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PRIME FOCUS EFFICIENCY, BLOCKAGE, SPILLOVER AND SCATTERING CALCULATIONS ON THE HP 9825A CALCULATOR

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Programs for the calculation of aperture efficiency and spillover have been in use at NRAO for some time (Weinreb and Jansson, 1970, EDIR #93; Leonard and Napier, 1973, EDIR #131). EDIR #93 describes a FORTRAN program which assumes a clear aperture and perfect phase and computes aperture and spillover efficiency and spillover temperature. An HP 9830A BASIC-language program which extends the calculations to a Cassegrain system is described in EDIR #131. The HP 9830A program adds phase efficiency, aperture blockage, aperture field distribution and radiation pattern calculations to the repertoire.

The program outlined in this report incorporates the equations set forth in the previous reports for efficiencies and spillover but takes a different approach to the treatment of blockage. The contribution of this program above what has been done before is an attempt to estimate the amount of ground radiation scattered into the feed by the support legs. The main purpose of this report is to describe the use of the program and the geometry which applied to blockage and scattering. This program is written in HPL for the HP 9825A computing calculator with the 9862A plotter.

Some typical results for the 140-foot and 300-foot telescope are given at the end of the report.

Efficiency and Spillover Equations

The following equations were taken from EDIR's 93 and 131 and incorporated in the 9825A program.

Taper efficiency:

$$\eta_T = 32\ (F/D)\ \frac{\left| \int_0^{\Theta_0} \sqrt{G(\Theta)}\ \tan\ (\Theta/2)\ d\Theta \right|^2}{\int_0^{\Theta_0} G(\Theta)\ \sin\ \Theta\ d\Theta}$$

Spillover efficiency:

$$\eta_S = \frac{\int_0^{\Theta_0} G(\Theta)\ \sin\ \Theta\ d\Theta}{\int_0^{\pi} G(\Theta)\ \sin\ \Theta\ d\Theta}$$

Phase efficiency:

$$\eta_P = \frac{\left| \int_0^{\Theta_0} \sqrt{G(\Theta)}\ e^{j\phi}\ \tan\ (\Theta/2)\ d\Theta \right|^2}{\left| \int_0^{\Theta_0} \sqrt{G(\Theta)}\ \tan\ (\Theta/2)\ d\Theta \right|^2}$$

Spillover temperature:

$$T_S = T_G\ \frac{\int_{\Theta_0}^{\frac{\pi}{2}} G(\Theta)\ \sin\ \Theta\ d\Theta}{\int_0^{\pi} G(\Theta)\ \sin\ \Theta\ d\Theta}$$

Taper efficiency with blockage:

$$\eta_{TB} = 32\ (F/D)\ \frac{\left| \int_0^{\Theta_0} \gamma(\Theta)\ \sqrt{G(\Theta)}\ \tan\ (\Theta/2)\ d\Theta \right|^2}{\int_0^{\Theta_0} G(\Theta)\ \sin\ \Theta\ d\Theta}$$

where Θ = feed look angle from antenna axis.

$G(\Theta)$ = power pattern of feed.

F = focal length.

D = diameter of dish.

Θ_0 = semiangle of dish.

ϕ = feed phase pattern.

T_G = effective ground temperature (assumed to be 250 K).

$\gamma(\Theta)$ = fraction of aperture annulus in direction Θ not blocked by feed support.

Linear interpolations are used between input data points and numerical integrations are performed in one degree steps. Data points should be no father apart than 10° to minimize interpolation errors.

Feed Support Geometry

Figure 1 gives the details of the antenna structure model and the notation used herein. This model is somewhat more complicated than is needed for aperture blockage corrections (see EDIR #131), but the detail is needed for scattered ground radiation computations.

From the principle of reciprocity we can estimate the contribution of scattered ground radiation to the system temperature by assuming that a ray emitted by the feed is scattered isotropically where it strikes the feed supports. At the telescope zenith position the fraction of the scattered radiation striking the ground is the solid angle between the horizon and the dish edge divided by 4π steradians. Ideally, the diffraction pattern of the support structure should be known, but this would make the problem intractable. An added simplification is made by assuming that the scattering point is on the telescope axis at height H so that ξ is not a function of azimuth. For relatively narrow feed leg angles this will not cause much error in the solid angle calculation.

For blockage and scattering computation the feed radiation pattern is divided into five sectors. Between $\Theta = 0$ and Θ_H all of the radiation is blocked and scattered by the feed support house (or ring). From Θ_H to Θ_C radiation is scattered above the rim of the dish. From Θ_C through Θ_B to Θ_A all of the blocked energy can only "see" the cold sky so is not included in the ground scatter integration. Between Θ_A and Θ_0 the scatter points can again see the ground, but here the supports are between the feed and the dish surface.

A simplified picture of the feed radiation pattern sectors included in the ground scatter integral is shown in Figure 2. In sector 2 the support leg dimension of importance is its vertically projected width. In sector 3 the leg width as seen from the feed is needed. If the leg is a cylinder these dimensions are the same, but on the 300-foot telescope the support cross sections are trapezoids with the small side inward. From the feed the 4-foot inner side subtends a larger angle than the 7-foot top side, but the vertically projected width is 7 feet. The program provides for the input of both widths.

The feed house can be any shape, but for this purpose it is assumed to be circular in cross section. The projected area, A, is input to the program, then

$$\Theta_H = \tan^{-1} (\sqrt{A/\pi}/F)$$

where F is the focal length. Taking the house to be at the focal point the angle subtended by the ground is

$$\xi_H = 90° - \Theta_0$$

and the ground solid angle divided by 4π is

$$\mu_H = \frac{\cos \Theta_0}{2}$$

The fraction of energy scattered to the ground by the feed house is then

$$S_H = \frac{\int_0^{\Theta_H} \mu_H \, G(\Theta) \sin \Theta \, d\Theta}{\int_0^{\pi} G(\Theta) \sin \Theta \, d\Theta}$$

In the region between Θ_H and Θ_A the fraction of energy blocked by the supports at a given Θ is

$$(1 - \gamma_\ell(\Theta)) \simeq \frac{Nw'}{2\pi F \left(\frac{2 \sin \Theta}{1 + \cos \Theta}\right)}$$

where w' is the vertically projected leg width, and N is the number of legs. The fraction of power scattered to the ground from all legs in region 2 of Figure 2 is then

$$5 = \frac{\int_{\Theta_H}^{\Theta_B} (1 - \gamma_\ell(\Theta)) \, \mu_\ell \, G(\Theta) \sin \Theta \, d\Theta}{\int_0^{\pi} G(\Theta) \sin \Theta \, d\Theta}$$

where

$$\mu_\ell = \frac{\sin \xi_\ell}{2}$$

$$\xi_\ell = \tan^{-1} (2H_\ell/D)$$

$$H_\ell = \mathcal{F} - (x - \ell)/\tan \beta$$

$$x = \frac{2F \sin \Theta}{1 + \cos \Theta}$$

ℓ = focus to inside leg horizontal distance.

$\mathcal{H}$ = $(D/2) \tan \Theta_0$ = height of focus above the rim,

Θ_0 = $2 \tan^{-1} (D/4F)$,

D = dish diameter, and

β = angle of the support from the axis.

The portion of the taper efficiency integral between Θ_H and Θ_B is

$$\Delta u(\Theta_H \text{ to } \Theta_B) = \int_{\Theta_H}^{\Theta_B} \gamma_\ell(\Theta) \sqrt{G(\Theta)} \tan(\Theta/2)\, d\Theta$$

In the sector between Θ_B and Θ_0 the fraction of energy blocked or scattered by the support is

$$(1 - \gamma(\Theta)) = N\phi/360°$$

where

ϕ = $2 \tan^{-1} (w/2d)/\sin \Theta$

d = $\ell[\sin \Theta + \cos \Theta/\tan(\Theta - \beta)]$, and

w = effective width of support as seen from the feed.

The fraction of radiation scattered to the ground between Θ_A and Θ_0 is

$$S = \frac{\int_{\Theta_A}^{\Theta_0} \mu(\Theta)\,(1 - \gamma(\Theta))\, G(\Theta) \sin \Theta\, d\Theta}{\int_0^{\pi} G(\Theta) \sin \Theta\, d\Theta}$$

where

$$\mu(\Theta) = \frac{\sin \xi}{2},$$

$$\xi = \tan^{-1} (2H/D), \text{ and}$$

$$H = \mathcal{F} - d \cos \Theta$$

The portion of the taper efficiency integral between Θ_B and Θ_0 is

$$\Delta u(\Theta_B \text{ to } \Theta_0) = \int_{\Theta_B}^{\Theta_0} \gamma(\Theta) \sqrt{G(\Theta)} \tan (\Theta/2)\, d\Theta$$

The total taper efficiency with blockage is then

$$\eta_{TB} = 32 \, (F/D)^2 \frac{\left| \Delta u(\Theta_H \text{ to } \Theta_B) + \Delta u(\Theta_B \text{ to } \Theta_0) \right|^2}{\int_0^{\Theta_0} G(\Theta) \sin \Theta \, d\Theta}$$

and the increment to the system temperature from scattered ground radiation is

$$T_S = T_G (S_H + S_\ell + S)$$

The printed output of the program separates this quantity into its components as P[1] = $T_G S_H$, P[2] = $T_G S_\ell$, and P[3] = $T_G S$.

The various pertinent angles are calculated as follows:

$$\Theta_c = \tan^{-1} [\chi'/(F - E\chi'^2)]$$

$$\chi' = \mathcal{F} \tan \beta + \ell$$

$$E = \frac{4F}{D} - \frac{2}{D \tan \Theta_0}$$

$$\Theta_A = \tan^{-1} (\tan \beta + \ell/\mathcal{F})$$

An iterative approached is used to get a good approximation to Θ_B:

$$\chi = F \tan \beta + \ell$$

$$h = E \chi^2$$

$$\chi = \chi - h \tan \beta$$

$$h = E \chi^2$$

$$\Theta_B = \tan^{-1}[\chi/(F - h)].$$

Using the Program

This program is stored on the NRAO GB#1 tape in files 4 and 5 of track 0. File 4 contains all of the data input code and does the unblocked aperture calculations. If blockage effects are opted for, file 5 is automatically called and run. The following steps can be used as a guide in using the program.

1. Insert GB#1 cassette after calculator has been turned on.
2. Execute "ldp 4".
3. Displayed will be "F/D?". Type in focal ratio (e.g., .423) and hit "Continue".
4. Displayed will be "# of Legs?". If blockage is not of interest type "0" and "Continue" and go to step 11.
5. Displayed will be "Diam.?". Type in dish diameter and "Continue". Any units are acceptable, but you must use the same units in the following steps.
6. Displayed will be "Feed House Area?". If the projected dimensions of the feed house are, say, 10 ft by 20 ft type in "200" "Continue".
7. Displayed will be "Proj. Leg Width: From Feed?". Type apparent width of support leg as seen from feed, e.g., "4" (ft) "Continue" for the 300-ft. A special fudge for the 300-ft has been coded into the program (lines 24-27 of file 5) to account for the fact that the feed supports on this telescope increase in width near the feed house.

8. Displayed will be "Vert.?". Type the vertically projected width of support legs, e.g., "7" (ft) "Continue" for the 300-ft.
9. Displayed will be "Feed-Leg Dist.?" Type the distance from the focal point to the support leg measured perpendicular to the axis, e.g., "4.7" (ft) "Continue" for the 300-ft.
10. Displayed will be "Leg Ang.?". Type the angle between the feed support leg axis and the telescope axis, e.g., "30.7" (degrees) "Continue" for the 300-ft.
11. Next the words "Angle?", "-Gain", and "Phase?" will continue to be displayed in succession. This provides for the entry of feed pattern data. Start at the axis (Angle = "0") giving the feed look "Angle", the "Gain" in dB below the peak (this is entered as a positive number), and the pattern "Phase" at that point. If the phase is not known or is not important enter "0" for each phase point. The data must be entered in increasing order of "Angle". If an angle equal to or less than the last one is entered "DATA OUT OF ORDER Try again" is displayed for $1^{s}.5$ and the calculator then is ready for a new try at the next data point. Because of interpolation errors no two data points should be more than 10° apart, and 5° spacing is better. Up to about 80 data points could be handled, and they need not be evenly spaced. The last data point <u>must</u> be at 110°; detection of this angle terminates the data entry routine and asks for feed gain beyond 110°. The printer then lists the entered data, each point with a serial number, and the opportunity to change any of the points is presented.
12. Displayed will be "Changes? N? (0 = none). Type the serial number of the point to be changed and proceed as before. When satisfied respond with "0".

13. Displayed will be "Set up plotter". Turn the plotter on, remove the pen cap, and align an appropriate piece of paper. Set up the lower left and upper right points with the plotter buttons and potentiometers. Hit "Continue". Axes will be drawn and labeled to display the entered feed pattern, etc. See Figure 3. If no plot is desired type "psc 0", "Execute" under keyboard mode, and respond with the "stop" key to steps 14-17.
14. Displayed will be "Label, then hit stop". The plotter is then in typewriter mode and any identification information can be put on one line of the plot. Steps 15-17 will call for some label information in addition. To get out of typewriter mode in each case hit the "Stop" key.
15. Displayed will be "Freq.?". Type the pattern measurement frequency and key "Stop".
16. Displayed will be "Pol.?". Type the pattern polarization and key "Stop".
17. Displayed will be "Plane?". Type the pattern measurement plane, and key "Stop".
18. After the calculations and plot are completed and blockage effects have been requested "Which telescope?" will be displayed. The telescope identification can be typed onto the plot. Hit "Stop" to move the pen off the plot area and end the program.

The various calculated parameters are recorded on the strip printer as shown with the program listing, and most are also put on the plot. The phase efficiency is calculated for five points on a focus curve separated by $\lambda/4$ in case the phase pattern was taken with the feed phase center longitudnally offset from the rotation axis. Less than about 1% error would be obtained by simply taking the highest of the five values, provided, of course, that the phase center was not offset by more than $5\lambda/8$.

The spillover temperature with blockage takes into account the fact that some of the spillover radiation is rescattered or blocked by the feed support legs. P[1], P[2], and P[3] are the feed house, dish to sky, and feed to dish scattered ground radiation temperatures, respectively. The total of the three is the increment to the system temperature due to feed support structure scattering. Calculation time without blockage is about 20^s and with blockage is about 30^s total.

<u>300-ft and 140-ft Parameters and Results</u>

Feed support leg dimensions for input to blockage calculations are given in Table 1.

Table 1: Program Input Dimensions.

	140'	300'
F/D	.429	.424
Number of legs	4	2
Diameter	140 ft	300 ft
Feed House Area	80 ft^2	162 ft^2
Projected Leg Width: From Feed ...	1.25 ft	4 ft
Vertical	1.25 ft	7 ft
Feed-Leg Distribution	4.4 ft	4.7 ft
Leg Angle	34.7°	30.7°

Qualitative differences between the 140-ft and 300-ft are illustrated with a typical feed pattern at the end of the program listing. Except for a slight difference due to different focal ratios the unblocked results are the same for both telescopes.

With blockage, however, the 300-ft is about 11% less efficient. One comparative measurement made at 21 cm on the two instruments gave a difference of about 6% at 21 cm. A small reduction of about 1 K in spillover temperature due to ground shielding by the supports is seen. The largest contribution to scattered ground radiation is due to the feed house (P[1] = 1.27 K) on the 140-ft, while the large angle subtended by the feed legs in region 3 (Figure 2) proves the dominant factor on the 300-ft (P[3] = 3.96 K). The total scattering contribution is 3.7 K on the 140-ft and 5.6 K on the 300-ft so the difference between the two telescopes is relatively minor.

The basic assumption of isotropic scattering by the support legs must be kept in mind when interpreting the latter quantities, but these calculations probably give a reasonable estimate of the size of the effect. Also, geometrical dimensions have been used for the support structure. A slight improvement in the blockage calculations might be made by using the electromagnetic scattering cross sections.

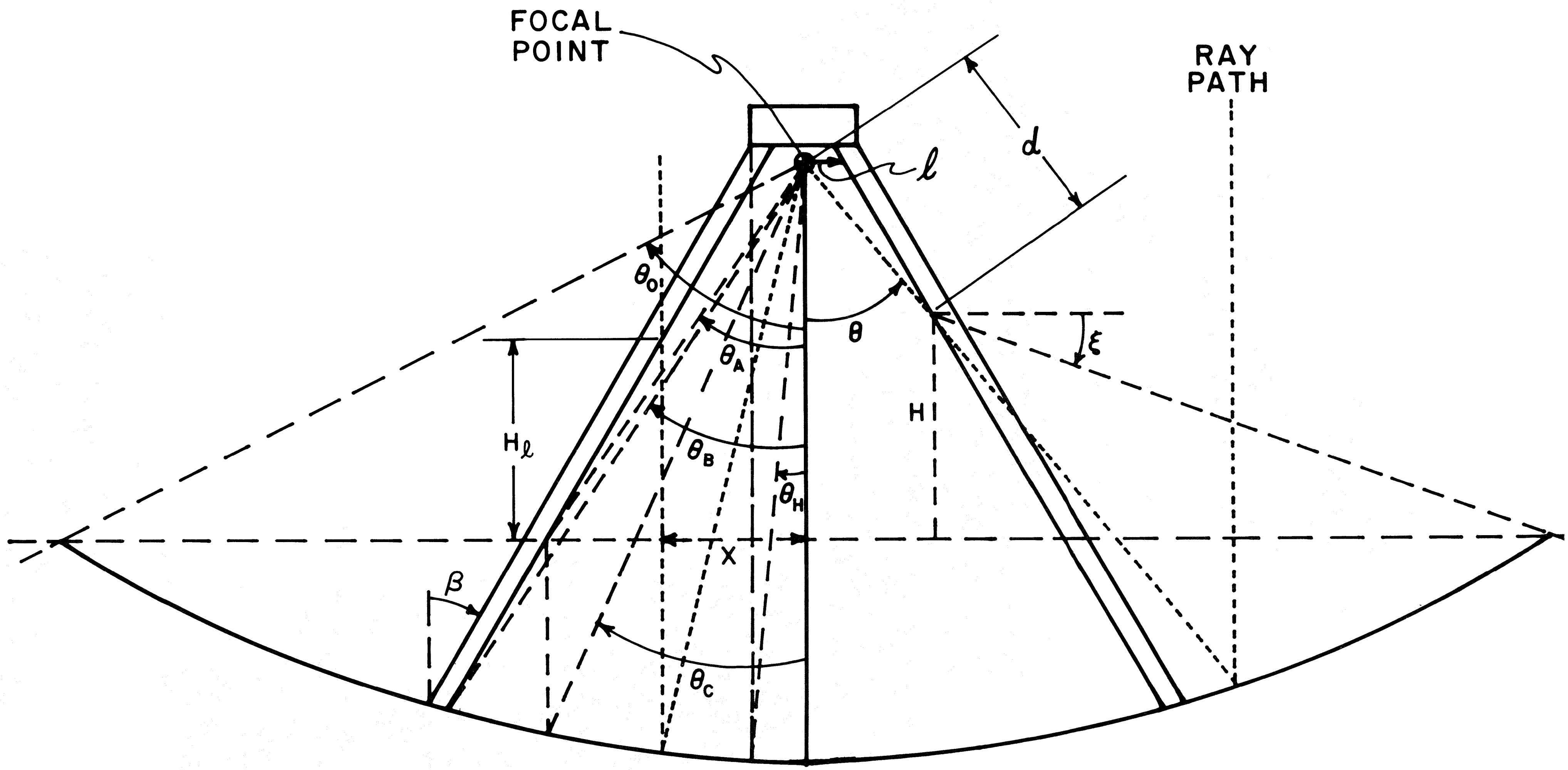

FIGURE 1. FEED SUPPORT LEGS

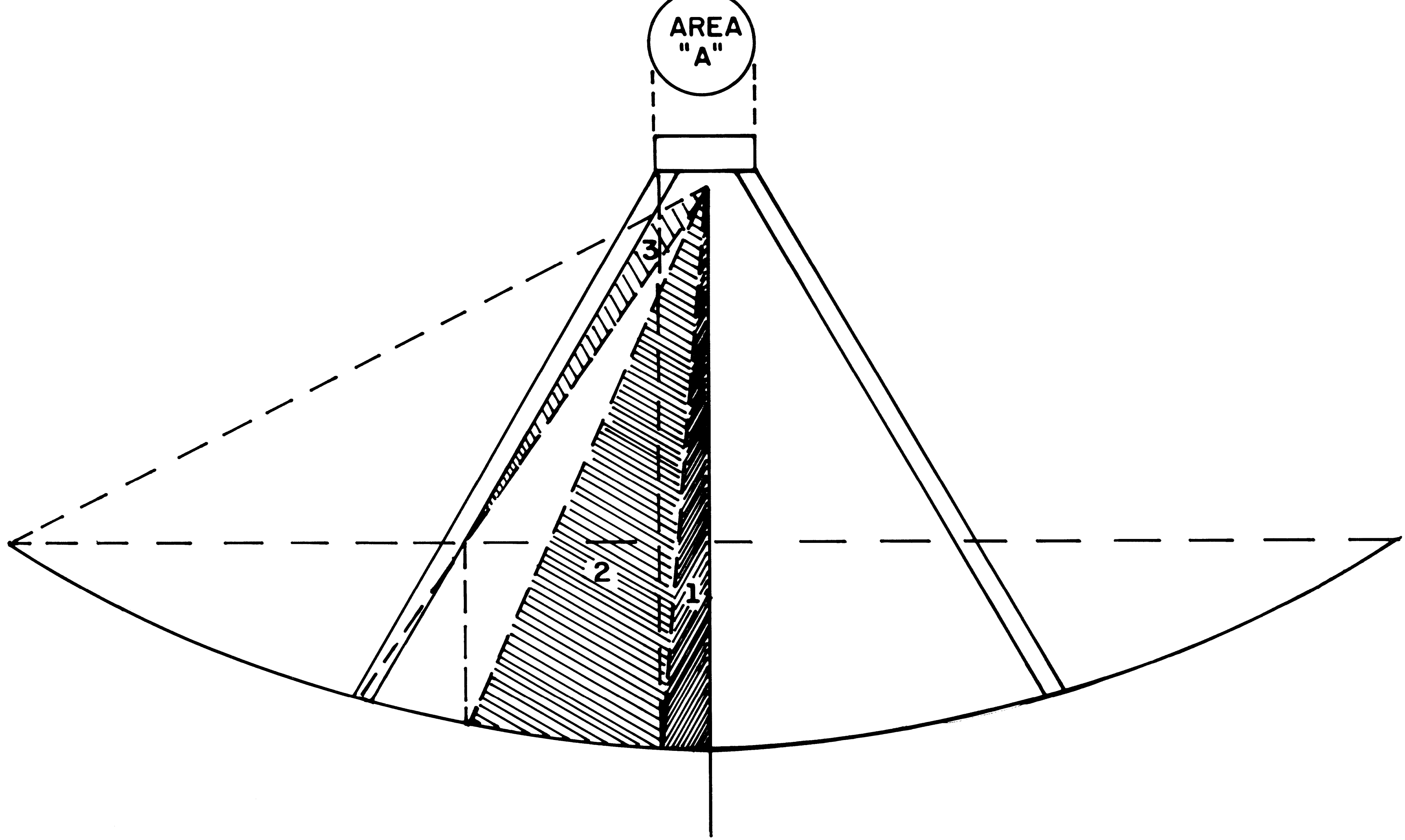

FIGURE 2. AREAS OF INTEREST IN GROUND RADIATION SCATTERING INTEGRALS.

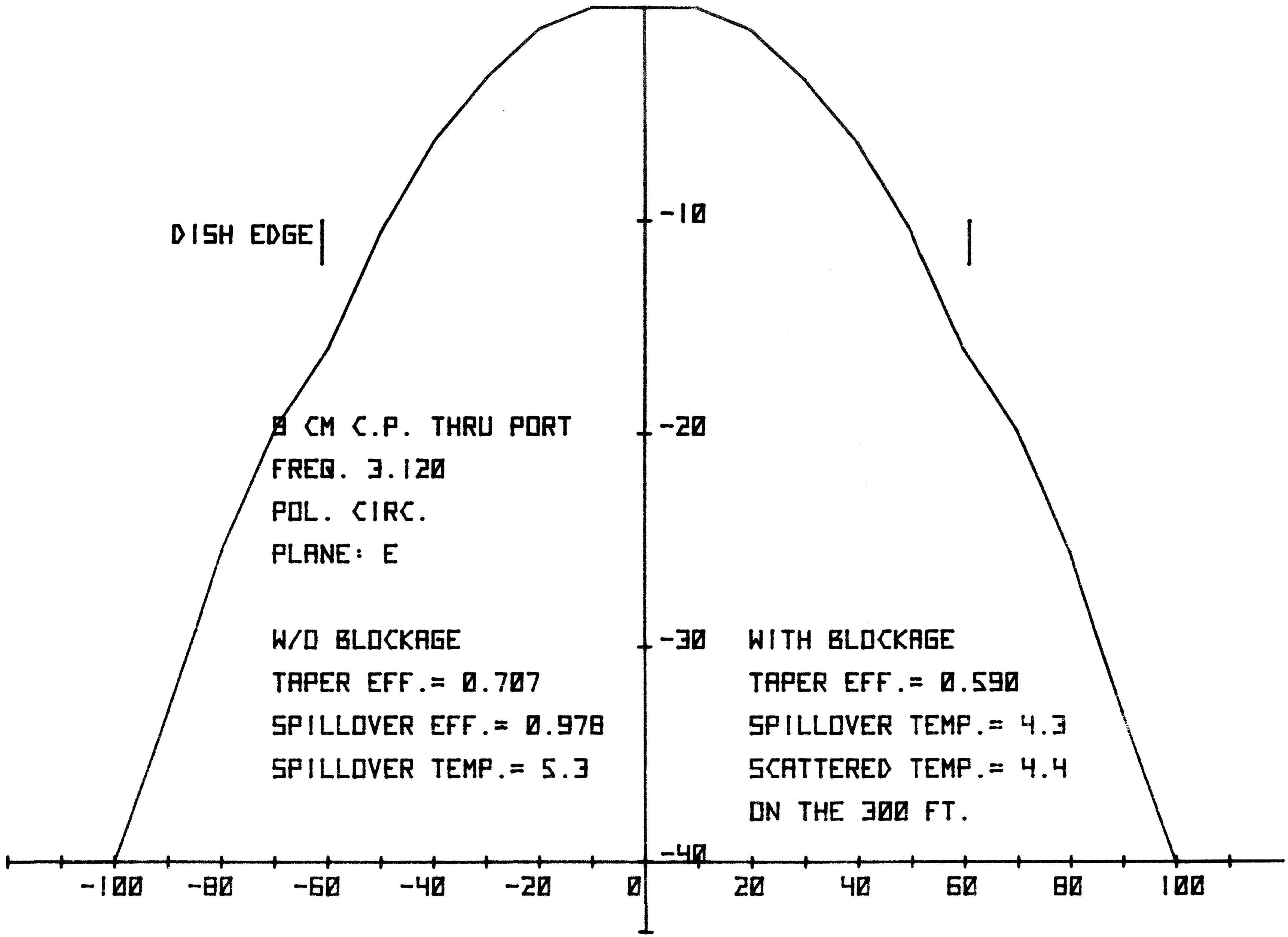

FIGURE 3. EXAMPLE OUTPUT PLOT.

THIS PLOT DOES NOT CORRESPOND TO DATA AT THE END OF THE PROGRAM LISTING.

TABLE 2

File 4

```
0: dim F[3],G[107],O[5],P[3],R[2],U[3],W[2],Q[70],H[5,2]
1: deg
2: -1→r0
3: enp "F/D?",F[3],"# of Legs?",N
4: if N=0;gto "nl"
5: enp "Diam.?",D,"Feed House Area?",A,"Proj. Leg Width: From Feed?",W[1]
6: enp "Vert.?",W[2],"Feed-Leg Dist.?",L,"Leg Ang.?",B
7: "nl":for I=1 to 56
8: ent "Angle?",rI,"-Gain?",G[I],"Phase?",Q[I]
9: if rI=110;gto "ed"
10: if rI<=r(I-1);dsp "DATA OUT OF ORDER! Try again.";I-1→I;wait 1500
11: next I
12: "ed":ent "-Gain Past 110 Deg.?",X
13: wrt 16," N Ang Gain  Ph"
14: fmt f2.0,f4.0,f5.1,f4.0
15: for J=1 to I
16: wrt 16,J,rJ,G[J],Q[J];next J
17: "ch":ent "Changes? N?(0=none)",J
18: if J=0;gto "nc"
19: ent "Angle?",rJ,"-Gain?",G[J],"Phase?",Q[J];gto "ch"
20: "nc":110→r100
21: scl -120,120,-50,0
22: dsp "Set up plotter";stp
23: axe 0,-40,10,10
24: plt -70,-20,1
25: dsp "Label, then hit stop";ptyp
26: plt -70,-22,1;lbl "freq. "
27: dsp "Freq.? then stop";ptyp
28: plt -70,-24,1;lbl "Pol. ";dsp "Pol.? then stop";ptyp
29: plt -70,-26,1;lbl "plane: ";dsp "Plane? then stop";ptyp
30: dsp " "
31: plt -rI,-G[I],1
32: for J=I-1 to 1 by -1
33: plt -rJ,-G[J],2;next J
34: for J=2 to I;plt rJ,-G[J];next J
35: fxd 0;for J=-10 to -40 by -10
36: plt 3.3,J,1;lbl J;next J
37: for J=-100 to 100 by 20
38: plt J-6,-41.5,1;lbl J;next J
39: for J=101 to 107
40: 10+r(J-1)→rJ
41: X→G[J];next J
42: 32F[3]↑2→C
43: 2atn(.25/F[3])→O[5]
44: plt -O[5]-28,-11,1;lbl "dish edge"
45: plt -O[5],-10,1;plt -O[5],-12,2
46: plt O[5],-10,1;plt O[5],-12,2
47: if N=0;4→O[4];3→O[3];2→O[2];1→O[1];gto "sa"
48: .5D/tan(O[5])→F[2]
49: F[3]D→F[1]
50: atn(√(A/π)/F[1])→O[1]
51: tan(B)→T
52: F[2]T+L→X
53: (4F[3]-2/tan(O[5]))/D→E
54: atn(X/(F[1]-EX↑2))→O[2]
55: F[1]T+L→X
56: X-ETX↑2→X
57: atn(X/(F[1]-EX↑2))→O[3]
58: atn(T+L/F[2])→O[4]
59: NW[2]/4πF[1]→E
60: "sa":110→X
61: G[I]→G[100];rI→r100
62: I-1→I
63: for J=99 to 96 by -1
64: X-5→X
65: if rI>X;I-1→I;gto +0
66: X→rJ
67: (X-rI)/(r(I+1)-rI)→Y
68: G[I](1-Y)+G[I+1]Y→G[J]
69: next J
70: 89→X;5→K
71: for J=95 to 1 by -1
72: if K=0;gto +7
73: if X>O[K];gto +6
74: O[K]→rJ;J→O[K];K-1→K
75: if rI>rJ;I-1→I;gto +0
```

Table 2 (continued):

```
76: (rJ-rI)/(r(I
 +1)-rI)→Y
77: G[I](1-Y)+
 G[I+1]Y→G[J];
 Q[I](1-Y)+Q[I+
 1]Y→Q[J]
78: next J
79: if rI>X;I-
 1→I;gto +0
80: (X-rI)/(r(I+
 1)-rI)→Y
81: X→rJ
82: if J>70;gto
 +2
83: Q[I](1-Y)+
 Q[I+1]Y→Q[J]
84: G[I](1-Y)+
 G[I+1]Y→G[J]
85: X-1→X;next J
86: fmt 2f7.2
87: for I=1 to
 107
88: tn↑(-.1G[I])
 →G[I];next I
89: 0→U[2]→U[3]→
 R[1]→Z
90: for I=1 to
 O[5]-1
91: (rI+r(I+1)).
 5→S
92: (r(I+1)-rI).
 017453→X
93: (G[I]+G[I+
 1]).5→Y
94: U[2]+Ysin(S)
 X→U[2]
95: rYtan(S/2)X→
 Y
96: 90cos(S)→X
97: for K=1 to 5
98: H[K,1]+Ycos(
 Q[I]+(K-3)X)→H[
 K,1]
99: H[K,2]+Ysin(
 Q[I]+(K-3)X)→H[
 K,2]
100: next K
101: Z+Y→Z;next
 I
102: for K=1 to
 5
103: (H[K,1]↑2+
 H[K,2]↑2)/Z↑2→H
 [K,1]
104: next K
105: U[2]→U[3]
106: for I=O[5]
 to 106
107: U[3]+.00872
 66(G[I]+G[I+
 1])sin((rI+r(I+
 1)).5)(r(I+1)-
 rI)→U[3]
108: if I=95;
 (U[3]-U[2])250→
 R[1]
109: next I
110: R[1]/U[3]→R
 [1]
111: fxd 3;fmt
 1,f5.3;spc 2
112: prt "W/O
 Blockage";spc
113: prt "Tap.
 Eff.=",Z↑2C/
 U[2]
114: prt "Spillo
 ver"
115: wrt 16.1,"
      Eff.=",U[2]
 /U[3]
116: prt "Phase
 Eff.="
117: for K=1 to
 5
118: prt H[K,1];
 next K
119: prt "Spillo
 ver";fxd 1
120: prt "Temper
 ature=",R[1]
121: plt -70,-
 30,1;lbl "w/o
 blockage"
122: plt -70,-
 32,1;lbl "taper
  eff.="
123: fxd 3;lbl
 Z;plt -70,-34,1
124: lbl "spillo
 ver eff.=";lbl
 U[2]/U[3]
125: plt -70,-
 36,1;fxd 1
126: lbl "spillo
 ver temp.=";
 lbl R[1]
127: if N=0;end
128: ldf 5
*10625
```

File 5

```
0: fmt 1,f5.3,
1: 0→P[1]→P[2]→P
 [3]→U[1]→R[2]
2: for I=1 to
 O[1]-1
3: P[1]+.0087266
 (G[I]+G[I+1])si
 n(.5(rI+r(I+
 1))(r(I+1)-rI))
 →P[1]
4: next I
5: 125P[1]cos(rO
 [5])/U[3]→P[1]
6: for I=O[1]
 to O[3]-1
7: sin(.5(rI+
 r(I+1)))→S
8: .017453(r(I+
 1)-rI)→X
9: .5(G[I]+G[I+
 1])→Y
10: 1-E(1+r(1-
 S↑2))/S→V
11: U[1]+rYVXtan
 (.25(rI+r(I+
 1)))→U[1]
12: if I>=O[2];
 gto +4
13: F[2]-(2F[1]S
 /(1+r(1-S↑2))-
 L)/T→M
14: .5sin(atr 2M
 /D))→M
15: P[2]+(1-V)SY
 XM→P[2]
16: next I
17: 250P[2]/U[3]
 →P[2]
18: for I=O[3]
 to 95
19: .5(rI+r(I+
 1))→Z
20: sin(Z)→S
21: .017453(r(I+
 1)-rI)→X
22: .5(G[I]+G[I+
 1])→Y
23: L(S+r(1-S↑2)
 /tan(Z-B))→V
24: if D#300;
 gto +4
25: if Z<38;gto
 +3
26: if I>=O[5];
 gto +2
27: 4+.17(Z-38)→
 W[1]
```

```
28: 1-(N/180)atn
 (.5W[1]/V)/S→M
29: if I>=O[5];
 gto +6
30: U[1]+rYMXtan
 (.5Z)→U[1]
31: if I<O[4];
 next I
32: .5sin(atn(to
 n(rO[5])-(2V/
 D)r(1-S↑2)))→V
33: P[3]+V(1-
 M)YXS→P[3]
34: next I
35: R[2]+SYXM→R[
 2];next I
36: 250R[2]/U[3]
 →R[2]
37: R[2]+.5(R[1]
 -R[2])cos(rO[5]
 )→R[2]
38: CU[1]↑2/U[2]
 →U[1]
39: 250P[3]/U[3]
 →P[3]
40: spc 3
41: prt "With
 Blockage";spc
42: wrt 16.1,
 "Tap. Eff.=",
 U[1]
43: prt "Spillov
 er"
44: prt "Tempera
 ture=",R[2]
45: prt " P[1]
 P[2] P[3]"
46: fmt 1,3f5.2
47: wrt 16.1,
 P[1],P[2],P[3]
48: fxd 3;plt
 20,-30,1
49: lbl "with
 blockage";plt
 20,-32,1
50: lbl "taper
 eff.=";lbl U[1]
51: plt 20,-34,
 1;fxd 1
52: lbl "spillov
 er temp.=";lbl
 R[2]
53: plt 20,-36,
 1;lbl "scattere
 d temp.="
54: lbl P[1]+
 P[2]+P[3]
55: plt 20,-38,1
56: lbl "on the
 ";dsp "Which
 telescope? then
 stop";ptyp
57: plt 109,0,1;
 dsp " ";end
```

Table 2 (continued):

TYPICAL OUTPUT

140'

```
F/D?
.429
# of Legs?
4
Diam.?
140
Feed House Area?
80
Proj. Leg Width:
 From Feed?
1.25
Vert.?
1.25
Feed-Leg Dist.?
3.6
Leg Ang.?
34.7
 N  Ang  Gain   Ph
 1    0   0.0    0
 2   10   0.2    0
 3   20   1.0    0
 4   30   3.0    0
 5   40   6.0    0
 6   50  10.0    0
 7   60  15.0    0
 8   70  20.0    0
 9   80  25.0    0
10   90  30.0    0
11  100  35.0    0
12  110  38.0    0


W/O Blockage

Tap. Eff.= 0.738
Spillover
     Eff.=0.975
Phase Eff.=
           0.829
           0.955
           1.000
           0.955
           0.829
Spillover
Temperature= 6.0



With Blockage

Tap. Eff.=0.643
Spillover
Temperature= 5.3
 P[1] P[2] P[3]
 1.27 0.92 1.52
```

300'

```
F/D?
.424
# of Legs?
2
Diam.?
300
Feed House Area?
162
Proj. Leg Width:
 From Feed?
4
Vert.?
7
Feed-Leg Dist.?
4.7
Leg Ang.?
30.7
 N  Ang  Gain   Ph
 1    0   0.0    0
 2   10   0.2    0
 3   20   1.0    0
 4   30   3.0    0
 5   40   6.0    0
 6   50  10.0    0
 7   60  15.0    0
 8   70  20.0    0
 9   80  25.0    0
10   90  30.0    0
11  100  35.0    0
12  110  38.0    0


W/O Blockage

Tap. Eff.= 0.730
Spillover
     Eff.=0.976
Phase Eff.=
           0.824
           0.953
           1.000
           0.953
           0.824
Spillover
Temperature= 5.6



With Blockage

Tap. Eff.=0.575
Spillover
Temperature= 4.1
 P[1] P[2] P[3]
 0.57 1.[illegible] 3.96
```