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Antenna Engineer

—predict performance of phased arrays with a TRS-80

This article is intended for use with a TRS-80 Level II 16K. The program listing is for the amateur who is interested in designing his own array of antennas and predicting the polar plot ahead of time. This ability to predict and create graphic displays on the TRS-80 saves me many hours which previously were spent in building antenna arrays—many of which never quite worked as I had hoped.

The program is set up for an array of up to 10 elements to be plotted, but with only a few program changes, it can calculate and plot any number of elements. All inputs to the program are prompted.

The program needs only five pieces of input information as described below.

1) The number of elements in the array.

2) The relative phase of each element. This is the phasing that each element in the array receives compared to the reference element. The reference element can be any element in the array, and is chosen by the user; all measurements of phase are referenced against it. The phase of the reference element is automatically made zero (0) degrees. The phase of each element in the rest of the array is then the difference in phasing in degrees from the chosen reference element. The examples will make this clear.

3) The angles of elements. The angle of the element is the angle which is made from the user's view of the antenna placement (See Fig. 1).

4) The relative amplitudes of elements. This is how much power each of the elements is getting compared to the reference element. If element #2 is getting the same amount of power as the reference, then the response to the program would be (1). If the element in question were getting twice as much power as the reference, then the reply to the program when asked this question would be (2), and so on.

5) Spacing to an element. This is the spacing, in degrees, from the reference element located at the center of the X-Y coordinate system to the element in question. If you are used to thinking in terms of spacing as parts of a wavelength then remember this: Spacing in degrees = 360° times spacing in parts of wavelength: 360 x .2λ = 72°.

To help clarify any of the above programming steps, refer to Fig. 2 and also to photo A which is the polar plot of the well-known two-element beam, with (1) 90-degree lagging phase, (2) equal power division, and (3) placed at 45 degrees in direction and .25λ, or 90°, from the reference element. The photo shows the cardioid pattern that accompanies the two-element beam. Fig. 2. shows also that the beaming action is at 45 degrees on our coordinate system, with the second element being placed in that direction and having a phase difference of 90

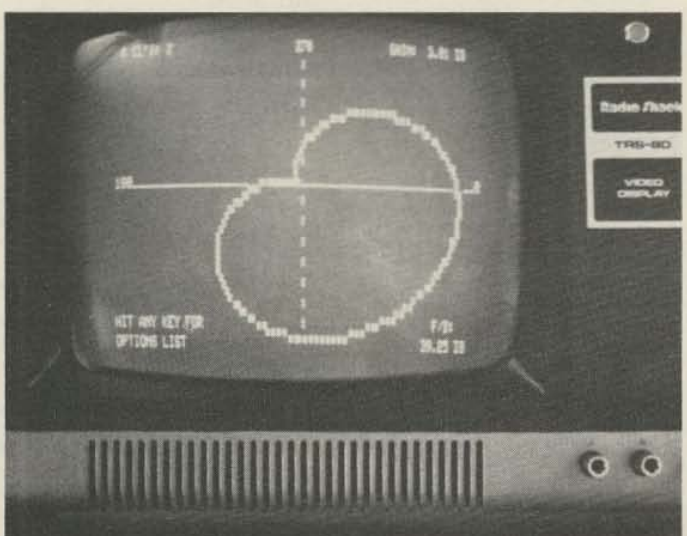

Photo A. Polar plot of two-element array.

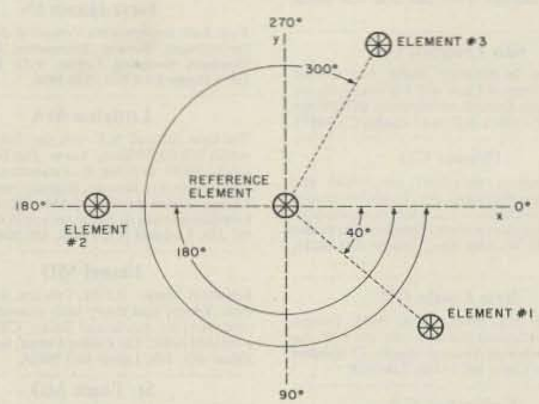

Fig. 1. The reference element is always centered on the X-Y coordinate system. All other element placements are measured as shown here.

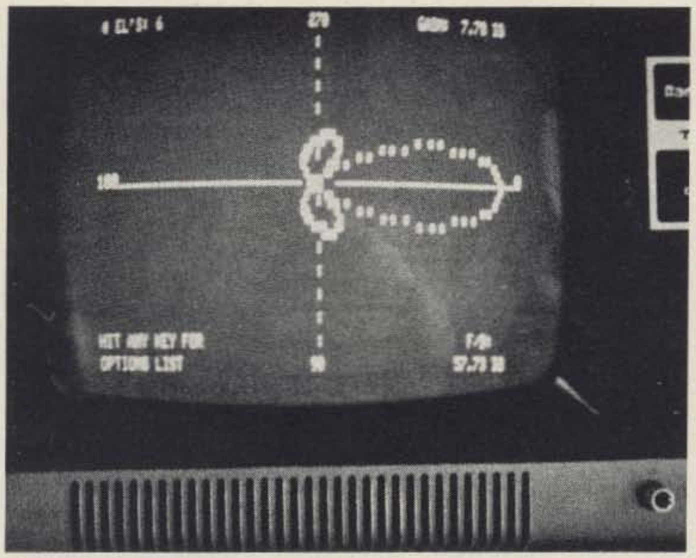

Photo B. Bobtail curtain with equal power division.

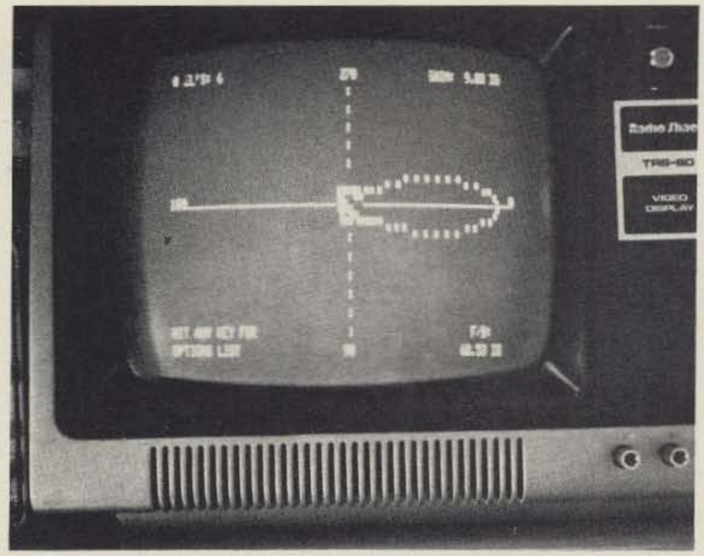

Photo C. Bobtail curtain with unequal power division.

degrees (−90 from reference).

The correct response to the program for a design of this two-element beam would be as follows:

- Relative phase of element #2? −90
- Angle to element #2? 45
- Relative amplitude to element #2? 1
- Spacing to element #2? 90
- Number of elements? 2

The program is very easy to use once the input parameter definitions as just outlined are known.

Lines 20 to 540 are simply inputs and their various formatting. Lines 560 to 780 compute the partials from each element to the total pattern of the array. Lines 820 to 920 are format to start the graphics plot routine. Lines 920 to 1060 scale the pattern to be plotted to fit into the TRS-80 picture format and then start the plot to the screen. The rest of the program consists of various formatting to display the different output routines from the program.

The program will give the

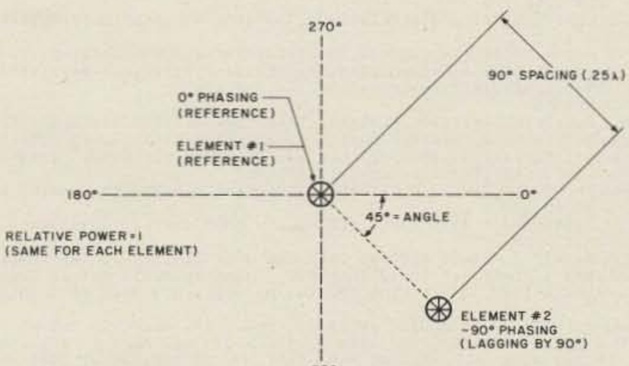

Fig. 2.

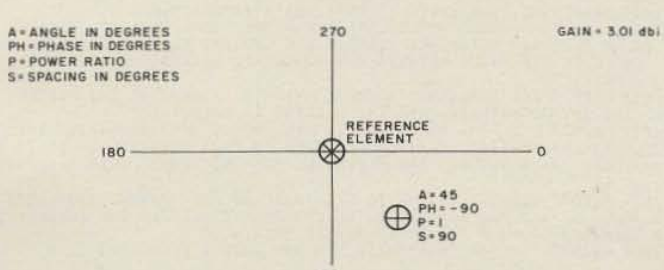

Fig. 3. Bird's-eye view of two-element antenna array placement.

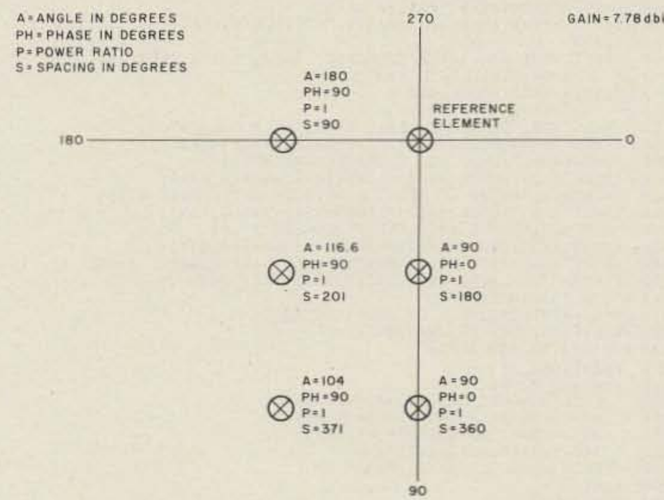

Fig. 4. Bird's-eye view of vertical element placement of Bobtail curtain, equal power division.

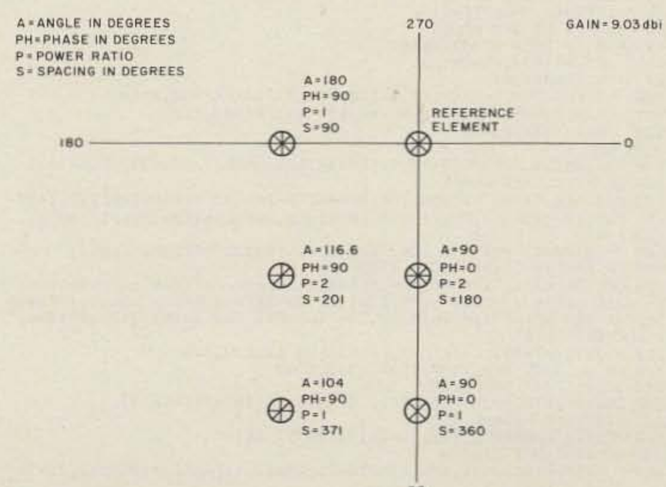

Fig. 5. Same as Fig. 4, with unequal power division.

following outputs at any time during the program once the initial plotting has been done:

- Plot pattern.
- Give gain data every 30 degrees.
- Give gain data every 2 degrees.
- Restart another array design.
- Give graphic element placement of the designed array.
- Give element parameter recap.

Fig. 4 and Fig. 5 and Photos B and C show the variations obtained with the Bobtail curtain antenna, changing only the power division (holding every other parameter constant). It can be seen readily that the correct division for best pattern and gain is in Fig. 5 and Photo C.

The Antenna Designer program can save many hours of field work by computer-designing an antenna idea. With this and imagination, some helpful inputs to one's antenna intuition should come.

There are some assumptions made when using this program that should be mentioned, however. The first is that all elements are assumed to be point sources (isotropic) and the actual pattern developed by most real-life elements is not isotropic. A vertical antenna at ground level can closely compare to an isotropic source better than most and has been my major line of study with this program. Second, the added beaming effect introduced by radiation outside of the plane in which the array lies, is not considered. And third, the problems of mutual coupling among the elements in the array are not considered.

Even with these assumptions, the program closely describes the field-strength patterns from every comparison made to date, and their being neglected should not alter much the pattern or gain of any amateur antenna attempted.

I have cataloged over 200 polar plots using a similar program written in Fortran, for variations of 2 to 10 elements. In all cases, they are essentially identical to other published patterns.

If the reader does not cherish the thought of retyping the listed program, a cassette on quality tape is available from me for $8.00. ■

Bibliography

1. "HP-67/97 Plots Antenna's Polar Pattern," *Electronics Magazine*, September 13, 1979.
2. W. L. Weeks, *Antenna Engineering*, McGraw-Hill, 1968.
3. J. Kraus, *Antennas*, McGraw-Hill, 1950.
4. *ARRL Antenna Handbook*.


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20 CLS
30 GOSUB1780
180 CLEAR 500
200 DIM GN(360),GM(360):AA=1:BB=2:RD=.0174533:CV=58:CH=95
220 VI=15360:ZL=10:F$="###.##":FI=0
240 G$="##.#####":HY$=STRING$(64,"-"):BL$=STRING$(64," "):B$=LEF
T$(BL$,15)
260 PRINT"INPUT NUMBER OF ELEMENTS  (MAX. 10)";:INPUT NI
280 IF NI=0 OR NI>10 THEN 260
300 CU=(NI+3)*64:GOSUB1440
320 FOR N=2 TO NI
340   PRINT@CU,"INPUT RELATIVE PHASE OF ELEMENT#";N;
360   INPUT A(N):GOSUB 1500:PRINT@(N+1)*64+14,A(N);
380   PRINT@CU,"INPUT ANGLE OF ELEMENT #";N;
400  INPUT O(N):GOSUB 1500:PRINT@(N+1)*64+28,O(N);
420  PRINT@CU,"INPUT RELATIVE AMPLITUDE OF ELEMENT #";N;
440  INPUT K(N):GOSUB 1500:PRINT@(N+1)*64+42,K(N);
460  PRINT@CU,"INPUT SPACING OF ELEMENT #";N;
480  INPUT B(N):GOSUB 1500:PRINT@(N+1)*64+56,B(N);
500  AN$="":PRINT@CU,"";:INPUT"IS THIS DATA CORRECT";AN$
520 IF AN$=""OR LEFT$(AN$,1)="Y",NEXT ELSE 340
540 GOSUB 1520:GOSUB1680
560 ZM=0:PRINT@896,"NOW CALCULATING FOR";
580 PRINT@965,"DEGREE BEARING";
600 FOR J=0 TO 360STEP2
620  PRINT@960,J;
640  FOR N=2 TO NI
660    C=(B(N)*COS((O(N)-J)*RD)+A(N))*RD
680    HO=COS(C)*K(N)+HO:VT=SIN(C)+VT
700    GN(J)=SQR((AA+HO)[BB+(VT[BB))
720    IFGN(J)>ZM,ZM=GN(J):P1=J
740    IFGN(J)<ZL,ZL=GN(J):P2=J
760  NEXT
780  VI=0:HO=0
800 NEXT
820 IFP1>=180THENP3=P1-180ELSEP3=P1+180
840 CLS:FORI=0TO15:POKE15392+(I*64),CV:NEXT
860 FORI=15808TO15871:POKEI,CH:NEXT
880 PRINT@511,"0";:PRINT@991,"90";:PRINT@448,"180";:
    PRINT@31,"270";
900 PRINT@962,"PLOTTING:";
920 FOR M=0 TO 360 STEP2
940 IF FI=0 THEN GM(M)=GN(M)
960   GN(M)=(23/ZM)*GN(M)
980   PRINT@968,M;
1000   X=COS(M*RD)*GN(M)*2.5:IFX<-64,X=-64:IFX>64,X=64
1020   Y=SIN(M*RD)*GN(M):IFY<-23,Y=-23:IFY>23,Y=23
1040   SET(64+X,23+Y)
1060 NEXT
1080 DB=10*(LOG(ZM)/LOG(10)):FB=10*(LOG(GM(P1)/GM(P3))/LOG(10))
1100 IF FI=0 THEN DC=DB
1120 PRINT@0,"# EL'S:";NI;:PRINT@48,"GAIN:";:PRINTUSINGF$;DC;:PR
INT" DB";:PRINT@951,"F/B:";:PRINT@1012,USINGF$;FB;:PRINT" DB";
1140 FI=1
1160 PRINT@896,"HIT ANY KEY FOR";:PRINT@960,"OPTIONS LIST";
1180 IF INKEY$=""THEN GOTO 1180
1200 CLS:PRINT@4,"ENTER";:PRINT@64,"1) PLOT PATTERN";:PRINT@128,
"2) GAIN EVERY 30 DEG.";:PRINT@192,"3) GAIN EVERY 2 DEG.";:PRINT@
256,"4) NEW START";:PRINT@320,"5) ELEMENT PLACEMENT";:PRINT@384,"
6) ELEMENT DATA"
1220 X=0:Y=0:INPUTLL:IFLL=1,ZM=23ELSE IFLL=3,J=2
1240 ON LL GOTO 840,1280,1340,1540,1560
1260 GOSUB 1440:GOTO1160
1280 CLS:PRINTTAB(20)"SYNOPSIS OF GAIN DATA":PRINTHY$;
1300 J=30:REM DEGREE STEP
1320 PRINT,"DEGREE","PWR. GAIN.","DB(I) GAIN"
1340 FORI=0TO360 STEP J
1360   PRINTTAB(16);I,:PRINTUSINGG$;GM(I),:IFGM(I)>=0PRINT,10*(L
OG(GM(I)) /LOG(10))
1380 NEXT
1400 GOTO 1160
1420 END
1440 CLS:PRINTHY$;:PRINT"EL.#";TAB(14);"PHASE";TAB(28);"ANGLE";
     TAB(42);"AMPL.";TAB(56);"SPACING":PRINTHY$;
1460 FOR I=2TONI:PRINTI;TAB(14);A(I);TAB(28);O(I);TAB(42);K(I);
     TAB(56);B(I):NEXT:PRINTHY$;
1480 RETURN
1500 PRINT@CU,BL$;:RETURN
1520 FOR I=CU TO 869 STEP64:PRINT@I,BL$;:NEXT:RETURN
1540 CLS:CLEAR: RUN180
1560 FOR PL=2 TO NI+1:IF B(PL)>BG,BG=B(PL):NEXT
1580 CLS:PRINT@511,"0";:PRINT@991,"90";:PRINT@448,"180";:PRINT@3
1,"270";:FOR RL=2 TO NI:XX=COS(O(RL)*RD)
1600 XX=XX*B(RL)/BG*56+64
1620 YY=SIN(O(RL)*RD)*B(RL)/BG*18+22:SET(XX,YY):SET(XX+1,YY+1):S
ET(XX-1,YY-1):SET(XX+1,YY-1):SET(XX-1,YY+1)
1640 NEXT RL
1660 FOR V=1TO20: SET(64,22):SET(65,23):SET(63,21):SET(65,21):SE
T(63,23):NEXT:FOR VV=1TO20:RESET(65,23):RESET(63,21):RESET(65,21)
:RESET(63,23):NEXT:IF INKEY$="",PRINT@896,"HIT ANY KEY TO";:PRINT
@960,"CONTINUE";:GOTO1660ELSE1160
1680 FOR PL=2TONI+1:IF B(PL)>BG,BG=B(PL):NEXT
1700 PRINT@896,"HIT ANY KEY TO";:PRINT@960,"CONTINUE";:IF INKEY$
=""THEN GOTO1700
1720 CLS:PRINT@511,"0";:PRINT@991,"90";:PRINT@448,"180";:PRINT@3
1,"270";
1740 FOR RL=2TONI:XX=COS(O(RL)*RD):XX=XX*B(RL)/BG*56+64:YY=SIN(O
(RL)*RD)*B(RL)/BG*18+22:SET(XX,YY):SET(XX+1,YY+1):SET(XX-1,YY-1):
SET(XX+1,YY-1):SET(XX-1,YY+1):SET(64,22):NEXT
1760 RETURN
1780 CLS:PRINTCHR$(23):PRINT@532,"HAM-";:FORI=1TO600:NEXT:PRINT@
532,B$:PRINT@538,"-TENNA":FORI=1TO600:NEXT:PRINT@538,B$:PRINT@532
,"HAM-";:FORI=1TO500:NEXT:PRINT@540,"TENNA";:PRINT@960,"";:FORJ=1
TO8:PRINT:FORI=1TO300:NEXT:NEXT:GOTO1800
1800 PRINT@518,"POLAR PLOTTING PROGRAM":PRINT@586,"FOR DRIVEN AR
RAYS":GOTO1820
1820 PRINT@960," 1979 - D.C.MITCHELL - K8UR";:FORI=1TO1500:NEXT:
CLS:PRINTCHR$(28)
1830 PRINT"     THIS PROGRAM LETS THE USER DESIGN HIS OWN PHASED
 ANTENNA  ARRAYS UP TO 10 ELEMENTS.  MORE ELEMENTS MAY BE USED B
Y CHANGING THE '10' IN LINE 280 TO THE DESIRED NUMBER OF ELEMENTS
"
.
1840 PRINT"     TO DESIGN AN ARRAY, PLACE THE ELEMENTS OUT AS DE
SIRED USING A 'BIRDS EYE' VIEW OF THE ARRAY AND AN X-Y  COORDINAT
E  SYSTEM WITH 0-DEGREES AT THE RIGHT,270 AT TOP,180 AT LEFT AND
90 DEGREEAT BOTTOM."
1850 PRINT"     THE PROGRAM WILL ASK YOU PHASE,ANGLE,AMPLITUDE A
ND SPACING.PHASE IS (-) FOR LAGGING PHASE AND (+) FOR LEADING  PH
ASE.PHASE IS IN DEGREES FROM THE REFERENCE ELEMENT. CHOOSE ONE  E
LEMENT OF THE ARRAY AS A REFERENCE."
1855 PRINT@960,"HIT ENTER TO CONTINUE";:INPUTUU$:CLS
1860 PRINT"     (ALL MEASUREMENTS FOR THE OTHER ELEMENTS WILL BE
 TAKEN FROM THE REFERENCE ELEMENT CHOSEN).ANY ELEMENT WILL DO. TH
E ANGLE IS THE ANGLE BETWEEN THE (0)DEGREE HEADING OF YOUR X-Y CO
ORDINATE, ";
1861 PRINT" THE REFERENCE ELEMENT WHICH IS ALWAYS AT THE CENTER
OF THE X-Y COORDINATE, AND THE ELEMENT IN QUESTION."
1870 PRINT"     THE AMPLITUDE IS THE AMOUNT OF POWER WHICH THE
ELEMENT IN QUESTION RECEIVES COMPARED TO YOUR REFERENCE.  IT IS E
XPRESSED  AS A RATIO.  THE REFERENCE ELEMENT ALWAYS GETS 1:1 POWE
R SO IF"
1875 PRINT" ELEMENT 2 WERE TO GET TWICE AS MUCH POWER, YOUR INPU
T WOULD BE (2) FOR AMPLITUDE.THE SPACING IS HOW FAR THE ELEMENT I
N QUESTION IS FROM THE REFERENCE IN DEGREES."
1880 PRINT"     SEE POOP-SHEET FOR ANY LAYOUT PROBLEMS.

1890 PRINT@960,"HIT ENTER TO CONTINUE";:INPUTUU$:CLS
1900 RETURN
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Program listing.