Profiling Microwave Paths Using a Microcomputer and Printer

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ABSTRACT

With the advent of metropolitan CATV systems utilizing expanded bandwidth, the area covered by a single headend is reduced. Consequently, to cover the required area, sub-headends or hubs are established. Microwave radio (particularly AML) is one of the more cost effective ways to transport signals to hubs. However, in most metropolitan areas, several paths must be considered before a final selection can be made. The path profile is perhaps the most tedious task of the preliminary engineering, taking one to two hours of an engineer's time per path. The BASIC computer program described uses a microcomputer with 16K bytes of memory and a DOT MATRIX printer to generate path profiles in minutes rather than hours.

INTRODUCTION

Faced with the task of determining the feasibility of inter-connecting several widely spaced communities in a major metropolitan market with AML microwave radio, I quickly determined that no less than twelve path profiles would be needed to make an informed decision. The work was an obvious task for the engineering department's Radio Shack computer. Since at that time I had little programming experience, I made a call to Lorri Kauffman, Application Engineer, at Hughes Microwave who provided a program that calculated earth curvature and Fresnel Zone clearances. Lorri offered the Hughes plotter program but we did not have a plotter and I felt the job should be done with existing resources.

Although calculating the clearance heights was quicker, the manual plotting of the profiles on graph paper continued to be drudgery of the worst sort. A remembered converstion with the boss about plotters and a close inspection of the printer sitting idly in the corner quickly brought forth the realization that a printer, after all, was a course plotter with a funny pen.

Checking the printer's character set revealed that graphics could indeed be coaxed from it with a few LPRINTCHR$ statements. With Lorri's program as a sound foundation I finally emerged from the quagmire of the BASIC language with the program described in this paper.

I have adapted the program to operate with two printers and have no reason to doubt that others could not be incorporated into the program. The program listed is for the Okidata Microline 83A printer and Radio Shack Level II BASIC. The Radio Shack model VI printer was also adapted. Tables 1 & 2 list the printer character codes and corresponding characters used in the program.

TABLE 1
MICROLINE 83 A

CODE	CHARACTER	USE
181		LEFT VERTICAL AXIS
176		LEFT VERTICAL AXIS
180		LEFT VERTICAL AXIS
151		RIGHT VERTICAL AXIS
131		RIGHT VERTICAL AXIS
135		RIGHT VERTICAL AXIS
140		TREE CHARACTER
166		TREE CHARACTER
179		TREE CHARACTER
157		TREE CHARACTER
149		HORIZONTAL AXIS

TABLE 2
RADIO SHACK MODEL VI

CODE	CHARACTER	USE
250	+	VERTICAL AXIS
241	—	VERTICAL AXIS
248	┴	LEFT VERTICAL AXIS
243	┬	RIGHT VERTICAL AXIS
239	■	TREE BODY
245	|	HORIZONTAL AXIS

OPERATION OF THE PROGRAM

Using the program to create a path profile is simple. You draw a path centerline on a 7.5 minute map in the same manner as a manual plot, check the proposed path for obstructions, calculate or measure the distance between the transmit and receive locations, decide on the spacing for the intermediate points and list ground elevations at transmit, receive and intermediate points. Maximum possible tower or antenna mounting heights should be selected next. Refer to a sea level refractivity chart and determine the "K" factor for your location. Using this value for "K" is recommended as it most closely represents the earth curve plus the bending of the radio "beam" due to climatic conditions. However, the program allows you to check the profile with different values of "K" so a worse case of K=2/3 may be used initially, and refined later.

Once you have completed the above steps the program is simple to operate. Enter the information when the program prompts as shown in figure 1. Your profile will be printed in the format shown in figure 2.

```
Microwave Path Clearance Calculations
Transmitter Location
Transmitter Tower Height ?
Path Length in Miles ?
Receiver Location
Receiver Tower Height ?
Distance Between Points ?
Ground Level @ 0 miles = ?
Ground Level @ .5 miles = ?
Ground Level @ 1 miles = ?
Ground Level @ 1.5 miles = ?
'K' Factor From Chart ?
Fresnel Zone Factor (1 or .6)?
Tree Height ?
```

SCREEN FORMAT
FIGURE 1

After the profile is printed you will have to use normal techniques in using a straight edge to find the critical points and if you have a viable path. Figure 3 depicts a completed profile showing earth curvature, ground height, tree height and fresnel clearance. The two paths shown represent two possible antenna mounting locations on each tower.

PROGRAM DESCRIPTION

The program is listed in Radio Shack Level II BASIC at the end of the paper. The comments included in brackets () are not part of the program and should not be entered when you load the program. To change the scale of the plot, line 40, variables VS and HS would have to be reset. If you use several scales, you may wish to change this line to:

```
40 INPUT "VERTICAL SCALE"; VS
   :INPUT "HORIZONTAL SCALE";HS
```

To adapt the program to another printer lines 470, 480, 510, 530, 540, 650, 660, 680 and 690 will have to be changed to include the unique printer character and control codes. For instance, for the Radio Shack Model VI printer line 470 is changed to:

```
470 Bs = CHRs(250) + CHRs(241) + CHRs(248)
    + CHRs(241)
```

Table 2 provides a description of this printer's characters. A profile using the Radio Shack Model VI printer is shown as figure 4.

Formulas used to calculate earth curvature and Fresnel Zone are found in lines 240 and 250. In ordinary form they are:

Earth Curvature

$$h = (d1 \times d2) / 1.5\ K$$

Where h is earth curvature in feet, d1 is distance from the transmitter in miles, d2 is distance from the receiver in miles and K is the factor for the curvature of the earth. K = 1 is the true curve of the earth, K = infinity is a flat earth, K < 1 is the case when the radio beam bends away from the surface and K> 1 is the case when the radio beam bends toward the surface.

Fresnel Zone

$$F1 = 72.1 \sqrt{\frac{d1 \times d2}{F \times D}}$$

Where F1 is the first Fresnel Zone in feet, d1 is distance from the transmitter in miles, d2 is distance from the receiver in miles, F is frequency in GHz and D is path length in miles.

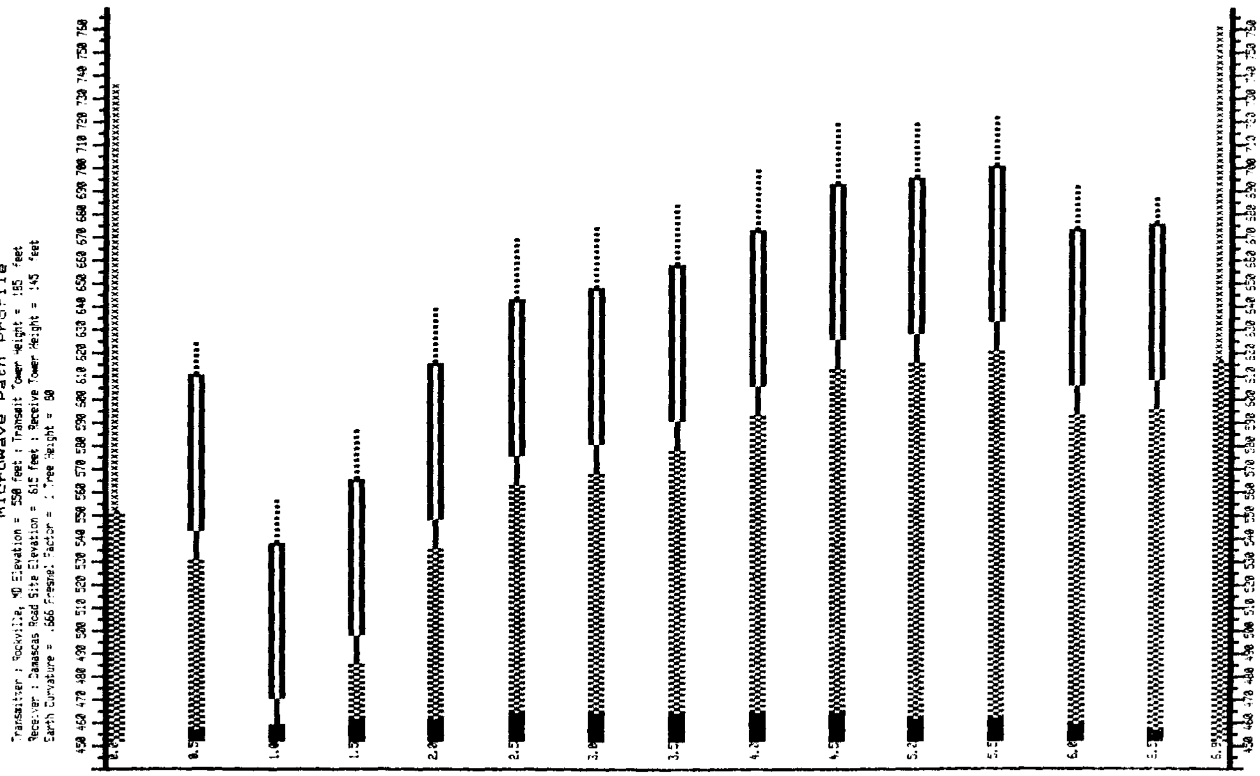


FIGURE 2
OKIDATA MICROLINE 83A

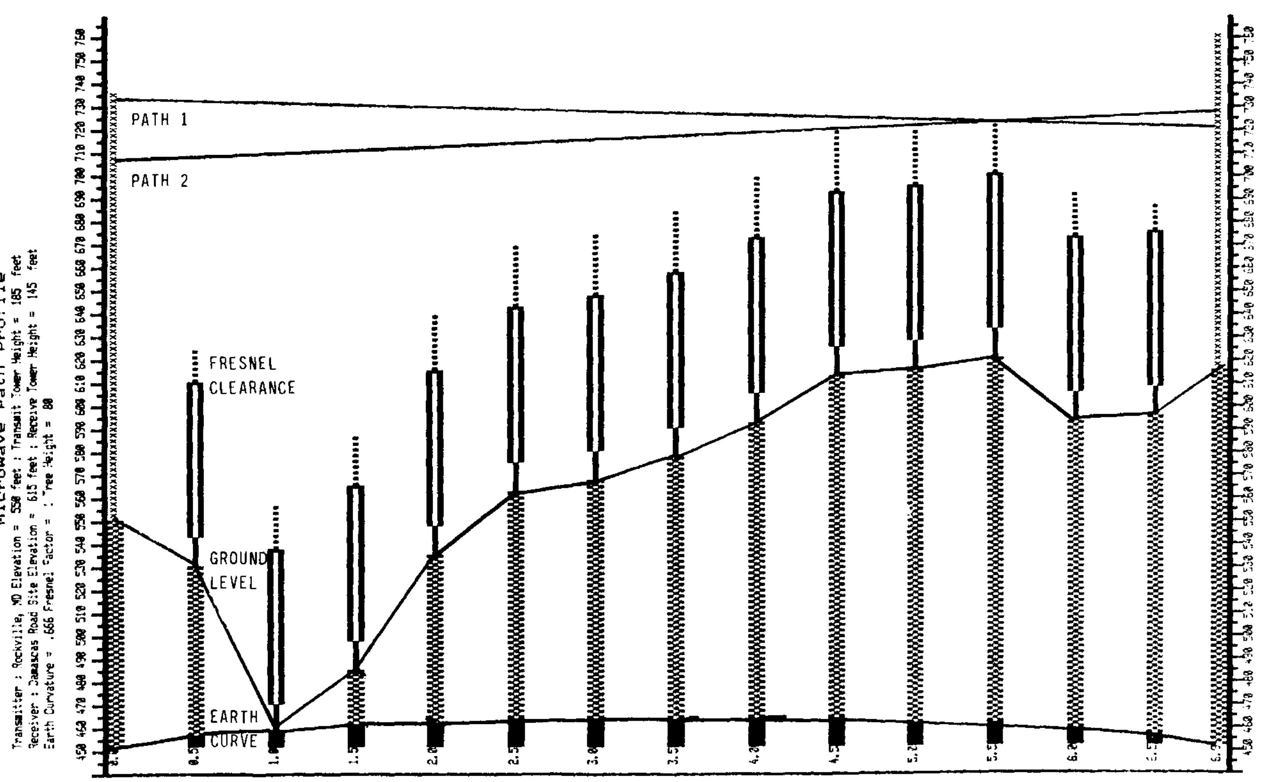
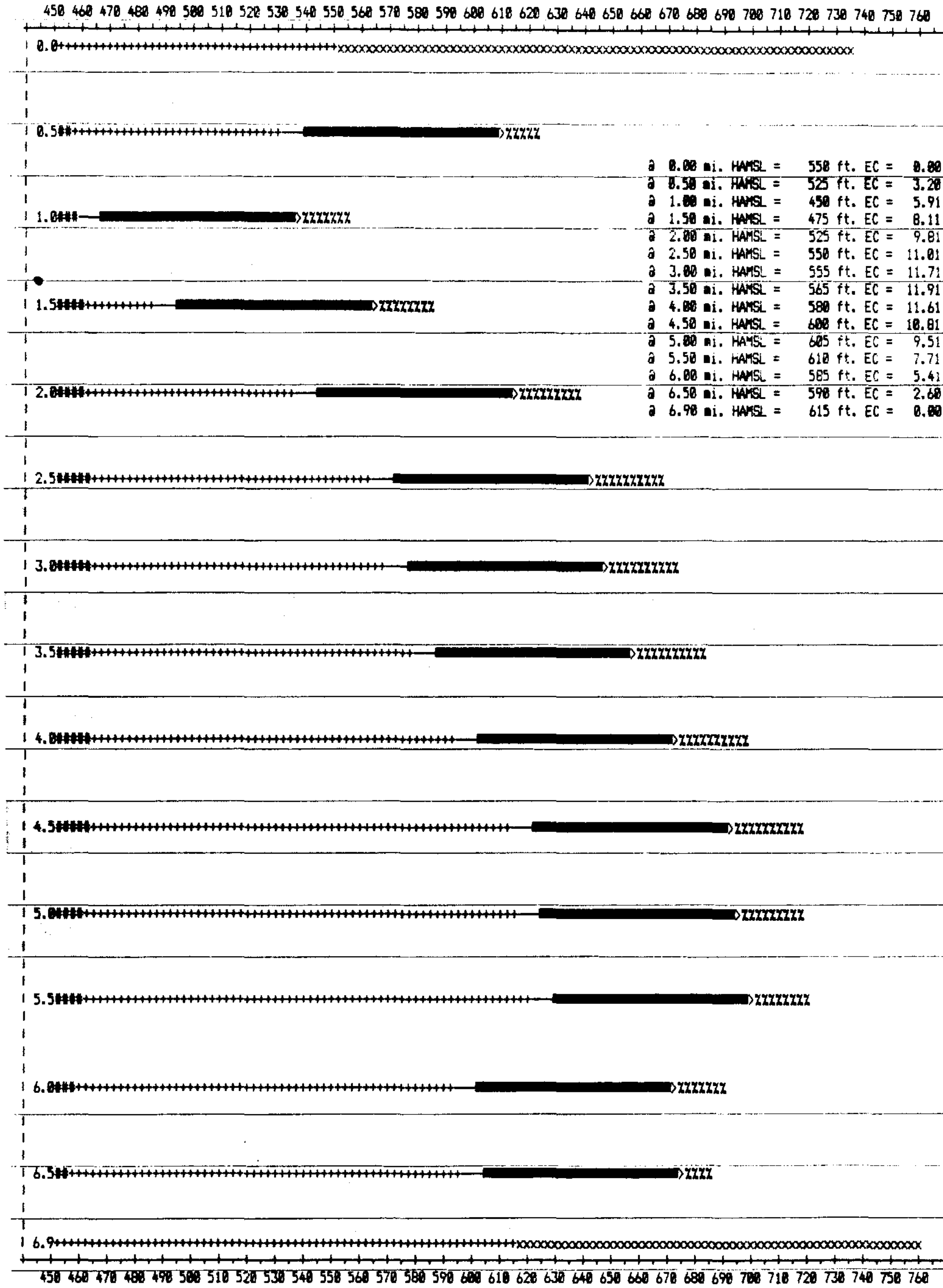


FIGURE 3
OKIDATA MICROLINE 83A

MetroVision, Inc.
Microwave Path Profile

Transmitter : Rockville, MD Elevation = 550 feet : Transmit Tower Height = 185 feet
Receiver : Damascas Road Site Elevation = 615 feet : Receive Tower Height = 145 feet
Earth Curvature = .666 Fresnel Factor = 1 Tree Height = 80



@ 0.00 mi. HAMSL = 550 ft. EC = 0.00 ft. FC = 0.00 ft.
@ 0.50 mi. HAMSL = 525 ft. EC = 3.20 ft. FC = 13.78 ft.
@ 1.00 mi. HAMSL = 450 ft. EC = 5.91 ft. FC = 18.71 ft.
@ 1.50 mi. HAMSL = 475 ft. EC = 8.11 ft. FC = 21.92 ft.
@ 2.00 mi. HAMSL = 525 ft. EC = 9.81 ft. FC = 24.11 ft.
@ 2.50 mi. HAMSL = 550 ft. EC = 11.01 ft. FC = 25.54 ft.
@ 3.00 mi. HAMSL = 555 ft. EC = 11.71 ft. FC = 26.35 ft.
@ 3.50 mi. HAMSL = 565 ft. EC = 11.91 ft. FC = 26.57 ft.
@ 4.00 mi. HAMSL = 580 ft. EC = 11.61 ft. FC = 26.23 ft.
@ 4.50 mi. HAMSL = 600 ft. EC = 10.81 ft. FC = 25.31 ft.
@ 5.00 mi. HAMSL = 605 ft. EC = 9.51 ft. FC = 23.74 ft.
@ 5.50 mi. HAMSL = 610 ft. EC = 7.71 ft. FC = 21.37 ft.
@ 6.00 mi. HAMSL = 585 ft. EC = 5.41 ft. FC = 17.90 ft.
@ 6.50 mi. HAMSL = 590 ft. EC = 2.60 ft. FC = 12.42 ft.
@ 6.90 mi. HAMSL = 615 ft. EC = 0.00 ft. FC = 0.00 ft.

FIGURE 4
Radio Shack LINE PRINTER VI

PROGRAM LISTING

The notes in the program listing explain the purpose of the lines. Adapting the program to other types of BASIC is beyond the scope of this article. However, it should present no problem for microcomputers that use Microsoft "BASIC". The command "PRINT USING" may be unique to Radio Shack but can be easily replaced with "PRINT TAB" statements.

```
10  REM "Computerized path profile using a
    printer as a plotter"
20  CLS         (clear the screen)
30  CLEAR2000 (clear 2000 bytes for string
              space)
40  VS = 2.5
    :HS = 10 ([VS] vertical scale: Used as
              a divisor in calculating the
              number of feet to be
              displayed as one character
              space on the printer.
              [HS] horizontal scale: Used
              as a multiplier in calculat-
              ing the fraction of a mile to
              be displayed as one line
              feed. 1/HS (ie. if HS =10
              then the scale is .1 mile to
              one line feed.).)
50  PRINT @200,"Microwave Path Clearance
    calculations"
60  LINEINPUT "Transmitter Location ";TL$
70  INPUT "Transmitter Tower Height (to
    nearest 5 feet) ";TT
80  INPUT "Path Length in Miles";PL
90  LINEINPUT "Receiver Location ";RL$
100 INPUT "Receiver Tower Height (to
    nearest 5 feet) ";RT
110 INPUT "Distance Between Points";DD
120 I = INT(PL/DD) ([I] counter used to
                    set space between
                    calculation points)
130 IF PL/DD = I THEN J = I
    ELSE J = I+1 (This line deletes the
                  additional space created
                  on the graph if the path
                  length is integraly divi-
                  sible by [DD]
140 DIM GH(J),GH$(J),GL(J),EC(J),EC$(J),
    EL(J),FC(J),FC$(J),FL(J),DT(J)
                 (DIMENSIONS [VARIABLES]
                  [GH] ground height;
                  [EC] earth curvature;
                  [FC] fresnel zone
                  clearance; [DT]
                  distance from the
                  transmitter;
                  [GH$] ground height
                  display character;
                  [GL] temporary variable
                  used in calculating
                  [GH$] from [GH];
                  [EL] temporary variable
                  for earth curvature;
                  [FL] temporary variable
                  for fresnel zone;
                  [EC$] earth curvature
                  character;
                  [FC$] fresnel zone
                  character)
150 FOR X = 0 TO J (lines 150 to 190 are a
                   loop for inputing
                   ground height at the
                   interval you desire to
                   create the path
                   profile.)
160 DT(X) = DD*X
170 IF DT(X)>PL THEN DT(X) = PL
180 PRINT "Ground Level @ ";DT(X);" miles
    = "; :INPUT GH(X)
190 NEXTX
200 INPUT "'K' factor From Chart ";K
210 INPUT "Fresnel Zone Factor (1 or .6)
    ";FF
220 INPUT "Tree Height ";TH
230 FOR X = 0 TO J (this loop calculates
                   the earth curvature and
                   fresnel zone clearance
                   from the formulae in
                   the text.)
240 EC(X) = DT(X)*(PL-DT(X))/(1.5*K)
250 FC(X) = 72.1*FF*SQR((DT(X)*
    (PL-DT(X))/(12.7*PL)))+10
260 NEXTX
280 LH = 15000 (lines 280-340 calculate
               the lowest ground height
               and sets that figure as a
               baseline for the graph. The
               variable is [LH] & [LI].
               [LT] is temporary.)
290 FOR X = 0 TO (J-1)
300 IF GH(X)> = GH(X+1) THEN LT = GH(X+1)
    ELSE LT = GH(X)
310 IF LT< = LH THEN LH = LT
320 NEXTX
330 LH = INT(LH/10)*10
340 LI = LH
360 FOR X = 0 TO J (lines 360 to 460
                   convert [GH], [FC] and
                   [EC] to scale and
                   creates the display
                   strings.)
370 GL(X) = INT(((GH(X)-LH)/VS )+.99)
380 GH$(X) = STRING$(GL(X),"+")
390 NEXTX
410 FOR X = 1 TO I
420 EL(X) = INT((EC(X)/VS)+.99)
430 EC$(X) = STRING$(EL(X),"#")
440 FL(X) = INT(FC(X)/VS)
450 FC$(X) = STRING$(FL(X),"%")
460 NEXTX
470 B$ = CHR$(181)+CHR$(176)+CHR$(180)
   +CHR$(176)
480 C$ = CHR$(151)+CHR$(131)+CHR$(135)
    +CHR$(131) ([B$] and [C$] are the
               border characters between
               tic marks. They must be
               created from the printer's
               character set.)
```

```
490 S = (DD*HS)-1 ([S] counter for line
                   feeds between
                   measurement points.)
500 TS = INT(TH/VS) (lines 500 and 510
                     create the character
                     for displaying
                     trees.They must be
                     created from the
                     printer's character
                     set)
510 TH$ = STRING$(4,CHR$(140))+CHR$(166)
    +STRING$((TS-6),CHR$(179))+
    CHR$(157)
512 TA = INT(TT/VS)
    :TT$ = STRING$(TA,"x")
                     (lines 512 and 513
                     create the character
                     for the transmit and
                     receive towers. [TT$]
                     transmit tower; [RT$]
                     receive tower.)
514 RA = INT(RT/VS)
    :RT$ = STRING$(RA,"x")
520 REM "####PRINT ROUTINE#####
                     (lines 530 to 610 are
                     the header.)
530 LPRINT CHR$(31)(expanded
    print);TAB(26)"MetroVision, Inc."
540 LPRINT TAB(22)"Microwave Path
    Profile";CHR$(29)(16.5 CPI)
550 LPRINT TAB(5)"Transmitter : ";TL$;
    " elevation : ";GH(0);"feet";
560 LPRINT "Transmit Tower Height : ";TT;"
    feet"
580 LPRINT TAB(5)"Receiver : ";RL$;
    " elevation:";GH(J);" feet ";
590 LPRINT "Receive Tower Height : ";RT;"
    feet"
610 LPRINT TAB(5)"Earth
    Curvature:";K;"Fresnel Factor:";FF;
    "Tree Height:";TH
                     (lines 620 and 630
                     print the vertical
                     scale.)
620 LPRINT " "
    :LPRINT "  ";
    :LPRINT USING "####";LH;
    :FOR X = 1 TO 30
    :LH = LH+(VS*4)
    :LPRINT USING "####";LH;
    :NEXTX
    :LH = LH+(VS*4)
    :LPRINT USING "####";LH
630 FOR X = 1 TO 32
    :LPRINT B$;
    :NEXTX
    :LPRINT B$
 640 LPRINT CHR$(149);"   ";GH$(0);TT$
                     (line 640 prints the
                     transmit site.)
650 FOR X = 1 TO (J-1)
    :FOR U = 1 TO S
    :LPRINT CHR$(149)
    :NEXTU
                     (lines 650 to 670
                     print the body of the
                     graph.)
660 LPRINT CHR$(149);
    :LPRINT USING "##.#";DT(X);
    :LPRINT EC$(X);GH$(X);TH$;FC$(X)
670 NEXTX
680 FOR X = 1 TO
((INT((DT(J)-DT(J-1))*HS))-1)
    :LPRINT CHR$(149)
    :NEXTX          (line 680 prints the
                    space to the receive
                    site .)
690 LPRINT CHR$(149);USING "##.#";PL;
    :LPRINT GH$(J);RT$(line 690 prints the
                       receive site.)
700 FOR X = 1 TO 32
    :LPRINT C$;
    :NEXTX
    :LPRINT C$ (lines 700 and 720 print
               the right vertical scale.)
710 LPRINT "  ";
    :LPRINT USING "####";LI;
    :FOR X = 1 TO 31
    :LI = LI+(VS*4)
    :LPRINT USING "####";LI;
    :NEXTX
    :LPRINT " "
    :LPRINT " "
720 FOR  X  =  0 TO J
    :LPRINT USING "@ ##.## mi.
    HAMSL =  ##,### ft. EC = ###.## ft.
    FC = ##.## ft. ";DT(X),GH(X),EC(X),
    FC(X)
    :NEXT X (line 720 prints the data used
            to create the graph.)
730 LPRINT CHR$(12)(form feed)
740 CLS
    :PRINT @200,
   "P R O F I L E   C O M P L E T E ! ! !
    If you want to run another profile for
    this path type 'Y' ;  Otherwise type
    'N' . Press<ENTER>"
750 INPUT A$
760 IF A$ = "Y" THEN GOTO 200
770 IF A$ = "N" THEN END
    ELSE PRINT "Answer 'Y' or 'N' only."
    :GOTO 750
```

REFERENCES

1. "Engineering Considerations for Microwave Communication Systems," GTE Lenkurt Incorporated, San Carlos, California, 1975.

2. Roger L. Freeman, "Telecommunication Transmission Handbook, 2nd Edition," John Wiley and Sons, New York, N.Y., 1981.

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