END
```

CCCCCCCC

SUBROUTINE VZTOS(Z11,Z12,Z22,S11,S12,S22)

```
*****
*
* PURPOSE: This program converts the open circuit parameters to
*           scattering parameters referred to a 50 ohm system.
*
* PARAMETERS: The open circuit parameters are Z11, Z12, and Z22 and are
*           are converted to the scattering parameters S11, S12, and S22.
*
*****
```

COMPLEX Z11,Z12,Z22,S11,S12,S22

Z0=50

S11=((Z11-Z0)*(Z22+Z0)-Z12**2)/((Z11+Z0)*(Z22+Z0)-Z12**2)

S12=2.*Z0*Z12/((Z11+Z0)*(Z22+Z0)-Z12**2)

S22=((Z11+Z0)*(Z22-Z0)-Z12**2)/((Z11+Z0)*(Z22+Z0)-Z12**2)

RETURN

END

[illegible]

```
*****
*                                     *
*  PURPOSE:  To provide input of antenna parameters.                      *
*                                     *
*****
```

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```
DECODE (5,12,IYP) YP
IF (IXP .EQ. " ") XP = XPO
IF (IYP .EQ. " ") YP = YPO
XPO = XP
YPO = YP
GO TO 13
10 WRITE (1,11)
11 FORMAT ('*** INPUT DATA IS BAD / JOB ABORTED')
STOP
12 FORMAT (F5.0)
13 WRITE (1,14)
14 FORMAT ('FO ^B^A^N^D. @B^/_^F .')
READ (2,15) FO, BAND, DELTAF
15 FORMAT (F8.0,X,F4.0,X,F4.0)
I = EOF(2)
IF (FO .EQ. 0) FO = FOO
IF (BAND .EQ. 0) BAND = BANDO
IF (DELTAF .EQ. 0) DELTAF = DELTAO
IF (FO * BAND * DELTAF .EQ. 0) GO TO 10
BANDO = BAND
DELTAO = DELTAF
FOO = FO
NFREQ = 1
IF (DELTAF .NE. 0) NFREQ = 0.5 + BAND*FO/(100*DELTAF)+1
IF (NFREQ .EQ. 2*(NFREQ/2)) NFREQ = NFREQ + 1
RETURN
END
```

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N/S
N/S

```

PRINT *, "*****"
PRINT *, "CP OR LINEAR (TYPE C OR L) ",
READ 75, CP
IF (CP .EQ. "C") GO TO 76
FACTOR = PIBY180
FACT = 1.0
DENSE = 91
LIMIT = 181
PRINT *, "*****"
PRINT *, "INDIVIDUAL NORMALIZATION (Y OR N) ",
READ 75, IQ
75 FORMAT (A1)
GO TO 77
76 FACTOR = PIBY180/4.
FACT = 0.25
DENSE = 361
LIMIT = 721
77 DO 3 J = 1, LIMIT
IF (CP .EQ. "C") IPSI = MOD(J-1,8) + 1
ANGLE = (DENSE-J) * FACTOR
CALL VPAT (ANGLE, 0., ET, EP, DELTA, (1.,0.), XP, YP)
IF (P .EQ. 1) GO TO 1
CALL VPAT (ANGLE, 0., ET1, EP1, DELTA, I2, XPP, YPP)
EP = EP + EP1
ET = ET + ET1
1 IF (CP .EQ. "C") GO TO 111
EXZX(J) = CABS(ET)
EXZY(J) = CABS(EP)
GO TO 112
111 EXZX(J) = CABS(EP*C(IPSI)+ET*S(IPSI))
112 CALL VPAT (ANGLE, PIBY2, ET, EP, DELTA, (1.,0.), XP, YP)
IF (P .EQ. 1) GO TO 2
CALL VPAT (ANGLE, PIBY2, ET1, EP1, DELTA, I2, XPP, YPP)
EP = EP + EP1
ET = ET + ET1
2 IF (CP .EQ. "C") GO TO 22
EYZX(J) = CABS(EP)
EYZY(J) = CABS(ET)
GO TO 3
22 EYZY(J) = CABS(EP*C(IPSI) + ET*S(IPSI))
IPSI = MOD(J-1,8) + 1
3 CONTINUE
CALL URESET
A1 = 0.
A2 = 0.
A3 = 0.
A4 = 0.
DO 5 J = 1, LIMIT
A1 = AMAX1(A1, EXZX(J))
IF (CP .NE. "C") A2 = AMAX1(A2, EXZY(J))
IF (CP .NE. "C") A3 = AMAX1(A3, EYZX(J))
5 A4 = AMAX1(A4, EYZY(J))
A = AMAX1(A1, A2, A3, A4)
CALL UPEN (0., 0.)
7 CALL UERASE
CALL UDAREA (0.4, 5.119, 0.4, 5.119)
CALL UWINDO (-1., 1., -1., 1.)
DO 8 J = 1, 5
8 CALL UCRCLE (0., 0., 0.2 * J)
CALL USET ("POLAR")
DO 9 J = 1, 36
ANGLE = J * 10
CALL UMOVE (0.2, ANGLE)
9 CALL UPEN (1., ANGLE)
DO 10 J = 1, 4
ANGLE = J * 90
CALL UMOVE (0., 0.)
10 CALL UPEN (0.2, ANGLE)
CALL USET ("LINE")

```

N/S

N/S

N/S

```

AA = A
IF (IQ .EQ. "Y") AA = A1
CALL UMOVE (EXZX(1)/AA, 90.)
DO 11 J = 1, LIMIT
  ANGLE = (DENSE - J) * FACT
11 CALL UPEN (EXZX(J)/AA, ANGLE)
  IF (IQ .EQ. "Y") AA = A3
  CALL UMOVE (EYZY(1)/AA, 90.)
  DO 12 J = 1, LIMIT
    ANGLE = (J + DENSE - 2) * FACT
12 CALL UPEN (EYZY(J)/AA, ANGLE)
    IF (IQ .EQ. "Y") AA = A2
    IF (CP .EQ. "C") GO TO 120
    CALL USET ("RECT")
    CALL UMOVE (0.8, -0.8)
    CALL UPEN (1.0, -0.8)
    CALL USET ("POLAR")
    CALL USET ("DASHLINE")
    CALL UPSET ("SETDASH", 5212.)
    CALL UMOVE (EXZY(1)/AA, 90.)
    DO 13 J = 1, 181
      ANGLE = (91 - J)
13 CALL UPEN (EXZY(J)/AA, ANGLE)
      IF (IQ .EQ. "Y") AA = A4
      CALL UMOVE (EYZX(1)/AA, 90.)
      DO 14 J = 1, 181
        ANGLE = (J + 89)
14 CALL UPEN (EYZX(J)/AA, ANGLE)
        CALL USET ("RECT")
        CALL UMOVE (0.8, -0.9)
        CALL UPEN (1.0, -0.9)
        CALL UDAREA (0., 6., 0., 5.119)
        CALL UPRINT (0.76, -0.688, IO)
        CALL UPRINT (0.76, -0.768, IO)
        CALL UPRINT (0.76, -0.688, IDASH)
        CALL UPRINT (0.76, -0.768, ISLASH)
        GO TO 121
120 CALL USET ("TEXT")
        CALL USET ("RECT")
        CALL UDAREA (0., 6., 0., 5.119)
121 CALL UPRINT (-1.0, 0., IYZ)
        CALL UPRINT (+0.76, 0., IXZ)
        CALL UPRINT (-0.40, -1.0, ID)
        CALL USET ("LINE")
        ENCODE (11, 16, FREQ) F
16 FORMAT ("F = ", F6.1, " ")
        CALL UPRINT (0.60, -1.0, FREQ)
        IF (NORM .NE. 2) GO TO 15
        CALL UFLUSH
        PRINT *, " ^> ^&
        CALL UPAUSE
        RETURN
15 CALL UREAD (-1., -1., KQ, 1., FLAG)
        IF (KQ .EQ. "S") NORM = 1
        IF (KQ .EQ. "M") NORM = 0
        IF (KQ .EQ. "A") NORM = 2
        IF (KQ .EQ. "R") GO TO 7
        IF (KQ .EQ. "T") ANS = 3
        CALL UERASE
        RETURN
END

```

N/S

N/S

SUBROUTINE VPLTS (F, Z11, Z12, Z22, IACC)

```

*****
*
* PURPOSE: This routine plots the "s" parameters of a two port
*          microstrip antenna using the input values of the
*          open circuit parameters. It uses the software of the GCS
*          system.
*
* PARAMETERS: F is the frequency in MHz.
*             Z11, Z12, and Z22 are the respective open circuit
*             parameters of the microstrip antenna (input).
*             IACC is set equal to zero when data is being
*             accumulated by the subroutine for later plotting.
*             It is set to unity when the accumulated data is
*             to actually be plotted.
*
* OPTIONS: At the end of each plot, one may input either a blank
*          character or an "R". The latter causes the system to
*          replot the graph.
*****

```

```

COMPLEX S11(100), S12(100), S22(100), Z11, Z12, Z22
DIMENSION ID(3)
INTEGER ONEONE, ONETWO, TWOTWO, S
COMMON /JID/ ID
COMMON /I1/ A, B, T, D, DIEL, LOSS, SIGM, P, XP, YP, XPP, YPP, L,
FO, NFREQ, KO, TWOPI, PDO2A, TPXPOA, BOA, BAND, PI,
ETAO, K, GAIN, DELTAF
COMMON /DELTA/ DELTA
S = "S;"
IX = "X;"
IO = "O;"
IS = "+";"
IC = "I;"
ONEONE = " 11;"
ONETWO = " 12;"
TWOTWO = " 22;"
ID(3) = ";"
IF (IACC .EQ. 1) GO TO 5
CALL VZTOS (Z11, Z12, Z22, S11(K), S12(K), S22(K))
IF (K .GT. 1) GO TO 3
Q = 1 / DELTA
CALL DATE (ID(1))
CALL TIME (ID(2))
WRITE (3,1) A, B, T, D, XP, YP, XPP, YPP, DIEL, LOSS,
SIGM, FO, DELTAF, Q, GAIN, ID(1), ID(2)
1 FORMAT("1",6X,"T W O P O R T R E C T A N G U L A R M I C R O
1 S T R I P",/,7X,"-----"
2-----",/,7X,"Dimensions (a X b X t) .....
3.....",/,7X,"F4.1," X ",F4.1," X ",F4.2," cm",/,7X,"F
4Ed data: (1) Width .....",/,7X,"F4.2," cm
5",/,18X,"(2) Port one .....",/,7X,"F4.1," ",F4.1,"
6) cm",/,18X,"(3) Port two .....",/,7X,"F4.1," ",
7F4.1," cm",/,7X,"Electrical parameters: (1)
8Dielectric .....",/,30X,"(2) Loss tangent
9.....",F7.5,/,30X,"(3) Conductivity ...",F5.1," KMho
s/Cm",/,7X,"Center frequency .....
1.....",F7.1," MHz",/,7X,"Frequency increment ..
2.....",F7.1," MHz",/,7X,"Quality fact
3or .....",F5.1,/,7X,"Gain .....
4.....",F4.1," dB",/,7X,"Date/time ..
5.....",2A10,/,7X,"Frequency
6Y",11X,"S",16X,"S",16X,"S",/,9X,"(MHz)",14X,"11",15X,"12",15X,"12
7",/,7X,"0"
3 WRITE (3,4) F, S11(K), S12(K), S22(K)
4 FORMAT (7X,F7.1,6X,3(" ",F6.3," ",F6.3," "),2X))
RETURN

```

```

5 CALL URESET
  CALL UERASE
  NO2 = NFREQ/2 + 1
  NO21 = NO2 + 1
  CALL USET ("LINE")
  CALL UWINDO (-1., 1., -1., 1.)
  CALL UDAREA (0.4, 5.119, 0.4, 5.119)
  CALL UCRCL (0., 0., 1.)
  CALL UMOVE (0., 1.)
  CALL UARC (1., 1., 90.)
  CALL UARC (1., -1., 90.)
  CALL UCRCL (0.5, 0.0, 0.5)
  CALL UMOVE (-1.0, 0.0)
  CALL UPEN (1.0, 0.0)
  CALL USET ("DASHLINE")
  CALL UPSET ("SETDASH", 5414.)
  CALL UCRCL (0., 0., 0.5)
  CALL USET ("LINE")
  CALL USET ("NX")
  CALL USET ("SOFT")
  CALL UPSET ("HORIZONTAL", 0.03)
  CALL UPSET ("VERTICAL", 0.03)
  DO 6 J = 1, NFREQ
    IF (J.EQ. NO2) CALL USET ("N*")
    IF (J.EQ. NO21) CALL USET ("NX")
  6 CALL UPEN (REAL(S11(J)), AIMAG(S11(J)))
    CALL UPRINT (0.75, -0.75, IX)
    CALL USET ("NO")
  7 DO 7 J = 1, NFREQ
    IF (J.EQ. NO2) CALL USET ("N*")
    IF (J.EQ. NO21) CALL USET ("NO")
    CALL UPEN (REAL(S12(J)), AIMAG(S12(J)))
    CALL UPRINT (0.75, -0.85, IO)
    CALL USET ("N+")
    CALL UPSET ("VERTICAL", 0.06)
    CALL UPSET ("HORIZONTAL", 0.04)
  8 DO 8 J = 1, NFREQ
    IF (J.EQ. NO2) CALL USET ("N*")
    IF (J.EQ. NO21) CALL USET ("N+")
    CALL UPEN (REAL(S22(J)), AIMAG(S22(J)))
    CALL UPRINT (0.75, -0.95, IS)
    CALL USET ("HARD")
    CALL UPRINT (0.85, -0.80, ONEONE)
    CALL UPRINT (0.85, -0.775, S)
    CALL UPRINT (0.85, -0.975, S)
    CALL UPRINT (0.85, -0.875, S)
    CALL UPRINT (0.85, -0.90, ONETWO)
    CALL UPRINT (0.85, -1., TWOTWO)
    CALL UDAREA (0., 5.5, 0., 5.5)
    CALL UPRINT (-0.47, -1.0, ID)
    CALL UREAD (-1., -1., IQ, 1., F)
    IF (IQ.NE. " ") GO TO 5
  CALL UERASE
  RETURN
END

```

სადაცაც იმყოფებით

```

B(K) = AIMAG(Y)
RETURN
10 CALL URESET
PRINT *, "*****"
PRINT *, "*****"
PRINT *, "*****"
PRINT *, "*****"
PRINT *, "RECTANGULAR, SMITH CHART, OR VS FREQUENCY PLOT (R, S, ",
1 "OR V)",
READ 2, CODE
2 FORMAT (A1)
IF (EOF(2) .NE. 0) RETURN
IF (CODE .EQ. "S") KKODE = 1
IF (CODE .EQ. "R") KKODE = 2
IF (CODE .EQ. "V") KKODE = 3
GO TO (5, 12, 15), KKODE
5 CALL UERASE
CALL USET ("LINE")
CALL UWINDO (-1., 1., -1., 1.)
CALL UDAREA (0.4, 5.119, 0.4, 5.119)
CALL UCRCL (0., 0., 1.)
CALL UMOVE (0., 1.)
CALL UARC (1., 1., 90.)
CALL UARC (1., -1., 90.)
CALL UCRCL (0.5, 0.0, 0.5)
CALL UMOVE (-1.0, 0.0)
CALL UPEN (1.0, 0.0)
CALL USET ("DASHLINE")
CALL UPSET ("SETDASH", 5414.)
CALL UCRCL (0., 0., 0.5)
CALL USET ("LINE")
CALL USET ("NX")
CALL USET ("SOFT")
CALL UPSET ("HORIZONTAL", 0.02)
CALL UPSET ("VERTICAL", 0.02)
DO 6 J = 1, NFREQ
Y = CMPLX (G(J), B(J))
GAMMA = (1-Y)/(1+Y)
IF (J .EQ. NO2) CALL USET ("N")
IF (J .EQ. NO21) CALL USET ("NX")
6 CALL UPEN (REAL(GAMMA), AIMAG(GAMMA))
CALL USET ("HARD")
CALL UDAREA (0., 5.5, 0., 5.5)
CALL UPRINT (-0.40, -1.0, ID)
CALL USET ("SOFT")
CALL USET ("ITALICS")
CALL UPSET ("HORIZONTAL", 0.03)
CALL UPSET ("VERTICAL", 0.05)
CALL UPRINT (0.4, -0.85, IFO)
CALL UPRINT (0.4, -0.92, IINC)
CALL UPRINT (0.4, -0.99, IDIM)
CALL UERASE
14 CALL UREAD (0., 0., CODE, 1., FLAG)
IF (CODE .EQ. "R") GO TO 10
GO TO 9
12 RMAX = 0.
XABSMX = 0.
DO 13 J = 1, NFREQ
Z = 1 / CMPLX (G(J), B(J))
XABSMX = AMAX1 (ABS(AIMAG(Z)), XABSMX)
13 RMAX = AMAX1 (RMAX, REAL(Z))
ABSMX = AMAX1 (RMAX, XABSMX)
DEC = ALOG10 (ABSMX)
IDEC = DEC
IF (DEC .LT. 0.) IDEC = IDEC - 1
DECADE = 10. ** IDEC
IDIGIT = ABSMAX / DECADE + 1
WINDOW = IDIGIT * DECADE
CALL UWINDO (0., 2.*WINDOW, -WINDOW, WINDOW)

```

```

TICK = DECADE
IF (IDIGIT .LT. 7) TICK = 0.5 * DECADE
IF (IDIGIT .LT. 3) TICK = 0.2 * DECADE
CALL UPSET ("TICK", TICK)
CALL UPSET ("TICY", TICK)
CALL UERASE
CALL UDAREA (0.4, 5., 0.4, 5.)
CALL UPSET ("YLABEL", "X;")
CALL UPSET ("XLABEL", "R;")
CALL USET ("GRIDAXIS")
CALL USET ("XBOTH")
CALL USET ("YBOTH")
CALL USET ("POINT")
CALL USET ("OWNSCALE")
CALL UAXIS (0., 2.*WINDOW, -WINDOW, WINDOW)
CALL USET ("LINE")
CALL USET ("NX")
CALL USET ("SOFT")
CALL UPSET ("HORIZONTAL", 0.02 * WINDOW)
CALL UPSET ("VERTICAL", 0.02 * WINDOW)
DO 130 J = 1, NFREQ
Z = 1 / CMPLX (G(J), B(J))
130 CALL UPEN (REAL(Z), AIMAG(Z))
CALL USET ("HARD")
CALL UDAREA (0., 5., 0., 5.)
CALL UWINDO (-1., 1., -1., 1.)
CALL UPRINT (-0.47, -1.0, ID)
CALL UPAUSE
CALL UERASE
CALL USET ("LINE")
GO TO 14
15 CALL UERASE
CALL UDAREA (0.4, 5.4, 0.4, 5.4)
CALL USET ("GRIDAXES")
CALL USET ("XBOTH")
CALL USET ("YBOTH")
CALL UPSET ("XLABEL", "FREQUENCY - F0;")
CALL UPSET ("YLABEL", "MAGNITUDE OF GAMMA;")
CALL USET ("AUTO")
CALL UAXIS (FREQ(1), FREQ(NFREQ), 0.00, 1.00)
CALL USET ("SOFT")
CALL UPSET ("HORIZONTAL", 0.02 * (FREQ(NFREQ) - FREQ(1)))
CALL UPSET ("VERTICAL", 0.02)
CALL USET ("NX")
DO 156 J = 1, NFREQ
Y = CMPLX (G(J), B(J))
GAMMA = (1-Y)/(1+Y)
156 CALL UPEN (FREQ(J), CABS(GAMMA))
CALL USET ("SOFT")
CALL USET ("ITALLICS")
CALL UDAREA (0., 7.49, 0., 5.71)
CALL UWINDO (0., 1., 0., 1.)
CALL UPSET ("HORIZONTAL", 0.015)
CALL UPSET ("VERTICAL", 0.03)
CALL UPRINT (0.7, 0.5, ID)
CALL UPRINT (0.7, 0.47, IF0)
CALL UPRINT (0.7, 0.44, IINC)
CALL UPRINT (0.7, 0.41, IDIM)
CALL UPAUSE
CALL UERASE
GO TO 14
9 RETURN
END

```

CHAPTER 3: EXAMPLES

This chapter contains examples of the use of this program to analyze a microstrip antenna. The specific case chosen was that of a nearly square microstrip antenna. This was chosen to illustrate that by making one side of the antenna a small amount larger than the other, and by properly feeding and loading the the antenna with a variable capacitor (such as a varactor), the antenna can be switched from left hand circular polarization to right hand circular polarization. This is consistent with both theory and experiments carried out at the University of Illinois and presented in references [4] and [6]. The output listed below is a copy of the actual graphical data displayed on a graphics terminal by the program. Explanatory remarks have been added to aid the reader.

```

. a . b . t . d . diel . loss . sigm . p .
? 7.62 7.80 .15 .25 2.62 1.0 270.
. x' . y' .
? 1.00 3.90
. f0 . band . af .
? 1215.0 10. 2.
Choose an option:
(1) Plot patterns at all frequencies.
(2) Plot pattern only at center frequency.
(3) Plot no patterns
Type option (1, 2, or 3):
? 2

```

```

CP OR LINEAR (TYPE C OR L) ? L
INDIVIDUAL NORMALIZATION (Y OR N) ? N

```

The option of plotting a pattern at the center frequency was chosen in this case. Additionally, within the plotting routine itself, the options of a linear polarization pattern without individual normalization were chosen.

In this example, a , b , and t are the geometrical parameters (in cm) of the microstrip antenna shown in Fig. 2. The parameter d is the "effective feed width" in cm. The dielectric constant relative to free space is the input under the "diel." The loss tangent of the dielectric (times one thousand) is typed under the "loss." The conductivity of the cladding is under the "sigm" in units of $K\Omega/\text{cm}$. The parameter, p , is the number of ports (either "1" or "2"). The default value of p is initially unity and its previous value in subsequent computations. The coordinate of the feed point is (x', y') corresponding to (x_1, y_1) in the discussion in Appendix 1. The impedance, and, optionally, the patterns will be computed for frequencies, f , in a range of approximately

$$\left(1 + \frac{\eta}{200}\right) f_0 \geq f \geq \left(1 - \frac{\eta}{200}\right) f_0$$

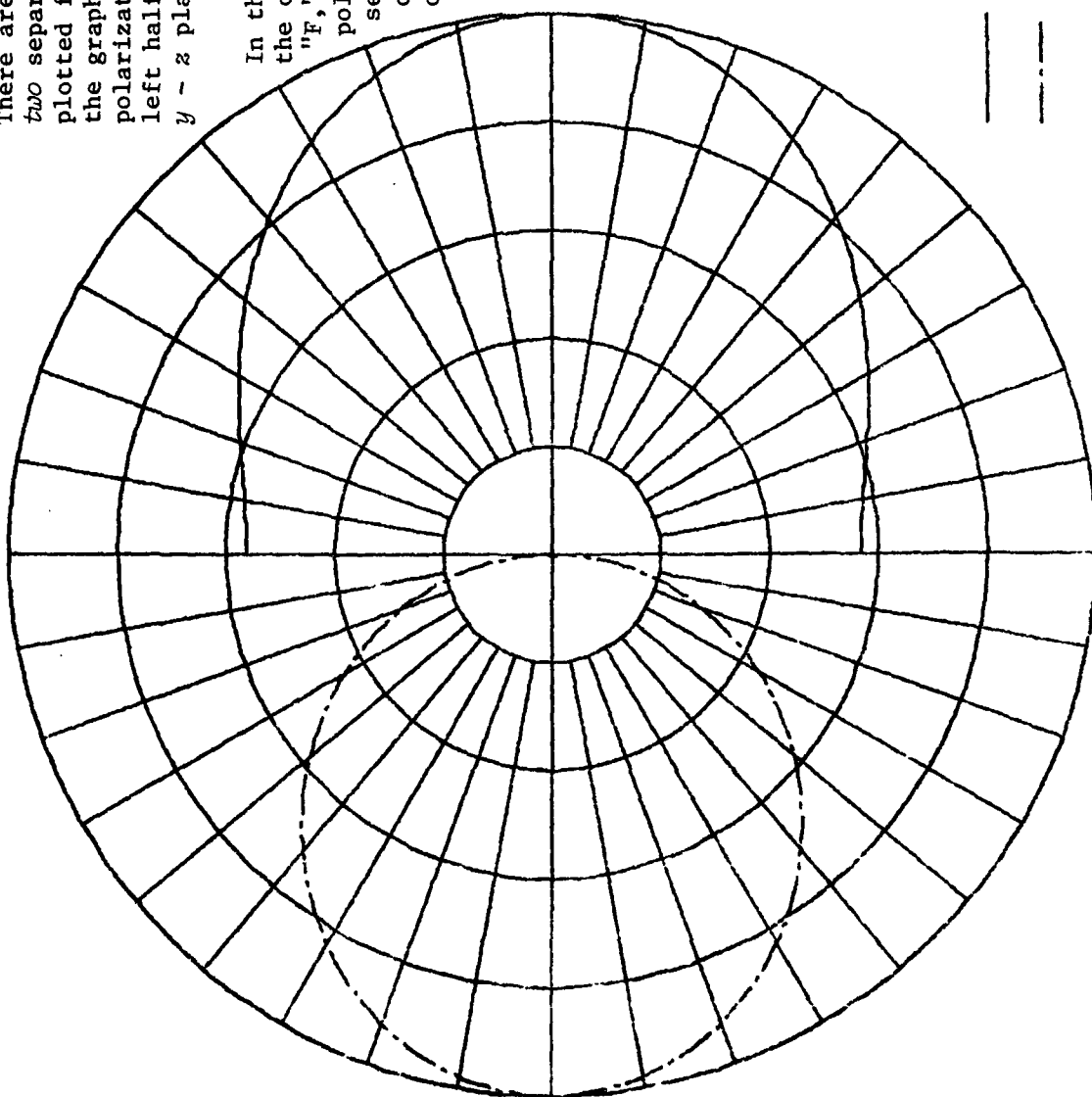
where η is typed in under "band" (in percentage), and f_0 is typed in under "f0." Computations are always performed at f_0 and at frequencies differing from f_0 within the band by integral multiples of Δf , the input under " Δf ."

There are two separate patterns in each of two separate planes. Both E_θ and E_ϕ are plotted for each plane. The right half of the graph represents a plot of these two polarizations in the $x - z$ plane, while the left half is a plot of these patterns in the $y - z$ plane.

In this particular example, because of the choice of feed point and frequency, "F," printed at the bottom, the cross-polarization is so small it cannot be seen. For the case where "cross-pol" can be seen clearly, refer to the end of the example.

The group of numbers directly under the graph is the "date/time-group."

This is used to identify the X-Z plot with the associated "hard copy" output that is automatically printed. It appears on all plots.



— θ
 - - - ϕ

39
 Y-Z

80/03/11. 11.20.42.

F = 1216.0

RECTANGULAR, SMITH CHART, OR VS FREQUENCY PLOT (R, S, OR U)? S

Here, the system is requesting the input of the desired type of impedance plot. If no plot is desired at all, the user can simply respond with a carriage return. In this case, the user chose a Smith chart plot.

80/03/11. 11.20.42.
FO - 1216.0 MHZ
INC - 2.0 MHZ
7.62 X 7.80 CM

Continue (type Y or N)

? a . b . t . d .diel.loss.sigm.p.

? x' . y' .
? 3.81 1:00

? f0 .band. Δf .
? 1188.0 10. 2.

Choose an option:

- (1) Plot patterns at all frequencies.
- (2) Plot pattern only at center frequency.
- (3) Plot no patterns

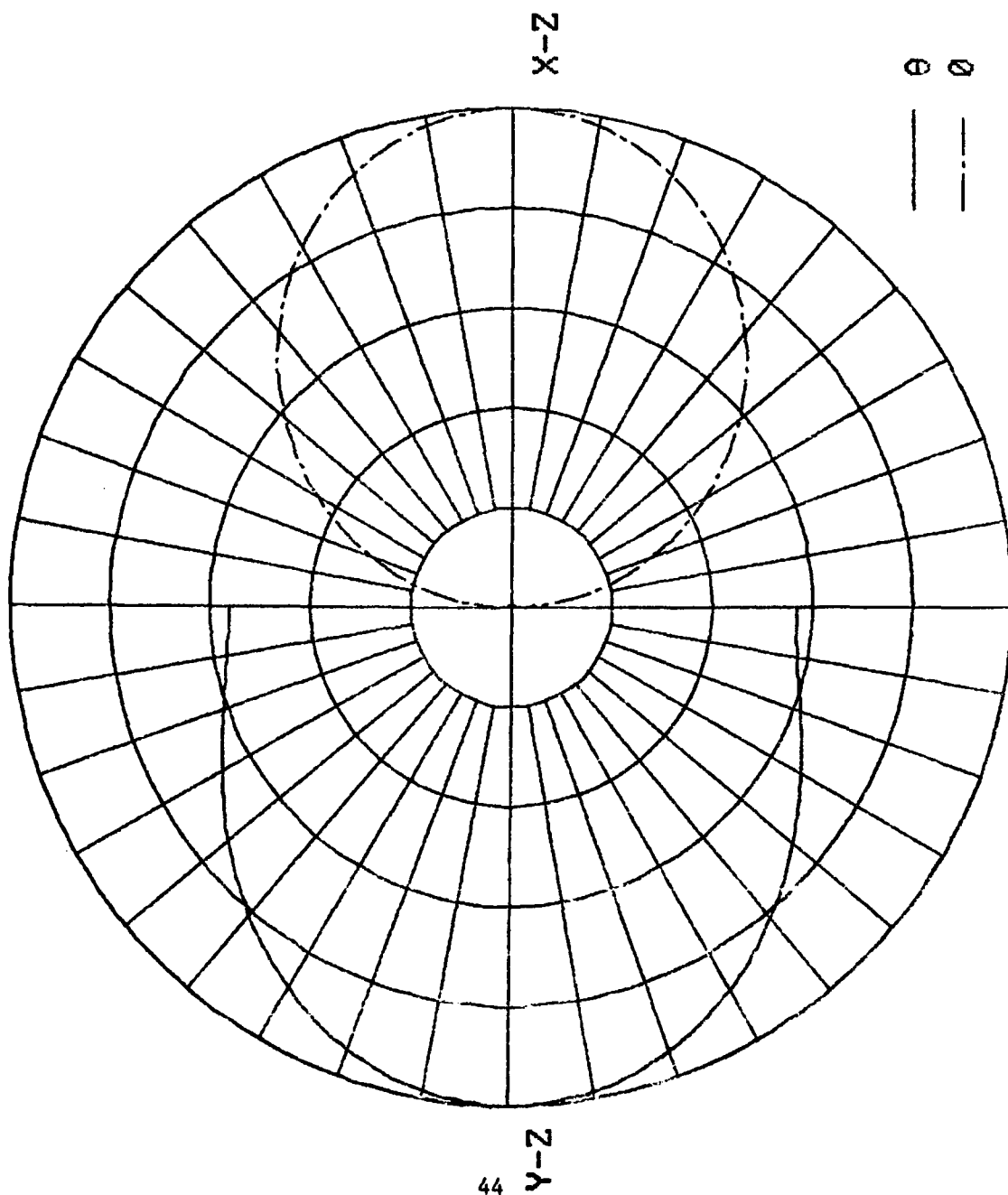
Type option (1, 2, or 3):
? 2

In this implementation, only those parameters which are to be changed from the previous calculation need be input.

CP OR LINEAR (TYPE C OR L) ? L

INDIVIDUAL NORMALIZATION (Y OR N) ? N

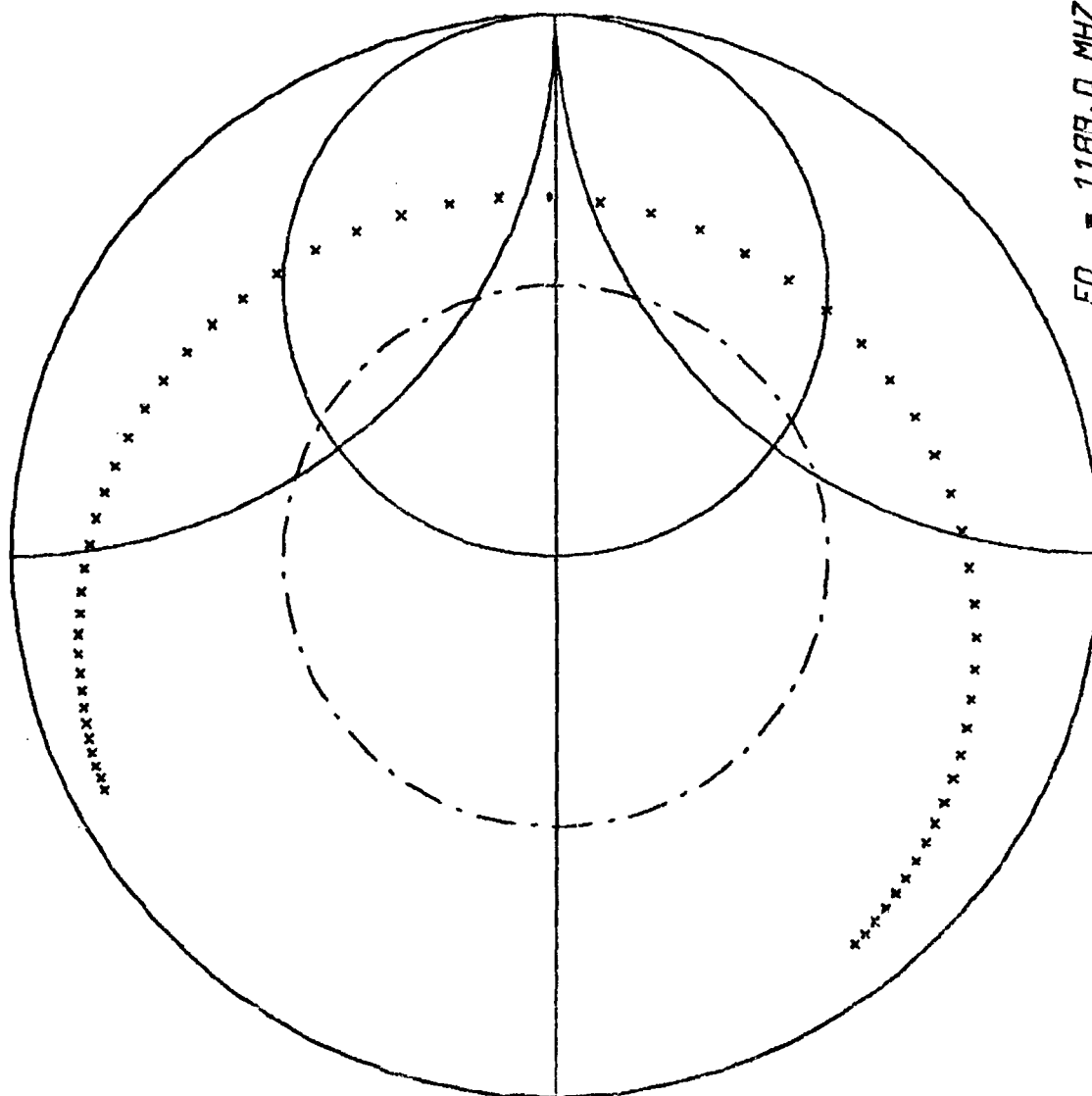
"Individual normalization," as used here means that all patterns are normalized by their own respective maximum values. Thus, information about the relative importance of cross polarization is lost under this option. The usual response is "N" (for "no"), the default. Under the "N" option, the patterns are all normalized by the same factor. This factor is the maximum of all four patterns.



F = 1188.0

80/03/11. 11.26.31.

RECTANGULAR, SMITH CHART, OR VS FREQUENCY PLOT (R, S, OR V)? S



FO = 1189.0 MHZ
 INC = 2.0 MHZ

80/03/11. 11.26.31. 7.62 X 7.80 CM

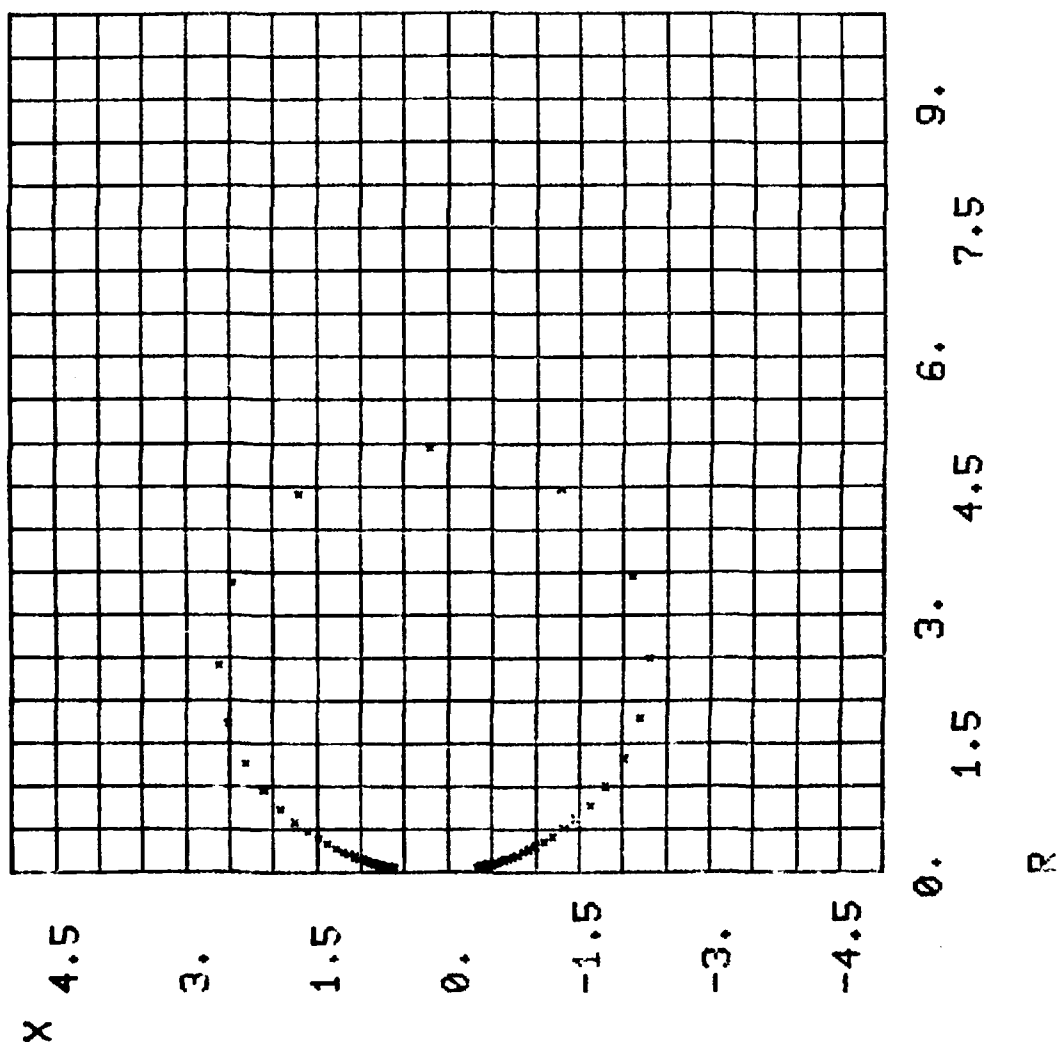
When the computer has completed an impedance plot, the program awaits (with no prompting) the input of a single character from the keyboard. If that character is an "R" (for "replot"), the program will again ask for a choice of the type of impedance plot desired and replot the *same* data. In this case, an "R" was input which caused the message below to be typed.

R

RECTANGULAR, SMITH CHART, OR VS FREQUENCY PLOT (R, S, OR U)? R

This time the user chose to plot in a rectangular system.

This type of graph plots the complex impedance in the impedance, Z , plane with the horizontal axis being $\text{Re } Z$ and the vertical axis $\text{Im } Z$.



Again, a replot was requested by entering an "R" from the keyboard.

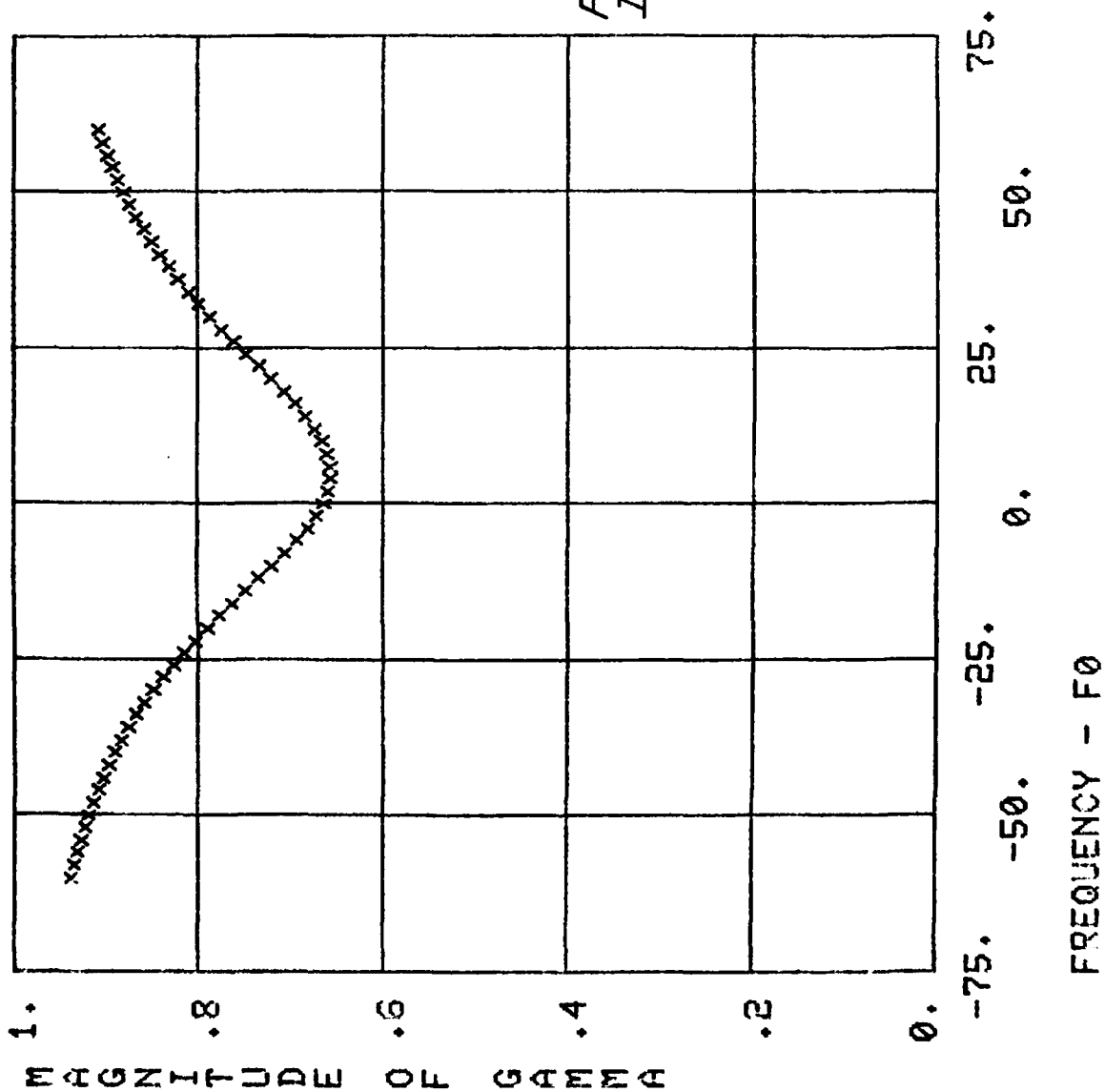
R

RECTANGULAR, SMITH CHART, OR VS FREQUENCY PLOT (R, S, OR U)? U

This time a "vs frequency" plot was requested.

This plots the magnitude of
reflection coefficient against
 $f - f_0$.

80/03/11. 11.26.31.
F0 = 1188.0 MHZ
INC = 2.0 MHZ
7.62 X 7.80 CM



Continue (type Y or N)

? N

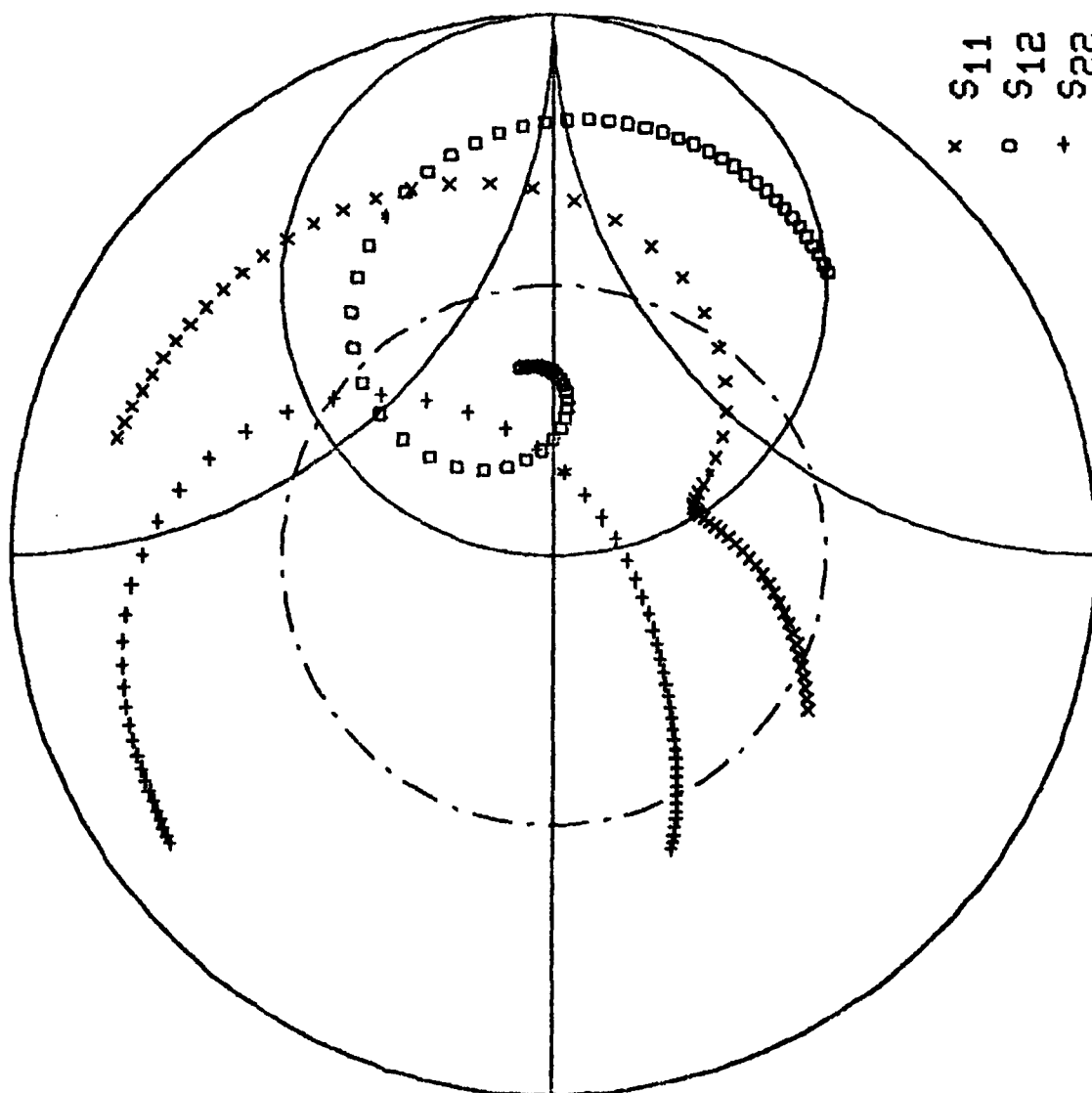
Choose an option:

- (1) Plot patterns at all frequencies.
- (2) Plot pattern only at center frequency.
- (3) Plot no patterns

Type option (1, 2, or 3):

(Also note that since this was the beginning of a new run (the previous run having been terminated), all parameters had to be input.)

This is a Smith chart plot of the s-parameters of the unloaded two-port. Again, the location of points corresponding to the center frequency are indicated by "x"s.



80/03/11. 11.49.40.

Continue (type Y or N)
? Y

? a . b . t . d .diel.loss.sigm.p.

? x' . y' . x" . y" .L. y

? f0 .band. af .
1194. 4. 1.

Choose an option:

- (1) Plot patterns at all frequencies.
- (2) Plot pattern only at center frequency.
- (3) Plot no patterns

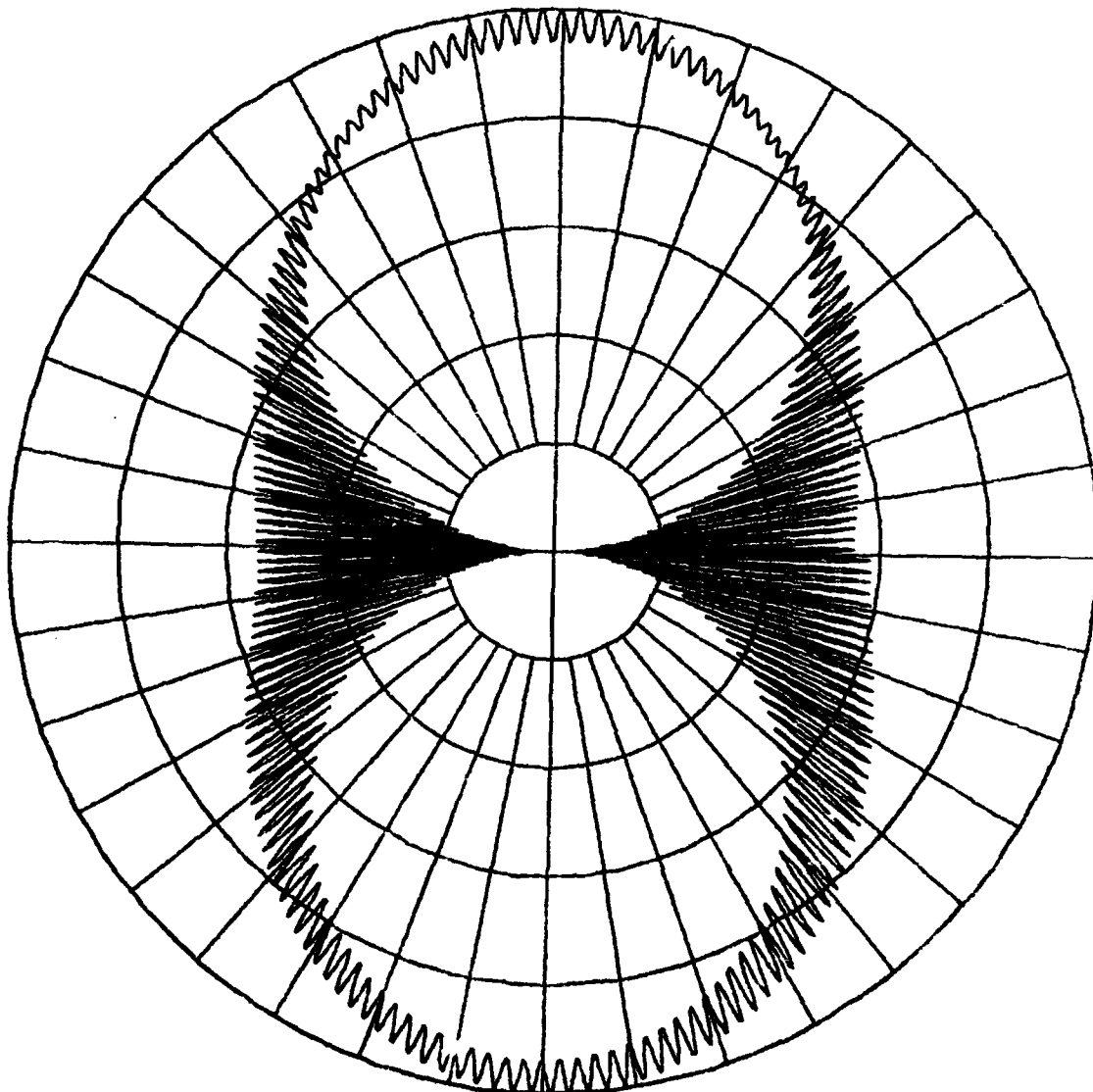
Type option (1, 2, or 3):
? 2

INPUT CAPACITANCE IN PICOFARADS: C = ? 1.35

Here, a load was added to the second port as indicated by the "y" below the "L." The type of load is determined by the user supplied subroutine, VLOAD, which must be loaded with the rest of the program prior to execution.

The particular load used in this example was the capacitor. The subroutine VLOAD was programmed to ask the user to input the capacitance, 1.35 pF in this case.

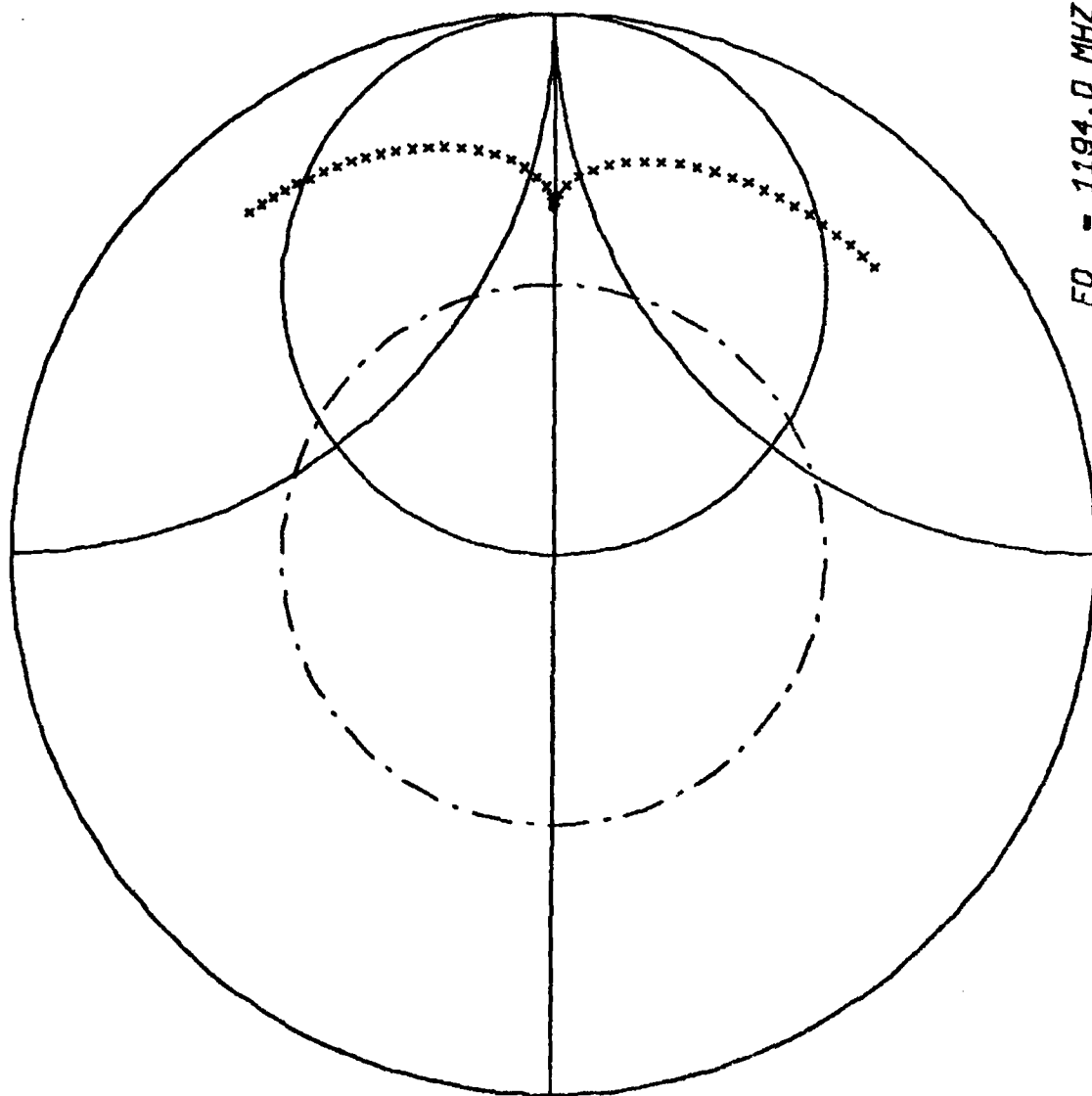
A plot at the center frequency for this example was also requested with the "C" option.



These patterns are the simulated responses of a rotating dipole which makes five full rotations per twenty degrees change in elevation angle, θ . Thus, when the antenna is producing circular polarization (CP) in a given direction, the oscillations in the response in that direction disappear.

In this plot, as in the linear polarization plots, the right half of the graph is the pattern in the $x - z$ plane, while the left half is the pattern in the $y - z$ plane.

RECTANGULAR, SMITH CHART, OR VS FREQUENCY PLOT (R, S, OR V)? S



FO - 1194.0 MHZ
INC - 1.0 MHZ
80/03/11. 11.53.52. 7.62 X 7.80 CM

? a . b . t . d .diel.loss.sigm.p.

? x' . y' . x" . y" .L.

? f0 .band. af .

? 1182.0

Choose an option:

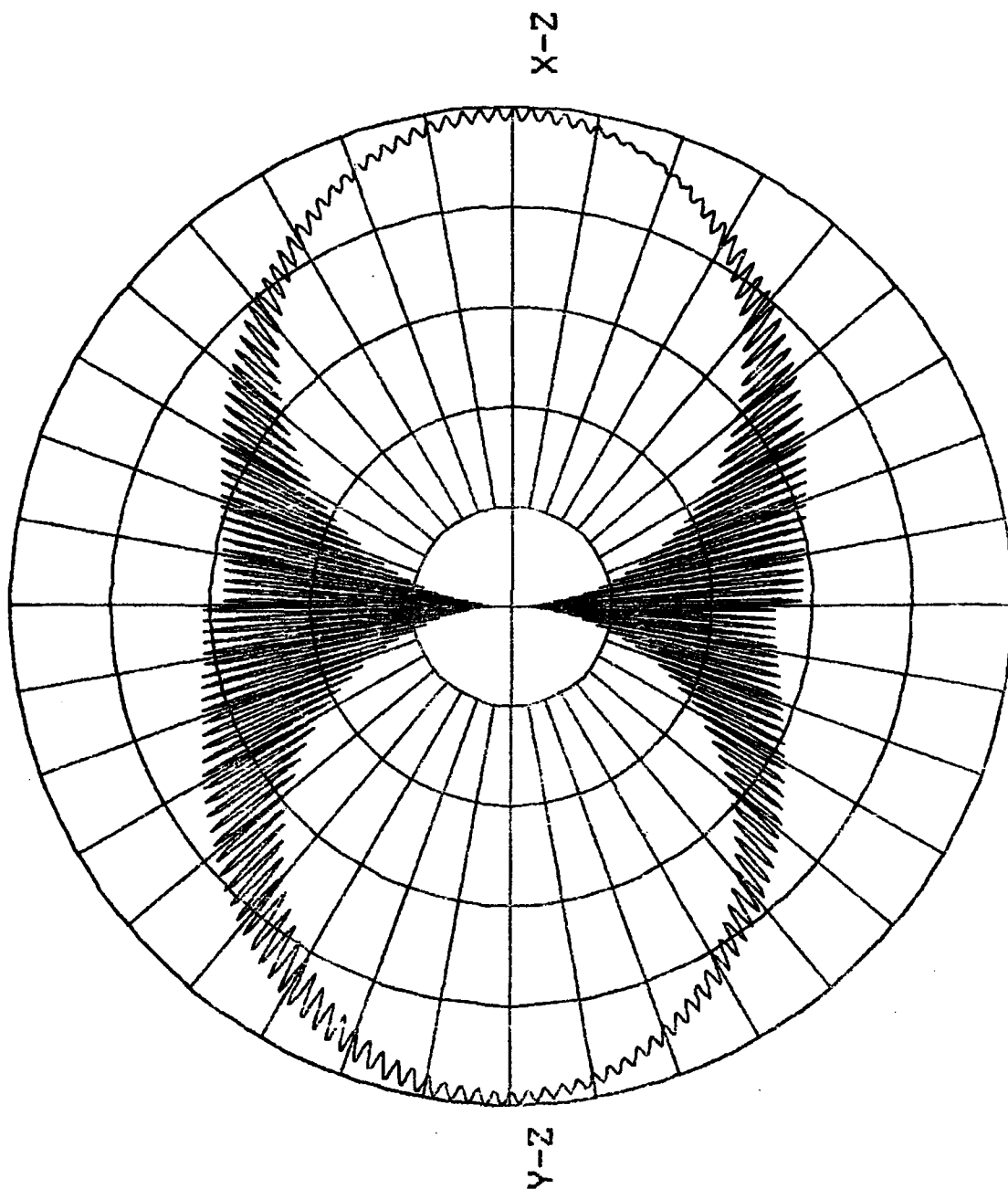
- (1) Plot patterns at all frequencies.
- (2) Plot pattern only at center frequency.
- (3) Plot no patterns

Type option (1, 2, or 3):

? INPUT CAPACITANCE IN PICOFARADS: C = ? 3.1

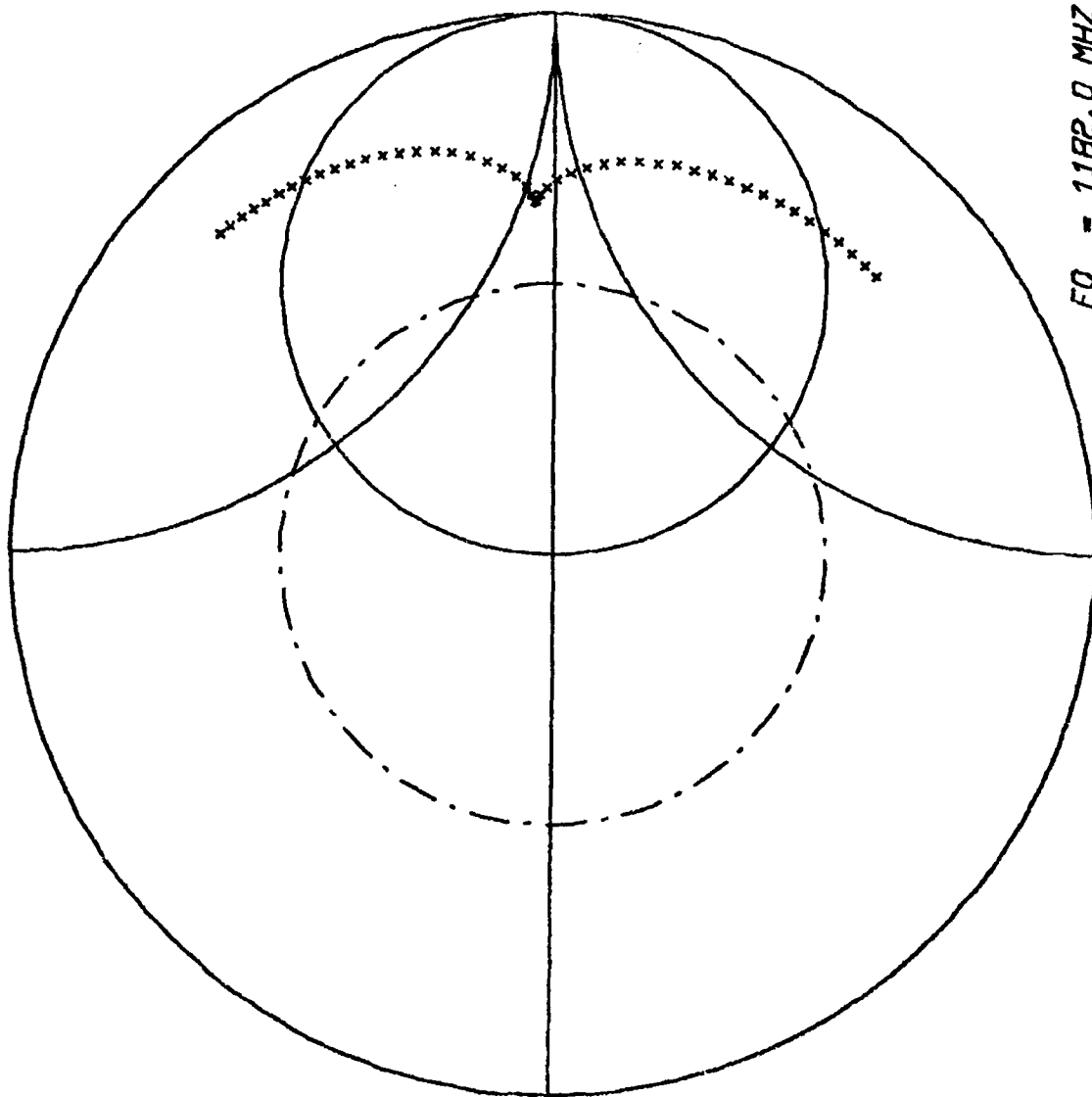
CP OR LINEAR (TYPE C OR L) ? C

In this case, the value of the capacitance has been changed from 1.35 pF to 3.1 pF. This change in load has the effect of reversing the sense of CP.



80/03/11. 11.59.54. F = 1182.0

RECTANGULAR, SMITH CHART, OR VS FREQUENCY PLOT (R, S, OR U)? S



FO - 1182.0 MHZ
INC - 1.0 MHZ
80/03/11. 11.59.54. 7.62 X 7.80 CM

Continue (type Y or N)

? Y

? a . b . t . d .diel.loss.sigm.p.

? x' . y' . x" . y" .L.

? f0 .band. af .
? 2 1.

Choose an option:

(1) Plot patterns at all frequencies.

(2) Plot pattern only at center frequency.

(3) Plot no patterns

Type option (1, 2, or 3):

? 1

INPUT CAPACITANCE IN PICOFARADS: C = ? 3.1

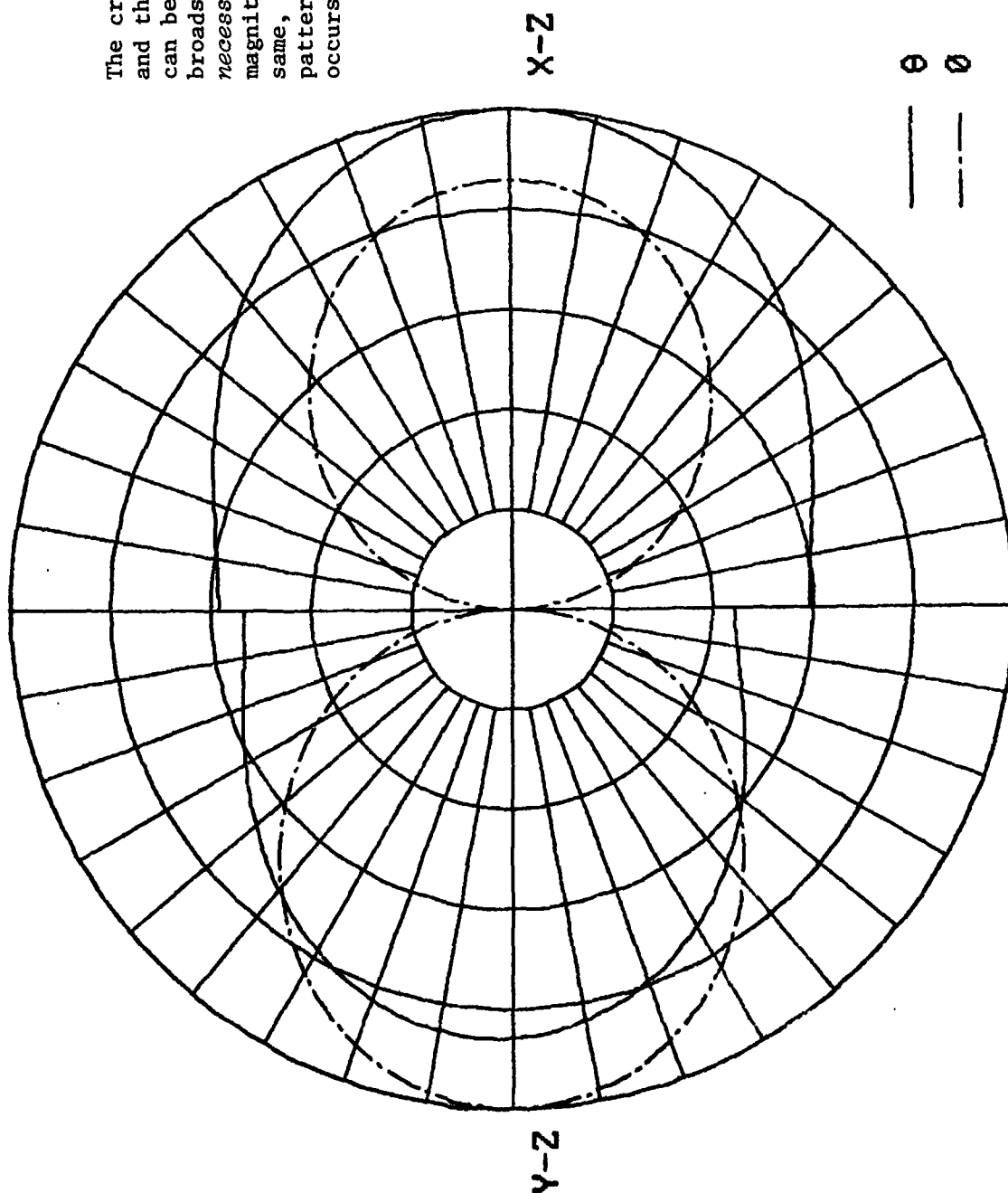
Notice that the band has been narrowed to 0.2% so that only a few patterns in the vicinity of the point at which CP is produced can be examined. To view all such patterns, the option "1" was selected.

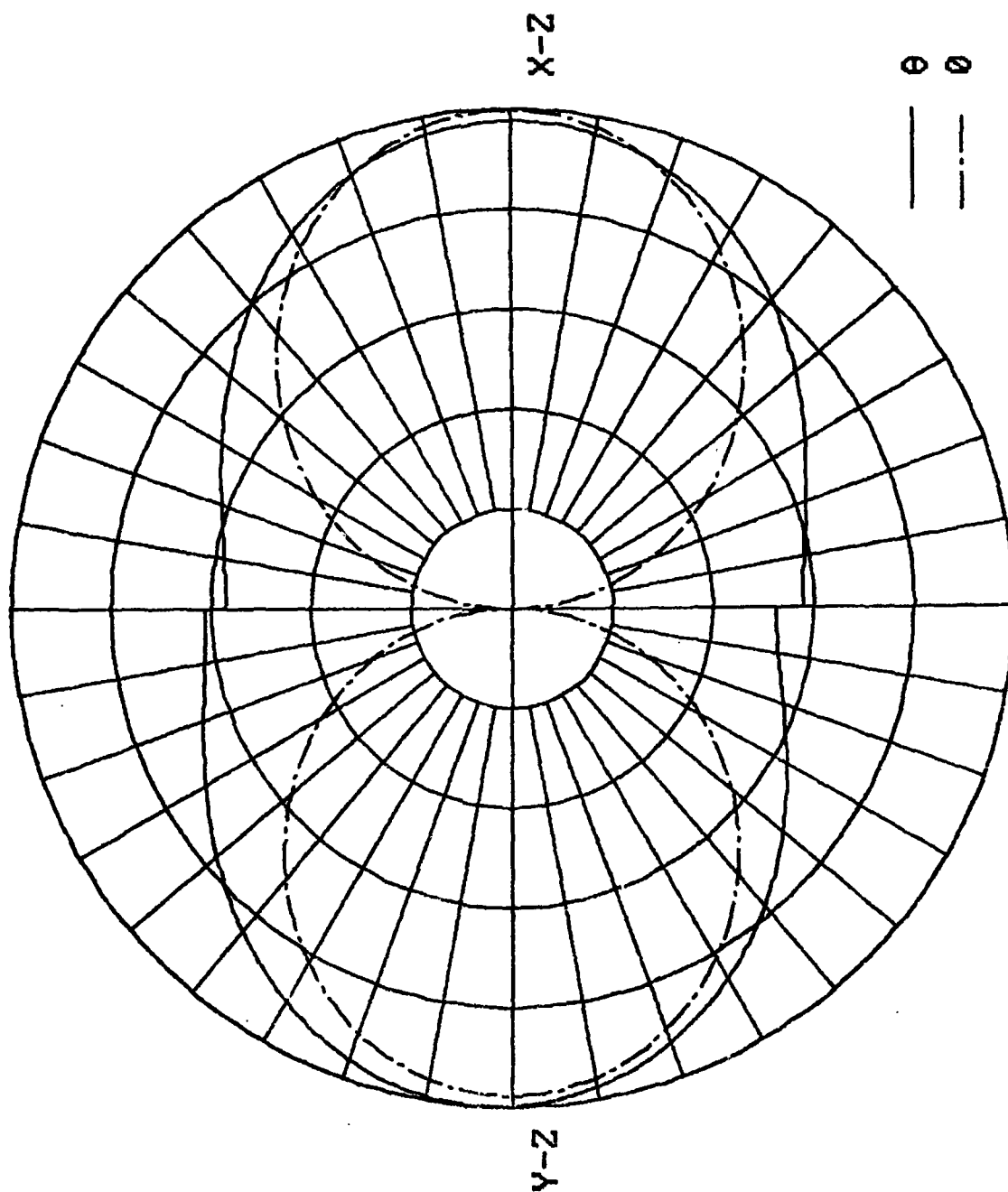
CP OR LINEAR (TYPE C OR L) ? L

INDIVIDUAL NORMALIZATION (Y OR N) ? N

In this case, the linear option has been chosen.

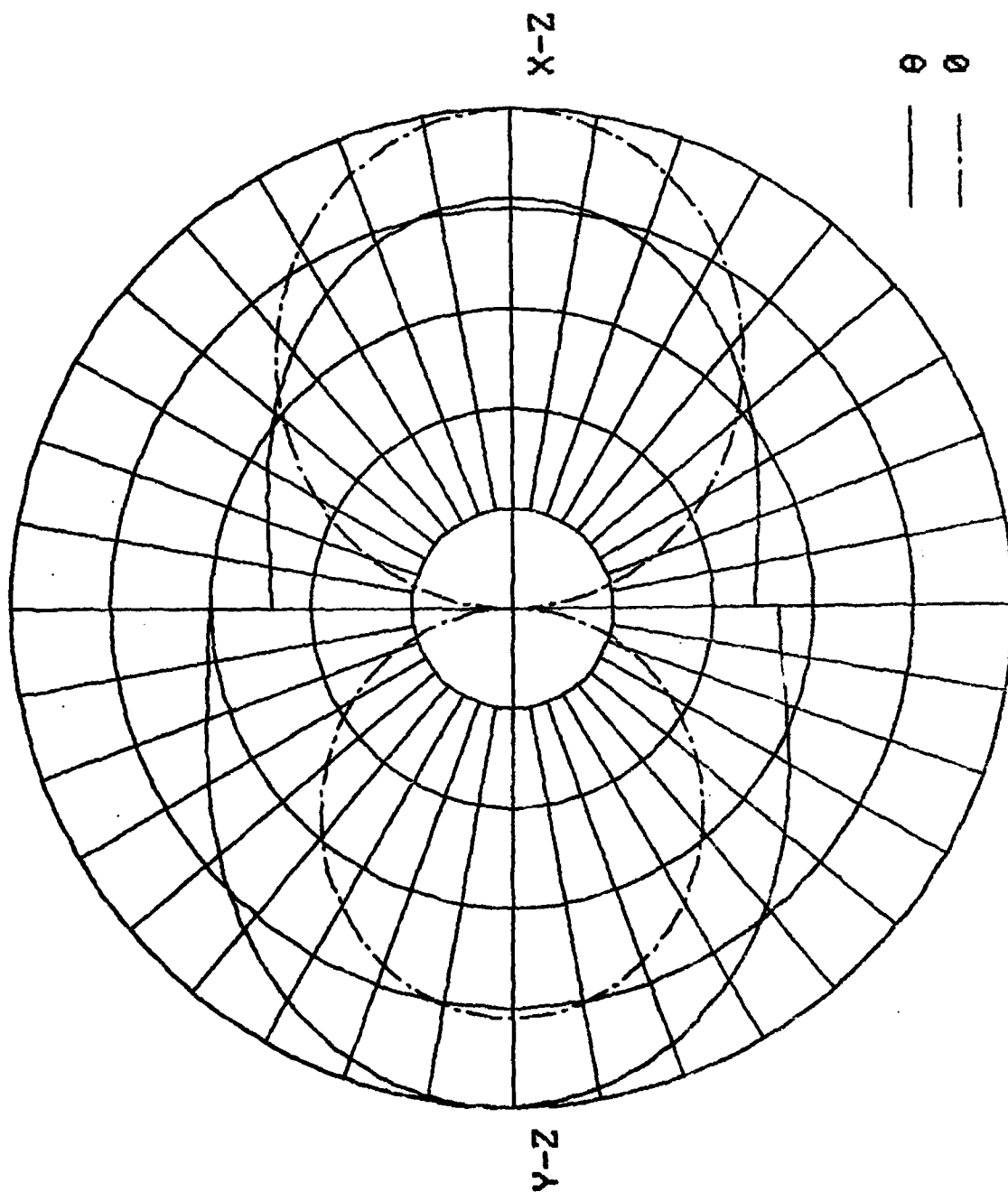
The cross-polarization in this and the subsequent patterns can be clearly seen. Since at broadside (the Z-direction) a necessary condition is that the magnitude of E_θ and E_ϕ be the same, a comparison of these patterns shows that the best CP occurs at $f = 1182$ MHz.





F = 1182.0

80/03/11. 12.08.57.



80/03/11. 12.08.57. F = 1183.0

RECTANGULAR, SMITH CHART, OR VS FREQUENCY PLOT (R, S, OR U)?

No impedance plot was needed since it was previously plotted and so a carriage return was input.

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[illegible]

සමස්ත සේවාව
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 - සියලුම සේවාවන්
 සේවාවන් සැපයීම සඳහා
 සියලුම සේවාවන්

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