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Calculating the Focal Point of an Offset Dish Antenna

It is assumed that readers know how to calculate the focal point of a symmetrical parabolic antenna.

Offset antennae are a different matter. The popular belief here is that the focal point can not be established by simple means. However, this is not correct.

To establish the focal point of an offset antenna, we need to measure three parameters instead of two: the large and small elliptical axes and the maximum antenna depth.

The bulk of an offset antennae is formed by a three-dimensional space (Fig.1a).

The similarity of offset antennae is determined by two parameters, but no explicit expression is available.

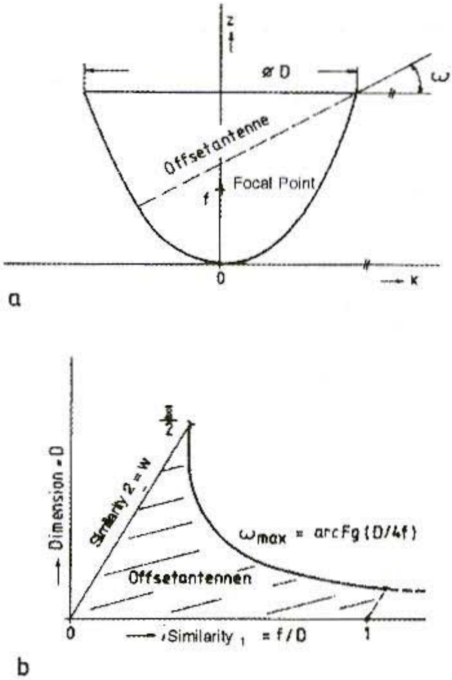

Fig.1: a. Definition of Offset Antennae
b. Similarity of Offset Antennae

The principle of offset antennae is described below, and the parameters and marginal conditions required to establish the focal point are given.

A listing of a small BASIC program is also included, together with some checking calculations.

Fig.2 shows an offset antenna with an even lateral face. It emerges as a section of a cylindrical paraboloid which is divided by a cut.

With a little effort, we can prove that:

1. Penetrating the plane and the surface of the circular paraboloid gives an ellipse
2. Projecting the penetration onto a plane running at right angles to the axis generates a circular line.

These important findings make it possible to establish the correction angle for the edge of the offset antenna:

$$\omega = \operatorname{arctg}\ u \qquad (1)$$

where

An equation can also be derived for the co-ordinate, x1:

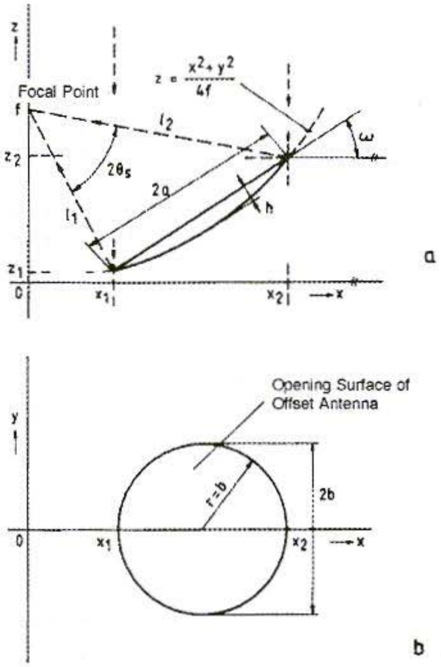

Fig.2: Offset Antennae with Even Lateral Faces in Two Views

For the focal point, the position is as follows:

The correction angle can be derived from equations (1) and (2) if it has not already been given by the manufacturer.

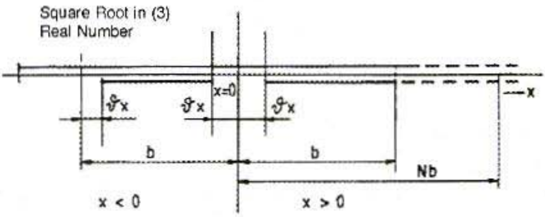

Fig.3: Aid to Solution of Equation (3)

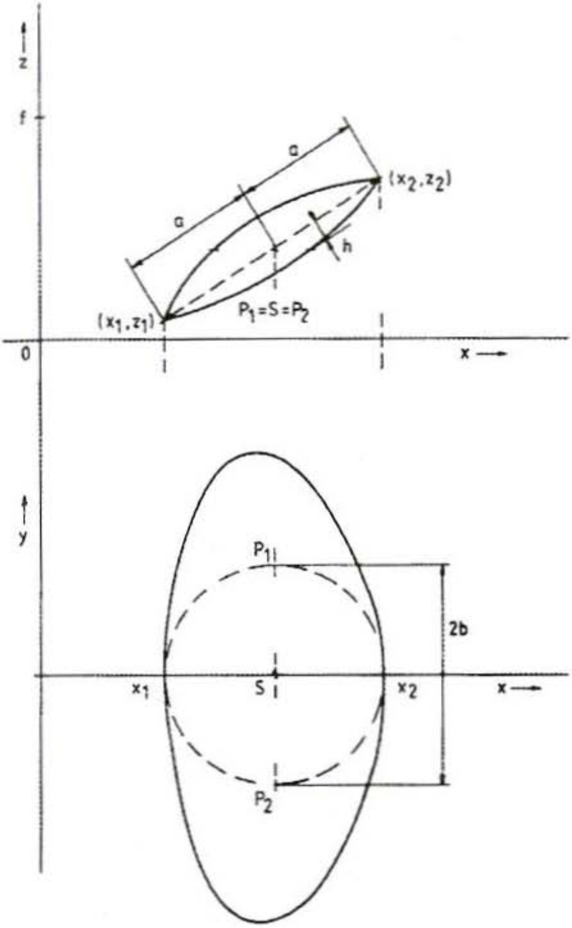

Fig.4:
Optimised Offset Antennae with Uneven Lateral Faces

There is a simple method by which it can be calculated from the reflector width. It is more difficult to solve equation (3). It can be solved, for example, using the small BASIC program, or with a programmable pocket calculator.

First we must delineate the areas on the x axis which lead to unambiguous solutions for equation (3) for $f > \phi$ together with $z_2 > z_1$. Fig.3 shows the interval selection for the solution of the equation by means of interval halving.

We begin in the range $x < \phi$, which emerges as the penetration of the two intervals referred to. If no solution is found, the search is continued in the range $x > \phi$.

It is advantageous to select the interval δx - b. It can be shown that in (3) a (+) in front of the root for $x > \phi$ never leads to a solution.

If no solution has been found, the areas outside the brackets, which have so far been established as the standard accuracy, $G = 0.001$ (in the program),

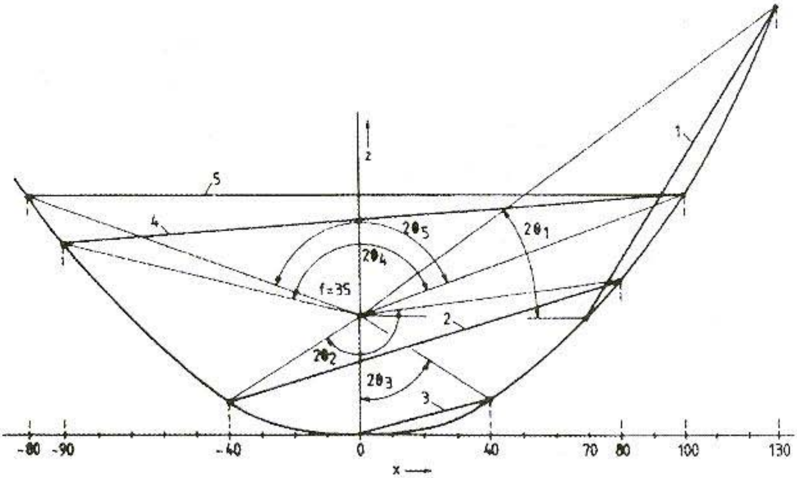

Fig.5: Examples of Offset Antennae with the same Focal Distance

δx = accuracy, b = DX (in the program) or N = 1 (δx - Nb), are expanded.

We now select a $G < 0.001$ or $N > 1$. The co-ordinate x1 is established with an accuracy of ± δx.

In order to obtain a narrower major lobe in the directional diagram of the offset antenna, antennae are manufactured which do not have an even surface (Fig.4). These antennae also have a plane of symmetry $y = \phi$, 2a and t can be measured in this plane.

The interval 2b can be measured in a plane which runs vertically to the plane y = diameter and which contains the points (x_1, z_1) and (x_2, z_2). To put it another way, for any even section selected through the surface of a rotation paraboloid, the points (x_1, z_1) and (x_2, z_2) can be obtained, which make it possible to measure the lengths 2a, 2b and t.

All the parameters can indeed be measured on a punched-out offset antenna. There remains only the problem of the correct classification of points (x_1, z_1) and (x_2, z_2), which are in the plane of symmetry.

In theory the classification is clear, but in practice there are always problems, so appropriate manufacturers' markings would be of assistance.

The point (x_1, z_1) lies at a position on the edge where the curvature of the section in the plane $y = \phi$ is greater than the curvature at point (x_2, z_2).

In many cases, only after precise antenna measurements can it be determined that the two points have been transposed. Fig.5 shows some examples for offset antennae. Here a focal length of 35 mm. is selected, and then some calculations are carried out.

The relevant parameters and results are shown in table form.

```
10   REM OFFSETANTENNE FOCAL POINT
20   REM J.OTYPKA, 1987
30   PI=3.141593
40   INPUT "2A (MM) = ;A
50   INPUT"2B(MM) = ;B
60   INPUT " T (MM) = " ;T
70   REM  SYMMETRICAL PARABOLIC
     ANTENNA ?
80   IF A<>B THEN GOTO 130
90   XI=-A/2: X2=A/2
100  F=A^2/16/T
110  Z1=T: Z2=T
120  OM=0: GOTO 710
130  REM ACCURACY G: DX=G*B/2
140  REM STANDARD G=.001
150  INPUT"STANDARD ACCURACY (Y/N)?";AO
160  REM X1MAX=N*B/2
170  REM STANDARD N=I
180  INPUT "N STANDARD (Y/N)?" ;BO
190  DX=.001*B/2
200  X1MAX=B/2
210  IF AO="J" THEN GOTO 240
220  INPUT"ACCURACY(1)=";G
230  DX=G*B/2
240  IF B0="J" THEN GOTO 270
250  INPUT " N (1) = " ; N
260  X1MAX=N*B/2
270  REM OUTPUT PARAMETERS
280  AB=A/B
290  U-SQR(AB^2-1)
300  REM CORRECTION ANGLE
310  OM=ATN(U)*18000/PI
320  OM=INT(OM)/100
330  POM=AB*T
340  X1MIN=-.5*POM/U+DX
350  X0MIN=-B/2+DX
360  IF X1MIN > X0MIN THEN GOTO 380
370  X1MIN=X0MIN
380  DEF FN F(X,K)=U/(B/2+X)-(X*U+POM+
     K*SQR((X*U+POM)^2-X*X*U^2))/(X*X)
390  REM SOLUTION EXISTS FOR X1<O ?
400  K=3
410  K=K-2
420  DMIN=FN F(X1MIN,K)
430  D0=FN F(-DX,K)
440  IF SGN(DMIN)=SGN(D0) AND K=I
     THEN GOTO 410
450  IF SGN(DMIN)=SGN(D0) THEN GOTO 530
460  X1=X1MIN
470  F1=DMIN
480  X2=-DX
490  F2=D0
500  GOSUB 990
510  XI=X3
520  GOTO 660
530  XI=DX
540  FL=FN F(X1,-1)
550  X2=X1MAX
560  F2=FN F(X2,-I)
570  IF SGN(FI)<>SGN(F2) THEN GOTO 620
580  AO="N"
590  BO="N"
600  PRINT "EXPAND LIMITS!"
610  GOTO 210
620  REM SOLUTION FOR XI>0
630  K=-I
640  GOSUB 990
650  XI=X3
660  REM PARAMETERS SOUGHT
670  F=(B/2+X1)/2/U
680  ZI=XI*XI/4/F
690  X2=XI+B
700  Z2=X2*X2/4/F
710  L1=SQR(X1*X1+(F-Z1)*(F-Z1))
720  L2=SOR(X2*X2+(F-Z2)*(F-Z2))
730  DZ=(L1^2+L2^2-A^2)/2/L1/L2
740  REM ACS:750-800
750  IF DZ<> THEN GOTO 770
760  DZ=90:GOTO 810
770  ACS-ATN(SQR(1/DZ/DZ-1))
780  IF DZ>0 THEN GOTO 800
790  ACS=3.141593-ACS

800  DZ=INT(ACS*18000/PI)/100
810  PRINT
820  PRINT "OFFSET ANTENNA
     PARAMETERS: "
830  PRINT
840  PRINT "2A (MM) ;A
850  PRINT"2B (MM) = ;B
860  PRINT"DEPTH (MM) = ";T:PRINT
870  PRINT "CORRECTION ANGLE
     (DEGREE) = " ;OM
880  PRINT"FOCAL POINT LENGTH F (MM) = F
890  PRINT"X1 (MM) = " ;X1
900  PRINT"Z1 (MM) = " ;Z1
910  PRINT"X2 (MM) = " ;X 2
920  PRINT"Z2 (MM) = ";Z2
930  PRINT"L1 (MM) = ";L1
940  PRINT"L2 (MM) = ";L2
950  PRINT"ANGLE 2DZ (DEGREE) = "DZ
960  PRINT
970  STOP
980  REM INTERVAL HALVING
990  X3=(X1+X2)/2
1000 DF=ABS(X1-X2)
1010 IF DF<DX THEN GOTO 1100
1020 F3=FN F(X3,K)
1030 IF SGN(F3)<>SGN(FI) THEN GOTO 1070
1040 XI=X3
1050 FI=F3
1060 GOTO 990
1070 X2=X3
1080 F2=F3
1090 GOTO 990
1100 RETURN
```

Table: GW BASIC Program Listing

If we use the BASIC program, we must initially increase the intervals after entering the standard parameters. The standard accuracy has been retained, N has been defined as $N = 2$, and finally $N = 3$ has been selected, which led to a solution. In the second case, it was not necessary to alter the standard parameters.

In the third case, in which the section ran through the impermissible area $x1 = \phi$, the intervals had to be increased again. So $G = 0.00001$ was selected and x1 calculated. The area around $x_1 = \phi$ can be avoided if the input parameter is altered "infinitesimally".

In practice, this case presents no difficulties, and so no special researches or calculations were needed.

In the fourth case, a higher accuracy was selected for x_1, from $x = 0.1$ mm. to $x = 0.01$ mm.. If we lay down that $2a = 2b$, we are pre-setting the values of a symmetrical parabolic antenna, which is shown in Fig.5.

In accordance with the principles set out above, here are some explicit examples of the application of the program:

1. Establishing focal point:
    a. For correct placing of radiator
    b. Determining phase centre of radiator used
2. Modification or copying of given parabolic antennae

LITERATURE

Otypka, J.:
Urceni ohniska ofsetore anteny
Sdelovaci technika, c. 8, 1992